Division 44
Environment and Infrastructure

sector project
ecosan – ecologically and economically sustainable
wastewater management and sanitation systems

ecosan – closing the loop

**Proceedings of the 2nd international symposium,
7th –11th April 2003, Lübeck, Germany**

Eschborn 2004

Foreword

Two and a half years after the first ecological sanitation conference in Bonn, the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and the International Water Association (IWA) jointly organised and held the 2nd International Symposium on ecological sanitation "ecosan – closing the loop" in April 2003 in Lübeck.

Having assumed my new position as Director Environment and Infrastructure at the GTZ shortly before, my colleagues entrusted me with the moderation of the opening session of this symposium. The contributions made during this session from a wide range of representatives of governmental and non-governmental organisations underlined in an impressive manner both, the seriousness of the current crisis in supplying sanitation and its inter-relationship with the water crisis. The description of currently ongoing wastage and deterioration of our natural resources, in contract to the motivation and vision of the speakers and participants in constructively addressing innovative views and solutions was rather impressive for professionals and newcomers to the subject. Already the opening session made quite clear that a vibrant international dialogue on the many facets of ecological sanitation already exists, not just in the direction North- South, but equally South-South and North-North. It became quite clear that appropriate, holistic and sustainable sanitation alternatives must be implemented as soon as possible --- and worldwide.

The "ecosan community" has come a long way since the first ecosan symposium, organised by the GTZ in October 2000 in Bonn, in establishing an active international network, and in drawing interest and attention from around the world. This was evident from the fact that for the second symposium the number of participants had doubled and we had to extend it from two to five days due to the large number of interesting papers submitted for presentation and discussion.

The first ecosan symposium was held with the aim of establishing a status what has been achieved and to define necessary international actions to further promote innovation in sanitation including the contribution of German technical co-operation to this work. This symposium highlighted the need for an improved system of knowledge management, an increase in the number of pilot projects, particularly in urban areas, and a strengthening of the international ecosan network. As a result, in May 2001, GTZ started a new supra-regional research and development project, ecosan, financed by the Federal Ministry for Economic Co-operation and Development (BMZ), which turned needs identified during the first symposium into its main activities.

Since then, with the active support of the GTZ ecosan project, the international ecosan network has become a dynamic and productive community involved in a wide range of activities around the world. It was a pleasure during the 2nd International Symposium to see this network continue to grow and include, for example, representatives of the United Nations Environment Programme (UNEP) and the European Commission participating and signalling their interest in becoming involved in ecological sanitation. Ecosan has also begun to attract the attention of national policy makers, as demonstrated by the keynote address of The Hon. Maria Mutagamba, the Ugandan Minister of State for Water expressing her governments' interest in ecosystem-based sanitation solutions and her strong conviction that these would contribute to the development of Uganda.

Apart from expanding and supporting the ecosan network, this second symposium provided experts from a wide range of disciplines with the opportunity for a professional exchange. The attendance of 350 enthusiastic experts from a wide range of disciplines from 60 countries ensured that the exchange was fruitful and addressed the complexity of the transition to new sanitation concepts. A further goal of the symposium was to develop a set of recommendations for the up-scaling and further development of ecosan, which the conference adopted as the “Ten Lübeck Recommendations for Action” on the final day.

Overall, the conference proved to be an important contribution of the German Federal Government to achieving the Millennium Development Goal of halving the number of people without access to adequate sanitary systems by 2015.

Since the symposium, the interest in ecological sanitation has continued to grow further. The electronic ecosan-Newsletter, produced on a quarterly basis by the highly motivated staff of the GTZ ecosan sector project, is sent to over 4700 subscribers and requests for further assistance are received by the ecosan team on a regular basis.

With these proceedings we want to provide a comprehensive overview of current activities, ideas and debates within the growing global ecosan network targeting a successful, worldwide re-orientation towards ecological sanitation in both the North and the South. We regard our work as an essential contribution to sustainable integrated management of water and other natural resources and for achieving the Millennium Development Goals. Continuing this work in the spirit of the symposium, the GTZ sector project will support and strengthen this network. We are committed to further support this worldwide activity by co-operative development and implementation of pilot projects, particularly in urban areas. We want to be successful by including international and local partners, and through the active dissemination and exchange of theoretical and practical know-how and information on existing and new ecosan-related developments. On behalf of the GTZ ecosan-team I cordially invite any party interested in productive co-operation to contact us and take part!

But before that, I wish you an interesting and inspiring reading!

Arno D. Tomowski

Director Environment and Infrastructure

In December 2003

Acknowledgments

The GTZ ecosan project team would like to take this opportunity to thank the many organisations and individuals who helped us realise what was not only a professionally fruitful, but also an immensely enjoyable exchange during the 2nd International Symposium on ecological sanitation. We would like to offer our particular heartfelt thanks to the following:

The International Water Association for the co-organisation of the conference, and particularly Håkan Jönsson, Ralf Otterpohl, Joachim Behrendt, Torben Lohmann and the members of the working group on ecological sanitation who organised the peer review process of the full conference papers.

The members of the symposium scientific committee, who kindly gave of their valuable time and energy for the evaluation and selection of the papers for presentation before the symposium, and their active participation in the peer review process of the full papers afterwards.

The German Federal Ministry for Economic Co-operation and Development for their financial support for the organisation of the symposium in Lübeck as well as for their continued support and encouragement of the GTZ ecosan project.

The co-sponsors of the symposium – the Technical University Hamburg-Harburg, the Swedish Urban Water programme, our close partners in EcoSanRes, the Water Supply and Sanitation Collaborative Council, UNESCO and the German Association for Water, Wastewater and Waste (ATV-DVWK) – for their contributions, ideas and close co-operation.

The members of the programme and organisational committee, who worked hard to prepare the symposium and equally hard behind the scenes in Lübeck ensuring that everything went according to plan.

The editing group for their hard work, patience and support in the preparation of these conference proceedings.

And finally to all the participants, who, with an abundance of energy and positiive engagement made the five days in Lübeck such a memorable experience for us. This conference gave many of us the chance to “close the loop” with colleagues from a diverse range of backgrounds and a wide range of experience, allowing us all to learn from one another.

To you all we would like to express our sincere gratitude

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This paper has been peer reviewed by the symposium scientific committee

Welcoming address

Wolfgang Schmitt

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Ladies and Gentlemen,

Excellency,

on behalf of the GTZ, I would like to cordially welcome you all to this 2nd international symposium on ecological sanitation. We at the GTZ believe that this conference, and others like it, will make a major contribution to finding solutions for the water and sanitation crisis currently facing us all.

It gives me a great deal of pleasure to be addressing such a large and varied audience gathered upon the invitation of the GTZ and the International Water Association. It really is very encouraging to see so many people interested in sharing their experiences and learning more about innovative sanitation solutions.

My special thanks go to those who have spared no effort in travelling great distances to participate in the symposium. It is also extremely encouraging to see the range of nations represented here among the participants. It highlights that in this most urgent field of developing and implementing appropriate, sustainable sanitation alternatives, there already exists a vibrant dialogue, not just in the direction North-South, but equally South-South and North-North.

The GTZ is pleased to be able to contribute to the intensification of these exchanges and help address the pressing need for ecologically sound sanitation.

We are extremely interested to learn about the experience of experts and practitioners from all countries, from abroad and within Europe, concerning the latest developments and experience in the application of ecosan, that we understand as a holistic new approach to wastewater management and sanitation based on the systematic closure of local material-flow cycles in order to close-the-loop between sanitation and agriculture.

Why have we decided to hold the conference in Lübeck?

The aim of our ecosan-project is to contribute to the development and global dissemination and application of ecosan approaches and establish these internationally as state-of-the-art techniques – in both developing and in industrialised countries. In Lübeck we have an example of a closed-loop oriented urban eco-settlement, which has gained international recognition since the World Exposition EXPO 2000.

Also in Hamburg, and its neighbouring areas there are other such examples of closed-loop sanitation systems that will be visited in the course of the excursion planned for Wednesday. More such sites are to be found in Denmark and Sweden, the neighbouring countries These will be visited during the post-conference study tour which will begin right here in Lübeck directly after the conference.

The existence of closed-loop oriented sanitation systems in industrialised nations should underline the fact that ecosan isn't an approach intended only for poorer countries, but that these concepts should be implemented in every nation.

In comparison with the first ecosan-symposium that we held in October 2000 in Bonn, the number of participants has doubled and we had to extend the conference to five days. I am very glad to see this huge increase in interest that ecosan is attracting, especially on the subject of sustainability in the field of water sciences, hygiene, energy and nutrition.

As the managing-director of the GTZ, I would like to give you a brief introduction of who we are, what we do and where we see the focal areas and our tasks for the future.

The Deutsche Gesellschaft für Technische Zusammenarbeit is a service enterprise for development cooperation with worldwide operations. Established in 1975, the GTZ is owned by the Federal Republic of Germany. Our organization operates as a non-profit private-sector enterprise with a development-policy mandate to improve and sustain the living conditions of people in partner countries and to conserve the natural resources on which life depends.

A major client of the GTZ is the Federal Ministry for Economic Cooperation and Development and I would like to extend my thanks to the BMZ for making this conference possible. The GTZ also supports development and reform processes on behalf of other German ministries and partner-country governments.

The cooperation with international organizations, such as the World Bank, European Union, United Nations Organisations and the African and Asian Development Bank is steadily increasing.

The private sector is also of growing importance to development cooperation. Public Private Partnership is the name given to cooperation between GTZ and the private companies in projects that combine beneficial development impacts with commercial gain for the enterprises involved.

Currently, the GTZ works in 131 partner countries and supports 2,703 development projects and programmes. All this is done with 10.977 staff members, 78% of them international employees.

One main focus of the German Technical Co-operation is the Water Sector. To date there has been much progress in the areas of fresh water supply, watershed and resource management, but unfortunately considerably less in the sound management of wastewater and excreta. It is therefore one of the factors that sets limits on human existence and development.

The supra-regional research and development project ecosan is financed by the Federal Ministry for Economic Co-operation and Development. The idea for the project arose 3 years ago out of other GTZ water-based programs and the recognised need to develop new economically feasible and ecologically sustainable sanitation solutions.

The great dynamics and diversity of our ecosan-project from the very beginning has contributed to a worldwide network of organisations and projects. Alone within the framework of German cooperation, ecosan-projects are currently being prepared or implemented in more than 20 countries. The Swedish International Development Cooperation Agency, which will be represented through several project representatives here in Lübeck, was the first actively promoting agency starting about ten years ago with ecological dry sanitation programmes.

We have learnt a great deal from them and our strategic partnership over the last few years has been very productive. Meanwhile we have integrated other household wastewater aspects into the ecosan-concept such as greywater treatment, biogas-technology and now, in China, for example, even waterborne ecosan-concepts will be integrated into new settlements in a Chinese-German eco-city-project.

The term “Ecological Sanitation” stands for ecologically and economically sustainable sanitation systems. It does not refer to a specific technology. We use it rather to describe a whole range of technologies and institutional arrangements, which address both the issue of water scarcity and better sanitation. “ecosan” covers closed-loop systems of wastewater management, which concentrate on the principles of recycling water and nutrients as well as reducing the need for fresh water and is a holistic alternative to conventional sanitary systems.

The ecosan-concept fits perfectly into the Millennium Development Goals for 2015 set at the UN Summit of 2000. The goals most relevant to water are to stop the non-sustainable exploitation of water resources and to develop strategies, which enable an affordable and reliable water supply at a regional, national and local level.

At the Johannesburg World Summit on Sustainable Development in August/ September 2002 one declared goal was to guarantee the provision of clean drinking water and adequate sanitation, necessary to protect human health and the environment.

In this respect, a declaration was made agreeing to halve the proportion of people without access to safe and affordable drinking water (as outlined in the Millennium Declaration) and the proportion of people who do not have access to basic sanitation by 2015. This will require actions at all levels to:

a) Develop and implement efficient household sanitation systems;

b) Improve sanitation in public institutions, especially schools;

c) Promote safe hygiene practices;

d) Promote affordable and socially and culturally acceptable technologies and practices;

e) Integrate sanitation into water resources management strategies.

At the World Water Forum in Kyoto two weeks ago ecosan emerged as a significant tool to help us meet the Millennium Development Goals. As a result, new partners have committed themselves to ecosan, while others have increased their resolve to ensuring an increased recognition for ecologically sound sanitation alternatives.

The number of international ecosan-partners is steadily increasing. The World Bank – Water & Sanitation Programme has decided to expand their group of experts significantly.

The United Nations Environment Programme will hold a meeting to elaborate strategies dealing with new ecosan approaches in October/ November of this year and we are pleased, that the Executive Director of UNEP has designated Mr. van de Guchte, to give a keynote speech on his behalf at this symposium.

I am also very glad to welcome Mrs. Maria Mutagamba, the Ugandan Minister of State for Water, who will give an opening speech to this symposium, as Uganda is one of the leading countries worldwide in the promotion of ecosan as a standard approach for sanitation.

I am also glad to welcome further high-ranking personalities from the United Nations Development Programme, the Centre for Science and Environment in India, the International Water Association, the Swedish Urban Water, the Stockholm Environment Institute the German Federal Ministry for Economic Cooperation and Development and last but not least, Kreditanstalt für Wiederaufbau, KfW, the German Development Bank, who will all be holding keynote addresses.

The coming five days will be filled with presentations from experts and practitioners with the focus on development work in both rural and urban areas. Social problems of participation and hygiene will be considered as well as the economic aspects.

Another goal of the symposium is to develop recommendations for action for the implementation of ecosan at a larger scale in rural and urban areas. These recommendations will be the subject of the side event on Tuesday evening and will be discussed and adopted in the panel discussion on Friday with the final recommendations then being made available for publication.

In closing I would like to take this opportunity to acknowledge the sterling work of our ecosan project team. In a relatively short period of time they have engaged in intensive international co-operations in a large number of countries, in many different fields of specialisation and are recognised as enthusiastic members of the international ecosan network. They have achieved this thanks to their hard work, their enormous creativity and their 100% commitment to spread and introduce the concept of closed-loop sanitation around the world. We at the GTZ are proud of their achievements to date.

I would also like to take this opportunity to extend our most sincere thanks and appreciation to all our partners who have helped us organise this symposium. I would like to thank the BMZ for their constant support of the GTZ ecosan-project, and their particular input into the organisation of this conference.

I would also like to express our gratitude to the International Water Association, the Technical University Hamburg-Harburg, EcoSanRes, Urban Water, the Water Supply and Sanitation Collaborative Council, the Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall and UNESCO – an international array of partners, all of whom have willing helped us in our organisational efforts for the symposium. I would like to say to you all that your close cooperation is greatly appreciated.

And finally let me thank both the ecosan "movement" that has proactively developed and spread an alternative water-wastewater concept worldwide, and all the participants that have gathered here. I wish you all success in all your efforts and hope we all have a very interesting, successful and productive symposium.

Ecosan – what kind of advocacy is needed

Maria Mutagamba

Minister of State for Water
P.O. Box 7122
Kampala, Uganda

Thank you very much chairperson for this session, our hosts this morning, participants, ladies and gentleman.

I am more than honoured today to be here to give the Keynote Address at this ecosan conference, and especially at this time, immediately after the 3rd World Water Forum in Kyoto.

Let me introduce myself. I am Maria Mutagamba, Minister of Water in Uganda.

Before I continue, I am sure that each one of you is an expert on ecosan, so I will give you the theme of my speech. It is sanitation and hygiene, and how sanitation and hygiene are connected to my portfolio as Minister for Water.

The previous speaker said, we must look at sanitation as an aspect of water resource management. Sanitation is therefore of key importance to my sector.

Poor sanitation has been recognized as a global problem, and as such it is everybody's responsibility. The World Health Assessment Report of 2000, published by the World Health Organisation and UNICEF, clearly pointed out that over 300 million people in Africa (that is over 40% of the African population) are without access to adequate sanitation. For the case of Uganda, the story is not any better. 50% of the population are without adequate sanitation and hygiene facilities. That is half of the population of Uganda, so for every ten people you see, five of them do not have access to sanitary facilities.

With such a crisis, what measures can we take?

In Africa we mainly use an on-site (i.e. decentralised) form of sanitation, the pit latrine. It is the most widely used type of sanitary facility.

Other practices exist however. For example if one cannot go out at night, (and one must always go outside to use a pit latrine) it is common practice to defecate in a container which is then emptied somewhere outside in the morning.

Then there are those who use what we call "flying toilets", where one defecates in a plastic bag and then disposes of it, often into garbage bins or into running water, which is very dangerous.

Of course we have tried other improved methods, such as ventilated improved pit toilets, but these are not very common. We have tried to install them in urban centres, health centres and a few schools, however only a small section of the population is covered by these.

We also have septic tanks for water flush toilets. These are basically used by people who have the financial means to construct their own houses and are connected to a water supply allowing them to flush their toilets. So when they flush the water goes into the septic tank rather than into a central sewerage system. Sewerage systems only serve around 12 towns in Uganda, estimated at around 10% of the population.

Due to the low availability of water and the fact that they are a relatively new concept, we are faced with the problem of emptying the septic tanks wherever we develop towns. How and where do we empty them? In areas like Kampala where there is a treatment plant it is comparatively easy, as the tanker only has to travel a distance of 10 km or so to the plant. But how about those areas outside Kampala, a 100 miles or so away, where can they dispose of the contents of their septic tanks? That remains a problem. And it is a problem that our planners and you people here are going to help us solve. Without a doubt it is a global concern.

We have the National Water and Sewage Corporation, I have my team here with me, they are the people that actually take care of the areas that are connected to the sewage system. And even there we still have a problem, as you know the sewage system dates from the 1960's and some parts are worn out and need replacement. Here we hope to learn and exchange ideas. We need to learn from those who have tried alternative solutions it and succeeded, we need to learn from your success stories in order to build ours. So for us it is a learning experience, especially in ecosan.

How are we going to translate what we hear and see here into an implementable and sustainable plan of action. Of course the current sanitary practices I have already mentioned are costly in terms of both their impact on health and the environment. They pollute and contaminate our water resources. In areas of high population density there is also a problem of space, as each family requires and area to dig their own pit latrine, and in areas with a high water table most of the faecal matter finds it's way into the water resources. When that pit is full a new one is made, rather than emptying the old one, and then another and another. You need to have plenty of land for this. But what should communities do when they live in areas with sandy soil conditions where the pit caves in, or with hard, rocky soil conditions where you cannot easily dig a pit?

In order to overcome the problems caused by a high water table, people have learnt to build what we call "storage toilets". Instead of digging a pit and going downwards, they build upwards, constructing a vault to contain the excrement. That however also often proves to be unsuitable, as seepage tends to leak through the vault walls because the excrement is above ground. This happens because they fill up much faster, and the liquid tends to find a way out. What often happens then is that people just remove a brick or two and empty the contents onto the surface, causing an additional hazard.

Septic tanks are also not a good solution as they are not affordable to the majority of the people and are expensive to construct, maintain and empty. The sewage system does not cover the larger parts of the urban centres that have already been earmarked for development. It is expensive infrastructure but it must be done.

So what do we do with all these problems facing us?

This dilemma has led us to embrace ecosan and critically look at the various lessons learnt. Not with the aim of scrapping or doing away with what we already have in place but to some how develop it further. So ecosan has come as a blessing and I think it can work.

However we have encountered some problems with it, the biggest being the attitude and behaviour of the people. In Uganda we have various communities and cultures. There are communities who have never believed in using a toilet. Especially the women who actually believe that if they use a toilet they may not be able to conceive. These communities need to be educated on these issues. During colonial times many toilets were built in these areas and the people misunderstood their purpose and did not accept them. We need to find a way of changing such attitudes and persuading them to use them.

It becomes even more difficult when you begin to tell the people that they must separate the liquid fraction from the solids, which they may not understand or accept. They believe what a person does in the toilet is their own private business and say that we are intruding a bit too far into their private lives, almost as if we are trying to supervise them there. The ecosan toilets we started off with in these areas had to eventually be locked up because they were being abused (or misused). The people just didn't know how to use them, and they became a problem in the area.

So how can we translate this information and get the message across?

We have to sensitise people and train them on what needs to be done. For us this is a new concept, a new approach to sanitation, and there is a need for a great deal of work. Therefore, while the technical people are busy developing various technologies, the rest of us, especially we politicians need to carry out advocacy work. However we also need to be trained for that, we need information that will help us sensitise the masses out there.

For instance, I've been in politics since 1989 and I have never seen or heard any of my colleagues, or even myself, going up on a platform to seek a vote on an issue of sanitation. Never! I have talked about water, I have talked about schools but never about sanitation, because it is taken for granted, it is somewhere there in the background.

We have to make it a political issue. We have got to do political advocacy, starting with individual efforts. We in government ought to be able to develop policy.

I am active in central or national government level but it is at local government level where issues should be identified. For a long time we have been planning from the top down and making the people at local level unsure of their role and abilities. Because they do not understand what we are telling them it makes it difficult for them to sustain the projects. So we are appealing to local government to start to initiate programmes or identify issues on sanitation and draft proposals and policies, and then to forward them to the top to make them national policy coming originally from the local areas. This will let them see that it's their issue not just a central government issue.

Then at a national level we can be able to communicate to our colleagues in cabinet and in parliament ensuring that they do not marginalize issues of sanitation. I should add that a large number of them do not understand or have even heard of ecosan, and to be frank I only heard about it when I became a minister.

So for us policy makers who do not know much about ecosan, I hope the experts here can translate the information into political messages that we can take to our people.

And then having talked about political advocacy, there are still some other areas where we can advocate, for example in the private sector. A previous speaker from the GTZ spoke of PPP (Public Private Partnerships), and I'm pleased to say that in Uganda something is happening in this regard. Two or three companies that have championed the introduction of ecosan have been very generous even by donating some sets to schools for demonstrations. So here the private sector is able to participate and demonstrate the construction of ecosan toilets.

And of course the private sector would like to go into an area that is profitable so they are looking at the tariffs that are involved. At the moment sanitation as a service is not so lucrative. Very few companies are going into sanitation. In fact, an investor came to me proposing that I negotiate with the Minister of Finance for a concession on taxation for materials needed so that they can make the sets cheaper and more affordable. The private sector is willing to take the lead and we must be able to assist them with the concessions they require in order for them to offer a service that is affordable.

Other industries that can benefit from this are the fishing industry and the manufacturing industry. For example, the soap manufacturers from hygiene promotion, and the beverage industry because their products eventually end up in the system. They cannot only contribute to the problem but to the solution also.

Another aspect for advocacy is through education. In Uganda at the moment, four ministries, namely water, education, health and local government, are handling sanitation issues. It would be good if we could get ecosan principles to be taught in our schools because children are a good medium of transmission as an entry point. Then we can encourage the private sector to make these ecosan sets available to the schools because schools can monitor and supervise their utilization and people can learn through that.

Another area is the religious institutions because religious leaders already have a forum through their followers in churches or mosques. They can teach ecosan, and even better if a set is available. The message would be carried even faster as people would come initially out of curiosity and then eventually get to appreciate the concept and take something home with them. More people would be converted to our gospel of ecosan through the religious institutions.

And then there are the cultural leaders. I come from a country where people believe in their kings or cultural leaders. We can use them as mobilisers to convey the message to their subjects who believe whatever they say. They can advocate for ecosan and grey water reuse for agricultural purposes and so on. Sanitation has always been viewed as something dirty so the idea of using dirty water for growing vegetables will first be shunned by the people. We need widely accepted mobilisers who can convince them that the vegetables are not going to be dirty. After all, they have been eating vegetables grown from where there used to be toilets, utilising the same nutrients. That is the kind of message our cultural leaders should convey.

Having looked at national efforts we can look at global efforts. We have been at various international forums, such as the World Summit on Sustainable Development in Johannesburg, where we raised our voices for sanitation. We have to continue making our voices heard. There is the G8 summit taking place in June and we have got to be there to let everyone know that sanitation is the key to liberating our people, the 2,4 billion people who are not served. Sanitation is the key to liberating these people from the vicious cycle of disease, poverty and hunger.

In Africa the African ministers responsible for water and sanitation will be meeting in South Africa, five days from now, to follow up on the commitments made in Johannesburg and Kyoto. As a way forward I request that we each find a way of sending a message to the African leaders to solidify sanitation issues into the NEPAD and AU agendas in order to divert the crisis that seems to be looming.

It has been mentioned that 6000 children are dying everyday because of poor sanitation. That catastrophe is equivalent to 20 Boeings crashing everyday. If that happened none of us would have been able to travel to be here today, but it's happening with poor sanitation.

So with those few words, ladies and gentlemen, I want to emphasise that sanitation, especially ecosan, requires a great deal of advocacy and here we are to amplify the message.

Thank you very much.

Why the flush toilet is ecologically mindless and why we need a paradigm shift in sewage technology

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A few years ago, attending the Stockholm Water Symposium, we had an invitation to a banquet from the king of Sweden. But instead of dining in splendour, my colleague, Anil Agarwal and I were inspecting toilets in some remote parts of the city. I was not sufficiently convinced of our mission as we opened the hatch of these "alternative" toilets bins where the faecal matter was being stored before composting and were regaled with information about how urine could be separated in the toilet and used directly for agriculture. Our friend, Uno Winblad, toilet crazy like Anil then took us to supermarkets in Stockholm city where there were a range of toilets – from water saving, to electric and of course, urine separating toilets. Anil who hated shops, was delighted and I began to understand the links.

The flush toilet and the sewage system – which I always believed was the epitomy of personal hygiene and environmental cleanliness – were a part of the environmental problem and not the solution. I came to understand from our research, the technology is quite simply, ecologically mindless.

The crisis of sanitation

"Sanitation is more importance than independence," said Mahatma Gandhi. It is clearly a critical issue, linked as it to human health and dignity. It is estimated that over 80 per cent in rural India and 50 per cent households in urban India have no access to sanitation.

The health costs are enormous. Dirty water kills more babies than any other substance in the world. A World Bank study estimates that there were 2.06 million deaths of children in 1999 in India, of which 90 per cent were in poor rural households. If all households had clean fuel, private (clean) water, private toilet it would reduce infant child mortality by roughly 1 million -- half the deaths. The sanitation mission is clearly too small a price a pay for saving precious human lives.

But sanitation is a double-edged sword. It is a vital part of the solution of human well being but it is also a part of the problem of human health. This is because modern sanitation based on the excessive use of water as a carrier medium and for disposal, adds to the problems of water scarcity and water pollution.

Growing water crisis

There are growing conflict over water in many parts of the world. There is also desperate scarcity of water, which is taking an enormous human toll. There is intense competition between competing needs of water in agriculture, industry, drinking and recreation. The conflicts between rural and urban settlements for water are real. Urban settlements are water guzzling and wasteful but powerful enough to source water from longer and longer distances. Water shortages now plague most large and small cities of India. Many cities get water for less than 20 minutes in a week. In rural India, the crisis is exacerbated by the fact that all traditional and community systems to manage local water resources have been lost over time.

But it is important to realise that water shortage is not about lack of water per se. A fascinating instance is Cherrapunji, located in the northeastern state of Meghalaya in India. This place could easily be known as the wettest place of earth, with rainfall levels of 14 meters annually – 14,000 mm. But it still suffers from acute shortages of drinking water because of lack of systems to hold and capture the rain that falls in the region. On the other hand, the desert city of Jaisalmer, which gets less than 100 mm of rainfall has been on major caravan routes for trade and has no recorded history of being evacuated for lack of water. Water scarcity is therefore, equally about the mindset of conservation and careful use. It is about the ability of humans to value each raindrop of rain.

It is important to note that to confront the water crisis of the world we need policies and practices that augment, minimise and recycle the resource. It is on this yardstick, when we measure the modern sewage system, we will find it is **ecologically mindless and inequitous**. This is because:

- **It is natural resource intensive**: It uses materials, energy and generates waste. It has high environmental and health costs.
- **It is highly capital intensive**: It divides the urban population into rich and poor, that is, between people who can afford the expensive urban services and those who cannot.

Flush and forget mindset

Consider how first a large amount of clean water is used to carry away a small quantity of human excreta. In India, flushes are designed to be particularly water-wasteful so with each flush over 10 litres of clean water goes down the drain. We build huge dams, irrigation systems and what not to bring water to urban areas. Then this water which is flushed down the toilet goes into an equally expensive sewage system, all to end up polluting more water – invariably rivers and ponds. Most of our rivers are dead today because of the domestic sewage load from cities. We have turned our surface water systems into open sewage drains. This is **hydrocide** – deliberate murder of our water bodies.

This heavy use of surface water leads to growing conflicts between urban and rural users. It also leads to overexploitation of surface waters. But then the discharge of domestic sewage leads to heavy pollution of rivers and urban groundwater aquifers.

The solution is to invest in huge river clean up programmes -- the Ganga Action Plan or the Yamuna or the National River Action Plan -- to treat sewage, which incidentally is from the flush toilets of the rich and not the poor. The expensive river action programmes, are sanitary engineers dreams. The thrust of these programmes is to divert sewage, which earlier flowed directly into the river, to a treatment facility.

We need to understand this political economy of defecation. The more water you use, the more investment is needed in cleaning it up. In big cities of India, 22900 mld of wastewater is collected through sewers and of this only 5900 mld is treated in sewage plants. Rest of the human waste is disposed off untreated in water bodies. An estimated 26 per cent of large city waste treated. Waste of smaller settlements is not even collected, let alone treated. Less than 50 per cent of urban dwellers in large cities, less than 14 per cent in smaller cities have access to sewage systems.

The political economy of sewer systems is extremely atrocious in poor developing countries. Hardly any poor city is able to recover its investments in sewer systems. As a result the users of these sewer systems get a subsidy. But almost all users in poor cities are the rich. Thus, sewers only lead to a subsidy for the rich to excrete in convenience. The poor always remain the 'unserved' in this waste disposal paradigm. In addition, the government has to invest in sewage treatment plants whose costs are again rarely recovered from the rich users of flush toilets.

Sewers cost us the earth

Worse, it is virtually impossible for governments to play catch with the targets of building and treating sewage plants. We chase targets hopelessly and remain miles behind the volume of sewage being generated. In a rapidly urbanising situation, the city would soon outgrow the sewage treatment capacity created at a high cost. Further investments will be needed all over again.

Take Delhi, as a typical instance. Yamuna is Delhi's main sewage drain. Yamuna enters Delhi at Wazirabad – where the city draws its water supply – and after this an estimated 1800 million litres per day (mld) of untreated sewage flows through 18 drains into the river. In the last four decades, the total sewage output has increased rapidly. Untreated sewage has grown even faster. In 1999, the Central Pollution Board estimated that Delhi produces over 2,547 mld of sewage of which only 885 mld is collected through the sewage network for treatment and the bulk – over 75 per cent flows into stormwater drains and then into the river. By late 2000, treated sewage had increased to 1333 mld as had the quantity of sewage. With this done, over 50 per cent of the city sewage was dumped into the river. By 2005, Delhi plans to triple its present sewage treatment capacity at a cost of Rs 750 crore. But even this, if built and operational, will be less than what is needed.

The even if Delhi builds all the sewage treatment plants, it will still not have the sewage to treat. Why? The city's sewage drains are choked and silted. The government admits that the present capacity of the sewage treatment plants is not being utilised and when it builds new treatment facilities, sewage never reaches these plants. On the other hand, sewage from these choked and broken lines is diverted to functioning lines and, as a result, the treatment plants at the end of these lines are overloaded leading to untreated sewage flowing into the river. Thus, there is an ironic situation. While some plants are overloaded, some are underutilised. The bill to refurbish the sewers is roughly Rs 500 crore, according to the government. Over and above this is the capital cost of the new sewage treatment plants.

Over and above this is the cost of maintaining and running sewage plants and ensuring that the released effluent meets quality standards. Even if the government were to bear the full capital costs of sewage treatment plants, few urban municipalities have the financial resources to bear the expensive operating costs. As a result, sewage treatment plants, even when built, often stand idle.

In urban areas, drinking water is a small component of the total water use. It is sewage and other waste disposal needs that require maximum water input. This huge demand for water for our cities comes at very high political cost as tensions between urban and rural users for water are reaching flashpoint.

Paying "full costs"

Worse, the political economy of defecation is such that no democratic government will accept the hard fact that it cannot "afford" to invest in modern sewage systems for its citizens.

Instead it would continue to subsidise the users of these systems, in the name of the poor, who would not be able to afford the systems otherwise. The cost to build sewage treatment plants is externalised through these environmental programmes. The logical policy would be to accept the cost and then to impose differential pricing so that while the rich pay for the cost of the capital and resource intensive sewage and waste disposal technology, the poor pay for the cost of their disposal system, which is invariably unconnected to the sewerage system and hence low cost.

For the poor even today, there is no free lunch. They pay — through their labour or with cash — for the meagre stinking water they get. In truth, they pay for it through worsening health. The relatively rich, in stark contrast, are grossly subsidised for the water they receive. Take Delhi. It costs the city public utility between Rs 9-10 per 1000 litres to treat and distribute water in the city. Its citizens pay 0.35 paise per 1000 litres — less than 4 per cent of the cost. Bangalore citizens pay the most: Rs 5 for 1000 litres. But their water cost is Rs 40 for the same quantity, so they pay 12 per cent of the cost. Compare this to bottled water, where we pay Rs 10 for each litre for the clean water.

But this we know is only half the story. The main cost is not in providing clean water, but in taking back the flushed dirty water in the sewage systems and treating it before discharging it into rivers. We know that sewage and drainage costs can be as high as 5-6 times more than the cost of water supply. And with increasing chemical pollution, water treatment costs are only going to increase.

The "socialist" framework in our countries forces political leaders to keep water and waste pricing affordable by large sections of urban populations. In this situation, private investment also looks for an easy way out. The answer is for them to invest in water services and to leave the costly business of cleaning up the waste to government agencies.

In the meantime, the use of sewer systems would have totally destroyed the aquatic ecosystems in the developing world, posing enormous threats both to public health and aquatic biodiversity. Literally, no small or medium river today is clean. Every river that passes through a city or a town becomes a stinking sewer.

All this makes water-borne sewerage a waste disposal paradigm that is extremely expensive because of its high economic, environmental and public health costs. And as a result it has very high political costs.

Going against the laws of nature

Sewer systems totally destroy nature's nutrient cycle in which nutrients collected from the land should be returned back to the land. With the use of sewers, this "waste" gets dumped into our aquatic systems. Therefore, while our nutrients in food come from agricultural lands, sewer systems dump the nutrients contained in human wastes into waterbodies. Over time, our agricultural lands get depleted of nutrients, which then need intensive artificial fertilization. The lack of these micronutrients not only becomes a limiting factor in plant productivity but the resulting lack of these nutrients in human food becomes a threat to human health.

A story of two cities: Roma and Edo

The water culture of people is an important indicator of their level of civilization. Take the two ancient cities, Rome and the town of Edo, which grew into the mega-metropolis of Tokyo. The people of Rome brought their drinking water with the help of long aqueducts, which today are regarded as architectural marvels of the bygone Roman civilisation. But the people of Rome lived on the banks of the river Tiber. They had no need to bring water from afar. Unfortunately, they did not know to dispose off their human wastes and like the modern Western civilisation they ended up polluting the river, thus forcing them to go far in search of clean water. This makes Roman aqueducts not a symbol of intelligence but one of great environmental stupidity.

On the other hand, Edo, which too was situated on several streams, ensured that all its human wastes were collected and returned to the farmlands. Its neighbouring rivers remained clean and it tapped its water from them through an extensive piped water supply.

But today we are all children of Rome and not Edo. We have turned our backs to our water bodies and if we don't have money to clean our mess, then we will have nothing but polluted waters.

Desperate for an alternative paradigm

Clearly we need to look for an alternative, cost-effective, non-sewage paradigm of human waste disposal. The capital-intensive, material-intensive urbanisation process of the West works only for rich countries, not poor countries.

But while our scientists think about going to the moon, the toilet is not in their vision at all. There is absolutely no thinking about the need to find environment friendly sewage systems in our countries. We need massive investments in R&D for non-sewage alternatives. While investments in sewer systems run into billions of dollars every year despite all the problems they create, research investments in non-sewage alternatives hardly exist.

But who will ask for an alternative paradigm? The entrenched interests and mindsets of our sanitary engineers being what they are, there is no demand for change from this community. But change, we must.

In this context we need to learn from what is happening across the world. There is a growing concern for ecological sanitation and this is giving rise to innovations from the concept of sewerless cities using new technological systems which use extremely low amounts of water or no water at all, and, in which all the wastewaters and the solid wastes are recycled.

These modern systems are built on the traditional science of recycling and composting human waste. But in a way that uses the best of modern science and technology to “sanitise” waste and match the convenience and public hygiene of the modern flush toilet.

Therefore, ecological sanitation is a paradigm that we must explore in all earnestness. But *we must make sure that the new technologies take into account cultural constraints* otherwise they are unlikely to succeed.

The most important issue is that these “alternative” technologies must be for the rich and not just for the poor. If ecosanitation technologies are “cost effective” technologies to serve the ‘unserved’ poor, these will only be an interim alternative, one to be discarded as soon as people become rich. We have to remember that it is the rich person’s flush that is the biggest environmental culprit today.

Challenges in the sanitation sector after Johannesburg

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Honourable Minister,

Dear colleagues, dear guests,

I would like to welcome you on behalf of the Federal Ministry for Economic Co-operation and Development, and in particular I warmly welcome all those, who have come from abroad to this beautiful city of Lübeck.

I would also like to welcome you on behalf of the Minister Heidemarie Wieczorek-Zeul and the Deputy Minister Uschi Eid. I know both of them would have liked to be here today, but you will understand that very important political issues keep them fixed to our capital. These are of course very critical, very intense times, where also people and politicians involved in development issues are very much in demand and have very difficult decisions to confront. So please understand, that they can't be here, and I hope you will be satisfied with my presence, a simple bureaucrat from a Ministry. As you don't expect a very thoughtful lecture from a bureaucrat, let me just give you three points that have come across my mind, three thoughts:

Firstly: I think we have seen a political breakthrough in Johannesburg with the introduction of the Sanitation Target that the World Community, the United Nations, has now adopted to halve the proportion of people without access to basic sanitation by the year 2015. And I must say it was a breakthrough because of the special problems associated when we talk about sanitation.

Maria Mutagamba has been very explicit on this. It has not been easy to bring the sanitation issue to the top of the political agenda. It has in fact been very hard work and I must say that we have been quite successful. We as organizers of the Bonn International Conference on Fresh Water were proud that we managed to persuade the conference to put the Sanitation Target right on top of its agenda.

And I remember the evening when we actually reached an agreement in Johannesburg. It was a very difficult conference; we had to fight very hard. I have respect for those partners who resisted, because their hesitation to agree to global targets also had good reasons. But I think in the end they came around and agreed to have this as one of the leading targets of the developing community around the world, to bring sanitation to the poor in particular in the developing countries.

I think this was a breakthrough, and also in Kyoto we witnessed that this has really changed the minds at least in the developing community. People are now talking about sanitation just as they are talking about water supply. Let's remember that years ago this was not the case.

Secondly: I think that after Johannesburg, with the decision to have this new target, we started to think about what will it take to reach this target.

The development community has now started to work really hard on what it will take to implement the targets. The World Bank has just prepared what I think is one of the most important documents in a new report that will come out of the meeting of the Development Committee next weekend.

It is a progress report and a report on the critical next steps in scaling up for all the Millennium Development Goals: Education for all, Health, HIV/AIDS, Water and Sanitation.

We are being told in this document that in fact the Sanitation Target is the most ambitious target of them all and that only 16% of the developing world is really on track to meet it. This is the lowest percentage for all of the Millennium Development targets.

For instance for the Water Supply Target, to halve the proportion of people without adequate access to water, the figure is 37%. It is still a quite low, but it is a much better figure when we compare it to the figure of the Sanitation Target.

Why is this a special challenge? Of course the focus in the past years has been on water supply. How does the water come into the household? And the focus has not been on the sanitation issue. I think this is not unusual. If we look at developments in Europe in the 19th century, it has not been different. But still it is a very critical issue because we have heard that sanitation is really the key to improve health and to improve general well being.

My third point refers to cultural dimension, and Maria Mutagamba has told us everything that we need to know about it. When we say that one of the obstacles in solving the sanitation problem is the cultural factor, we mean the need for people to change their habits. That makes it more difficult to make progress. If addressing the sanitation problem were simply about investment, we would know much better how to solve it, but it is also about changing peoples minds, and this is much more difficult.

It is very important that we have so many of you working on the ecosan approach. The ecosan approach is one of the keys to realistically achieving the sanitation target. I think Sunita Narain has already given all the figures that need to be known about this - that if we tried to provide everyone in the world with a flush toilet, we simply would not have enough water for it.

Another interesting cultural factor is that in Germany we faced real difficulties after Johannesburg in translating the sanitation target into German. It is about access to basic sanitation but how can you translate "access to basic sanitation"? It was very difficult because we don't have a word in German for sanitation. We have the word "Abwasser", but that means "waste water", so in German, "sanitation" and "waste water management" are almost identical in lingual terms. One newspaper proudly reported on the Sanitation Target by saying that: "*The United Nations decided that everyone should be connected to a sewage pipe*"!

That was the reference to the Basic Sanitation Target , but when you work in countries in Africa and Asia, you know that this has nothing to do with a sewage pipe. And a sewage pipe is a solution, which is very expensive and which is affordable only in countries in Europe or in North America.

So this tells you a little about the cultural difficulties in translating this approach and how the ecosan approach is really helping us, also in the North, to understand the cycle and the ecological implications. And I fully subscribe to what Sunita Narain said: "*It is not just a technology for the poorest of the poor, but it is also a technology for the richest of the rich*".

In closing I would like to say that we are very proud to have such a dedicated team at the GTZ led by Christine Werner to work on the issue of ecological sanitation. We are committed to co-operation, to development co-operation in the water and sanitation sector. We have one of the largest development cooperation programs of all bilateral donors, and our government has committed itself to spend in the next years 350 million euros annually on water and sanitation.

Thank you for being here, and I hope you have a very good meeting.

Ecosan – experiences and conclusions from the KfW's perspective

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Dear Mr. Schmitt,

Dear Mrs. Narain and Mr. Konukiewitz, distinguished colleagues,

About two and a half years ago, in October 2000, I was holding an opening speech at the first International Symposium on Ecological Sanitation which took place in Bonn. At that time, I expressed my interest for this new approach on sanitation which was still new to me and my colleagues from KfW. Since then, we have witnessed various activities from different promoters on an international scale and we have become much more familiar with the concept of ecosan. The GTZ ecosan project has contributed largely to this. Therefore I would like to congratulate my colleagues from GTZ for their efforts undertaken so far.

This week, we are here in Lübeck to follow up on the progress made during the last years and to discuss the challenges lying ahead for a broader introduction of ecosan approaches. In my speech, I would like to give you first of all a general overview on KfW's activities in the water and, especially, sanitation sector. Secondly, I would like to present to you our point of view with regard to the experiences made so far with the ecosan concept. To finish my speech, I will draw a few conclusions from these experiences.

As a public-owned governmental development bank, KfW is committing each year funds of around 40 billion EUR to promote the German economy as well as the developing countries. In the framework of German Financial Co-operation, KfW is committing around 1.5 billion EUR of investment loans and grants per year. With some 260 million EUR dedicated per year towards water supply and sanitation projects and programmes, German Financial Cooperation is the world's second largest bilateral source of financing in this sector.

Currently, we are supporting over 25 countries in the water and sanitation sector. Our efforts focus on the Middle East and North Africa, various countries in sub-Sahara Africa, the Balkans and Caucasian region, but parts of India and China as well as countries like Peru and Bolivia are also covered by our activities.

The overall objective of our activities in the water and sanitation sector is to contribute to the realisation of the relevant International Development Goals including the Millennium Development Goals, i.e. to halve the proportion of people without access to safe drinking water as well as to basic sanitation. This can only be achieved if the access of the poor to water and basic sanitation is going to be improved dramatically. Taking into consideration the prevailing water shortage in many regions of the world on the one hand and the limited availability of the poor to pay for services on the other hand, it is needless to say that these goals are very demanding making new and innovative approaches necessary.

Presently, we are therefore focusing on the approach of integrated water resources management taking into consideration the whole water cycle – including wastewater treatment and reuse - on the one hand and the competition for water between human use, agriculture and industry on the other hand. We are following this approach not only through project and programme financing, but also through the sector dialogue with the governments and project sponsors of our partner countries. An appropriate design of sectoral framework conditions is obviously crucial for the sustainability of investments.

Within the sanitation sub-sector, the spatial focus of our activities is on urban and semi-urban areas. We are aware that conventional, centralised wastewater treatment systems do not represent a universal solution for all situations and places. Conventional systems are usually cost-intensive and quite often, proper operation of the sanitation system poses problems due to capacity constraints of the operators. Therefore, we are actively promoting the introduction of new, alternative approaches to sanitation. Such projects include water and nutrient re-use schemes with different levels of decentralisation and technological standards.

Please let me give you a few examples:

- In our rural water supply and sanitation projects, predominantly in Africa, we promote traditional on-site sanitation systems using faeces in agriculture.
- A number of urban wastewater projects, which include the re-use of treated wastewater, are currently under preparation, amongst others in Tunisia, in Jordan and in Yemen.
- Concepts for using sewage sludge in agriculture have been successfully developed in Turkey. The implementation of these concepts has generated positive results.
- A plant for purifying pre-treated wastewater to produce drinking water went into operation in Namibia in 2001.

Details on these as well as other projects will be presented tomorrow by my colleagues, Uwe Stoll and Bernd Schönewald.

Dear colleagues, since the first ecosan symposium held in Bonn in October 2000 KfW is following with interest the activities of the GTZ-ecosan project as well as of other promoters of the ecosan approach. Furthermore, KfW is currently preparing ecosan related project components as part of German Financial Co-operation projects to assist in gaining experience with these concepts, often together with our colleagues from GTZ. Pilot projects for urban or semi-urban areas, which are most relevant for German Financial Co-operation, are being prepared for Yemen, Egypt and Zambia. In the case of Yemen, experts will study alternatives for solutions to realise the International Development Goals including ecosan approaches. This example will be presented to you on Thursday by Mr. Oldenburg from the consultancy firm Otterwasser GmbH.

Obviously, we cannot yet draw conclusions from these pilot projects since none of them is being implemented yet. However, taking into consideration ecosan projects promoted by other organisations in different parts of the world, we would like to highlight two aspects which will be crucial for the broad application of ecosan approaches and for which we do not yet see solutions: the integration of ecosan concepts in urban areas and the acceptance of ecosan systems by decision makers as well as customers. I will illustrate the latter aspect in more detail in a minute.

As you may know, German Financial Co-operation is following a comprehensive approach with regard to the sustainability of its project and programmes: apart from ecologic and social sustainability, financial and economic sustainability are essential for the success of projects and programmes. Thus, by identifying and designing projects and programmes, all of these aspects have to be taken into consideration. Of course this holds also true for any ecosan project or project component.

Ecosan oriented projects, by its definition, should be ecologically sustainable. Contrarily, as regards social and financial sustainability, we see challenges especially in the following:

- A low level of accepting ecosan approaches by the relevant decision makers. Existing standards in most countries presently do not allow the introduction of such approaches. Furthermore, in developing countries, decision makers strongly prefer standards and project concepts which are applied in the industrialised countries. Engineers often visited universities in these countries and thus are familiar with conventional techniques. They are reluctant to accept new approaches.

- A low level of acceptance by the customers, since they would generally be faced with an elevated handling time and / or higher handling costs in comparison to conventional systems. This is due to the fact that ecosan systems are by its definition decentralised systems posing a higher burden on the end users.
- With regard to financial feasibility, systems already existing in a project area need to be taken into account for any new investment, may it be a replacement of or an extension to the existing system. Thus, it will usually not be financially feasible to replace an existing conventional system by an ecosan system in case the existing system has not yet been fully depreciated. Since most of the bigger cities do have existing conventional sanitation systems, also in the developing countries, these systems can only be gradually replaced.

Dear colleagues, please let me draw a few conclusions from what I have mentioned:

1. In order to have ecosan systems introduced on a large scale, their functioning and acceptance would still have to be proven. To achieve the latter, it is of utmost importance to successfully hold the dialogue with politicians and other decision makers. Therefore, I would like to recommend you to sacrifice some time during this symposium to discuss, how the political – as well as the legal – framework conditions could be improved in order to allow for a broader realisation of the ecosan approach.
2. We feel it to be unlikely that ecosan systems are going to be introduced in developing countries on a large scale as long as they have not been introduced and operated in the industrialised countries in a much wider scale, showing clearly the advantages to the existing conventional systems, especially in urban and semi-urban areas.
3. Even if all other challenges with regard to the implementation of ecosan approaches have been overcome, we are convinced that a comprehensive realisation of these approaches will still take at least some 30 to 50 years time. Until then, conventional systems and ecosan systems would exist in parallel, even within one city or community.

Notwithstanding the above said, it is clearly in our interest to promote the development and improvement of adapted and sustainable solutions with regard to sanitation problems. Therefore, KfW will continue to follow closely the further development of ecosan approaches. We will also continue to actively support the ecosan project of GTZ in implementing pilot projects. As soon as sufficiently tested solutions exist, we will be more than happy to study the possibilities for a broader introduction of ecosan concepts into Financial Co-operation projects.

Distinguished colleagues, please let me finish my short speech in wishing you interesting and fruitful discussions during this week and a successful Symposium. My colleagues and I are at your disposal for the ensuing discussion.

Thank you very much for your attention!

Reasons for and principles of ecological sanitation*

Christine Werner, Papa Abdoulaye Fall, Jana Schlick, Heinz-Peter Mang

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Abstract

In order to achieve the Millenium Development Goals and the Johannesburg Plan of Implementation, new holistic sanitation concepts are needed, focussing on economically feasible closed-loop ecological systems rather than on expensive end-of-pipe technologies. Ecological sanitation systems are approaches that advance a new philosophy of dealing with what is presently regarded as waste and wastewater. They are based on the systematic implementation of the reuse and recycling of nutrients and water as a hygienically safe, closed-loop and holistic alternative to conventional solutions. Ecosan systems enable the recovery of nutrients from human faeces and urine for the benefit of agriculture, thus helping to preserve soil fertility, assure food security for future generations, minimize water pollution and recover bioenergy. They ensure that water is used economically and is recycled in a safe way to the greatest possible extent for purposes such as irrigation or groundwater recharge.

World water crisis and millennium development goals (MDG)

Water problems with respect to increased scarcity and degraded quality are now present in various parts of the world and are becoming increasingly serious. All signs suggest, that it is getting worse and will continue to do so, with the most recent UN World Water Development Report talking about the serious world water crisis we are facing. The world economy has grown steadily in recent decades, bringing widespread prosperity and lifting many millions of people out of poverty, particularly in Asia. Nevertheless, there are still 1.1 billion people who lack access to a safe water supply, and 2.4 billion with no access to basic sanitation. In the next 25 years, the world's population is projected to grow by about another 2 billion people, most of whom will be born in developing and emerging market economies and will be living in urban areas. Without a concerted effort, many of these people will be doomed to poverty. The limited progress in reducing poverty has many causes. Some of the most dramatic ones are directly related to our present situation of wastewater management and sanitation, which consists of using surface and groundwater as a sink for human excreta and wastewater, resulting in increasing health hazards, environmental and water pollution, the steady degradation of natural resources and also the permanent loss of nutrients and organics from the soil sphere.

Water treatment and supply are often granted a much higher priority than wastewater collection and treatment, despite that fact that sanitation deserves a greater emphasis due to the impact that poor sanitation has on everyday lives, especially on those of the poor. It is the poor who suffer most from the decreasing quality and growing scarcity of water, and from the burden of

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water related diseases and the degraded and dangerous environment.

Untreated excreta and wastewater contains organic matter, plant nutrients, trace elements and micronutrients as well as pathogenic bacteria, viruses, helminths, endocrine substances and medical residues. If they are badly managed they are a major source for the spread of deseases and environmental harm; yet if well-managed they can make a positive contribution to local resources.

Currently more than 90 % of wastewater and excreta worldwide is either only poorly treated or not treated at all at discharge. In addition to the problem of the pollution of water sources, such as rivers and aquifers, poor wastewater management also often leads to pools of stagnant water which may become breeding grounds for insects, with children playing on wet ground or near such pools being exposed to the dangers of infection. The pools may also become evil-smelling and unsightly. Badly designed or operated on-site sanitation is also contributing to groundwater pollution and contamination of the local environment. Sludge emptying is often ignored or the sludge is disposed of in the surrounding environment without precautions for the hygienic safety of the population.

In 2000, the estimated mortality rate due to hygiene related diarrhoea and other water and sanitation related deseases (schistosomiasis, intestinal helminth infections etc.) was about 2.2 million. Worldwide, over 2 billion people were infected with schistosomes and helminths, of whom 300 million sufferred serious illness, most of them children under the age of 5.

A large amount of investment has been made in water supply and sanitation over the last two decades, however the resulting health benefits have been limited by an inadequate focus on hygiene and sanitation and have often even been counter-productive as the improvement in the water supply has resulted in larger wastewater flows.

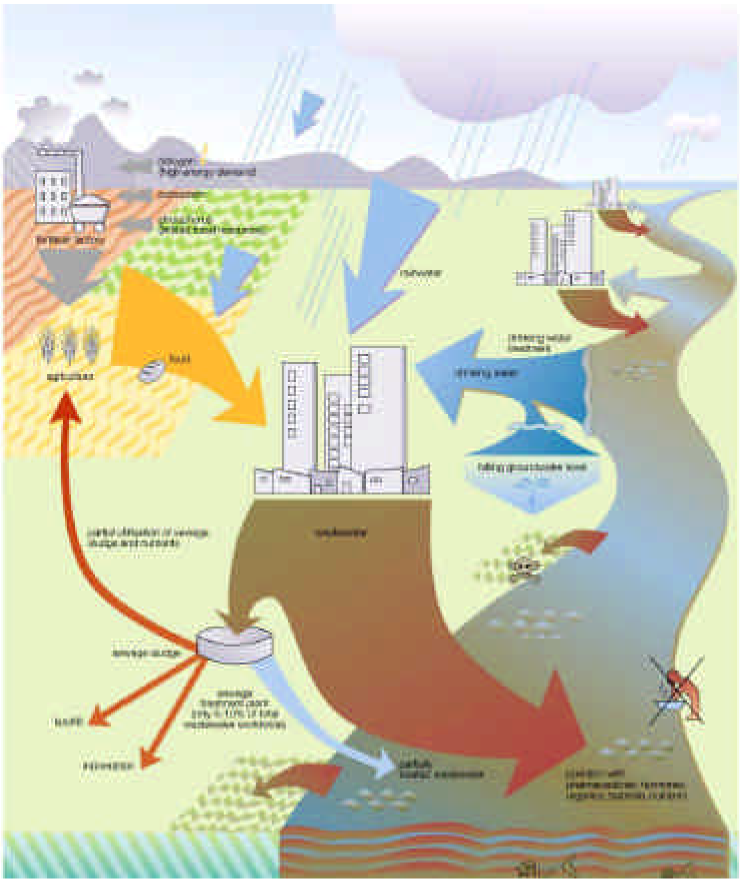
In light of the fact that humanity and the global environment continue to suffer, different conferences and summits have been organized and resolutions adopted to explore and draw up solutions which may lead to sustainable development. Thirty years ago, in Stockholm, agreement was reacxhed on the urgent need to respond to the problem of environmental deterioration. Ten years ago, at the United Nations Conference on Environment and Development, held in Rio de Janeiro, it was admitted that the protection of the environment, and social and economic development are fundamental to sustainable development, based on the Rio Principles (Agenda 21). To achieve such development, a new programme, the Plan of Implementation, including Millenium Development Goals (MDG), was adopted in Johannesburg in September 2002. According to this programme, poverty eradication, which is one of overarching objectives of, and essential requirements for, sustainable development, could be reached by rapidly increasing access to basic requirements such as clean water, sanitation, adequate shelter, energy, health care, food security and the protection of biodiversity.

The set target for water and sanitation is to halve the number of people without access to safe drinking water and those without adequate sanitation. This new commitment to give sanitation the same priority as water supply is a very positive development. It is however, also a very big challenge, which for both economic and ecological reasons requires a revolution in our wastewater and excreta management strategies.

The problem with conventional wastewater management and sanitation

Present conventional forms of wastewater management and sanitation fall either under the category of either waterborne systems or pit latrines. The design of these “flush and discharge” or “drop and store” technologies was based on the premise that excreta is a waste and that waste is only suitable for disposal. It also assumed that the environment could assimilate this waste. ”Modern” water-carriage sewer systems are actually a relatively new technology, which only began to spread in European cities from around the end of the 19th century, when piped water supply systems lead to an increased water consumption and subsequent wastewater production. Stagnant water pools and streams of wastewater in the streets of the cities lead to outbrakes of cholera and other diseases.Sewer systems were gradually introduced. Later, when this resulted in the heavy pollution of waterbodies, mechanical wastewater treatment plants, biological treatment and tertiary treatment for the removal of nutrients (which is now the present state-of the art in wastewater treatment), were added in order to reducetheir eutrophication.

At first glance, conventional sanitation systems therefore seem to present advantages, as they allow, at least when functioning correctly, a relatively well assured hydraulic transport of excreta, used water and rainwater away from urban areas. Polluted surface waters in urban areas, which are a source of health and environmental problems, are also avoided. The hygienic situation of inhabitants in urban areas is thereby improved. This is however not correctly applied in many countries, especially where the urban populations are increasing rapidly, as these technologies are very expensive in investment, maintenance and operation. These are not problems limited only to developing countries, as the most recent UN-report revealed, with the water quality in Belgium being so poor that it is ranked last in the water quality assessment given in the WWDR. This is due to severe groundwater pollution, high industrial pollution and the fact that Belgium was cautioned by the European Court for directly discharging the wastewater of the more than 1 Mio inhabitants of Brussels directly into a small river.



- unsatisfactory purification or uncontrolled discharge of more than 90 % of wastewater worldwide
- pollution of waters by organics, nutrients, hazardous substances, pathogens, pharmaceutical residues, hormones etc,
- unbearable health risks and spread of disease
- severe environmental damage and eutrophication of the water cycle
- consumption of precious water for transport of waste (water carriage waste disposal systems)
- high investment, energy, operating and maintenance costs
- frequent subsidization of prosperous areas, neglect of poor settlements
- loss of valuable nutrients and trace elements contained in excrement due to discharge into waters
- impoverishment of agricultural soils, increased dependence on fertilizers
- combined central systems are predominant in organized wastewater disposal, resulting in problems with contaminated sewage sludge
- **linear end-of-pipe technology**

Figure 1: Shortcomings of conventional wastewater management systems

If considered more closely, conventional waterborne sanitation reveals shortcomings of even greater importance than their high costs. As water is used as a medium to transport the wastes, these systems are becoming increasingly more difficult to apply in regions of aggravating water scarcity, in arid zones and in poor countries. The high water-consumption connected with our sanitary systems is incompatible with arid countries in the long term and is already leading to an irreversible exploitation of non-renewable water resources. Drinking water is therefore becoming an expensive property only available to the financially well off who are usually in good health. However, clean water is too precious to be flushed down the toilet and it is not the most pleasurable experience to operate a water flush toilet, when the water supply only operates a few hours per week. Additionally, even if these systems may contribute to a healthier environment in the cities located upstream, they do the contrary for those living downstream, as even the state of the art multistage wastewater treatment facilities do not eliminate the pathogens and many other substances contained in the effluent. If rain falls, in combined sewer systems the diluted wastewater is generally conveyed directly into the rivers as the treatment plant is designed only for a limited influent. In recent research there is an increasing awareness regarding the effects of endocrine substances contained in human excreta that can, for example, have an effect on altering the sex of male trout. The effects of pharmaceutical residues in the effluents and their impact on environment and humans living downstream and obtaining their drinking water from the same river are also being discussed.

The search for appropriate solutions has become a pressing problem, particularly for arid and semi-arid zones. With increasing population density and the resultant groundwater pollution, conventional decentralized disposal systems, such as latrines and seepage pits, are also not viable alternatives. In many densely populated areas, the contamination of groundwater by nitrates for example is several times greater than the maximum level recommended by the WHO for drinking water and represents a serious mortal danger to babies. Shallow groundwater is still a major source for local and reliable water supply, especially for the poor in rural and peri-urban areas. The design of the conventional “drop and store” pit-latrines (and of most other on-plot systems) however deliberately aims to retain only the solids and infiltrate as much of the liquids into the sub-soil as possible. As these liquids contain all the soluble elements of the excreta as well as the viruses and pathogens, this type of sanitation can be considered a highway to groundwater contamination.

In theory, these pits latrines should be emptied when they are full and the content should be treated before being put on the land. In practise however, old pits are often abandoned with people preferring to build completely new pit latrines, as emptying the pit is an extremely unpleasant job. However digging a new pit, and building a new superstructure each time the old pit is full is very expensive, and it is very difficult for the homeowners in densely populated areas, where plots are small and tend to be already crowded with many previously abandoned old pits. In addition, many conventional latrines smell and are a breeding place for flies and other insects and are inconvenient to use especially for children, girls and women, as they have to be built at a distance from the house.

The fundamental problem however, and probably the most important, is that conventional wastewater disposal systems directly impair soil fertility as the valuable nutrients and trace elements contained in human excrement are not usually rechanneled back into agriculture. Even where sewage sludge is put to agricultural use only a small fraction of the nutrients are reintroduced into the living soil layer. Most are either destroyed (e.g. by nitrogen elimination) or enter the water balance, where they pollute the environment. Frequently, the use of sewage sludge from central wastewater systems is also restricted as it contains too high a concentration of heavy metals and other hazardous substances, often as a result of intermixing household with industrial wastewater and with rainwater from contaminated streets.

In fact, our conventional wastewater systems are largely linear end-of-pipe systems where drinking water is misused to transport waste into the water cycle, causing environmental damage and hygienic hazards. If we continue to promote these technologies in order to meet the MDGs, the overall result would be worse than our present situation as the hygienic situation of our waters would be further deteriorated and even more resources would be dissipated and introduced into water bodies.

Advantages of ecological sanitation

An alternative approach to avoid the disadvantages of conventional wastewater systems is ecological sanitation, 'ecosan' for short. This is based on an overall view of material flows as part of an ecologically and economically sustainable wastewater management systems tailored to local needs. It does not favour a specific technology, but constitutes a new philosophy in handling substances that have so far been seen merely as wastewater and water-carried waste for disposal.

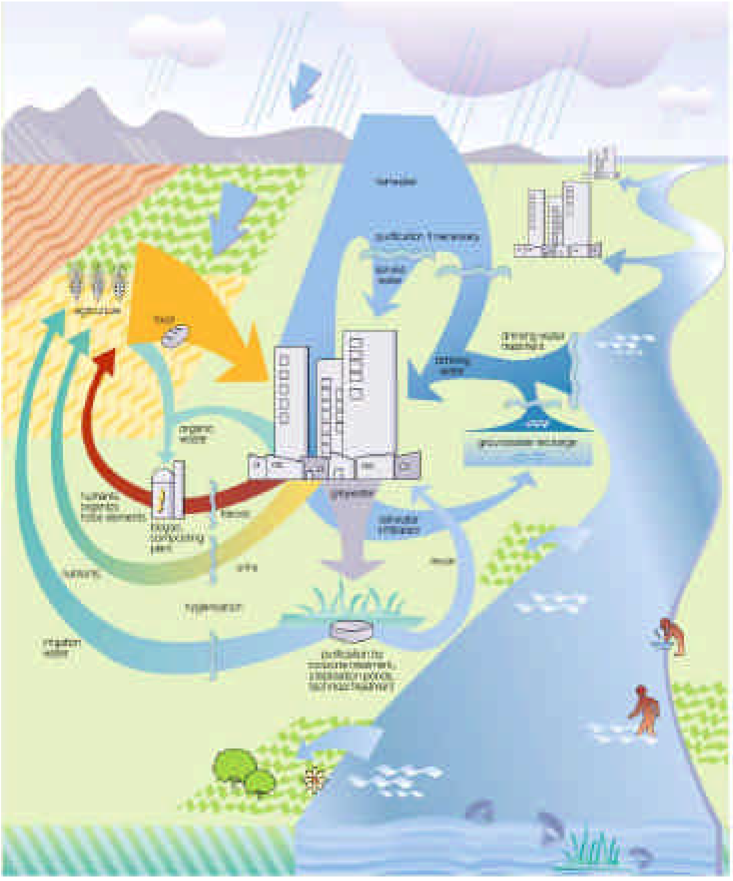


Figure 2: Advantages of ecological sanitation

- improvement of health by minimizing the introduction of pathogens from human excrement into the water cycle
- promotion of recycling by safe, hygienic recovery and use of nutrients, trace elements, water and energy
- conservation of resources through lower water consumption, substitution of chemical fertilizers, minimization of water pollution
- preference for modular, decentralized partial-flow systems for more appropriate, cost-efficient solutions
- possibility to integrate on-plot sanitation into households, increasing user comfort and security for women and girls
- preservation of soil fertility
- improvement of agricultural productivity and hence contribution to food security
- promotion of a holistic, interdisciplinary approach (hygiene, water supply and sanitation, resource conservation, environmental protection, town planning, agriculture, irrigation, food security, small-business promotion etc.)
- **Material-flow cycle instead of disposal**

Systems based on this approach are used for the systematic closure of local material flow cycles and thus ultimately enable recycling systems as are already in common use for solid waste. They also restore a remarkable natural balance, that is between the quantity of nutrients excreted by one person in one year and that needed to produce his food (7.5 kg nitrate, phosphorous and potassium for 250 kg grain). Ideally, ecosan systems enable an almost complete recovery of all nutrients and trace elements in household wastewater and their reuse in agriculture - after appropriate treatment. In this way, they help preserve soil fertility and safeguard long-term food security.

As an integral alternative, a hallmark of ecosan is its interdisciplinary approach that goes beyond the narrow domestic water supply and technological aspects to subsume agricultural use, sociology, hygiene, health, town planning, economic/small-enterprise promotion, administration, etc. in system development.

In practice, the ecosan strategies of the separation and separate treatment of faeces, urine and greywater, for example, minimize the consumption of valuable drinking water and treats the separate wastewaters at low cost for subsequent use in soil amelioration, as fertilizer or as service or irrigation water. Rainwater harvesting and the treatment of organic domestic and garden wastes and of animal manure may also be integrated into ecosan-concepts.

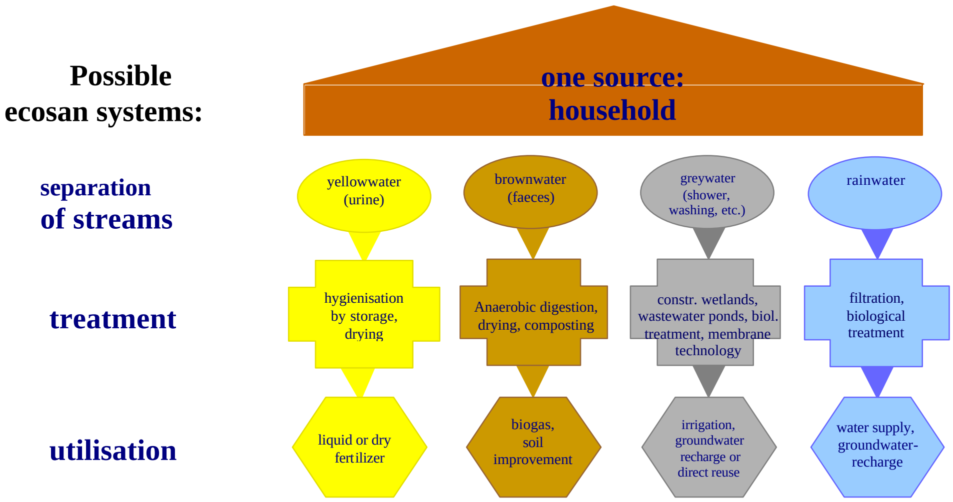


Figure 3: Separation of substances and examples of possible ecosan elements

Of particular importance here are innovative logistics to return nutrients to farmland, marketing strategies for the recovered nutrients and directions for their safe application in agriculture. New ecosan schemes may also entail setting up service enterprises and hence implementing income-generating measures for the construction and easy and safe operation of the installations as well as the collection, treatment and marketing of recyclates.

Closing local nutrient cycles by retrieving and using nitrogen, phosphorus, potassium, trace elements and organic components contained in excrement are even more important considering some of the disadvantages of mineral fertilizers. They are too expensive in many parts of the world or are unavailable to local farmers, and their effects on soil and food quality are in dispute. Additionally, large amounts of energy and finite fossil resources are used to produce them. An example of this is phosphorus: It is currently estimated that reserves will be exhausted in about 60 years at the present rate of consumption. Also in this regard, ecosan is a decisive factor for environmental protection and resource conservation, sustainable food production and a stable future in food and health.

Individual, successful and promising examples of ecological disposal systems already exist in various countries, but a great deal of research and development work still needs to be done before ecosan is established internationally as a way of solving the many different problems. Also, applications to date have tended to concentrate on rural areas, with experience in urban and peri-urban areas still being quite limited. Faced with rapid world-wide urbanization there is a pressing need for solutions in conurbations.

Split-stream collection, treatment and reuse of the different partial flows of wastewater offer new possibilities for more specific and cost-efficient solutions. These partial flows can be characterised as blackwater (faeces and urine with or without flushing water), yellowwater (urine with or without washing water), brownwater (blackwater without urine) and greywater (domestic water without faeces and urine).

fraction	characteristic
1. faeces	• hygienically critical • consists of organics, nutrients and trace elements • improves soil quality and increases water retainability
2. urine	• less hygienically critical • contains the largest proportion of nutrients available to plants • may contain hormones or medical residues
3. greywater	• of no major hygienic concern • volumetrically the largest portion of wastewater • contains almost no nutrients (simplified treatment) • may contain sprent washing powders etc.

Figure 4: Characteristics of substances

The human faeces obtained after separation show valuable soil improvement qualities (an improved structure and an increase in the water retention capacity). They are treated, if necessary together with organic waste and according to local conditions (climate, power demand and sociocultural acceptance etc), using the processes of either dehydration, composting, stabilization, soilisation or fermentation. Thus, the organics and nutrients contained in faeces can be used in concentrated and hygienically safe form as a dry fertilizer, compost or fluid fertilizer. Dependent on the type of treatment, energy can be produced if necessary in the form of biogas after anaerobic digestion.

The urine, or yellow water, contains the highest proportion of natural nutrients (nitrogen, phosphorus and potassium), which are directly available to plants and equally effective as mineral fertilizers. Urine contains approx. 90% of the total nitrogen, 55%% of the total phosphorus and a substantial portion of the potassium contained in human excrement. A partial flow separation and use of the urine is particularly advisable due to its low volume and the high concentration of nutrients it contains. In order to obtain the yellow water fraction devices such as urine separation toilets or waterless urinals can be used.

The greywater from washing, rinsing, showers etc., while representing the largest fraction of the total wastewater flow, has only a very low nutrient content. Therefore, it can be treated to a high quality using simple techniques such as unventilated gravel filters and biofilm procedures and is thereafter ready for reuse. This water can be put to particularly good use in agricultural irrigation (especially in water scarce regions), but may also be used for groundwater recharge or discharged into surrounding watercourses.

Thus, diverse technologies can be used in ecosan systems, from simple low-tech to sophisticated high-tech solutions. These currently range from compost toilets or urine-separating dry toilets, to water-saving vacuum sewage systems, possibly with separate collection and subsequent treatment of urine, faeces and greywater through to membrane technology for material separation and hygienization. Generally, precedence is given to appropriate modular and decentralized facilities, but in very densely populated areas centralized systems may still be needed. The essential advantage of the modular components is the optimal adaptation to the local social, economic, ecological and climatological conditions. As a result they represent a comparatively rapidly realizable alternative to conventional systems.

The implementation of sustainable sanitary approaches such as ecological sanitation "ecosan" systems is one of the most relevant solutions for sustainable development and goes towards the Poverty Reduction Strategy (PRSP) initiated in 1999 and supported by the World Bank Group and the IMF. Ideally, ecosan systems enable the recovery of all nutrients which help to restore soil fertility and thus to assure food security and minimize water pollution, thereby improving the situation for farmers, and particularly for women, in at least two ways. The first is the improved yield of vegetables and other crops strengthening their income. The second is the possibility of building ecosan toilets indoors even in very poor areas, as these toilets, when well managed, have no flies and no odour. Thus, also very cheap ecosan toilets can function well indoors even in poor peri-urban areas. Indoor toilets improve the security situation, which is especially important for women and girls at night. Furthermore, they also save much time, as the women can help the children to the toilet with only a minimal delay in other activities.

The ecosan-approach is also in accord with the Bellagio Principles and the Household Centered Environmental Sanitation Approach (HCES), which has been developed by the environmental sanitation working group of the Water Supply and Sanitation Collaborative Council (WSSCC), and recommends that waste be considered as a resource that should be diluted as little as possible, and that sanitation problems should be solved on the minimum practicable size (household, community, town, catchment etc.).

Conclusion

To realistically have a chance of meeting the Millennium Development Goals, we need a revolution in our way of thinking in order to see human excreta and domestic used water not as a waste but as an important natural resource.

The focus of the efforts for the next years should concentrate on developing and implementing new approaches on sustainable wastewater treatment and sanitation for a variety of suitable closed-loop systems in urban areas including the efficient agricultural reuse of organics, nutrients and water.

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Current technical options for ecological sanitation

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Ladies and gentlemen,

let me welcome you on behalf of the International Water Assiciation, IWA. It is new that the IWA is on board with ecological sanitation, and especially since the 3rd World Water Forum 2003 in Kyoto, ecosan has really become part of the key strategic issues of the organisation. We had our own IWA session on ecosan in Kyoto, even having the president of the IWA, Prof. Tambo with us. The director Paul Reiter and deputy director Marc Pascoe are supporting ecosan strongly. This is really good news that the major international organization of the water professionals is taking notice of this key issue. However, active promotion of ecosan it is certainly not done by all members yet.

To start with some of the current ecosan-options available I want to go briefly into the background of why we are doing this. For many conventional engineers this is very weird, so the first presentations I gave about ten years ago people were just incredulous of what I was talking about. And then a few years later they would first laugh and then discuss, but now it has become a key issue even internationally.

The basic thing is that we have to look at wastewater in a different way. I've put up a chart showing all the wastewater flows that are typically produced in houses. On one side, greywater being the largest amount but with a relatively small load of nutrients. It can be re-used in simple ways after appropriate treatment, including recharge of aquifers where appropriate. But this can only be done with affordable technology if it is not mixed with faecal matter. The mixing of faeces with the big amount of wastewater is the crime that has so often been committed and has and does result in the death of so many million people. It is done simply because we are used to it, having learnt it at home and at school so we think it's normal. But now is the time to relearn, because faecal matter has got nothing to do with the water loop but it belongs to the nutrient loop. On the other side of the slide I show you that large amounts of water can be saved if we do not flush it down the toilet. It also shows that the amounts of urine and faecal matter are very small compared to the massive amounts of wastewater. The faecal matter is the smallest part and if kept separate and treated in the appropriate way, it is a simple material to handle and can even provide renewable energy and restore soil fertility. Throwing this into water creates a hazard, making it very difficult to treat the water at the other end of the pipe. The urine is the major nutrient resource, a natural fertilizer, in principle easy to collect and to use. Subsidies for commercial fertiliser are reduced around the world, many farmers now find it essential to be able to have cheap local fetiliser, and urine is the answer. We should get away from our understanding of what we still call wastewater to maybe blackwater, brownwater, greywater, yellowwater, etc, the new colours of sanitation.

Now I want to go briefly through some technological applications, starting with some high-tech solutions. These include necessarily low-diluting toilets. The main thing is that we have toilets that minimize dilution in such a way that we can produce fertilizer and ensure sanitization.

I start with the vacuum toilets, which many of you know from aeroplanes, which have a high-tech appeal about them. Then there are the sorting toilets which have been re-invented in modern times. They were used is several places around about 100 years ago but did not get the attention at they deserve at that time. Finally there are the desiccation- and composting toilets.

Source control in urban and rural water management is first of all about finding ways of dealing with human excreta in a different way, and there are many ways. Ecosan specialists are working in different areas, from densely populated urban areas to sparsely populated rural areas. Of course we need very different approaches for these different situations. Ecosan is available for the rural and less densely populated peri-urban areas. We do have many choices and can make appropriate designs, at very low prices in many cases. Operation and interacted implementation in co-operation with users and operators are essential for success. There are many people living in metropolitan areas for who we need a lot more ecosan development. There are some promising approaches for those situations, but little experience so far. Some high-tech and some low-tech approaches, as demonstrated by the model of EcoSanRes from Sweden, showing how we can deal with black and brownwater in urban areas in relatively simple way.

Now I show you what the consultancy Otterwasser has built here in Lübeck, one of the reasons why we are holding the symposium here in this beautiful historic UNESCO world heritage city. It is a vacuum toilet system for urban areas that can be adapted even for high-rise buildings with its vacuum collection system, with urban production units for energy and fertilizer. The greywater is available for reuse, infiltration or discharge after appropriate treatment. This system can be used from around five hundred to maybe twenty thousand inhabitants in densely populated settlements, suitable for areas where a certain technological complexity can be handled. It is not, of course, a solution for all areas but a good model to illustrate the wide range of solutions that follow the ecosan principles. There are examples of similar developments in Berlin, Norway, Holland and China.

The same type of technology can be implemented in a more low-tech way with simple digesters especially in warm climate countries. It is far easier to install ecosan in new housing developments rather than retrofitting existing ones. There is a lot of construction done around the world, especially in south-east and east Asia. This type of technology can be incorporated into new construction projects to offer more cost effective solutions that have a number of advantages.

There are more toilet types based on the same principle where, even in urban areas, urine can be collected in tanks for agricultural purposes. But the amount collected in urban areas would be too much to be consumed in the neigbourhood. In my Institute at Technical University of Hamburg we are working on ways to make it more concentrated. This is mainly for transportation reasons and also because the agricultural industry would rather use it in dry form. The problems around micro-pollutants have to be addressed specially for pharma residues in urine, however this is also a major problem in conventional systems with their shortcut to the drinking water taps.

Composting toilets are probably the oldest form of ecological sanitation toilets in modern times. They are mainly found in central and northern Europe. I have to say that they still have too many failures and more developmental is needed, one of the major changes will be to divert the urine and install moisture control.

And then we have the composting tank system which is still in research and development phase. It is based on the principle of flushing with very little water and having a composting tank outside the house. The is a promising idea adopted from Australia to introduce some special type of worms in such a tank to help with the decomposition and sanitization process, preliminary experiments in Hamburg where very promising (see www.ecosan.org). The greywater can be treated in different ways for re-use, especially for recharging aquifers with the additional treatment in soil passage. Membrane-biology systems can be used for densely populated city areas with very little space. The technology is available at reasonable prices now and the membrane prices are still dropping. If we want to turn the greywater into tap water (not drinking water) then we need one more step, preferably reverse osmosis. The combination of the two systems can be installed de-centrally, saving money by avoiding the often excessive costs of big central systems of supply and wastewater transport. This money can then be used for more intelligent technologies that are potentially cheaper and adaptable to local situations and water scarcity.

We must not forget the rainwater, especially in urban areas. It is one of the tasks of the engineers to get rid of the stormwater run-off. But once again we need to get it to infiltrate and refill the aquifers so that decentral water supply systems can make use of this water. Of course we must make sure that we use enough of the infiltrated water in the region, otherwise we may flood these areas. Careful survey of the geological situation and the expected waterflows is of course necessary.

To say it once more: For most of the ecosan applications the key is to keep the faecal matter apart from the greywater. I also want to repeat that more than five million people, mostly babies and small children, a year are dying from polluted water, the main reason being that our profession is still mixing faecal matter into the waters.

There are many good ecological solutions of low-tech decentral ecosan which are working very well. The interesting thing is that on the one hand there can be local economic benefits generated from the manufacturing of these units by local companies while the money can circulate within the community and then not be drawn out. On the other hand there are low operation costs of the system, and the high-tech systems do not necessarily perform better than the simple ones. In fact all ecosan systems, if implemented correctly, perform better than the large-scale central wastewater treatment plants. They may look very shiny but they do not perform a very thorough recovery and cleaning job, compared to ecosan systems.

Finally I want to show the valuable resource of sunshine in warm climate areas. This unused resource can perform dehydration in sanitation systems very well if implemented correctly: Built above ground to avoid contact of water and faeces, two chambers alternating yearly, diverting the urine and making use of it. One sad thing I have seen with some ecosan projects is that often urine is simply infiltrated into the ground, and that will contribute to problems of nitrates in the groundwater. The re-use of urine in agriculture is the key to making the loop complete, one person produces fertiliser for around 100 to 400 m^2.

So ecosan can be a dry or flush (little dilution) system. It can even be the conventional flush system upgraded by urine diversion and from an ecological point of view it is not a bad system at all. In the city of Hamburg the Hamburger Stadtentwässerung is looking at the possibility of converting the city, over 50 years, into a urine diversion system in partnership with the fertilizer industry. This would be a major step indeed.

Thank you very much for your attention. I am sure we will have a most interesting conference and hope you will discuss many creative solutions following the principles of ecosan.

The role of ecosan in achieving sustainable nutrient cycles

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Keywords

Plant nutrient flow, fertilising effects, environmental effects, hormones, pharmaceutical residues

Abstract

The present flush-and-discharge sewage system introduces a large one-way flow of excreta, containing organic matter, plant nutrients, hormones etc. from terrestrial to aquatic environments. This flow has proven to be a serious impediment to the development of a sustainable society.

End of pipe solutions (sewage treatment works) have so far not been able to make up for this impediment and will probably not be able to do so in the future either. This is shown by the continuously increasing number of problems observed due to this flow of excreta; eutrophication and algae blooms, depletion of arable fields, fish affected by endocrinal disruptions and water polluted by pharmaceutical residues.

EcoSan systems direct the excreta flow in the correct direction, closing the nutrient loop and diverting the hormones to arable land, just as previously during evolution. Furthermore, practical and resource efficient sanitation methods can be employed, since the excreta are collected in a small volume. Therefore, the hygiene standard of EcoSan systems can be higher than that of the present flush-and-discharge system. Furthermore, EcoSan systems also increase the possibility of developing practicable treatments for inactivation of pharmaceutical residues, should this be prioritised by society.

Introduction

We have not inherited this globe from our ancestors, but borrowed it from our children. It is therefore our obligation to strive towards sustainable development. This implies that the use of our two most important sources of food, water and arable soil, must be sustainable. The plant nutrients of the food must be recycled to arable fields, from where they originate. The plant nutrients must flow in closed loops, in the way they have always flowed. With closed nutrient loops, plant production can be sustainable over a very long time perspective. This is illustrated by the African savannah, where plant production has been sustainable for such a long time that the giraffe has had time to evolve its long neck to graze from the trees (Figure 1). This is real sustainability!

This is far from the situation of the present society, where nutrient flows are linear and one-way. Plants take up nutrients from arable soil. We then consume the plant nutrients in the form of food and excrete them in the form of urine and faeces. However, the excreta nutrients are currently not recycled to the fields. If a flush-and-discharge sewage system is used, they are instead flushed away. In some places of the world, the phosphorous and nitrogen in sewage are efficiently reduced before the sewage is emitted to recipient waters. In such cases, most of the phosphorous usually ends up on a landfill (Figure 2). However, in most places, sewage receives no, or very little, treatment before being emitted. The excreta nutrients fertilise algae instead crops. It is quite unavoidable that worldwide eutrophication is increasing.

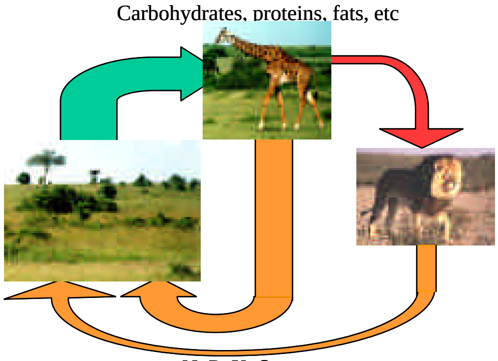

Figure 1: The nutrient loops on a savannah.

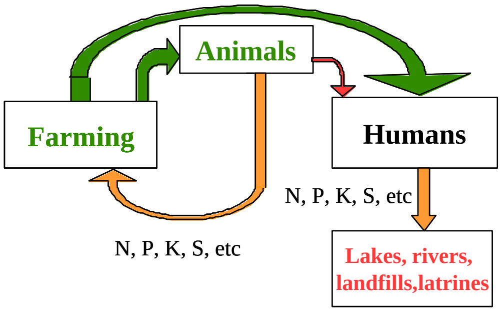

Figure 2: The linear one-way nutrient flow from fields to lakes, rivers and landfills of current human society.

At the other end of the flow, arable fields are being depleted of their nutrients, with decreasing productivity as a result. To remedy this, the fields are supplemented with chemical fertilisers when these can be afforded. Chemical fertilisers are produced by the use of fossil resources, e.g. phosphates and potassium from mines and oil and natural gas to produce plant available nitrogen. In many countries agricultural fields are supplied with doses of plant nutrients that are far larger than any that plants have been exposed to before during their evolution. Naturally, this increases the leakage of nutrients from the fields.

The ample supply of chemical fertilisers also decreases the motivation to recycle excreta nutrients to arable land. This is one factor behind the rapid spread of the conventional water-borne flush-and-discharge sewage system, introduced in Western Europe during the late 19th Century. For city populations, the introduction of the water-borne system led to improvements in health, because it rapidly removed infectious wastes from densely populated areas and because it improved the drainage of the cities. However, excreta may contain pathogens in large concentrations and the flush-and-discharge sewage system normally does not destroy these. Instead the pathogens are partly accumulated in sludge or sediment and partly flushed out with the effluent.

Excreta contain not only plant nutrients and pathogens, but also organic macro and micro substances, e.g. hormones. The flush-and-discharge sewage system drastically increases the flow of excreta, and thus of a large number of different substances, from terrestrial to aquatic environments. This has led to serious eutrophication and oxygen deficiency in the recipient waters. To remedy these negative effects, advanced sewage treatment plants were developed, including processes to remove biodegradable organic substances, nitrogen and phosphorous. However, new negative effects are continually being discovered. One example is the negative effect on aquatic wildlife caused by the female hormone oestrogen in the sewage effluent. Another example is pollution by pharmaceutical residues, which are being discovered in more and more places, even in groundwater resources used for production of drinking water.

The linear flow of excreta substances thus causes eutrophication, depletion of fields and problems with endocrine disruptors in the marine environment. Therefore, it becomes ever more evident that the linear substance flows introduced by the water-borne flush-and-discharge sewage system are major violations of ecology. The sustainable solution to this is not to improve the present end of pipe sewage treatment. It is instead to introduce a sanitation system that supports, instead of violates, the natural cyclic substance flows of nature. It is to introduce EcoSan.

EcoSan - substance flows and hygiene

Ecological Sanitation, EcoSan, is designed to support the natural cycles of plant nutrients and other natural components of excreta, e.g. hormones. When fully implemented, all excreta are returned to arable land in a hygienically and chemically safe way. Thus, the cycles of the plant nutrients contained in food are closed and the other natural constituents of excreta, e.g. natural hormones, also flow to soil, just as previously during evolution.

There is a mass balance in the human body. Excreta contain approximately the same amount of heavy metals as food and therefore there is no risk of heavy metal accumulation in soil due to these fertilisers. They are chemically safe. Of course, this assumes that infrastructure systems are well designed and do not themselves contaminate the excreta.

Pharmaceutical residues are often cited as a new and additional risk when using excreta fertilisers, i.e. in EcoSan systems. This risk has not yet been verified, as far as I know, but risk assessments are underway. Meanwhile, before these studies are reported, my guess is that it actually is the other way around. The risks associated with pharmaceutical residues in EcoSan systems are probably smaller than in the conventional flush-and-discharge system. Downstream from the sewage effluent outlet of big cities, the concentration of many pharmaceutical substances is large enough to be detectable. In some places medical residues have even been detected in the groundwater. These findings are worrying as ground and surface waters are the sources of our drinking water.

Studies have also shown that pharmaceutical compounds degrade to varying degrees in sewage treatment plants and that this degradation increases with the retention time. Since arable soil contains the same types of microorganisms as treatment plants, it is reasonable to assume that the degradation will be high, or essentially total, since the retention time in the soil is very long. However, EcoSan also offers another unique possibility of eliminating the risk of pharmaceutical residues. This possibility is due to the small volumes of excreta collected, which increases the possibility of finding practicable and resource efficient treatments that eliminate or inactivate these substances. For example, incineration of dry faeces will not only sanitise them, but also eliminate pharmaceutical residues.

In EcoSan systems the excreta are source separated, i.e. they are collected and treated in a separate system from the greywater. Since the excreta are collected, stored, treated and transported before being reused as fertilisers, it is very important for practical reasons that they are collected in a minimal volume. The volumes of the excreta themselves are quite small, that of urine being only 1-1.5 litres per person and day and that of faeces only 0.1-0.3 litre. To keep the total volume down, no or very small amounts of flushwater are used in EcoSan systems for collection of excreta.

EcoSan strives towards a sustainable society. The recycling of excreta nutrients for sustainable production of food is a requirement for this society. However, this is not enough. To be sustainable the food produced must also be safe and of high quality. This implies that, while the plant nutrients should be recycled, pathogens should not. This is a very important requirement and at least two barriers against spreading pathogens should be implemented. Several barriers are possible. One is to sanitise the excreta well, another is to handle the excreta in such a way that they do not contaminate food consumed raw. Still another is not to harvest until a long time after fertilising with excreta.

Urine diversion is a component of many EcoSan systems, mainly because urine diversion simplifies the construction of hygienic, no odour, no fly and no water toilets. Therefore, urine diversion toilets with dry collection of faeces can be built inside the house.

Urine diversion also has the additional advantages of simplifying the sanitation of the excreta and of providing two fertilisers with different properties, instead of one, which makes it possible to address the specific nutrient requirements of different crops.

Urine diversion simplifies the sanitation of excreta. This is because the faeces accounts for only a small fraction of the volume but essentially the whole hygiene risk. The small volume of the dry faeces, i.e. without urine or flushwater, makes it easier to contain them and to sanitise them. They can be sanitised already in the toilet, for example by a combination of regular addition of ash or lime and dehydration, which also decreases the risk of flies and odour. The faeces can also be sanitised upon removal from the toilet by a secondary treatment, for example digestion, composting, incineration or by addition of urea or other chemicals. Further studies and developments are needed on these sanitation methods to minimise their need of resources for meeting a specified hygiene standard. Until such studies have been carried out and hygiene guidelines developed, it is important to apply the faeces before planting/sowing, to incorporate them well and not to use them for vegetables eaten raw.

The hygiene risk associated with urine is very small compared to that with faeces. Therefore, provided that the diversion of the urine functions well, the diversion itself can be seen as a hygiene barrier. Urine should also be incorporated well into the soil, to maximise its fertilising effect. In addition, as a hygiene safety measure, until hygiene guidelines have been developed, it is recommended that crops consumed raw are not fertilised with urine closer to harvest than one month (Schönning, 2003). This also ensures that the plant nutrients have time to be taken up and utilised by the crop.

The hygiene risk associated with latrine or blackwater (urine mixed with faeces and in the case of blackwater also with flushwater) is the same as that of faeces. It is therefore important that several hygiene barriers are enforced.

Fertilising effects

Urine is a complete fertiliser that is rich in nitrogen. It can be used in the same way as a nitrogen rich liquid chemical fertiliser. For biological fertilisers, the plant availability of the urine nutrients is uniquely high. In experiments, the phosphorous effect has been as good as that of chemical fertiliser (Kirchmann & Pettersson, 1995) and the nitrogen effect has varied from around 70% to more than 100%, compared to chemical fertiliser. On average the nitrogen effect has been around 90%, after deduction of the nitrogen lost as ammonia (Figure 3; Johansson et al., 2001). In Swedish experiments, the nitrogen loss in the form of ammonia has varied from less than 1% to more than 10%. On average it has been around 5%. To keep the ammonia loss low, it is important to mix the urine into the soil as quickly as possible. The best method is probably to apply it in furrows or holes, which are then covered over immediately after application.

Faecal matter is an organic fertiliser that is rich in phosphorous, potassium and organic matter. Faeces improve soil fertility and increase the buffering capacity of the soil, especially if they have also been mixed with ash or lime. The availability of the nutrients in faeces is slower than of those in urine.

Thus, urine and faeces supplement each other well. Urine is well suited as a fertiliser for nitrogen demanding crops, like maize and spinach, while faeces are well suited as a fertiliser for crops without any large nitrogen demand, like legumes. So far, documented experiments are lacking concerning blackwater. However, since it is a mixture of urine and faeces, and urine contributes most of the nutrients, its fertilising effect should be fairly similar to that of diverted urine.

If plant nutrients are wisely used, introduction of EcoSan will lead to improved production of food. In deprived circumstances and, especially in subsistence farming, this factor can improve both health and economy. EcoSan fertilisers are well balanced complete fertilisers, as they contain the elements in the same ratios as the crops removed them from the fields. Therefore, the risk of unbalanced fertilisation is far less with EcoSan fertilisers than with chemical, which simplifies soil management and decreases the need for chemical soil analyses.

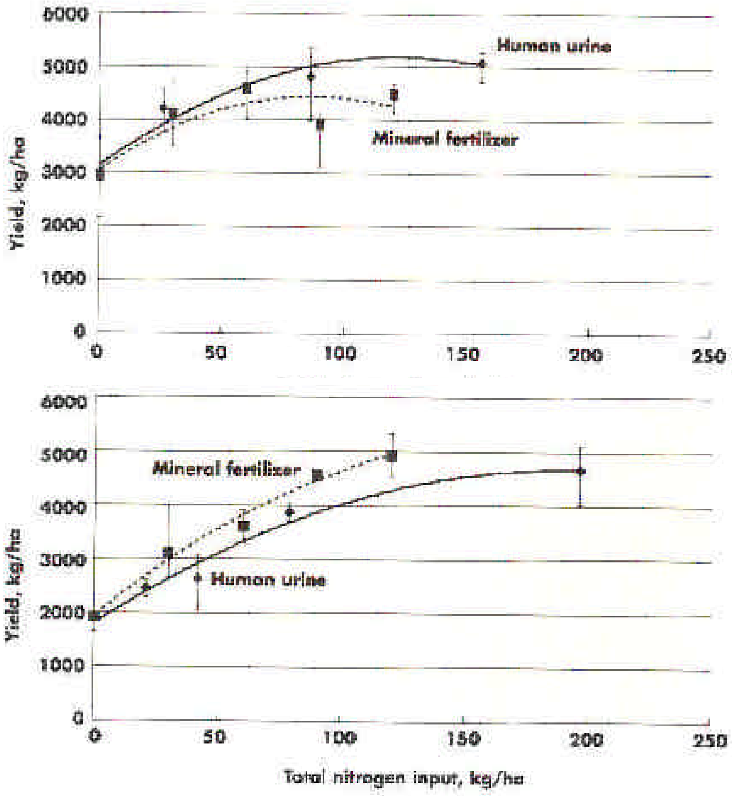

Figure 3: The effect of urine and mineral fertiliser on the yield of barley in an experiment in Sweden 1998 (upper diagram) and 1999 (lower diagram) (Johansson et al., 2001).

Environmental assessments

It is obvious that EcoSan recycles far more nutrients to arable land and emits far less nutrients to water than a conventional flush-and-discharge system, even if the conventional system contains a very effective treatment. For blackwater systems this has also been shown in a number of environmental systems analyses (Bengtsson et al., 1997; Kärrman et. al, 1999; Balmer et al., 2002). These studies also confirmed the low concentrations of heavy metals in excreta, and thus that it is a very pure and unpolluted fertiliser.

However, they also showed that the energy usage of existing blackwater systems is very high. This is due to the large energy usage both by the vacuum system used for collection and by the sanitation process, liquid composting or thermophilic digestion. One conclusion from these studies is that the development of resource efficient sanitation processes should be given the highest priority. Another conclusion is that further development of collection systems is needed, to increase their resource efficiency and decrease their use of water.

Conclusions

The present flush-and-discharge sewage system introduces a large one-way flow of excreta, containing organic matter, plant nutrients, hormones etc., from terrestrial to aquatic environments. This flow is an obstacle to a sustainable environment. End of pipe solutions (sewage treatment plants) can probably never be a sustainable remedy to this imbalance. This is indicated by the continuously increasing number of problems observed, eutrophication, depletion of arable fields, fish affected by endocrinal disruptions, water polluted by pharmaceutical residues.

EcoSan systems make the excreta flow in the natural direction, closing the nutrient loop and directing the hormones to arable land, just as previously during evolution. Since the excreta are collected in a small volume, practicable and resource efficient sanitation methods can be developed. The hygiene standard of these systems can therefore be higher than that of the present flush-and-discharge system. Furthermore, these systems also increase the possibility of developing practicable treatments for the inactivation of pharmaceutical residues, should this be prioritised by society.

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Addressing the environmental dimensions of sanitation

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Firstly, I would like to offer my compliments to the organisers of this symposium, especially to the GTZ, as well as to the governments of Sweden and Germany for their active involvement in this field and for making this symposium possible.

My first slide, a picture of a child standing inside a large wastewater discharge pipe, addresses the environmental dimensions of sanitation. It clearly shows that there is something wrong with both human and environmental health. The agreed target of Johannesburg, as mentioned earlier today, challenges the mandates of organisations, groups and professionals to put more energy into halving the proportion of people without access to sanitation by 2015, which is often seen as only being limited to household sanitation services but should be regarded in a holistic view to provide benefits for both humans and the environment.

Fortunately we do not have to act alone in this world, and many partnerships exist between different organisations. There are numerous groups operating in their own niches. Ecosan however is not simply a GTZ niche but represents more a collaboration with other partners to jointly address specific issues. I think it is the strengths of such partnerships that will make it possible to achieve the 2015 targets.

Although east and south Asia currently have the biggest problems of poor sanitation coverage we are aware that these problems are not only in Asia, but also on other continents such as Africa, South-Pacific, and South America including the Caribbean, which over the last decade were unable to keep up with their population growth. Here the numbers of the unserved population have increased over the last decade and we must pay attention to these regions. In addition to this, and often forgotten, are the problems that will be faced by the other half of the unserved population that do not receive the adequate sanitation aimed for in the Johannesburg targets. What will happen to them? And who is addressing the needs of the poorest of the poor? The poorest of the poor are quite often living in slums in poor countries with unstable economies. Poor countries where the international financing institutions tend to withdraw their support. It is one of the concerns of the United Nations Environmental Health Programme to address those issues of traditional financing mechanisms which lead to strained relations.

The rather traditional approach to sanitation; sewage treatment and discharge of wastewater requires that we look for innovative approaches to sanitation. Ecological sanitation is part of the toolbox containing these innovations. We therefore need to get the message across to the professionals and the financing institutions, and we need to strategise and professionalise the message for those we wish to reach.

It will be a time consuming process to shift from a use and discharge, to a use and re-use mindset. It will be a time consuming process to not only have household sanitation at the centre of achieving the targets of Johannesburg but also to include efforts considering the environmental dimensions of treatment and discharge of wastewater, and the re-use of nutrients as fertiliser rather than treating them as waste.

At UNEP we address issues of environmental protection, develop guidelines, key principles and knowledge bases in partnerships with other international organisations, and have a strong mandate concerning the environmental conventions currently being implemented. And I think that within the framework of these environmental conventions UNEP strategies can help to implement ecosan as one of the solutions where governments have committed themselves to address environmental issues.

It is through setting targets, and outlining the necessary measures to implement them, that environmental conventions can assist parties involved, including NGO's, communities, governments and the financial sector. It is these types of statements that are being used at a political level to address environmental dimensions in step-wise approaches. For sanitation programmes these targets should be feasible and should encourage the joint development, in a professional way, of the guidelines to implement them.

I would like to use this opportunity to mention one of the ways in which we can further our debates, as ecosan is one of the tools in addressing the environmental dimensions of sanitation, and to promote the e-mail based conference due to take place at the end of April 2003. It addresses sanitation for the health of the environment. Another conference, planned for November, on sustainable environmental technologies, is being co-organised through our offices in Japan and the International Technology Centre of Japan.

Finally, to end my presentation I would like to repeat this statement „we need to professionalise the ecosan movement". At this conference we have gathered as friends and colleagues sharing a vision, but I believe it is time to include those who do not share this vision in our discussions and work. I hope this symposium will succeed in producing such sound messages.

I wish you all a productive symposium over the coming days.

Thank you.

The UNDP's approach and activities in ecological sanitation

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Keywords

Ecological sanitation, UNDP, Millennium Development Goals

Abstract

United Nations Development Programme is the United Nation's development agency. It works with global and national counterparts on solutions to achieve the overarching goal of cutting poverty in half by 2015, one of the Millennium Development Goals (MDGs) pledged to by world leaders. UNDP activities, covering 166 countries, help countries strengthen their capacity to achieve sustainable development, seeking out and sharing best practices and providing policy advice that help the poor build sustainable livelihoods. Access to safe water and sanitation services is essential to reach the targets of the MDGs, to reduce poverty and achieve sustainable development.

Global UNDP concerns:

- Currently more than 1 billion people living in developing countries lack access to safe water supply and about 2.5 billion lack adequate sanitation.
- Modern waste management practices, such as water-based sewage where safe drinking water is used to flush away human excreta, are abusive to human well-being, economically unaffordable and environmentally unsustainable.
- Shallow ground water, which is the main source of accessible water for poor people, is increasingly becoming polluted and depleted.
- In the next two decades it is estimated that water use by humans will increase by 40% and that 17% more water will be needed to grow food for growing populations in developing countries.

UNDP priorities:

- Improve national and local capacities to manage water recourses, sanitation and water services including civil society, public and private sector,
- Support communities/households with small grants to improve water and sanitation - emphasis on ecological sanitation.
- Promote ecosystem based solutions to the management of excreta to prevent disease and protect the environment,
- Supporting and enhancing women's involvement in sanitation, water supply and water resources management.

UNDP's ecological sanitation activities are to a large extent funded by the Swedish Government and UNDP's projects are carried out in close collaboration with Sida. The basic strategy is to complement and add value to what is implemented under Swedish bilateral assistance which includes to introduce ecological sanitation to countries where Sida has no presence as well as to support the conceptual development e.g. for application in peri-urban areas.

In addition **UNDP's focus** is to:

- develop the concept and promote its application in activities of other agencies / sectors.
- explore linkages between ecological sanitation, urban agriculture, community composting etc.
- identify and address gaps in research and development (e.g. gender).
- identify opportunities, give advice, build capacity and provide funding for pilot studies and demonstration projects.
- disseminate information and knowledge - case studies, networking (Red Seco, Indian Lecture tour).

The geographic focus of UNDP's work on ecological sanitation is Latin America and Asia / Pacific. Countries benefiting from UNDP support include India, Sri Lanka, The Philippines, Vanuatu, Kyrgyzstan, Mexico, Peru, and Mozambique.

Focal point and consultant for Latin America is Ron Sawyer (http://www.laneta.apc.org/sarar),

Asia/Pacific Paul Calvert: (http://www.eco-solutions.org/).

Main UNDP publication: Closing the Loop – Ecological Sanitation and Food security, UNDP/Sida, 2001, available in English and Spanish on web site: http://www.laneta.apc.org/sarar/

More information about UNDP's work in sanitation and water: http://www.undp.org/water/

Putting ecosan on the global agenda - results from the 3rd World Water Forum, Kyoto, March 16-23, 2003

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Keywords

Ecosan, ecological sanitation, global, Millenium Development Goals, Kyoto

Abstract

The Third World Water Forum provided a major opportunity to put ecological sanitation onto the global agenda. A series of key workshop and lecture sessions were organised in collaboration with the IWA, City of Kyoto, Japan Toilets Association and the EcoSanRes Programme. A resolution on ecosan was written and agreed to by a number of organisations including multi-lateral, bi-lateral, finance institutions, national governments, etc. This represents a paradigm shift in the making where sanitation is no longer a practice of disposing human excreta in deep pits and water courses but one centred around the all-so-important relationship between humans and soil systems The 3rd WWF Ministerial Declaration and Commitments from UN agencies also referred to new opportunities where positioning of ecological sanitation will be possible. The linkage to the Millennium Development Goals was also made and details describing the roadmap ahead for the Water and Sanitation goals are described.

Ecosan at the Third World Water Forum

The Third World Water Forum was a large meeting involving many parallel sessions, plenaries and a Ministerial meeting covering virtually all aspects of water concerns from all over the planet. This is not meant as a summary or review of the 3rd WWF but merely a bridging introduction to help kick off the 2nd International Symposium on Ecological Sanitation held in Lübeck no April 7 to11, 2003. The 3rd WWF contained some 351 sessions covering 33 themes and 5 regions of the world. One of the main themes of the Forum was sanitation and ecological sanitation was given a large opportunity to show its presence. This is the main message of this paper – that ecosan was put on the global agenda at the 3rd WWF.

In collaboration with IWA, Japan Toilet Association, City of Kyoto and the EcoSanRes Programme, the following sessions dealing with ecosan were organized:

- Ecological Sanitation – Progress Being Made Around the World: What is Ecosan and what is Being Done Generally? (Uganda Ministry present)
- Ecological Sanitation – Closing the Nutrient Loop Through Ecosan in Rural and Urban Areas (Swedish Minister present)
- Affordable & Ecologically Sound Community Sanitation – New Solutions to Old Problems (IWA Head present)
- Proper Toilets for Everyone All Over the World

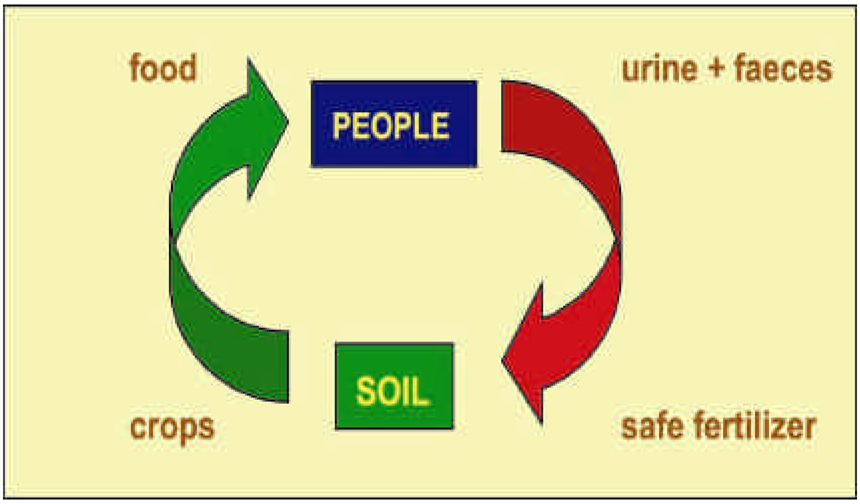
These were well-attended attracting practitioners and policy-makers and provided new insights into latest developments and the progress made thus far within the field of ecological sanitation.

The Kyoto Resolution on Ecosan

A resolution was generated and consensus achieved along the following lines:

- Ecological sanitation (ecosan) is an environment-friendly and safe approach to sanitation.
- Ecosan is holistic in that it saves water, prevents water pollution, sanitizes and recycles the nutrients and organics to restore soil and soil fertility.
- Ecosan includes low- as well as high-cost solutions for rural and urban settings. Ecosan can be more cost-effective than conventional sanitation and thereby offering a greater chance of meeting the Millennium Development Goals and the Johannesburg Commitments on Sanitation.
- Ecosan is applicable to a wide array of local physical, cultural and economic conditions providing permanent installations.
- Ecosan concepts and techniques can also be used to upgrade conventional pit latrines and flush systems.
- Ecosan is being applied successfully in many locations in Africa, Asia, Europe, the Americas, and Oceania.
- At the Kyoto 3rd WWF, ecosan emerged as a significant option in meeting the Millennium Development Goals and the Johannesburg Commitments on Sanitation and is supported *inter alia* by UNDP, UNEP, UNICEF, Water and Sanitation Programme (World Bank), EU, Government of Uganda, GTZ (Germany), Sida (Sweden), Austrian Aid, SDC (Switzerland), IWA, CREPA (West Africa), Mvula Trust (South Africa), the City of Kyoto and the Japan Toilets Association.

A new paradigm is thus in the making, whereby sanitation should be based on the relationship and dependency that people have on soil systems and should not continue the common practice of disposing of human excreta in deep pits (ground water) or water courses. This shift in thinking is depicted by the following diagram:



Ministerial Declaration

The Ministerial Declaration arising from the 3rd WWF included several statements referring to topics related to ecosan. Under the heading Safe Drinking Water and Sanitation the following was resolved:

- §16. Achieving the target established in the MDGs to halve the proportion of people without access to safe drinking water by 2015 and that established in the Plan of Implementation of the WSSD to halve the proportion of people without access to basic sanitation by 2015 requires an enormous amount of investment in water supply and sanitation. We call on each country to develop strategies to achieve these objectives. We will redouble our collective efforts to mobilize financial and technical resources, both public and private.
- §17. We will address water supply and sanitation in urban and rural areas in ways suitable for the respective local conditions and management capacities, with a view to achieving short-term improvement of water and sanitation services as well as cost-effective infrastructure investments and sound management and maintenance over time. In so doing, we will enhance poor people's access to safe drinking water and sanitation.
- §18. While basic hygiene practices starting from hand washing at the household level should be encouraged, intensified efforts should also be launched to promote technical breakthroughs, especially the development and practical applications of efficient and low-cost technologies tailored to daily life for the provision of safe drinking water and basic sanitation. We encourage studies for innovative technologies to be locally owned.

Kyoto Commitments

Several organizations announced new commitments at the 3rd WWF. The following four samples are relevant to ecosan and should be seen as opportunities:

- The **Water and Sanitation Program** (World Bank) commits itself to funding national capacity building projects for MDG monitoring. Candidate countries are welcomed to apply.
- The **WSSCC** is committed to publishing every three years a 'People's Report' that will present progress towards hygiene, sanitation and water for all. The first one is due in December 2003, and thereafter at each WASH Global Forum.
- The **United Nations Development Programme (UNDP)** commits to a Community Water Initiative, aimed at building on the power of the local community to solve water and sanitation challenges. Its aim is to provide innovative communities with small grants to expand and improve their solutions to the water and sanitation crisis. The Community Water Initiative has an estimated target budget of $50 million for 2003-2008.
- **UN-HABITAT** signed a memorandum of understanding with the Asian Development Bank (ADB) to create a programme to build the capacity of Asian cities to secure and manage pro-poor investments and to help the region meet the Millennium Development Goals (MDG) of halving, by 2015, the proportion of people without safe drinking water and basic sanitation. The programme will cover a pipeline of US$10 million in grants from ADB and UN-HABITAT for the first two phases and US$500 million in ADB loans for water and sanitation projects in cities across Asia over the next five years. Additional funding for Water for Asian Cities has also been made available to UN-HABITAT by the Government of Netherlands.

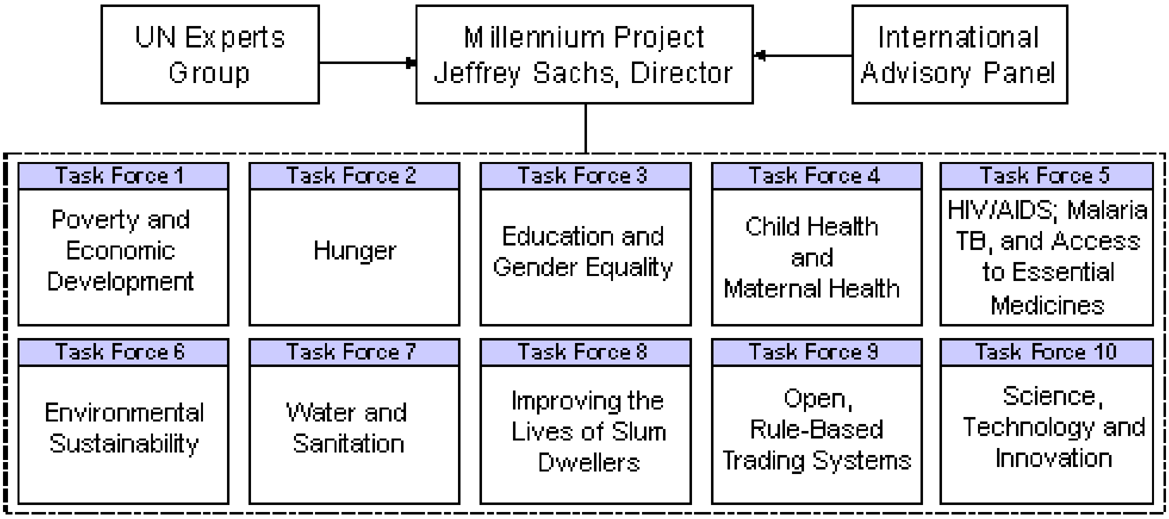
The UN Strategy for the Millennium Development Goals

The UN MDG strategy is also relevant in providing opportunities for ecosan development. The following are the four main features of the MDG process:

- The Millennium Project, which analyses policy options and will develop a plan of implementation for achieving the Millennium Development Goals. Headed by Jeffrey Sachs, Columbia University.

- The Millennium Campaign, which mobilizes political support for the Millennium Declaration among developed and developing countries. This is led by Evelyn Herfkens, the Secretary-General's Executive Coordinator for the MDG Campaign.
- Country-level monitoring of progress towards achieving the Millennium Development Goals, led by the UN Development Group.
- Operational country-level activities, coordinated across agencies through the UN Development Group, which help individual countries implement policies necessary for achieving the Millennium Development Goals.

A battery of Task Forces have been set up one of which deals with the issues of water and sanitation:



The MDG timeline is as follows:

- **Late-2002.** Completion of background papers, which map out the planned research work of each Task Force.
- **Mid-2003.** Publication of the Human Development Report 2003, which will focus on the Millennium Development Goals and draw upon research contributed by the Millennium Project Task Forces.
- **Mid-2004.** Presentation of the Millennium Project Interim Report to the UN Secretary-General and the UNDP Administrator.
- **June 30, 2005.** Presentation of final recommendations by the Millennium Project to the UN Secretary-General.

The Water and Sanitation Task Force includes the following representatives:

- *Coordinators*: Roberto Lenton (Columbia University and GWP) and Albert Wright (Africa Water Task Force, GWP, World Bank)
- Ingvar Andersson Senior Water Advisor, (UNDP)
- Michel Camdessus, Chair, Panel on Water Infrastructure Financing
- Margaret Catley-Carlson, Chair, lobal Water Partnership
- Ivan Cheret, Suez Lyonnaise des Eaux

- Kamla Chowdry, Vikram Sarabhai Foundation (VSF), India
- William Cosgrove, Vice President, World Water Council
- Manuel Dengo, Chief, Natural Resources, United Nations Department of Economic and Social Affairs (DESA)
- Halifa Drammeh, Deputy Director, Division for Policy Development and Law, United Nations Environment Programme (UNEP)
- Gourisankar Ghosh, Executive Director, WSSCC
- Richard Jolly, Emeritus Fellow, Institute of Development Studies, University of Sussex
- Torkil Jonch-Clausen, Chairman, GWP-TAC
- Mike Muller, Director General, South Africa Department of Water Affairs
- Kalyan Ray, Chief, Water, Sanitation and Infrastructure Branch, United Nations Human Settlements Programme (UN-Habitat)
- Frank Rijsberman, Director General, International Water Management Institute
- Jamal Saghir, Director, Energy and Water, The World Bank
- David Seckler, Former Director General, International Irrigation Management Institute
- Andras Sollosi-Nagy, Deputy, Assistant Director-General, Science Sector Director, Division of Water Sciences, (UNESCO)
- Vanessa Tobin, Chief, Water, Environment and Sanitation, United Nations Children's Fund (UNICEF)
- Gordon Young, Coordinator, World Water Assessment Program

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Session A

Progress, policies and legislation

Chairpersons

Ingvar Andersson (UNDP, USA)

Xiangjun Yao (Ministry of Agriculture, China)

Lectures

The EU water initiative, its research component and ecosan
Zissimos Vergos (European Commission, Belgium)

The BMBF programme "decentralised (alternative) water systems" - international projects
Rüdiger Furrer (Research Center Karlsruhe, Project Agency for Water Technology and Waste Management, Germany)

Demand on and difficulties for implementation of ecosan concepts in China
Jiang Zhang (Institute for Sustainable Technology, Zhejiang University, China), *Jun Chen*

New legislation for on-site sanitation in Finland*
Harri Mattila (Häme Polytechnic, Environmental Engineering, Finland)

Key-activities, services and current pilot projects of the international ecosan programme of GTZ*
Christine Werner, Heinz-Peter Mang, Ve Kessen (GTZ, Germany)

EcoSanRes - a Swedish international ecosan-programme
Arno Rosemarin (Stockholm Environment Institute, Sweden)

Guidelines for the implementation of the Bellagio Principles and the household centred environmental sanitation approach (HCES) *
Roland Schertenleib, Antoine Morel, (EAWAG/ SANDEC, Switzerland), *John Kalbermatten, Darren Saywell*.

Tentative guidelines for agricultural use of urine and faeces*
Björn Vinnerås, Håkan Jönsson (Swedish University of Agricultural Sciences, Sweden), *Eva Salomon, Anna Richert-Stinzting*

Oral poster presentations

Ecosan - clean production mechanism under the Kyoto-protocol
Gert de Bruijne, Nadine Dulac (WASTE, Netherlands)

Rainwater harvesting, water re-utilisation and ecological sanitation - further developments
Dietmar Sperfeld, Erwin Nolde (Fachvereinigung Betriebs- und Regenwassernutzung e.V., Germany)

This paper has been peer reviewed by the symposium scientific committee

The EU water initiative, its research component and ecosan

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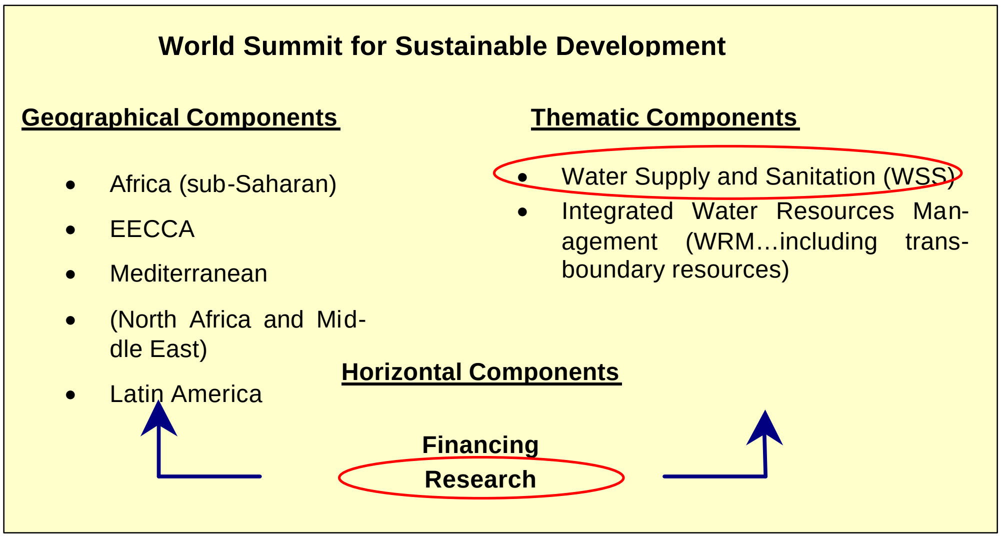
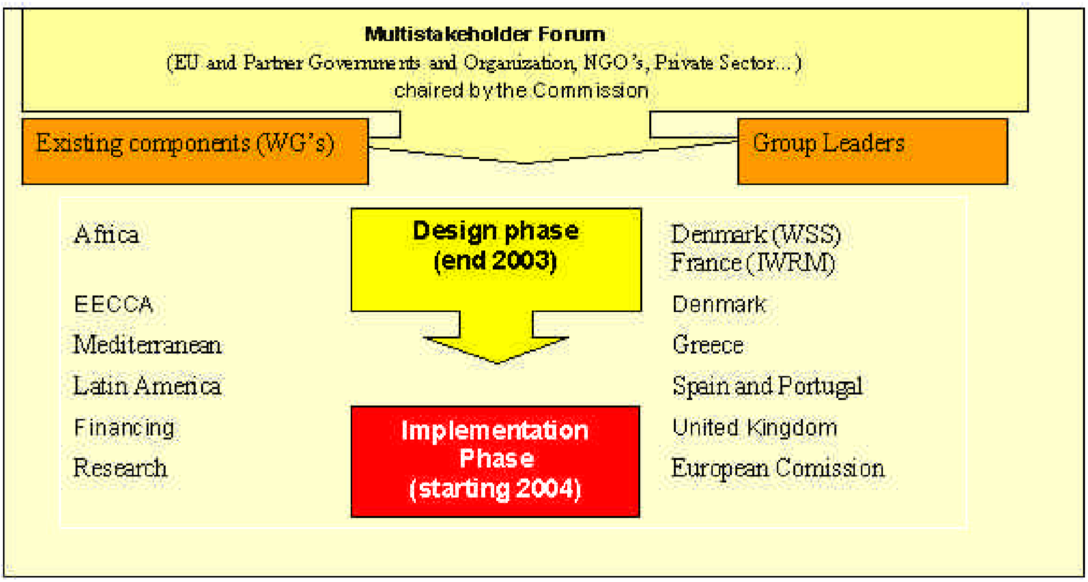
Session A

EU water initiative - A quick overview



EU water initiative – organization



EU water initiative - research component: aims and expected contribution to the water initiative

- Co-ordination, coherence and complementarities of European efforts
- Higher impact, critical mass and strategic partnerships
- Support and Feedback for policy formulation and integrated water research approaches
- Awareness, proactive participation, human resources and better knowledge and innovation management in developing countries
- Integration and operational feedback between development co-operation and research

EU water initiative - research component: the mapping of European efforts

- Policy frameworks
- Major Organisations and Institutions
- Strategic Approaches
- Problems and best practices
- Targeted Water Research areas
- Beneficiary regions/countries

EU water initiative - research component
Preliminary conclusions from mapping exercise

- High profile of international water research at EU Member States and Community level
- Significant efforts taking place = systematic analysis is needed for capitalising on lessons and best practices
- Added-value, critical mass and higher impact can be derived from better co-ordination
- Diversity of strategic approaches of international co-operation in water research
- More integrated approaches are needed to tackle existing problems
- Planning should be demand orientated, based on stakeholders analysis and public participation
- Additional efforts shall be put into better streamlining and integration of water research in development co-operation efforts

EU water initiative - research component
The way forward

- Finalise mapping, assessment and dissemination of results and feed back from concerned stakeholders
- Operational links with the other Working Groups, promotion of strategic partnerships and integration with development co-operation programmes
- Identify target regions and thematic areas (pilot integrated water research activities)

- Intensify dissemination of Public Information and Awareness to institutions and stakeholders in European and Partner countries

International research co-operation
6th research framework programme (2002-2006)

Potential interfaces for ecological sanitation
Specific measures in support of international co-operation (INCO)

Developing Countries - Rational Use of Natural Resources

- Humid and semi-humid ecosystems (call 2003)
  - Ecosystem dynamics and use of renewable natural resources.
  - Integrated approach to natural and agro-resource use systems.
- Multiple Demands on Coastal Zones (call 2003)
- Food Security (future call)
- Arid and Semi-Arid Ecosystems (future call)

Mediterranean - Integrated Management of Limited Water Resources

- Policy for Integrated Water Planning (call 2003)
- Improving Water Consumption (call 2003)
  - Non-conventional water resources.

- Fertilisation and Plant Nutrition.
- Advanced Water Treatment, re-use and energy implications (call 2003)
  - Efficient use of treated water and multiple uses of water resources for a variety of uses.
  - Institutional and legal mechanisms for water purification and reuse

Potential interfaces for ecological sanitation
Specific measures in support of international co-operation (INCO)

Western Balkans - Environment (calls 2003)

- Development of waste water treatment and reuse technologies (including agricultural water use)
- Innovative cost-effective techniques for the efficient treatment of industrial and municipal waste and the use of recycled materials through bio-depuration and composting.

Russia and other NIS (EECCA) - Environment and Health Protection

- Stabilisation of research and development potential, changes in the industrial production system, environment and health protection and related safety aspects.

Potential interfaces for ecological sanitation

Thematic priority 6: Sustainable Development, Global Change and Ecosystems

Sub-priority: Global Change and Ecosystems

- Integrated water management at river basin level, African and EECCA countries
  - Twinning European/Third Countries river basins (call 2003)
  - Methodologies of IWRM and Transboundary Issues (IP or NoE - call 2004)
- Integrated urban water management, problems of African, Asian and South American mega-cities and peri-urban areas
  - Wastewater reuse (call 2004)
  - Integrated Urban Water Management (IP or NoE - future calls)
  - Strategies, technologies and Management Practices for Drinking Water supply (future calls)

Potential interfaces for ecological sanitation

Thematic priority 6: Sustainable Development, Global Change and Ecosystems

Sub-priority: Global Change and Ecosystems

- Management of water under scarcity, focussed on South Mediterranean countries
  - Technologies for monitoring and mitigating the impact of water scarcity (call 2003)
  - New approaches to water stress (IP or NoE - call 2004)
- Development of scenarios of water demand and availability at 25-50 years, with focus on South and East Mediterranean and EECCA countries
  - Water Scenarios for Europe and neighbouring countries (IP or NoE - call 2004)

Session A

Potential interfaces for ecological sanitation

Potential Interfaces for Ecological Sanitation
Community Development Co-operation-Water Sector

Regrouping different kinds of activities, in which water is central or in which water-related investments are important, into four 'Focus Areas'
Addressing functions rather than technical aspects in isolation

Cross-cutting focus area

- ✓ **Water resources assessment and planning (WARP)**

Three specific societal functions

- ✓ **Basic water supply and sanitation services (BWSS)**
- ✓ **Municipal water and wastewater services (MWWS)**
- ✓ **Agricultural water use and management (AWUM)**

Local Participation & Ownership
Decentralised & Community based management
NGOs
Appropriate Technology
Public & Private Sector

Research work related to ecological sanitation
5th research framework programme

In Europe and Third Countries

- Water Conservation and Water Saving
- Wastewater treatment, recycling and re-use in agriculture
- Economic, social and environmental sustainability
- Water Contamination and Pollution Control
- Cost-Effective Reclamation Technologies for domestic wastewater
- Groundwater and Soil Interactions
- Public Health, Sanitation and Hygiene
- Cost-effective rehabilitation of water supply and sewer networks
- Private sector involvement in water supply and sanitation

Member states - international research - focal points

Austria: Federal Ministry of Finance and BOKU - University of Natural Resources and Applied Life Sciences, Vienna - Austrian Development Co-operation.

Belgium: Directorate General for International Co-operation in the Ministry of Foreign Affairs

Denmark: Development Research Department in the Danish International Development Agency (DANIDA)

Finland: Department for International Development Co-operation in the Ministry for Foreign Affairs

France: Ministry for Foreign Affairs and the Commission pour la Recherché Agronomique Internationale (CRAI).

Germany: Federal Ministry for Economic Cooperation and Development (BMZ) and Federal Ministry of Education and Research (BMBF)

Greece: Ministry and Mediterranean Information Office for Environment, Culture and Sustainable Development (GWP-MED)

Ireland: Development Co-operation Division (Ireland Aid) in the Department of Foreign Affairs.

Italy: Directorate General for Development Co-operation in the Ministry of Foreign Affairs and guided by the Instituto Agronomico per l'Oltremare

Luxembourg: Ministry of Finance

The Netherlands: Directorate General for International Co-operation in the Ministry of Foreign Affairs

Portugal: Office for International Relations in Science and Higher Education

Spain: Ministry of Science and Technology and Spanish International Co-operation

Sweden: Department for Research Co-operation (SAREC) in the Swedish International Development Agency (SIDA)

The United Kingdom: Department for International Development

Some concluding remarks

- Ecological Sanitation is a **concept perfectly in line with the sustainable development perspective and major orientations of the Community Research Framework Programmes** in the water and sanitation sector.
- The **EU Water Initiative** includes sanitation as one of its focal areas providing a fertile ground for extending **environmental sanitation into ecological sanitation** in developing countries.
- Existing **strategic partnerships and field work in ecosan are of particular relevance to the EU Water Initiative**, and vice versa, and **effective linkages shall be established.**

The BMBF programme “decentralized (alternative) water systems” - international projects

Rüdiger Furrer

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Introduction

The projects funded by the BMBF/PTWT+E concerning decentralized (alternative) water systems are based on an announcement in the “Bundesgesetzblatt” (Federal Law Gazette) of June 27, 2001.

All the drafts (112 in total) were surveyed on behalf of the BMBF by an external committee consisting of experts in water management, associations, universities, and members of industry. The announcement itself was made in accordance with the BMZ/GTZ project “ecosan”. The levels of international development, technical feasibility, and administrative requirements were compiled from two studies carried out by the University of Witten-Herdecke and the University of Munich.

Especially with the international projects, we wish to contribute to a more conscious and sustainable use of water, a resource that cannot be replaced. Accordingly, these projects contribute to the ambitious aims of the Sustainability Summit of Johannesburg, which was to halve, by the year 2015, the proportion of people who are unable to reach or afford safe drinking water and do not have access to basic sanitation.

The BMBF research program is mainly designed to combine and to improve existing components. Apart from the reduction of the drinking water consumption key aspects are to decouple materials and water flows such that recovery of nutrients and energy will be possible and economically efficient.

Subjects of investigation are: Anaerobic waste water treatment, membrane filtration, processes close to nature, reuse of gray water and rainwater, separation vacuum and compost toilets, winning of biogas and decentralized power stations, production of compost and fertilizers, economic, sociocultural, and legal aspects.

Concerning the implementation and dissemination of the research results an adequate contribution from German private companies as well as from the foreign partners is required. (The system of project funding does not allow a direct funding of foreign partners.)

Current projects: Vietnam - (Dr. Clemens - University of Bonn)

Topic:

Closing of agricultural nutrient cycles via hygienically harmless substrates from decentralized water systems in the Mekong delta

University of Bonn:

working group materials flows — Dr. J. Clemens

working group hygiene	Dr. Th. Kistemann
working group sociology	Prof. Dr. Th. Kutsch
working group agricultural ecology	Prof. Dr. M. Becker
working group agricultural water management	Prof. Dr. A. Rieser
University of Bochum:	
working group drinking water	Prof. Dr. H. Stolpe
University of Can Tho	Prof. Le Quang Minh

Level of knowledge:

About 17 million people are living in the Mekong delta (40,000 km²). The population density is twice as high as in Germany. The delta is mainly used for the growing of rice, vegetables, and fish farming. Less than 50 % of the total population has access to fresh water, in rural areas less than 10 %. Instead of drinking water, people use collected rainwater (pathogenic germs) or water from uncontrolled wells (chemicals for use in agriculture, seawater intrusion)

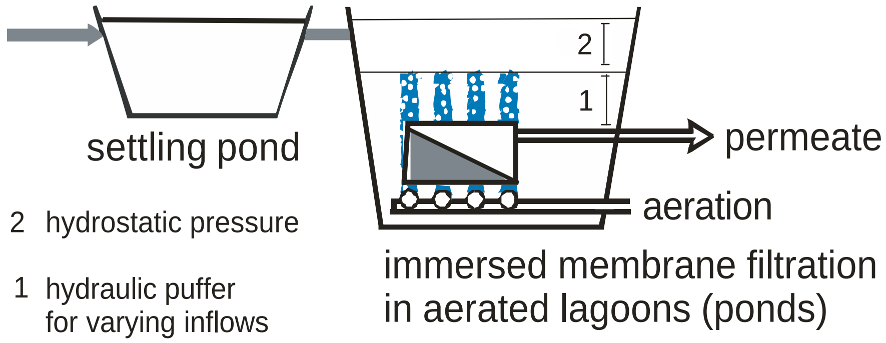

Figure 1: Sketch of the pilot plant

Main activities:

In the first part of this project the soils, groundwater, water and materials flows, and the agricultural use of two different areas in the Mekong delta will be studied in detail.

The varying demands of soils for fertilizer/sludge or humus/compost will form the basis on which the most suitable waste water concept will be worked out.

Concerning drinking water, the disinfection with soil filtration, solar energy and the sustainable abstraction of groundwater will be examined.

Comment on project funding:

The Mekong delta is considered typical for many territories of South Asia:

- alternation between flood and demand for irrigation
- pollution of the raw waters (groundwater, surface water)
- rural areas which are intensively used for agriculture

Construction and maintenance of drinking water treatment and waste water treatment plants are expensive, especially in areas with low average income. The idea of this project is to adapt the waste water treatment system directly to the demands of agriculture. This will increase the consumer acceptance and decrease the costs of the maintenance.

Egypt (Prof. Hegemann - Technical University of Berlin)

Topic:

Improvement of the effluent quality of aerated lagoons (ponds) by membrane filtration

Institute for Technical Pollution Control — Prof. W. Hegemann

National Research Center — Prof. Abdel Shafy

Level of knowledge:

Lagoons are widely spread because of the simple and cost-saving construction and maintenance. However, the rate of degradation and the retention of bacteria and germs are limited compared to activated sludge plants. Strictly speaking, direct use of the effluents for irrigation purposes is not possible.

Main activities:

A pilot plant will be constructed and transferred to an existing waste water treatment plant in a village near Cairo. The pilot plant will serve for about 500 population equivalents.

The device will be optimized to reduce water evaporation, to increase retention of pathogenic germs, the operation safety, and to reduce the costs of maintenance.

After membrane filtration, the treated waste water is intended to be reused for irrigation or as industrial process water.

For applications in Germany or Eastern Europe, where lagoons are frequently met, operation conditions for N- and P-removal will be studied. The treated waste waters should then be discharged into receiving water bodies or infiltrated into the ground.

Comment on project funding:

In the case of success, this project will contribute to the improvement of existing simple waste water treatment plants. It is designed to save rare drinking water resources and reduce the costs for fertilizers. Egypt was chosen as location as it is considered typical for all semi-arid climates.

The operation conditions with N- und P-removal will allow to optimize existing lagoons (ponds) in Germany and Eastern Europe, respectively.

Turkey (Dr. Theilen - AT-Association)

Topic:

MODULAARE - Integrated modules for high-efficient waste water treatment, waste treatment and recovery of energy in tourism resorts

partners:

AT association — Dr. U. Theilen

University of Stuttgart

Department of Waste Water Technology — D. Steinbach

Department of Municipal Solid Waste Management — Mrs. A. Schultheis

Iberotel Sarigerme Park (TUI) — Heinz H. Fugger

Level of knowledge:

The materials flows in (tourist) hotels are extremely high:

waste/hotel	up to 2.5 kg/guest day
average/Germany:	about 0.5 kg/inhabitant day
drinking water consumption/Hotel	up to 1.200 L/guest day
average/Germany:	< 130 l/inhabitant day

Proper recycling management is generally not applied in hotels or tourist resorts.

Sarigerme Park Hotel situated on the Turkish Aegean coast about 372 beds and was selected for the following reasons:

- there is sufficient place for pilot plants
- the hotel provides the necessary technical equipment to support the research program.
- the hotel is connected to a municipal waste water treatment plant. In the case of operation troubles or reconstruction measures there will not occur any problems.
- the hotel has been granted different environmental awards and was certified according to DIN EN ISO 14001. This shows the commitment of the hotel management to a sustainable tourism.

Main activities:

A large closed-loop recycling waste water and solid waste is intended to be achieved by the activated membrane reactor the fermentation module.

The membrane module will produce industrial process water. Its suitability for irrigation, fertilization, and the hotel laundry will be investigated.

Cut grass, kitchen garbage and the surplus sludge will be treated in the fermentation reactor. This module will be optimized in terms of amount of produced biogas, quality of compost, and pre-treatment of the input materials.

A concept to make use of the biogas (i.e. decentralized power station) will not be realized at the moment.

Comment on project funding:

Since the tourism industry is an important economic factor in Germany, we are particularly responsible for supporting sustainable tourism. In a lot of touristic areas the situation is quite similar.

Due to the modular concept, an adaptation to various places and climatic zones seems to be easily realizable.

Brazil (Dr. Sternad - Fraunhofer Gesellschaft, Institute for Interfacial Engineering and Biotechnology)

Topic:

Decentralized water supply and waste water treatment combined with recovery of nutrients and energy under consideration of hygienic aspects for Piracicaba

Partner

Universidade Metodista de Piracicaba A. Nascimento

Level of knowledge:

Only 9.6 % of all South American bigger cities (> 50,000 inhabitants) treat their waste waters. In the city of Piracicaba (320,000 inhabitants) about 35 % of the waste waters are treated in 45 usually smaller treatment plants. The waste water is frequently treated in open ponds, so that the dengue fever and other tropical diseases have spread.

Solid waste is deposited on unsuitable dumps, no recycling has been applied up to now.

Main activities:

Waste Water:
Improvement of waste water treatment in Piracicaba.
- A study will be carried out regarding the optimization of existing treatment plants. They will be evaluated concerning the production of biogas, production of N-, P-fertilizers, disinfection of the effluents.
Most of the existing waste water treatment plants start with an anaerobic stage. (target: optimization of the anaerobic reactor.)
Most of the plants apply an aerobic reactor as second step. At the biggest waste water treatment plant (Piracicamirim) it is intended to install a closed pilot reactor developed in Germany.
Waste:
- A concept for the separation, recycling of waste, and production of biogas will be worked out. A pilot plant for the production of biogas will be constructed on the campus.

Comment on project funding:

The city of Piracicaba is considered a promising location in Latin America. The region has a good reputation regarding its commitment to environmental protection. The first environmental associations were founded in Piracicaba. So we are looking forward to finding highly motivated local authorities.

The concept developed by FhG strongly considers the local infrastructure which is characterized by a lot of small (decentralized!) plants, no space for enlargement, and frequently the above mentioned two-stage construction.

With the help of two pilot plants it is intended to show an economically efficient way to improve existing plants.

Ghana (Dr. Geller - Ingenieurökologische Vereinigung e.V.)

Topic:

Ecological recycling management at the Valley View University in Accra

Partners:

Bauhaus University of Weimar/ecological engineering	Prof. Dr. D. Glücklich
University of Hohenheim/Tropics center	Prof. Dr. J. Sauerborn
Valley View University	Dr. S. Laryea

Level of knowledge:

- biggest private university of Ghana (about 710 students, 50 lecturers/administration)
- water supply is mainly managed by trucks because of the inefficient public supply
- no utilization of rainwater or water-saving technologies
- old-fashioned waste water treatment
- the university will be enlarged (2005: about 1300 students)

Main activities:

- The present concept for the enlargement of the university will be extended to an ecological master plan (subjects: urban development, transport; energy, water, and waste; social and cultural activities).
- Reconstruction of a building with water saving toilets, construction of a new building with water saving toilets, compost toilets, and utilization of gray water.
- Storage of rainwater in a cistern for irrigation
- Recycling of biowaste, compost, urine, in agriculture, production of biogas.

Comment on project funding:

This project addresses to a target group that is highly interested in new technologies. We expect this to be of great advantage to the implementation of the joint research results, because the graduates of the university will spread their acquired knowledge to their home countries.

It will be interesting to study the social acceptance and the technical advantages or disadvantages of different techniques (water-saving toilets, compost toilets etc.) applied at the same place.

The results of this cooperation will be incorporated into a new study course called "Community and International Development Studies" at the Valley View University.

Projects in preparation

Four more projects are in preparation, which are briefly introduced in the following:

China:

This project is designed for rapidly growing urban areas. The most effective size of waste and waste water treatment plants will be determined regarding the recovery of energy and raw materials.

Algeria:

Waste water without or with little pretreatment will be reused to irrigate municipal areas to improve the air quality of the city of Algiers (i.e. along the main roads). The waste water will be taken directly from the sewer system. (GTZ cooperation).

China/Tanzania:

A new concept to obtain drinking water from the humidity of the air will be studied. The problem of the energy need will be solved by the exchange of radiation with the atmosphere.

South Africa:

Construction of a so-called "water house" designed for all water-related activities to improve the hygienic conditions in villages of developing countries.

Demand on and difficulties for implementation of ecosan concepts in China

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Jun Chen Zheda - Zhejiang University Enterprise Group

Session A

Urbanisation and water pollution in China

The delayed family planning policy has resulted in a continuous population increase over one hundred years, and the social and economic development results in urbanisation. China is undergoing a precedent-less quick urbanisation process.

Summarizing various data sources the urbanisation in China can be reflected in the following figures.

Year	1980	1995	2010
Urbanisation grade	19.39%	28.85%	Ca. 40 %
Urbanised population	191 mio.	352 mio.	Ca. 520 mio.
Cities	223 cities	640 cities	?

Table 1: Urbanisation in China

Uncontrolled exaction of groundwater resulted in significant decline of groundwater level. Municipal and industrial wastewater as well as runoff from farmland pollute the insufficiently available water resource. The shortage of clean water has become to an essential limiting factor for the social and economical development.

Currently in more than 70 % of the Chinese cities the clean water resource is scare. Most Chinese lakes in and near cities are overloaded by nutrients phosphor and nitrogen.

According to the official source the treatment rate of the wastewater in China nowadays is only 7 %. At the same time the urbanisation speed is 8.3 % with an increasing trend.

Analysis of the countermeasures currently being implemented in China

In order to solve the problems China is undertaking the following measures in the field of urban construction:

1. Increasing the wastewater treatment rate with conventional European sanitation concept and centralised wastewater plants
2. Increasing reuse rate of effluents from the centralised wastewater treatment plants
3. South-water to northern projects

These measures are analysed and evaluated based on concrete examples. The results reveal the following problems:

1. According to both Chinese and European experiences the water pollution problem, particularly eutrophication problems in Chinese lakes cannot be sufficiently solved by the central-

ised wastewater plants, because of the very limited dilution possibilities and the huge difference between the nutrients concentration in effluents of wastewater plants and the requirement for surface water bodies.

2. Case studies showed that the possibility of reutilisation of effluents of wastewater plants is very limited in the praxis.
3. "South-Water to northern" can improve the water quantity situation in the northern cities but not the water quality situation. On another side, comparing the precipitation in northern Chinese cities with some European cities, for example with Berlin, it can be concluded that many northern cities are not absolutely water-"poor". A comprehensive water management including rainwater harvesting is much more necessary.
4. Ecological sanitation and source control of wastewater (Otterpohl, 2000 etc.) can be regarded as very sustainable solutions for Chinese urban areas, particularly for construction of the new settlement areas and sanitation of old downtowns.

Comparison of south control measures with traditional sanitation concepts with preliminary model analysis

One of the typical pattern of urbanisation in China is the development of suburban area to urban area. A preliminary model analysis has been made for a new settlement with a total area of 10 km² and a projected population of 100,000.

The water consumption is divided into: drinking water, kitchen and shower water, washing water, toilette flushing water, water use in summer for green areas/facilities, road and street cleansing, water demand for scenery water bodies for compensation of evaporation loss, water used for construction, car washing etc.

Alternatives for water supply and treatment are compared with each other with cost estimates. The result shows the advantage of the source control concepts in ecological and economic terms.

Implementation conditions

The acceptance in Chinese circles, particularly politicians for such as source control measures in urban construction is still very low. Reasons are many. One of the typical questions is that "we are learning European well proved experiences and concepts, these are centralised plants with thick pipelines".

Current regulations and financing systems in China for urban construction are analysed, suggestions for research and development works as well as possibilities for application of ecosan concepts are made.

References

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New legislation for on-site sanitation in Finland*

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Keywords

Legislation, on-site sanitation, wastewater management

Abstract

Decentralised sanitation is very prominent in Finland at the moment. New legislation has caused and will cause further, number of changes in existing practices. These changes will cost billions of euros over the coming years.

The magnitude and speed of the development in the sector of decentralised sanitation is causing much confusion among authorities, manufacturers and other entrepreneurs and house owners.

Municipal authorities should now take a firm hold of the new tools (laws, decrees, municipal ordinances, etc.) and start requiring an improved standard of wastewater treatment also in rural areas. If they are not strict enough, they might lose the power of the new tools. It is easier to loosen one's grip in the future (if necessary) than to tighten it.

Workable solutions will require totally new thinking as regards services. There will be new types of companies, co-operatives and entrepreneurs producing wastewater services.

Composting toilets should be promoted more forcefully as an alternative in the process of selecting proper sanitation management. But the reputation of dry toilets must first be improved. We all have mental pictures of old earth toilets that were cold, dark, smelly and had flies. That is why dry toilets are not very much appreciated in Finland today.

The need for on-site sanitation in Finland

The Finns have loaded their watercourses relatively heavily with different pollutants during the past decades. From about 1950 onwards, industrial development began, and the pulp and paper industry polluted badly certain rivers and lakes. At the same time, cities grew and the expansion of water distribution networks resulted in an extra load of wastewater on the same receiving waters. The use of artificial fertilisers in agriculture and forestry and subsequent leaching and runoffs into receiving waters has also increased. All these causes of pollution are now controlled to some extent. (Mattila, 2001)

Successive governments have supported rural areas in constructing drinking water supplies up to now, but wastewater treatment has been largely neglected. Now developers are working to keep the countryside alive, by trying to slow down migration from rural areas to cities. That is why farmers are supported in their efforts to process their products locally. And that is why there are projects aiming to improve the standard of the summer cottages to make them suitable for year-round living. The downside of these activities is that they increase the wastewater load on the watercourses[LHL1].

*This paper has been peer reviewed by the symposium scientific committee

Wastewater treatment by industry, cities, and even villages, developed rapidly from the late 1960s to the early 1980s (see Figure 1). Today, diffuse pollution is the major concern in water protection. Watercourses downstream of big cities and industries are improving, but other waters are in danger of becoming contaminated, because they are receiving more nutrients, solids and even bacteria, than they can tolerate.

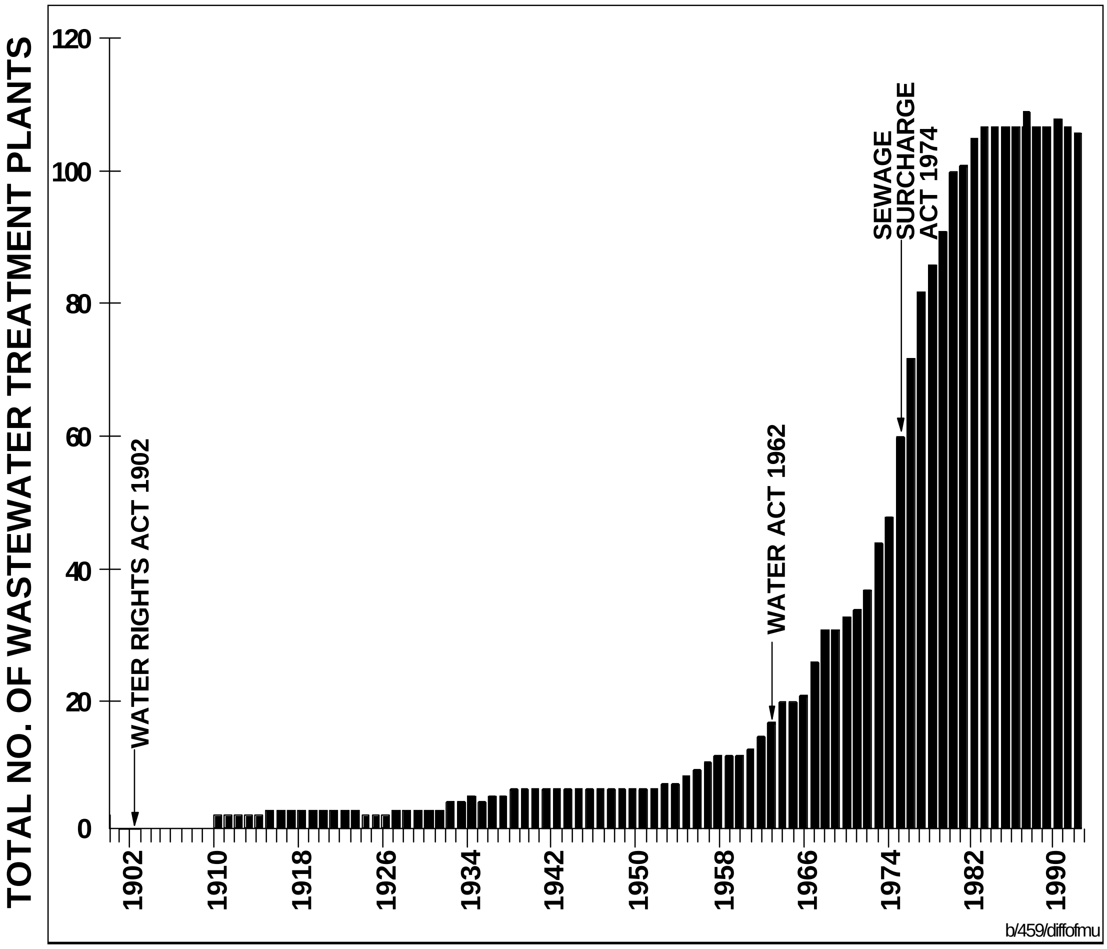

Figure 1: Number of wastewater treatment plants in cities in Finland (1900–1993) (Katko and Lehtonen 1999).

Because of the major sources of pollution mentioned above, the wastewater load from individual households outside of sewer networks has so far been neglected. Even the Finnish Water Act has become outdated in this regard. Until February 2000, it was only acceptable to treat wastewater in septic tanks. Yet, it is known that even properly working septic tanks can only remove a maximum of 70% of the solid matter in wastewater (Mäkinen 1983; Santala 1990). Dissolved impurities flow freely into the environment, often directly into a ditch or a river.

National targets for water protection in Finland until 2005 were set in 1998. The targets for scattered settlements are ambitious. The BOD load should be reduced by 60% and the phosphorus load by 30% (Ministry of the Environment 1999).

There is also a real need of on-site sanitation in Finland for technical and economical reasons. With a population density of about 17.3 /km^2 for the whole country and only about 11.7 /km^2 outside of the capital area, it is clear that the centralised systems would be either too complicated, too expensive, or both in many areas.

The changed on-site sanitation legislation

The **Environmental Protection Act** was amended on 1 March 2000 to meet the targets for 2005. The new act states that wastewater in rural areas must be treated to the extent that it cannot have a negative impact on the environment. The treatment technology, or even the methodology, is not specified in the law, but municipalities are given the right to issue local ordinances on these matters based on local circumstances. On the other hand, municipalities are also responsible for controlling the quality of wastewater treatment in their areas.

The Environmental Protection Act also has some other important sections dealing with on-site sanitation.

The general principles of the Environmental Protection Act are:

- environmental damages must be prevented beforehand
- environmental damages must be minimised
- people must exercise caution in their actions
- BAT (Best Available Technology) must be applied
- BEP (Best Environmental Practices) must be applied
- the one causing environmental damages must also pay for the rehabilitation.

The Environmental Protection Act gives the Ministry of the Environment the right to issue a decree on wastewater treatment in rural areas. Such a decree was ratified on the 11th of June 2003 and it will come into force on the 1st of January 2004.

According to the decree (Committee of Ministry of the Environment 2001):

- Wastewater must be treated so that
  - BOD load is diminished by 90 %,
  - total phosphorous content by 85 % and
  - total nitrogen content by 40 %.

  The measured effluent quality will be compared with the so-called house-specific wastewater load. It can be calculated by multiplying the number of occupants of a house by the average wastewater load per person and day which is equivalent to 50 g of BOD_7 and 2.2 g of total phosphorous plus 14 g of total nitrogen.
- A municipality can lower the percentages to 80 % (BOD), 70 % (P) and 30 % (N) in an area which is not very sensible as to environmental damages.
- Each and every household without a sewer connection must have a written (and drawn) description of its wastewater treatment system.
- Each wastewater treatment system must be designed according to the guidelines given in the decree.
- Sludges from septic tanks, other treatment units and containers must be collected from the properties like solid wastes. Thus, the municipality must organise centralised collection if the house owner cannot show he has made a contract concerning the collection with a company or an entrepreneur.
- The decree must be followed immediately from the beginning of 2004 with regard to new houses and within ten years with regard to existing houses.

The Environmental Protection Act gives municipalities the right to issue local environmental ordinances according to local circumstances. This means that a municipality can, for example, deny water closets in a certain area where water or groundwater pollution could seriously contaminate water supplies or, for example, nature.

Further, the Environmental Protection Act gives the municipal environmental authority the right to make inspections on site. If there is sufficient reason, the authority can demand improvements, for example, to the wastewater treatment system.

According to the Environmental Protection Act, it is not permissible to spoil the quality of groundwater or the soil. This is a quite important fact to remember when designing soil treatment systems for wastewaters.

The **Water Supply Act** is another new law affecting the sanitary solutions in rural areas. The act states that municipalities must have a Development Plan for Water Supply Services approved by the end of February 2004. This is the most essential section of the act. In the development plan municipalities are to present time schedules for the expansion of water and wastewater supply networks in the near future. This will provide the properties now outside of the networks valuable information the kind of technology and the size of investment reasonable for them.

According to the Water Supply Act, all the properties within the operational area of a water supply company have, on the one hand, the right to be served by the supply and, on the other, the responsibility to connect themselves to the network.

The **Land Use and Building Act** is a new act as well. It has the aim of improved quality of planning and construction. A design of a new house with a design of an on-site sanitation system must be approved by the municipal authority before the construction. Some of the sections of the act deal with the qualifications of persons involved in the construction business.

Quite an interesting and valuable section of the Land Use and Building Act is the one requiring that all new houses must have operation and maintenance guidelines in written form. These would be beneficial in the case of old houses and their equipment as well.

The **Health Care Act** gives the municipal health authority the right to make inspections on site. If some defects that could possibly cause health problems are found, the authority can demand improvements, for example, to the wastewater treatment system.

Will the new legislation be followed?

The mentioned acts as well as some lesser acts will lead to quite an improvement in on-site sanitation in Finland in the near future, especially if the municipal authorities are willing to use the available tools.

Figure 2 shows the changed situation with respect to the legislation concerning of on-site sanitation in Finland. The practical application of the new acts might be difficult in those Finnish rural areas where municipalities have few inhabitants. Thus, it may not always be easy for local politicians to set strict enough requirements: on-site wastewater treatment always means extra costs to households.

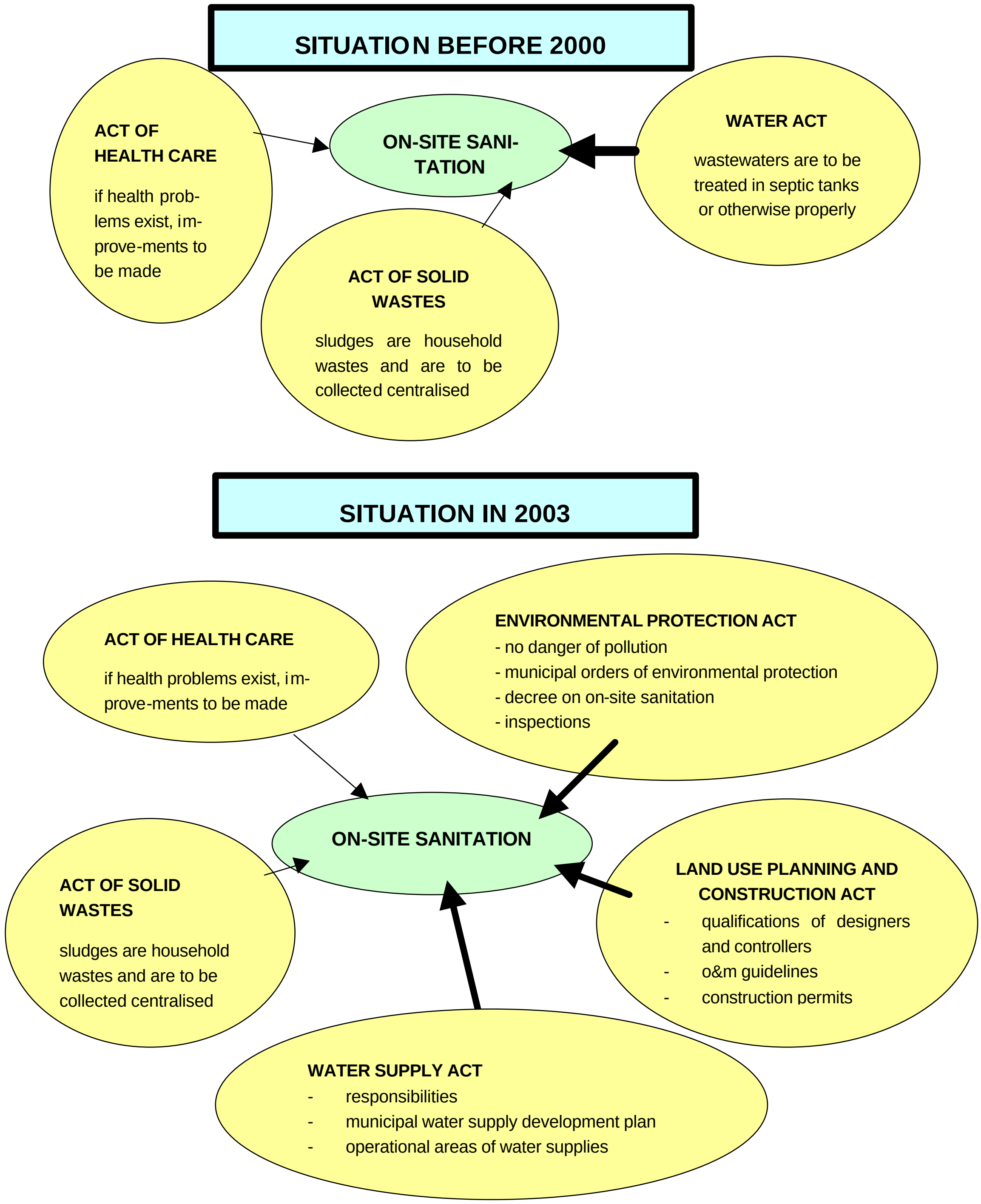

Figure 2: The changes in legislation for on-site sanitation in Finland

However difficult it will be to apply the new legal tools to achieve better on-site sanitation in municipalities, the authorities should be quite strict when doing so. If even the weakest tool is broken the stronger ones can also become useless.

New services are required

As long as on-site sanitation means wastewater (especially black wastewater) treatment on the property, house owners themselves cannot assume responsibility for designing, constructing, operating and maintaining the treatment units. In many cases even the septic tanks have proven too difficult to them to take care of, not to speak of more complicated systems.

Thus, successful on-site sanitation requires new actors to be involved. There are some 350,000 houses and 450,000 summer cottages outside of sewer networks in Finland (Committee of Ministry of the Environment 2001). Even though the sites are many, it is obvious that the big consultancy and construction companies are not very interested in tendering for this type of work where the unit prices are minimal.

Due to the new legislation on wastewater treatment in rural areas, product development work is very intensive in companies manufacturing treatment units. The BAT principle of the Environmental Protection Act requires that a person maintaining on-site sanitation systems must be a professional. Only a person involved in the sector daily knows always what is the newest and best technology for the property in question.

There are so many properties with on-site sanitation systems in municipalities that the municipal environmental protection authority cannot visit all of them to exert control. That is why control of the type in Figure 3 is suggested. The professional performing the maintenance on the on-site system reports major needs for repairs and other bigger undertakings not only to the house owner but also to the municipal authority. The authority can then make a control visit to the properties time allowing.

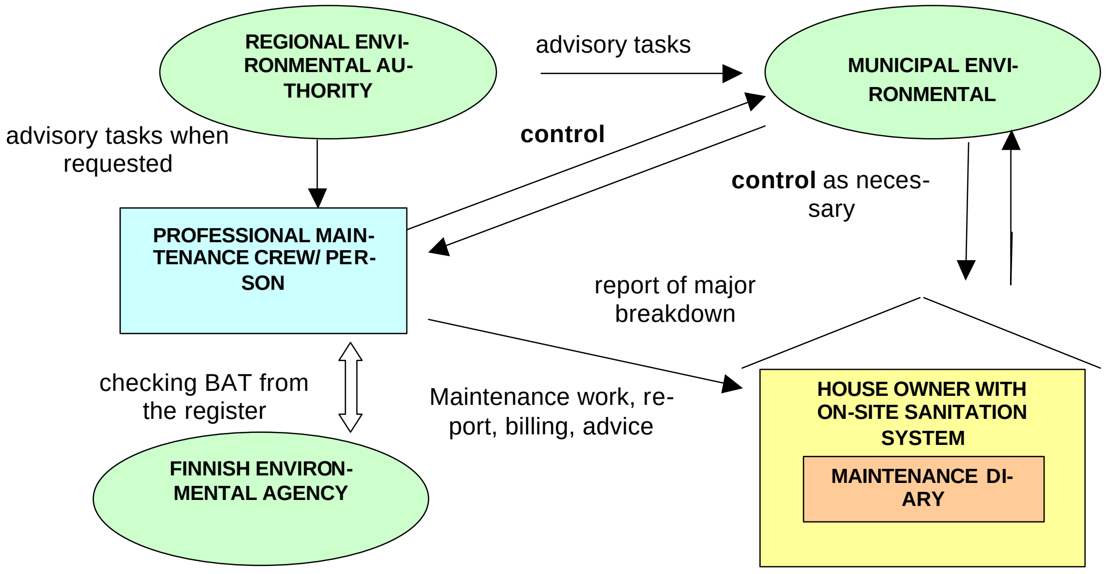

Figure 3: Proposed control system for on-site sanitation (proposal by the author)

In future, the Finnish Environmental Authority (FEA) is to keep a register of the on-site sanitation systems which meet the requirements of the decree on wastewater treatment in rural areas (Committee of Ministry of the Environment 2001). That will ensure that BAT is used as far as possible.

The Regional Environmental Authorities (REA) are given an advisory role in the process. They have the latest information on, for example, the legal and financial aspects.

Of course, all the parties can consult FEA when-ever necessary. And the houseowner can contact REA to check, for example, the possibilities of getting financial aid for investments.

The dry toilet could solve water protection problems

Most of the nutrients, especially in black wastewaters, come from urine and faeces (Table1).

	BOD		P		N	
	g/pd	%	g/pd	%	g/pd	%
faeces	15	30	0.6	30	1.5	10
urine	5	10	1.2	50	11.5	80
grey water	30	60	0.4	20	1.0	10
total	50	100	2.2	100	14	100

Table 1: Content of black wastewater (Committee of Ministry of the Environment 2001)

Considering the requirements of the decree on wastewater treatment in rural areas (page 3), it becomes obvious that the utilisation of dry toilet technology could help meeting the targets of water protection.

Treatment of grey wastewater is much easier than that of black wastewater. In most cases grey water infiltration would be successful, and if not, there are several rather simple treatment units for sale purifying them.

There is dire need to promote the use of dry toilets in Finland. In this country of tens of thousands of lakes the recreational use of water courses is quite popular during the summer. The problem is the very low discharge of smaller streams and rivers in midsummer which is the season for their recreational usage. When there is little natural flow, the bigger portion of the flow consists of wastewaters. This means that the bacteriological quality of waters is not satisfactory. If black wastewater is not led into ditches and rivers the situation improves significantly.

Yet, it is not too easy to promote the use of dry toilets in Finland. The time people still used traditional earth toilets is not too far behind. Their use in the cold climate with the associated smell and flies do not bring back fond memories. Thus, we should develop the existing composting toilets to bring them up to a level where they can truly compete with the comfort of water toilets. But even this is not enough: powerful marketing efforts are also required to make the new toilet technology popular.

Conclusions

The existing acts and other legal tools are sufficient for solving the wastewater problems of Finnish rural areas. It is more a question of common will and appropriate management solutions than inadequate tools. Municipal authorities should now take a firm hold of these new tools and start insisting on an improved standard of wastewater treatment in their areas.

The design, construction, operation and maintenance of on-site sanitation systems cannot be made the sole duty of homeowners. The appropriate solutions will require totally new thinking as regards services. There will be new types of companies, co-operatives and entrepreneurs producing wastewater services for consumers.

Until now, the sanitation of rural areas has not been controlled carefully enough. The new tools also make control of the work possible, if so desired.

We should promote composting toilets more forcefully as an alternative in proper wastewater management. There is no sense in mixing pure tap water with faeces and trying to separate them some 10 meters away on the other side of the wall. But the reputation of dry toilets must first be improved. We all have mental pictures of old earth toilets that were cold, dark, smelly and had flies. That is why dry toilets are not very much appreciated in Finland today.

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Key-activities, services and current pilot projects of the international ecosan programme of GTZ*

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Keywords

Ecological sanitation programme activities, knowledge management, advocacy and networking, ecological sanitation pilot projects

Abstract

The GTZ started its international ecosan research and development project in May 2001 and is financed by the German Federal Ministry for Economic Cooperation and Development (BMZ). The aim of this project lies in promoting the development and pilot application of integral ecologically, economically and socially sustainable recycling-based wastewater and sanitation concepts in developing countries. Furthermore it aims at contributing to the global dissemination and application of ecosan approaches and establishing these internationally as state-of-the-art techniques – in both developing and in industrial nations.

Introduction

German development co-operation considers ecosan, including rainwater harvesting, as a new approach representing a series of technologies that are important in order to resolve the increasingly urgent problems related to the global water crisis. These approaches should serve as a key element in finding the necessary solutions if we are realistically to have any hope of achieving the Millennium Development Goals (MDG) in water supply and sanitation of halving the proportion of poor people without access to safe water and sanitation by 2015, and to contribute tremendously to environmental protection, sustainable natural resources management and safeguarding our future food security on earth.

The GTZ started its international ecosan research and development project in May 2001, with the project being financed by the German Federal Ministry for Economic Cooperation and Development (BMZ). The aim of the project is to promote the development and pilot application of integrated ecologically, economically and socially sustainable recycling-based wastewater and sanitation concepts in developing countries. Furthermore it aims at contributing to the global dissemination and application of ecosan approaches and establish these internationally as state-of-the-art techniques, in both developing and industrial nations, and at mainstreaming ecosan-approaches into technical and financial German development co-operation.

Ideally, ecosan systems enable an almost complete recovery of all organic nutrients and trace elements contained in domestic wastewater. Appropriately treated, such raw materials can be returned to agricultural processes, where they help maintain soil fertility and ensure long-term food security. At the same time, ecosan systems contribute to the conservation of our water resources and to reducing water-related environmental pollution and health risks.

This paper has been peer reviewed by the symposium scientific committee

Key activities of the GTZ ecosan project

Know how management and networking

In co-operation with international and local partners, the ecosan project collates existing know-how so that existing experience on ecological sanitation can be used and further developed. This knowledge may include publications and practical know-how from users and experts on established as well as new ecosan specific developments, the problems encountered, news of successful projects, research findings and much more.

The ecosan project promotes the systematic development of a global sector-specific network of people, institutions and projects. It addresses experts, potential users and decision-makers who are looking for information, seeking concrete answers to specific questions, in need of decision-making tools or looking for contacts.

The GTZ ecosan project supports this network in several ways:

- e-newsletter

  Since June 2001, the ecosan project has been producing a multilingual electronic newsletter (in English, German, Spanish and French); it contains news of interesting new developments in ecological sanitation, information on, and downloading options for, current publications, details of upcoming events, contacts and interesting links, plus a sector forum for communicating with a readership of several thousand. The electronic GTZ ecosan newsletter appears quarterly. You can subscribe to the newsletter by sending an e-mail containing the words “subscribe ecosan” to majordomo@mailserv.gtz.de

- ecosan website

  Current information on closed-loop wastewater management and sanitation is available in German and English at: www.gtz.de/ecosan.

- ecosan project data sheets

  in cooperation with the SIDA (Swedish International Development Cooperation Agency) funded EcoSanRes-Programme of the SEI (Stockholm Environment Institute) and other partners, the GTZ-ecosan-project is compiling and constantly extending an overview list of existing pilot and research projects. Additionally, information concerning interesting and exemplary projects will be realised in the form of project data sheets.

- ecosan technologies data sheets

  with the support of the technical working group, the gtz-ecosan-project is elaborating technology data sheets on various ecosan-components.

- other publications on ecosan

  ecosan-experiences and know-how are published by the ecosan-project along with brochures, posters, magazines, technical publications, films and other media

- conferences and workshops

  Organization of, and participation in, international events and workshops.

  (The 1st and 2nd international symposia on ecological sanitation Bonn 2000 and Lübeck 2003, 1st international conference on ecological sanitation, Nanning, China 2001, and many others.)

- co-operation in the field

  to advance ecosan ideas and to ensure that practical applications of ecosan result in good practise, a close co-operation between the experts working in the new field of ecosan and a constant exchange of views and experiences between them is needed. The GTZ supports this co-operation through the exchange of experts between projects, through common evaluations, local workshops, and through the joint development and implementation of pilot projects.

- national and international working groups

  This involves the initiation and coordination of expert working groups as project think-tanks, to establish basic materials and develop model ecosan concepts. So far a German-speaking technology working group has been established to compile, discuss and further develop various ecosan suitable technologies. Another international working-group for the subject of participation, awareness raising and education in the field of ecosan-promotion is in preparation in order to develop strategies, guidelines and tools for application in ecosan-projects.

Design and implementation of pilot projects

The design and implementation of research and demonstration projects with a focus on urban areas is the second main focus of the GTZ's ecosan project. The aim of such pilot projects is to arrive at cost-effective, user-needs-oriented, practical ecosan solutions, which benefit users. In addition to addressing sanitation technology issues, another essential component of ecosan pilot projects are the concepts needed for the safe agricultural and horticultural application of the recovered products. Market analyses and suitable marketing strategies for the recovered recyclates are also necessary. Cost comparisons with conventional systems are just as important as the development of training modules for users, service enterprises and farmers, and health education measures.

At present, pilot demonstration projects are being prepared or implemented with the support of the GTZ- ecosan project in more than 20 countries. As the overall budget of the international GTZ ecosan project is limited, the main activities lie in laying the foundations for projects by researching, preparing and elaborating a financing concept as well as supporting the elaboration of baseline-studies, feasibility studies and project proposals which may be submitted to financing agencies or investors. Also ecosan-consultancy and knowledge management during the project implementation phase is offered.

Implementation on a larger scale and particularly in urban areas demands larger investments, as well as additional financing for the planning and development of innovative solutions, awareness raising and community participation. More funds are necessary if scientific research also forms a part of the project along with the promotion of agricultural use. Therefore, a commitment and budget is needed from local communities, bilateral German technical or financial cooperation, research programmes, other donor agencies or private investors.

Ecosan pilot projects supported by German Development Cooperation

Botswana - ecological sanitation as an element of sustainable natural resources management

In many African countries, including Botswana, conventional forms of wastewater disposal have drawbacks for the general population. Most households located outside the major urban centres are not connected to any existing waste management and sanitation system. Droughts and inadequate water resources make an already unsatisfactory situation even worse.

Over the next five years, a project devoted to sustainable regional resource management will be co-operating with local authorities, the International Union for the Conservation of Nature (IUCN) and the German Development Service (DED) to develop, test and demonstrate sustainable, decentralized wastewater management and sanitation systems and methods. Initially, private households in the districts of Ghanzi, Gaborone and Serowe are to be tied into the research activities. Later, the approach will be extended to the municipal level. One of the aims of this GTZ-project is to recover nutrients and trace elements from domestic wastewater, faeces and urine for use in agriculture. This not only contributes toward long-term food security, but also provides the people with an opportunity to earn extra money.

Figure 1: Workshop on village level

Egypt – Soilization of sewage sludge

In many countries, the use of sewage sludge in agriculture is thwarted either by the complexity of the processing technology or by the poor quality of the sludge, which arouses very little interest among farmers for its use as a soul conditioner. In Egypt, the GTZ has therefore supported a large scale field test, carried out by IPP Consult, of a process of sewage and faecal sludge upgrading, or soilization, by means of sewing sludge polders with grass or common reed. The results are promising and the process will be introduced in other ongoing ecosan pilot projects of GTZ in Kafr el Sheikh in Egypt and in Mali:

- process technology is easy to manage and economical
- structural, aesthetic and hygienic attributes of the soilised sludge are superior to those of dried sludge
- soilised products find more acceptance and the market potential is improved

Figure 2: Large scale test on soilisation of sewage sludge with plants

Mali - On-plot ecosan systems for the treatment of faeces, urine and greywater

Koulikoro has a central potable water supply system dating from the 1970s, but as yet no sewage system. In an arid sub-Saharan country like Mali, where financial and water resources are scarce, a water-carried sewage system resembling those used in Europe would be inappropriate and too expensive. Mali is also faced with the steadily worsening problem of soil degradation, including desertification, chiefly as a result of agricultural overuse and an insufficient return of nutrients.

Figure 3: Greywater garden and experimental sanitation module

An affordable means of proper wastewater disposal is needed. The GTZ has therefore developed an on-plot household ecosan system in which faeces, urine and greywater are separately collected and treated. This offers major advantages over conventional latrine-based systems, as it enables the hygienic recovery of soil amending substances from faeces and of nutrients from urine and purified greywater. The ecosan system is also in harmony with local traditions. In 2002, the National sewage and Solid Waste Department at the Malian Ministry of the Environment incorporated the grey-water gardens and separating toilets developed by the ecosan initiative into its program. Together with the GTZ, the department is now examining their suitability for a widespread introduction. Ultimately, however, the success of grey-water gardens depends solely on the degree to which they are accepted by women for growing vegetables, bananas and papayas. At present, preparations are being made within a GTZ-supported decentralisation programme in a 2nd region, for a further development of this ecosan concept and its dissemination in 19 densely populated urban areas with between 2.000 to 130.00 inhabitants.

China - Municipal ecosan concepts in a Beijing suburb

Located in one of Beijing's three river basins, Yang Song covers a little more than three square kilometres and is home to some 21,000 people. With its intensive livestock farming and grain and vegetable production, the region is a major source of food for the city of Beijing. The community currently produces roughly 15 tonnes of solid waste each day. Less than 10 % of the town's wastewater is treated prior to being discharged into the rivers or groundwater. Within the scope of a local ecosan project, the community is to be provided with a modern, material-separating disposal and recycling concept for wastewater and organic wastes that is in line with the

Figure 4: Model of Yangsong Development Plan

principles of closed-loop wastewater management and sanitation. The GTZ, Chinese and German scientists and companies are working together to analyse and compare different sanitation, wastewater treatment and recycling options in various harmonized systems. The cost-effective recovery of useful materials and energy is the main objective

There are also plans to use water-saving vacuum technology and urine separation systems. Organic waste from kitchens and markets will be collected, shredded and, finally, fermented in a bioreactor system. The resultant fertilizer and hygienized urine will be suitable for use in growing flowers and vegetables. Greywater will be used for watering public parks and gardens.

Figure 5: New housing area in Yang Song

Cuba – ecosan research into non centralized applications

Throughout Cuba, and particularly in urban areas, the wastewater management and sanitation systems lack capacity and are in urgent need of rehabilitation. Most notably in peri-urban areas with considerable agricultural activity, the soil, groundwater and watercourses are heavily polluted. As a result, health conditions and odour-nuisance levels are critical in many places.

Moreover, many households do not have access to electricity. This forces many people to use ecologically questionable forms of fuel for there everyday needs.

To address the situation, a GTZ-supported ecosan research project is conducting field tests on various household sanitation systems and looking for appropriate-technology solutions that may generate cooking energy. For example, on several city farms in two different project regions, the utilization of household sewage and organic waste is being integrated into the in-house production of fertilizer and cooking energy. In a third region, pre-fabricated components are being designed and developed for diverse decentralized disposal systems, and in a fourth region, different ecosan systems are being implemented in urban centres. The four regions in question are located in different parts of the island to ensure the study of the representative of the island's diverse climatic, structural and social conditions.

Figure 6: A common type of agricultural biogas plant in Cuba consisting of a long plastic tunnel with an in- and outlet made of concrete tubes:

Ecological sanitation concept in Lesotho, water borne closed loop

Lesotho is selling drinking water to South Africa, but in their capital Maseru, high quality drinking water is scarce. Groundwater and lake water pollution in the city area was measured and pit latrines and septic tank overflows have been identified as contaminating source. The rocky underground is impermeable. At the other side, the large urban housing plots could be more efficiently used for urban agriculture and gardening, a need in a land where the arable space is under pressure. The central sewage treatment system is under loaded, because only a small part of Maseru city is connected and even half this sewer-connected area does not reach the treatment plant, as the pumping station has not been functioning for several years due tom high operation costs and technical difficulties, which has resulted in a shortcut of the used untreated water to the border river.

Supported by the German Embassy, the German Development Service (DED) is realising some training and demonstration measures for household centred and community based closed loop on plot reuse of all wastewater and nutrients, driven by a market oriented sanitation approach.

Figure 7: Construction work in Lesotho

The first system consists of a small bore sewer grid for eight houses (40 persons), a biogas-septic tank unit, an upflow filter based on recycled plastic bottles, a wetland, 800m² vegetable and fruit garden, and two household connections for the biogas as a full cooking energy source (for two families), has been installed and has been in service for one year. Moreover, the organic waste of the whole neighbourhood is composted in the garden area. The demonstration has shown, that year round gardening is possible, with higher yields and quality than only rainwater dependent agriculture and much cheaper than the use of piped fresh water for irrigation with additional fertilizer use. Driven by private demand and investment, an extension of similar systems for individual households and neighbourhoods (3-10 houses) is ongoing. Due to the German support, each site is actually used for training of private constructors and engineers, even from South Africa.

As the non-separation of streams results in a potential over-fertilisation of the garden area, and as first results of the pilot unit show that the biogas-septic tank unit could be smaller with the same energy efficiency if the hydraulic charge is lowered, the next steps planned are the stream separation of grey water and black water and the subsequent introduction of urine diversion. However, this last step will only be taken, when the gardening and urban agricultural demand is established and the liquid fertiliser demand is stabilised.

Further projects in preparation

Other projects are presently being prepared with the support of GTZ-ecosan in several other countries, where advocacy workshops, baseline and feasibility-studies are currently running or being organised:

Figure 8: Further projects in preparation

Conclusion

The joint development and implementation of, mainly urban, pilot projects with other international and local partners in developing countries are a major pillar of the GTZ ecosan project. Pilot projects are indispensable, firstly because a great deal of research and development is still necessary to develop economical, workable and replicable ecosan solutions geared to user needs in urban areas and, secondly, because successful demonstration projects are the best publicity for recycling-based strategies.

Public relations, also via functioning demonstration projects, are enormously important for the successful and sustainable application of new eco-sanitation systems and their acceptance by the actors concerned. These actors include, on the one hand, the users, whose awareness, habits, convenience standards, finances and technical ability must be catered for in developing and implementing ecosan strategies, but also the private sector, public institutions and political decision-makers. The basic idea is to alter perception and concepts: Solid waste and wastewater should be seen primarily as resources containing nutrients rather than waste loads or pollutants.

In addition to addressing technological issues in wastewater disposal, the development work still needs to underpin new integral wastewater and sanitation strategies tailored to various framework conditions by way of pilot projects, including a range of investigations into the hygienic application of recyclates in agriculture and horticulture. There is also a need to prepare market analyses and develop suitable marketing strategies for the recovered recyclates. It is equally necessary to make economic comparisons with conventional systems, as it is to develop training modules for users, service enterprises and farmers as well as measures in health and hygiene education.

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GTZ-ecosan project (August 2002) recycling beats disposal –flyer

Internal information of GTZ

EcoSanRes – a Swedish international ecosan programme

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Keywords

Ecosan, ecological sanitation, EcoSanRes, Sweden, global, pilot projects

Abstract

Now that sanitation has made it to the global agenda and that it is one of the Millenium Development Goals, sustainable alternatives to conventional practice need to be brought forward. Up to now the sector has not benefited from the 15-year learning curve on sustainable development. Ecological sanitation provides a battery of choices to communities both rich and poor and features source-separation and containment of human excreta, sanitization and recycling, all of which conventional approaches fail to do. Most of the world practices unsafe, and unsustainable sanitation and only an elite group of countries can afford to build and maintain sewage collection and treatment systems. The EcoSanRes programme has been set up by Sida in Sweden to develop ecological sanitation methods and promote these through full-scale pilot projects in selected developing countries. The outcome of this work will help meet the global needs for improved sanitation using safe, environment-friendly approaches that everyone can afford.

The sanitation crisis and the ecosan challenge

There are at least 2.4 billion people in the world without improved sanitation (defined by the World Health Organization as connection to a public sewer, connection to a septic system, a pour-flush latrine, a simple pit latrine or a ventilated improved pit latrine), primarily residing in rural Asia and Africa. But technically, even access to “improved” sanitation does not solve the problem because conventional pit latrines usually fail to sanitize and they contribute to groundwater pollution. Also, septic systems and sewage treatment plants often discharge into the environment with little or no sanitization or nutrient removal. So in actuality, far more than 2.4 billion people need to gain access to effective and sustainable sanitation.

Taking a somewhat radical view and considering that conventional solutions like pit latrines serving some 2.8 billion people, are often both health and environmental hazards, and that 70% of the sewage systems in the world, serving about 1 billion people, are often dysfunctional, the global sanitation crisis involves most of humanity (Matsui, 2002). Sanitation has somehow escaped entirely the debate on sustainable development. Thus the ecosan challenge is really of global proportion.

Reaching the WSSD target

The UN World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa in autumn 2002, articulated several targets for the coming decade. Among them, “halve, by the year 2015, the proportion of people that do not have access to basic sanitation”. This has been built into the UN Millennium Development Goals project within the Task Force on Water and

Sanitation. An initial background document has been released (Millenium Project, 2003). An action plan will be produced in 2005.

The World Summit for Children in 1990 called for universal sanitation by 2000. With significant effort, the 1990s saw a ten percent increase in global sanitation coverage, rising from 51%-61%, meaning an additional one billion people gained access to improved sanitation. However, the discrepancy between rural and urban sanitation improvement is high, with urban sanitation coverage consistently eclipsing rural sanitation coverage, where 80% of the people without sanitation live. Realizing that population growth is increasing, and that in addition to ensuring the 1.2 billion people in need of sanitation gain access, we must also secure sanitation for the expanding population – projected growth is about 20% by 2015 – the WSSD targets are less idealistic than the World Summit for Children goals, calling for universal sanitation coverage by the year 2025. Still, the consistent delay in reaching international sanitation goals should not be overlooked. The present timeline has already been pushed back 25 years since the status of sanitation in the world reached a crisis level almost 15 years ago. More than 4 billion people will need to gain access to basic sanitation to meet the 2025 target for universal coverage, according to the Global Water Supply and Sanitation Assessment 2000 Report (WHO, UNICEF, WSSCC, 2000).

No sanitation is dangerous

The health risks of a lack of, or inadequate, sanitation are mortal. The Framework for Action on Water and Sanitation, produced in conjunction with the WSSD, indicates close to 6,000 children die each day from diseases related to inadequate sanitation and hygiene, and a lack of access to safe drinking water. "In China, India and Indonesia, twice as many people are dying from diarrhoeal diseases as from HIV/AIDS" (WEHAB, 2002).

"Approximately 4 billion cases of diarrhoea each year cause 2.2 million deaths, mostly among children under the age of five. This is equivalent to one child dying every 15 seconds, or 20 jumbo jets crashing every day", states the Global Assessment on Water and Sanitation 2000 Report. Other indicators of health risks associated with poor sanitation are the frequency of related parasites that have human faecal origin – about 1 billion people are infected with roundworm and 700 million with hookworm.

Uncontained and untreated human excreta pollute groundwater, streams, lakes and coastal zones, helping to perpetuate the cycle of human disease and upsetting fragile aquatic ecosystems by nutrient overloading and eutrophication. Just the need to "close the loop" on nutrients dictates the necessary paradigm shift toward sustainable sanitation. The health risks of conventional approaches are calling for immediate global action.

Inadequate sewage treatment creates problems downstream

The United States operates close to 100 million flush toilets, averaging 15-19 litres of freshwater per flush as a means to transport human excreta. Conventional sewerage is not a sustainable sanitation system, even for wealthy countries. Sweden, with a population of less than 9 million, produces about 1 million tons of wet sludge each year, most of which cannot be recycled to forests or agriculture due to heavy metal contamination. Of 540 major European Union cities, only 79 have advanced sewage treatment and 45% have either no treatment or incomplete primary or secondary treatment (EU, 2001). In February 2002, the European Commission took legal action against France, Greece, Germany, Ireland, Luxembourg, Belgium, Spain and the United Kingdom for alleged failure to implement various environmental laws for water quality protection. Of the 1 billion people that have flush toilets in the world, only 30% receive advanced sewage treatment (Matsui, 2002).

For developing countries attempting to use conventional flush sewerage systems, the situation is worsened by the resulting surface and groundwater pollution, resulting in an estimated 1 billion people left without access to clean drinking water.

Socio-economic impact

According to the Water Supply and Sanitation Collaborative Council's Vision 21, "recognition of water and sanitation as basic human rights, and of hygiene as a prerequisite…form a major component in poverty reduction".

Hygiene, safe water and sanitation are fundamental human rights. Ecological sanitation can improve social and economic conditions for all, especially for impoverished communities. Ecosan offers empowerment and safety, particularly to women and girls in urban and peri-urban areas that are often without sanitation, by providing a private and dignified environment for urinating and defecating. The use of sanitized human excreta as a fertilizer stimulates crop growth and, as a result, increases nutrition for those who depend on subsistence farming, or helps to generate or supplement income for those who sell the products they grow.

The challenges

Because 80% of the people without adequate sanitation (2 billion) live in rural areas – 1.3 billion of those in China and India – the barriers to communication present a significant impediment to informing these people about ecological sanitation. Television advertising, newspapers or printed material do not reach most of these people. Government services make infrequent calls to remote areas and NGOs serve a small segment of this population. Instead, most information is exchanged through face-to-face communication. How can we spread the message about sanitation alternatives and improved hygiene behaviour to such a large number of people living outside the reach of familiar communication channels?

Need for alternatives

Even if the sanitation crisis can be communicated to and understood by more people, the need to find sustainable alternatives to conventional approaches for both developed and developing countries remains. Sustainable and ecological sanitation requires a holistic approach, building on the intimate relationship between ***people and soil***. Sanitation cannot be a linear process where excreta is hidden in deep pits or flushed untreated downstream to other communities and ecosystems.

Ecological sanitation

Ecological sanitation provides alternative solutions with or without water, while providing ***containment, treatment and recycling*** of excreta. It can involve soil-based composting toilets in shallow reinforced pits, dry urine-diverting toilets with storage vaults, urine-diverting mini-flush toilets and even high-tech vacuum systems. Cost-effective ecosan can be adapted for developing and developed countries. In arid zones, water resources can be saved for more important needs like personal hygiene and growing food. In humid areas with high water tables, above-ground and shallow ecosan systems can remain functional during seasonal floods. Ecosan provides human health and environmental protection using affordable and appropriate technologies to match the needs of the entire world. Figure 1 illustrates the ideal ecosan model.

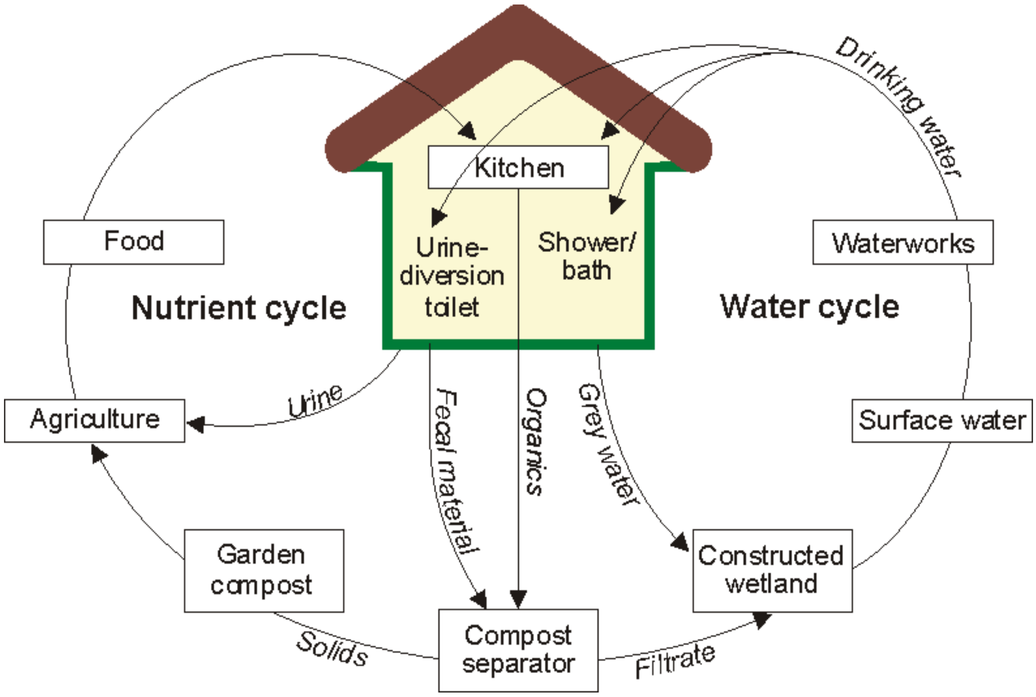

Figure 1: Ecosan model with closed nutrient and water cycles (based on Oldenburg et al., 2003)

The need for safe sanitation

Pathogens and parasites found in human excreta, if ingested, can result in a variety of illnesses, including diarrhea leading to malnutrition. If left untreated these illnesses can result in poor growth, iron deficiency (anemia), vitamin A deficiency, and leave the body's immune system weakened and susceptible to more serious infections. Not all pathogens and parasites result in death, but the resulting malnutrition creates poor health and a predisposition to continual disease and death from other causes.

The limitations of present day sanitation

Conventional sanitation is currently offered by two models: pitsan (pit toilets) or flushsan (flush toilets). Although conventional sewage systems transport excreta away from the toilet user, they fail to contain and sanitize, instead releasing pathogens and nutrients into the downstream environment. This is considered the "linear pathogen flow" (Esrey *et al*., 1998). These systems mix faeces, urine, flush water and toilet paper with grey water, storm water and industrial effluents, usually overtaxing the design capacity of the treatment plants, if such a facility exists, as very few communities in the world are able to afford fully functional sewage systems. Simply put, flushsan has a dismal track record because all sewage systems contaminate the environment. Far more common than flush sanitation is the pit toilet, primarily because it is inexpensive and requires no infrastructure. This method fails to contain and sanitize excreta since pathogens and nutrients seep into the groundwater. Deep pit latrines also fail to recycle since the excreta is too deep for plants to make use of the nutrients. Pits are prone to periodic flooding, causing them to spill their contents. In general, pits are smelly, are often infested with flies, and in most parts of the world, are poorly maintained and continue to be a source of disease and pollution.

Ecosan is a real option

An essential step in the process of sanitation is the containment of that can cause disease. Human faeces contain bacteria, viruses and parasites, which, if not properly treated, can result in spreading of disease. Ecological sanitation systems are designed around true containment and provide two ways to render human excreta innocuous: dehydration and decomposition. The preferred method will depend on climate, groundwater tables, amount of space and intended purpose for the sanitized excreta. Dehydration is the chemical process of destroying pathogens by eliminating moisture from the immediate (containing) environment. Some drying materials, like wood ash, lime and soil are added to cover the fresh deposit. Ash and lime increase pH which acts as an additional toxic factor to pathogens if the pH can be raised to over 9.5. The less moisture the better, and in most climates it is better to divert the urine and treat it separately.

Figure 2: Dry, double-vault urine diversion toilet from Mexico.

Figure 2 shows a dry, double-vault urine diversion toilet, a model being used in China, India, Vietnam and Mexico. It takes an average family 6 months to fill one of the vaults. Then the second vault is used. The first vault is emptied following an additional 6 months of sanitization and the material is taken to a soil compost. Urine is never mixed in this toilet but continuously diverted into a separate container and later used in diluted form as plant fertilizer. The dry ecotoilet meets all necessary health and environmental protection criteria and goes well beyond what conventional approaches can offer (Stenström 2002), saving water and preventing water pollution. It produces no smell, does not attract flies and is an affordable solution inside and outside of dwellings throughout the world.

Figure 3: *Fossa alterna*, a shallow reinforced pit, soil-composting toilet in use in Mozambique (Source: Water Aid)

Soil-composting toilets make use of the process of decomposition, a biological process carried out by bacteria, worms and other organisms to break down organic substances. In a composting environment, the competition between organisms for available carbon and nutrients continues until the pathogens are defeated by the dominant soil bacteria. Soil-composting toilets are constructed using shallow, reinforced pits where soil and ash are added after each use. Toilets such as the *Fossa Alterna* (Figure 3) and *Arbour Loo* (Morgan 2001) have been successfully tested in Mozambique and Zimbabwe. The Fossa Alterna uses two alternating pits with a similar frequency of alternation as the double-vault dry toilet. Once sanitized and composted, the contents are removed and used in agriculture. The Arbour Loo is a single shallow pit which receives soil additions after each use and a tree is planted in the pit when it is full.

Recycling

The recycling of nutrients in urine and faeces is one of the key benefits of ecological sanitation. The nitrogen and phosphorus found in urine is a valuable fertilizer and the high organic content of faeces makes the composted product – humus – an excellent soil conditioner. In addition, it is important to recover and reuse these nutrients toward sustainable ecosystems to reduce the drain on natural reserves and lessen the dependence on artificial chemical fertilizers. Some countries and cultures have been recycling human excreta for agricultural purposes for thousands of years, especially in China and Southeast Asia, but often excreta have not been properly sanitized therefore perpetuating disease. By implementing ecosan, we can safely recycle nutrients without risking people's health and polluting the environment.

Urine contains 75-80% of the nutrients leaving the human body and 80% of the volume of excreta as well (Table 1). By using urine diversion we can reduce the nutrient load in sewage systems – thus eliminating the need for tertiary treatment. By using low-water or dry toilet systems we can reduce further the size of the sewage problem. Containment of dry faecal material and secondary treatment in eco-stations ensures that enteric pathogens are not released into the environment as is the case today with conventional sewage and pit systems.

	Urine	Faeces
volume (L/p/d)	1.2 litres	0.15
Nitrogen (g/p/d)	11	2
Phosphorus (g/p/d)	1	0.6
Potassium (g/p/d)	2.5	0.6

Source: Del Porto & Steinfeld (1999).

Table 1: Average production of urine and faeces and nutrient content

By year ca 2100, economical sources of mined phosphorus will be nearing depletion (Steen 1998). A global program for phosphorus recycling from agriculture and humans must be in place within a few decades. The geopolitics of phosphorus are more delicate than oil due to skewed distribution (60% of the resource is in one location, Morocco). World fertilizer consumption (ref. IFA) is about 85 million tons of nitrogen and 14 million tons of phosphorus per year. Recycling of urine and faeces applied globally could answer for at least a third of the nitrogen and a quarter of the phosphorus we use in agriculture.

Ecosan for grey water treatment and composting of household organics

The ecological sanitation approach can be broadened to cover all organic material generated in households (kitchen and food wastes). If these organic materials are sorted within the home, rather than mixed with solid waste and dumped, they become valuable recyclable materials once composted. Grey water can be treated using biological systems, such as evapotranspiration beds and constructed wetlands, and rainwater harvesting can be implemented to harness water for personal hygiene and irrigation (Figure 1).

The EcoSanRes programme

In 1993, the Swedish International Development Cooperation Agency (Sida) launched a sanitation research programme called SanRes, under the direction of Uno Winblad. The objectives of the programme were to:

- promote affordable and reproducible ecological sanitation systems

- establish pilot projects in various countries (China, Vietnam, Mexico, Bolivia, Chile, El Salvador and Guatemala)
- help build local capacity for research and development
- and to facilitate collaboration between developing nations in the field of applied sanitation research.

The eight-year mandate for the SanRes programme was fulfilled in 2001 and proved so successful it has evolved into a full-scale initiative sponsored by Sida and managed by the Stockholm Environment Institute, Akkadia Environment and SwedEnviro – the **EcoSanRes Programme**. The EcoSanRes Programme consists of three components: *outreach, capacity* and *implementation*.

Guidelines development

The EcoSanRes Programme is researching and testing methods of sanitation, primarily focusing on the safe removal of pathogens from human excreta and its subsequent optimal uses in agriculture as a fertilizer and soil conditioner. The end results of these investigations are guidelines to aid professionals, people and communities in implementing ecological sanitation systems. Guidelines are being written for safe handling of urine and faeces, agricultural reuse of human excreta, grey water treatment and management, and implementation and planning of ecosan projects.

Studies

Sanitation is usually heavily regulated at all levels of government, due to its impact on public health and safety, and it is also a subject traditionally approached with discomfort and inhibition. But, the need for sanitation is so basic it affects humans indiscriminately. Realizing the sensitivity of this issue and the reluctance of governments to embrace change, the EcoSanRes Programme has undertaken studies to explore the more elusive and social aspects of sanitation, such as regulatory frameworks, a review of alternative sanitation systems and legislation and norms and attitudes.

Implementation

The EcoSanRes Programme has established itself, and the concept of ecological sanitation, as legitimate by promoting local input to and adaptation of sanitation systems. Sida is implementing pilot projects in West Africa (eight countries), East and Southern Africa (Uganda, Mozambique and Zimbabwe), South Africa, China, India, Latin America (Bolivia, Guatemala and Mexico) and the Middle East (Palestine).

Efforts are in progress to provide new methods to help meet the Millennium Development Goals. Since the SanRes Programme was introduced in southern China in 1997, more than 100,000 urine diversion double vault toilets have been built in the Guangxi Region (Wei Bo, 2002), and ecological sanitation activities are increasing in half of the Chinese provinces.

Eco-Town projects

The full-scale ecological sanitation projects being initiated by EcoSanRes are efforts to generate the necessary data, technology and policies required to affect a major change in the way human settlements relate to the environment. The objective of one such project is to build a small eco-town in Inner Mongolia, China, with about 1,000 households, with an emphasis on testing, research and development and social marketing, as well as cultural, financial, legal and institutional issues. This pilot project represents an evolutionary advancement in the implementation of ecological sanitation. It includes the management of grey water and solid waste, and the agricultural reuse of household residues. The incorporation of secondary treatment for faeces and solid waste in eco-stations differentiates this project from others because it is extending the concept of ecosan into a comprehensive sanitation system. It marks a shift from concentrating on small-scale household implementation to embracing a holistic approach to sanitation on a larger, urban scale. The goal is to provide the world with an example of a sustainable eco-town. Similar projects are being set up in Mexico and South Africa during the period 2003 to 2007.

Capacity building and training

One of the keys to successful implementation of ecosan is education. By funding training programs the supporters of ecological sanitation, including Sida and the EcoSanRes Programme, help to create a knowledgeable base of people who can promote the concept and act as a resource pool for others interested in ecological alternatives to conventional sanitation. Training courses gather experts from a variety of disciplines to strengthen capacity for planning, managing and implementing ecological sanitation systems. In particular, the focus of the courses is on how ecological alternatives to sanitation can be affordable and contribute to health and personal security, improve nutrition and protect drinking water and the surrounding ecosystems from pollution. Training courses were held in Uganda and South Africa in 2002, and courses are planned for India, China and Tanzania.

Organisations involved with EcoSanRes (www.ecosanres.org)

- Stockholm Environment Institute
- Akkadia Environment Management Consultants
- SwedEnviro Consulting Group
- Linköping University
- WKAB Consulting
- Swedish Institute for Infectious Disease Control
- Swedish University of Agricultural Sciences
- Aquamor – Zimbabwe
- Eco-Solutions – India
- Espacio de Salud – Mexico
- REDSECO – Latin America
- City of Kampala – Uganda
- CSIR – South Africa
- Mvula Trust – South Africa
- WaterAid – Mozambique
- Palestinian Hydrology Group – Palestine
- CREPA – Burkina Faso and West Africa
- Municipality of Erdos, Dong Sheng District, Inner Mongolia, China
- Ministry of Health– China
- Government of Bolivia
- Government of Guatemala
- Unicef
- UNDP
- World Bank (WSP)

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Guidelines for the implementation of the Bellagio-Principles and the household centred environmental sanitation approach (HCES)*

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Keywords

Environmental sanitation, household-centered approach, nutrient recycling, sanitation planning

Abstract

In response to the fact that almost half of the world population still lack access to adequate sanitation and in recognition that the conventional approaches to Environmental Sanitation are unable to make a significant change in this appalling situation, an Environmental Sanitation Working Group of the Water Supply and Sanitation Collaborative Council (WSSCC) developed in 1999 the Household-Centred Environmental Sanitation (HCES) approach. The HCES approach is a radical departure from past central planning approaches as it places the household at the core of the planning process. The approach responds directly to needs and demands of the user and attempts to avoid the problems resulting from either "top-down" or "bottom-up" approaches. Successful implementation of the HCES approach requires the dissemination of information and assistance to those responsible for improving environmental services, such as municipal officials, urban planners, and policy makers responsible for creating an enabling environment. Based on these considerations, provisional guidelines were prepared. They provide specific guidance for (a) creating an enabling environment for the use of the HCES approach and (b) undertaking a 10-STEP-process for its development and implementation.

Introduction

Since the earliest urban settlements, it has been recognized that some services have to be provided to ensure that the inhabitants are healthy and able to live in decent conditions. These services are: provision of safe water supply; the sanitary disposal of wastewater and human wastes; the proper management of solid wastes; and effective storm water drainage. In this paper these services are referred to as Urban Environmental Sanitation Services (UESS). Throughout the past few decades, efforts to improve living conditions among those lacking basic amenities have emphasized the provision of potable water. The other, equally vital, UESS

*This paper has been peer reviewed by the symposium scientific committee

components have invariably been considered less important. As a result, 2.4 billion people stilldo not have access to proper sanitation (WHO/ UNICEF/WSSCC, 2000), less than 50% of municipal solid wastes are collected (WRI et al., 1996) and no one knows how many people are flooded out each year.

Although there are several reasons for the neglect of these other components and especially for the failure to achieve satisfactory sanitation coverage (Simpson-Hebert and Wood, 1998), the WSSCC Working Group on Environmental Sanitation came to the conclusion that poor planning lies at the heart of current shortcomings in environmental sanitation interventions (EAWAG/ SANDEC and WSSCC, 1999). Too often only lip-service is given by environmental sanitation professionals to environmental management issues and services are not conceived in an integrated way. For example, provision of a water supply without allowing for the removal of wastewater may create standing water, thereby producing health hazards and poor living conditions. Nor is sufficient attention paid to the fact that the reduction of waste and the more efficient use and reuse of water and materials is the most effective way to reduce demand for waste treatment and disposal.

There has also been a tendency to develop systems that respond to problems of environmental waste management as perceived by policy makers and professionals, rather than to households' and communities' perceptions of their actual needs. Conventional UESS planning usually consists of what became to be known as a "Top-Down" approach. Needs are determined by well-meaning officials at central, regional and even municipal levels, based on their own perceptions. Those to be provided with services are "Target Beneficiaries" without much, if any, say in matters of service level or determination of priorities.

The Bellagio Principles for sustainable environmental sanitation

A representative group of experts drawn from a wide range of international organisations involved in environmental sanitation accepted the need to challenge conventional thinking and called in the Bellagio Statement for a radical overhaul of conventional policies and practices world-wide based on the following lessons learned from past efforts to improve UESS:

(a) “Business as usual” is not sustainable even in the industrialized countries; (b) the under-utilization of organic residues is economically wasteful; (c) the pressure of humanity on a fragile water resource base, and the corresponding need for environmental protection and freshwater savings, require that wastewater and wastes be recycled and considered as resources; (d) sanitation systems designed and implemented without consultation with stakeholders at all levels, and without their participation, are ineffective; (e) there is a lack of integration between the provision of water supply and arrangements for disposal of wastewater, and between excreta and wastewater management, solid waste management, and storm water drainage; (f) without sanitation and hygiene education, the health impacts expected from water supply are greatly diminished; and (g) the export of industrialized-world models of sanitation to environments characterized by water and resource scarcity is inappropriate.

In the light of these compelling arguments for radical re-thinking, the following principles were proposed as the underpinning basis for a new approach in environmental sanitation:

1. Human dignity, quality of life and environmental security at household level should be at the centre of the new approach, which should be responsive and accountable to needs and demands in the local and national setting.
2. In line with good governance principles, decision-making should involve participation of all stakeholders, especially the consumers and providers of services.
3. Waste should be considered a resource, and its management should be holistic and form part of integrated water resources, nutrient flows and waste management processes.

4. The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, community, town, district, catchment, city) and wastes diluted as little as possible.

The Bellagio Principles were endorsed by the members of the Water Supply and Sanitation Collaborative during its 5th Global Forum in November 2000 in Iguacu (Brasil).

The Household-Centred Environmental Sanitation Approach (HCES)

The Household-Centred Environmental Sanitation Approach (HCES) developed by the WSSCC Environmental Sanitation Working Group is largely based on the Bellagio Principles (Schertenleib, 2000). There is consensus among the members of the Water Supply and Sanitation Collaborative Council that it offers the promise of overcoming the shortcomings of conventional approaches because its two main components correct existing unsustainable practices of planning and resource management. These components are:

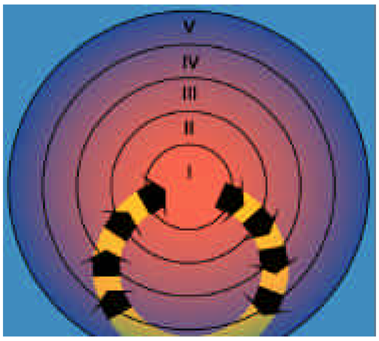
- The HCES approach makes the household the focal point of Environmental Sanitation Planning, reversing the customary order of centralized top-down planning. It is based on the concept that the user of services should have a deciding voice in the design of the service, and that environmental sanitation problems should be solved as close as possible to the site where they occur. Only problems not manageable at the household level should be "exported" to the neighbourhood, town, city and so on up to larger jurisdiction. Making the household the key stakeholder also provides women with a strong voice in the planning process, and changes the government's role from that of provider to that of enabler.
- The *Circular System of Resource Management (CSRM)* that, in contrast to the current linear system, emphasizes conservation, recycling and reuse of resources. The circular system practices what economists preach: waste is a misplaced resource. By applying this concept, the circular system reduces "downstream" pollution.

Structure of decision making in the Household-centred approach

The conventional approach to water supply and environmental sanitation is based on a highly-centralized system of decision-making, usually under the control of the national government. In recent years, many governments have attempted to decentralize by delegating their functions to second-and third-tier governments (for example, to provinces and municipalities). However, the results of these efforts have been mixed. Delegation often leaves central policy-makers in charge and does little to encourage initiatives by local office-holders and managers. The problems with devolution generally result from the fact that only the new responsibilities, not the means of implementing them, are transferred to the local authorities.

The HCES Approach is a radical departure from past central planning approaches. As shown in the figure on the following page, it places the stakeholder at the core of the planning process. Therefore, the approach responds directly to the needs and demands of the user, rather than central planner's often ill-informed opinions about them. It is based on the following principles: (a) Stakeholders are members of a "zone", and act as members of that zone ("zones" range from households to the nation). Participation is in accordance with the manner in which those zones are organized; (b) zones may be defined by political boundaries (for example, city wards and towns) or reflect common interests (for example, watersheds or river basins); (c) decisions are reached through consultation with all stakeholders affected by the decision, in accordance with the methods selected by the zone in question (for example, votes at national level in a democratic system, town hall meetings at local level, or informal discussions at neighbourhood level); (d) problems are solved as close to their source as possible. Only if the affected zone is unable to solve the problem should the problem be "exported", that is, referred to the zone at the next level.

The HCES approach attempts to avoid the problems resulting from either “top-down” or “bottom-up” approaches, by employing both within an integrated framework. The needs are determined in a bottom-up approach where decisions flow from the household to the community to the city and finally to the central government based on informed choices at all levels. The top-down part of the HCES approach consists then of fitting the proposed program within the municipality’s overall UESS strategy and ensuring support for its implementation.



I Household

II Community/Neighborhood

III Local Government

IV District Government

V National Government

Circular System of Resource Management

An important concept of the HCES approach is to minimise waste transfer across circle boundaries by minimising waste-generating inputs and maximum recycling/reuse activities in each circle. In contrast to the current linear system, the *Circular System of Resource Management (CSRM)* emphasizes conservation (reducing imports) of resources, and the recycling and reuse of resources used (minimizing exports). Resources in the case of environmental sanitation are water, goods used by households, commerce and industry, and rain water. The circular system practices what economists preach: waste is a misplaced resource. By applying this concept, the circular system reduces “downstream” pollution.

Strength and weakness of HCES

HCES is a multi-sector, multi-actor approach to delivering integrated urban environmental services. As already mentioned, it is designed to respond to household needs and priorities, since the household is the level at which decisions on investments are made and where behaviour change begins. Its main *strength* is that it offers the possibility of providing an integrated, affordable and sustainable package of services meeting the users’ priorities. Its potential *weakness* is that it requires collaboration and coordination between multiple agencies which may have different capabilities and little commitment to working together.

Guideline for implementing the HCES approach

Successful implementation of the HCES approach requires the dissemination of information and assistance to those responsible for improving environmental services. Therefore, preliminary guidelines were prepared which are mainly targeted at municipal planners (especially those responsible for planning urban environmental services) and civic officials, such as mayors and city managers. These are the people who will initially have to take the decisions on whether and how to apply HCES, who will implement and support the process, and who will be responsible to their citizens for the results. The guideline is intended to assist them to understand the HCES approach, to apply it in their own circumstances, and to be able to explain it to the user communities. Other potential users of the guideline are municipal/state/provincial and central government officials, whose support is essential once local authorities decide to undertake HCES-based programs. The provisional guideline provides specific guidance for:

a) Creating an Enabling Environment for the use of the HCES approach

b) Undertaking a 10-STEP Process for developing and implementing the HCES approach

Creating an enabling environment for implementing the HCES approach

An "enabling environment" is important for the success of any investment program, but it is especially vital when applying an innovative approach, such as HCES. Most of the critical elements should be identified or become evident during the program development process. Ideally, they should be identified, at least in broad terms, prior to the program launch so that the entire process does not start off with misunderstandings. It is essential that they are recognized before or during the identification and evaluation of options at the latest, since if these critical elements cannot be assured, then some of the options may not be feasible.

Government Support

Political support at all levels is essential. HCES involves departures from conventional methods, especially in its institutional approaches, and the program promoters should plan to devote considerable efforts to familiarizing elected officials, senior sector staff and advisers with the concepts. This will involve presentations, seminars, visits to demonstration projects in communities to learn about the possibilities offered by HCES.

Legal Framework

The most obvious immediate need for change in order to accommodate HCES is in the matter of standards. Many existing standards (national or municipal) are based on those developed in industrialized countries, under conditions totally different from those applying today in developing countries, and so they are often inappropriate. Even where they are in theory appropriate, they often cannot be applied (because they are too expensive), and enforcement is weak. Nevertheless, it is dangerous for a public sector official to reject the standards explicitly, because then the official may become personally liable for any resulting problems. Part of launching HCES should therefore to be to secure a moratorium on the application of existing standards to the program area, and part of the overall exercise should be to try to identify standards which would be more appropriate.

Institutional Arrangements

Stakeholder service demand and delivery capacity will vary from zone to zone, and so will the need for support services. Local (neighbourhood) organizations will therefore require specific support inputs not only from similar organizations (that is, from similar zones), but from organizations in larger zones with greater responsibilities and (hopefully) greater capacities. The most significant change introduced by the HCES approach is the participation of stakeholders that previously have often had little opportunity to participate under the conventional system of project planning and implementation. Most UESS organizations are unfamiliar with the concept of basing their program planning on responding to household demands and arriving at solutions acceptable to the household through a consultative process. Existing organizations will have to change their modus operandi from managing to supporting, requiring a good deal of reorientation and retraining of staff. For now, NGOs often bridge the gap between central organizations and stakeholders at the lower, community levels. This gap should eventually be eliminated, with more permanent arrangements between central organizations and organisms created by the community to satisfy its needs (which might still involve NGOs). Prior to program launch, a preliminary assessment should be conducted to determine the capacities of the various UESS organizations and others who might become involved (including private sector and NGOs), and the existing status of collaborative planning activities. This knowledge will help planners to take quick action to remedy problems identified during the program launch meeting and throughout the HCES implementation.

Required Skills

Many groups and organizations will need training and orientation. For example **householders** will need to understand more about the implications of the options open to them, and will also have to be shown how to exert quality control over local builders and contractors, to make sure that they are not being cheated. **Communities and their organisations (CBOs)** which will undertake construction, O&M and/or management of local UESS will need training on technical matters, accounting and simple financial management, basic contract procedures, and monitoring and reporting. **NGOs** that will become involved in the program need similar training, but at a more advanced level, as they are probably going to have to train the participating communities. They will also need to become familiar with the social factors affecting the selection and proper use of UESS, and with supporting communications strategies. **Municipal staff** will need to be reoriented away from their present perception, that UESS deficiencies are primarily due to lack of technical solutions developed in industrialized countries. Instead, they should be helped towards a better understanding of the social, institutional, financial and other factors that have to be addressed. All of these groups and individuals will need training in "commercializing" waste recycling and urban agriculture/horticulture activities (e.g., marketing) if the full potential that is offered by the application of the circular system is to be achieved. Only then can the simultaneous improvement of both the health and economic productivity of members of the participating households be achieved.

Credit and other Financial Arrangements

A major recurring problem encountered by low-income customers and small entrepreneurs is the lack of capital to finance investments or equipment, even when they are capable of paying small amounts for current expenses. Rather than to resort to grants or subsidies, governments and their agencies should consider the establishment of a line of credit, or the provision of equipment and materials against regular payments. The provision of grants and subsidies often has the unintended effect of encouraging users and organizations (at whatever level) to choose systems and technologies they are unable to sustain, which later leads to rapid deterioration of facilities and deficient services.

10-STEP-process for developing and implementing the HCES approach

The last section of the guideline describes ten typical STEPs involved in developing and implementing an HCES programme. These STEPs are presented here in sequence, but in practice they will usually overlap, some STEPs may need to be repeated more than once in an iteration to find acceptable solutions, and they will always need to be undertaken bearing in mind the concerns of the municipality as a whole.

STEP 1: Request for assistance

The HCES process should start in response to a request for assistance from the people who will benefit from the services: in the model used in the guideline, this request would be made to the mayor (or other professionals serving the mayor), by the users themselves, their political representatives or local community leaders.

STEP 2: Launch of the planning and consultative process

Once a request for assistance in developing an HCES-based programme has been received, it is important to check that all the participating stakeholders really understand and accept the implications, for example: intensive user involvement; close collaboration between various agencies; and the possibility that the integrated, balanced, multi-service solution finally adopted may not exactly correspond to what the individual sectoral agencies had envisaged.

STEP 3: Assessment of current status

The next Step in the development of the programme is a comprehensive, participatory assessment of the current level of UESS service. This is a more complicated process than that carried out in typical conventional single-sector planning, which is often confined to trying to answer questions such as 'What is needed in order for the water company to provide water through standpipes?' An HCES assessment needs to cover all the services, must be participatory in its methodology, and understand how services are provided and used within a particular social context.

STEP 4: Assessment of user priorities

The results of the status assessment (STEP 3) should be reported to the community through a participatory process (i.e., meeting, focus group discussions) at which representatives of relevant agencies are also present - but as equal participants, not as leaders. The objectives of this part of the process are to (a) present the findings of the assessment, (b) correct possible factual errors, and (c) Establish, in broad terms, the 'ground rules' for the next, most intensive part of the study: deciding which deficiencies should be given priority, what levels of service should be considered, what institutional arrangements would be acceptable, etc. The setting of priorities is ultimately done by the householders, taking into account the Bellagio principles.

STEP 5: Identification of options

The identification of the various options for UESS services that are conducted using the HCES approach have to cover the same broad range of topics as those conducted for any feasibility analysis; they must examine the technical, institutional, financial and social feasibility of each option, and assess other factors such as its impact on the environment. The guideline does not discuss these techniques, which are covered by a number of standard texts. However, some special features are discussed which set the HCES analysis apart from conventional analyses.

STEP 6: Evaluation of feasible service combinations

Once the costs and implications of various options are known, at least approximately, work can begin on determining which combinations are likely to be feasible. The lowest desirable level of service should have been decided during the consultations in STEP 4. Above this lowest level, the task is primarily matching a particular level of service with the associated on- and off-site facilities (for example, flush toilets are not feasible without a high level of water supply and effective means of wastewater collection, treatment and disposal).

STEP 7: Consolidated UESS plans for the study area

The objective of this STEP is to develop a programme that will cover the entire study area (as defined in STEP 2). The various options identified during STEP 6 are likely to be suited to particular neighbourhoods or communities, depending on factor such as income level, housing type, soil conditions and topography. The challenge now is to assemble and integrate these into a broader UESS network.

STEP 8: Finalising of consolidated UESS plans

The consultation involves three stages: (a) planners present the options that appear feasible for individual neighbourhoods; (b) planners explain the interactions between neighbourhood choices; and (c) planners assist the community on reaching a consensus on a broader programme. It may be more efficient to conduct the first two stages separately, neighbourhood by neighbourhood, but if this approach is taken, each neighbourhood must clearly understand and accept that the final stage may lead to later adjustments and modifications.

STEP 9: Monitoring, (internal) evaluation and feedback (MEF)

MEF must be thought of as one integrated process, even though it consists of three separate elements. There is no point in collecting data (monitoring) unless the data is then analyzed critically (evaluation), and then the conclusions of the evaluation used to improve the process being monitored (feedback). Good MEF is absolutely essential to the success of HCES programmes.

STEP 10: Implementation

The final guideline will include a section on matters requiring attention during implementation, because programmes undertaken using the HCES approach are likely to require adjustment and fine-tuning during the implementation process, especially if new communities are added to the programme as work proceeds. However, this section on implementation can only be prepared after the HCES approach has been applied to actual projects or programmes based on the preliminary guideline.

Conclusion

A new approach (HCES) has been suggested to overcome the shortcomings of conventional approaches in environmental sanitation planning by placing the household at the core of the planning process and by introducing a circular system of resource management. In order to implement the HCES approach, preliminary guidelines were prepared to give guidance how to create an enabling environment and how to apply the HCES approach. The provisional guideline should be tested on selected projects, which should be subjected to careful monitoring and evaluation. That process should not only test the provisional guideline and reveal areas which need to be improved, it should also bring out the topics which need to be particularly stressed during implementation, and the issues which are likely to arise.

Acknowledgement

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Tentative guidelines for agricultural use of urine and faeces*

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Abstract

Plant nutrients are a necessary input in high-productive and sustainable crop production. The plant nutrients in both urine and faeces emanate from arable fields and thus should be recycled as fertilisers to support sustainability and to retain the fertility of the fields.

This paper presents tentative general guidelines for use of urine and faeces as fertiliser. Urine is a quick acting fertiliser rich in nitrogen, and with a composition of nutrients that well matches the needs of many crops. Urine and faecal matter well supplement each other, since faecal matter is slower acting and rich in phosphorous and potassium. It also contains organic matter and will increase the buffering capacity and the organic matter of the soil. Faecal matter should be sanitised before reuse, since it can contain high concentrations of pathogens.

More research on use of urine and faeces is needed in order to make the recommendations more detailed and to develop new ways to efficiently use human excreta in agriculture. The guidelines are developed by EcoSanRes, a programme supported by Sida.

Introduction

Many of the nutrients used today are either fossil resources or consume large amounts of fossil resources during their production. During food production, nutrients are removed from the soil and these nutrients have to be replaced by plant-available unpolluted nutrients. The main urban nutrient source is toilet waste and together with organic household waste, these fractions contain more or less the same amounts of nutrients removed from the field during food production.

The major proportion of the nutrients in wastewater originates from urine. Of the amounts consumed in food, about 70-90% of the nitrogen, 45-80% of the phosphorus and 70-95% of the potassium are found in this fraction while the rest is found in the faeces (Lentner et al., 1981; Guyton, 1992; Vinnerås 2002). The urine nutrients are water-soluble and relatively available for plants to take up or easily transformed into plant-available compounds (Kirchmann & Pettersson, 1995).

Plants take up nutrients in ionic form and the nutrients in urine are easily plant-available, since they are in ionic form, or rapidly degrade to this form. Most of the nitrogen in urine is excreted as urea, which is easily degraded to ammonium, often already during collection and storage.

*This paper has been peer reviewed by the symposium scientific committee

Otherwise, degradation takes place within hours of application. In the soil, ammonium is oxidised to nitrate and both ammonium and nitrate are plant-available. The phosphorous in the urine is in ionic form at excretion, but during storage some precipitates as calcium and magnesium phosphates and all of these forms are plant-available. The potassium and the sulphur are in ionic form and easily plant-available. Urine is a nitrogen-rich fertiliser with high plant availability.

Faeces are by weight the smallest of the biodegradable waste fractions. Between 30 and 110 kilograms, wet weight, of faeces are produced per person and year. This corresponds to 10-15 kilograms of dry matter (Lentner et al., 1981; Vinnerås 2002). The volume produced per person depends upon the composition of the food consumed. Meat and other foods low in fibre produce smaller volumes than food high in fibre (Guyton, 1992).

Faecal nitrogen is mainly found as organic nitrogen and has therefore to be mineralised before it becomes available for plants. Phosphorus is mainly found as small grains of calcium phosphates in the faeces (Frausto da Silva & Williams, 1997) and this phosphorous is available to plants. Potassium is mainly found in its water-soluble ionic form (Berger, 1960) and is therefore readily available. Faeces are high in phosphorous and potassium, but also contain slow release nitrogen.

The amount of nutrients found in the urine and the faeces depends on the nutrient content of the food consumed. This varies from person to person and region to region. Vinnerås & Jönsson (2003) present the estimated average composition of urine and faeces for different regions according to the average food consumption as given by the FAO.

The nutrient requirements of plants

Elements essential for the growth of plants are normally called nutrients. The nutrients used in the largest amounts are the non-mineral elements, i.e. carbon, hydrogen, and oxygen. These substances are mainly derived from carbon dioxide (CO_2) and water (H_2O). All other nutrients are mainly taken up from the soil by the roots. Increasing the supply of light, CO_2, water and mineral nutrients from the deficiency range increases the growth rate and crop yield. The yield response curves for a particular mineral nutrient can be illustrated as in Fig. 1. When the supply of one mineral nutrient or growth factor is increased, other mineral nutrients or growth factors then become important as limiting factors (Fig. 1).

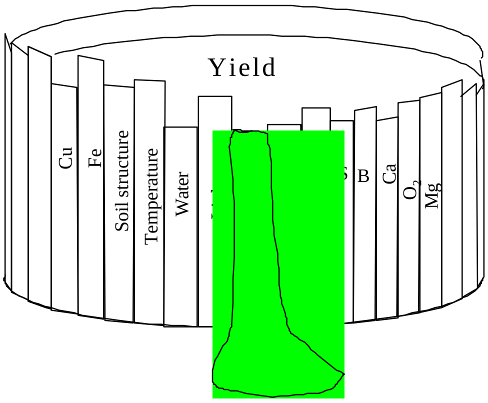

Figure 1. The limiting factors regulating the growth of plants. If the most limiting factor is improved, e.g. here by addition of nitrogen, some other factor or element will limit the growth.

Nutrients can be divided into the two categories macronutrients and micronutrients and the total uptake of macronutrients is about 100 times that of micronutrients. The macronutrients are the six elements nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg). Of these, yearly additions are usually needed of the first four (N, P, K, S), while the soil supply of Ca and Mg is usually sufficient provided that the pH is not too low. All over the world, nitrogen is frequently the most limiting nutrient for plant growth. The main natural sources of plant-available N are degradation of organic matter in the soil and N fixation by microorganisms living in symbiosis with the roots of legumes. The visible fertilising effect of using urine as a fertiliser usually comes from its N content. The natural supply of P comes from mineralisation of phosphates and from degradation of organic matter in the soil. In acidic soil the availability of P is often low, due to strong bonds between phosphates and metal ions at low pH. The high water solubility of K often results in a good supply of plant-available K. However, many crops such as vegetables need large amounts of potassium and therefore additional fertilisation improves plant growth. S is also highly water-soluble and most crops need it in somewhat smaller amounts than P. Even so, on many soils yearly additions of S are needed.

Micronutrients are also essential for plant growth, but the uptake of these elements is in small (micro) amounts. The elements normally considered to be micronutrients are boron, copper, iron, chloride, manganese, molybdenum and zinc (Frausto da Silva & Williams, 1997). Most micronutrients are needed for formation of different enzymes. These nutrients mainly come from degradation of organic material and erosion of soil particles. Only in special circumstances does scarcity of micronutrients limit plant growth. When human excreta are used as a fertiliser, the risk for such deficiency is minimal as excreta contain all the micronutrients.

Application strategies for human excreta

Fertilisation only increases crop yield if the plant nutrient supply is one of the most limiting growth factors (Fig. 1). No yield increase is to be expected when fertilising crops that are mainly limited by factors other than nutrient supply, e.g. lack of water, too low or too high pH, etc.

Often when human excreta are used for fertilisation, the available amount is very limited in relation to the amount of plant nutrients needed. Therefore, it is important that the excreta are used in the most efficient way and this differs depending on the amount of available nutrients in relation to the available space.

There is enough space to utilise all of the nutrients to their full potential if the average application of available nitrogen is below dose A in Fig. 2. Dose A is the dose up to which the yield increases linearly with increasing application. Dose A differs between different crops, regions and climate. If its size is not known, then the application of the urine from one person during a full day per square metre (approx 1.5 litres of urine/m^2) can be used as a rule of thumb. This corresponds to application of approximately 40-80 kg N/ha.

When space is not a limiting factor, the full fertilising effect can easily be gained from urine, even if the urine is applied at different dosages in different places, as long as the dosage in all places is below dose A (Figure 2).

The best fertilising efficiency when space is so limited that the average dose has to be above A is obtained by keeping the dose even over the whole available space, if all the crops have the same nitrogen demand. The yield increases when the application is increased from dose A to dose B (Fig. 2). However, both the quantity and the quality of the yield are important and high doses of available nitrogen (i.e. urine) can also affect the quality. For example, the quality of wheat is generally improved by a high nitrogen dosage, while the quality of, for example, Irish potatoes may decrease since the tubers can become watery.

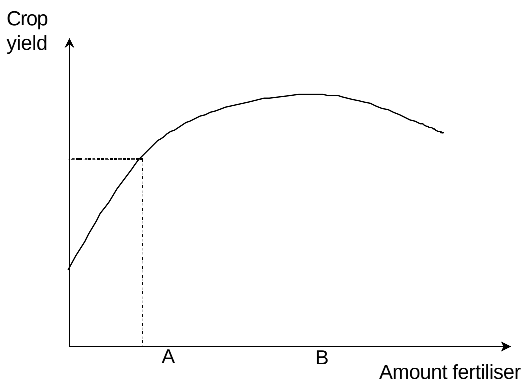

Figure 2: The effect on the yield of increasing doses of available nitrogen (urine). Up to dose A, the increase in yield is linear to the addition of urine. Between dose A and dose B, the yield still increases in response to the increased fertiliser application, but at a slower rate. Beyond dose B, additional fertiliser application becomes toxic and the yield decreases if the application is increased.

If no information is available on dose B, then a dose 5 times as high as dose A can be used as a rule of thumb, i.e. applying the urine from one person during one day on an area of 0.2 m^2.

If space is even more limited, i.e. so that the average dose would be above dose B, where additional amounts of urine become toxic, then the dose should be limited to dose B. The amount of urine that cannot be utilised as a fertiliser should be disposed of in some other way, i.e. as an accelerating agent when composting.

Use of urine as a fertiliser

The fertilising effect of urine is similar to that of a nitrogen-rich chemical fertiliser and urine should be used similarly. Therefore, urine is best utilised as a fertiliser to nitrogen-demanding crops and vegetables. If crop- and region-specific recommendations are available for the use of such a chemical fertiliser, a good starting point when using urine is to translate this recommendation to urine. This translation is simplified if the nitrogen concentration of the urine is known. If it is not, then as a rule of thumb, a concentration of 3-7 grams of nitrogen per litre of urine can be expected, or approximately half that concentration if flushed urine-diverting toilets are used (Vinnerås, 2002, Vinnerås & Jönsson, 2003).

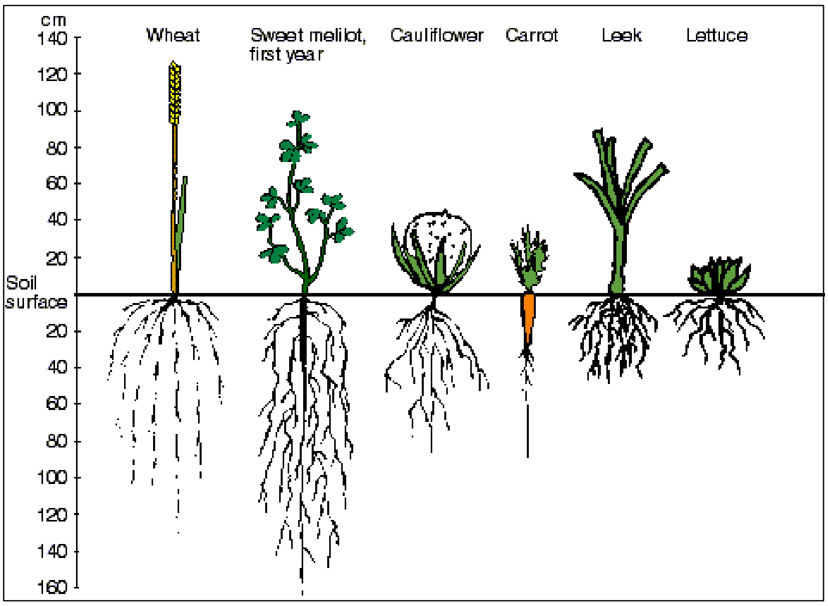

Figure 3: Root structures of different crops. (Picture by Kim Gutekunst, JTI.)

Just prior to or during sowing/planting, the soil should normally be fertilised for the first and sometimes only time. The nutrient supply even at this early stage of plant life affects the yield. However, care should be taken to protect the seedlings from high concentrations of nutrients. In the early stages of cultivation, the availability of phosphorus and potassium is the most important factor. In large-scale crop production, the normal fertilisation strategy is application once or twice per growing season. If fertiliser is applied only once, this should be carried out prior to or at the time of sowing/planting. If the crop is fertilised twice, the second fertilisation should be performed after approximately 1/4 of the time between sowing and harvest. The crop can also be continuously fertilised, e.g. if the urine is collected in smaller cans and used more or less directly. However, the nutrients are not well-utilised after the crop enters its reproductive stage. An example is maize; fertiliser applied until the plants are setting ears is well-utilised, but after this stage the uptake of nutrients from the soil is negligible (Marschner, 1997).

Vegetables are normally harvested before they reach their reproductive stage and therefore fertilisation can be continued until some time before the harvest. As a rule of thumb, fertilisation should stop after between 2/3 and 3/4 of the time between sowing and harvest. The amount of nutrients and the intervals depend mainly on nitrogen usage by the plant and root size. Root size varies between different crops (Fig. 3). Plants with inefficient or small root systems, e.g.

carrots or lettuce, could possibly benefit from several applications of nutrients throughout the cultivation time (Thorup-Kristensen, 2001.) In Swedish field trials with leeks fertilised with human urine, only small differences in yield were observed between leeks fertilised twice during the growing period and leeks fertilised every second week, i.e. eight times during the growing period, on clay soil. The total fertiliser dose was the same for both strategies. The yield was only slightly higher in plots fertilised every two weeks on the clay soil while on a sandy soil, there were no significant difference (Båth, 2003). However, as a hygiene safety measure, until hygiene guidelines have been developed, it is recommended that crops consumed raw are not fertilised with urine closer to harvest than one month (Schönning, 2003).

If the storage capacity during the non-cultivation period is insufficient, the urine can be utilised as a fertiliser for trees and bushes or it can be "stored" in the soil by application and incorporation of the urine in the field during the dry season, followed by normal crop cultivation when it is suitable according to rain and irrigation conditions. The main proportion of the nutrients will then remain in the soil and be available for the plants during the growing season, even if some nitrogen is lost. Further investigations are needed to determine the nitrogen loss during such storage.

Application technique

For best fertilising effect, the urine should be mixed into the soil as soon as possible after the application, instantly if possible. This can be done for example by applying it in small furrows that are covered after application. It can also be done by applying water after the urine, thereby washing the nutrients into the soil. When applying the urine, spraying of leaves with urine should be avoided as this can cause foliar burning due to high concentrations of salts if urine is left to dry on the leaves. Spraying urine in the air should also be avoided as the nitrogen in the urine is then partly lost as gaseous emissions of ammonia (Rodhe et al, 2003).

It is not necessary to dilute the urine before application. However, the whole root of the plants should not be thoroughly soaked with undiluted urine, as this might be toxic and even lethal, especially for small plants. Instead, the urine should be applied either prior to sowing/planting or at such a distance from the plants that the nutrients are within reach of the roots, but that they are not soaked.

Use of faeces as a fertiliser

The nutrient content in faecal matter is considerably lower than that in urine, especially the amount of plant-available nitrogen. The main contribution from the faecal matter is the content of phosphorus and potassium and the increase in buffering capacity of the soil.

The effect on soil pH and on its buffering capacity is important in areas with such a low soil pH that the growth potential of plants is affected. The importance of this effect, which is increased if ash is added to the faeces, has been shown in field trials in Uganda. The soil pH was low and the fertilising effect of urine and faeces+ash was better than that of urine only (Figure 4).

As faecal matter is one of the major sources of pathogenic microorganisms, this fraction has to be sanitised before usage. The faecal matter should preferably be treated on site at the point of collection to avoid handling of the pathogen-containing material, as one of the major transmission routes is direct contact with raw untreated faecal matter (Faechem et al., 1983). Alternatives for the sanitation of faecal matter are biological treatment, chemical treatment or incineration.

Composting is a traditional biological treatment of organic matter. To be sure that the microorganisms are inactivated, all of the material has to attain a high temperature for a period of time (Vinnerås et al., 2003). This method requires good technological skills to function well. Composting reduces the amount of organic matter and therefore there is less left in the finished compost. Faecal matter to which ash or lime has been added seems to have too low a concentration of organic matter to attain temperatures high enough to sanitise the faecal matter (Vinnerås et al., 2003).

Figure 4: The quality of the maize cobs varied between the treatments . Cob no. 1 from the left was fertilised with faeces + urine, Cob no. 2 with urine, while Cob no. 3 received no fertiliser.

Traditionally chemical treatment of faecal matter has been performed by addition of ash and lime. More recent studies have also shown good effects from the addition of urea (Vinnerås et al., 2003). The advantage of chemical sanitation of the faecal matter is that it can be performed at the collection site and it requires less technical skill than composting. It is important to use sufficient ash material to sanitise the faecal matter. An additional effect from chemical treatment with ash and lime is an increased buffering capacity and increased pH in the soil after application.

A third alternative is to incinerate the faecal matter. If the faeces are collected separately in a ventilated chamber, the dry matter content often becomes high enough to be combustible. When all the material is incinerated the risk of pathogens is small, as they are destroyed during the process. However, almost all of the nitrogen and carbon is lost during the process, although the amount of plant-available nitrogen is low in the faecal matter from the start. The other nutrients remain in the ash and become available to the plants when spread on soil. However, the nutrient concentration in this ash is high and therefore it should be carefully dusted out over a larger area.

As a hygiene safety measure until hygiene guidelines have been developed, we recommend that faecal matter, even if it is sanitised, should not be used as a fertiliser to vegetables that are eaten raw.

Faeces are rich in phosphorous and potassium and should therefore preferably be used on crops that have a high demand for potassium and phosphorous. The dose can be based on the recommended dose for use of phosphorous in chemical fertilisers. The risk of over-application is small, but toxic effects can occur at high application rates if the faeces are mixed with large amounts of ash.

Application technique

To gain the maximal effect from faecal matter it should, just as urine, be applied close to the roots of the plants, but not in such a way that it is the only growing medium available for the root. The easiest way to do this is by application in holes or furrows close to the plant. Faecal material should be cultivated into the ground and covered as soon as possible after application, to prevent unwanted contact with potential remaining pathogens. For best effect, it should be applied before sowing/planting. Care should be taken to prepare a proper seed bed.

Conclusions

The following tentative recommendations are based on our current knowledge of the use of urine and faeces in small- and large-scale cultivation.

Urine

- If it has been collected and stored in a correct manner, urine is a quick-acting nitrogen fertiliser. Application of urine can beneficially take place from prior to sowing up to between 2/3 and 3/4 of the period between sowing and the harvest.
- The amount of urine that is used should be based on the amount of nitrogen that is recommended when fertilising with urea-based fertilisers. If no better knowledge exists, an estimate of the nitrogen concentration in urine of 3-7 g per litre can be used.
- If no recommendations can be obtained, a rule of thumb is to apply the urine collected from one person during one day to one square metre of land. The maximum dosage before risking toxic effects is approximately 5 times this dosage.
- Until further knowledge becomes available, the roots of plants should not be soaked with urine, in order to minimise possible risks of root toxic effects. Experience shows that while there is no risk with many crops, some are sensitive, especially as seedlings.
- Fertilisation with urine can be done once in the cultivation period, or repeatedly. Normally the effect on yield of repeatedly applications of urine is small if the total dosage remains the same.

Faeces

- Faecal matter is a fertiliser rich in phosphorous, potassium and organic matter. Faeces should be applied and mixed into the soil before cultivation starts.
- Faeces contain organic matter that improves soil fertility and increases the buffering capacity of the soil, especially when it has been mixed with ash. These effects are especially important on soils with low pH.
- The faeces should be placed within reach of the roots of plants in order to maximise the utilisation of the nutrients.
- The amount of faeces used should be based on the current recommendation for the use of phosphorous-based fertilisers. There is no risk of toxic effects even at higher dosage except when the faeces are mixed with large amounts of ash.
- For hygienic reasons, the faeces should be sanitised before usage. We also presently recommend that the faecal matter is covered after application and not used as fertiliser to vegetables that are consumed raw.

Lack of documented research in this area makes the development of definite guidelines difficult. Research on the use of urine and faeces as fertiliser is needed, especially in the following areas:

- Nutrient effects of excreta on crops and soil
- Fertilisation strategies when using excreta
- Efficiency of “storage” of urine in soil
- Simple and resource-efficient sanitation techniques for faeces

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EcoSan – clean production mechanism under the Kyoto-protocol

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Introduction

The Kyoto-protocol provides instruments to reduce the greenhouse emissions that can be applicable for the development of EcoSan. The article will give arguments and supporting analysis that EcoSan must be regarded as clean production mechanism (article 12). Through support of EcoSan development in developing countries, industrialised countries must be allowed to claim the emission reduction that is achieved by these measurements. In a similar way joint implementation of EcoSan projects must be accounted for, and therefore become an option for investment.

The authors want to underline that EcoSan is a fundamental aspect of (urban) sustainable agriculture in the light climate change considerations, and should therefore be promoted according to article 2 of the Kyoto-protocol.

This would provide those countries extra means to invest in a sanitation approach that will avoid the introduction of sanitation system that itself also would contribute to global warming through the use of mineral energy for the construction (sewers) and operation (wastewater treatment) of the system. In addition, it will avoid the greenhouse gasses, such as methane (CH_4) will be release as a result of anaerobic digestion of wastewater.

Methods

The article will be a part of the C-N research under the UWEP-Plus programme of WASTE that studies the effects of ISWM on the use of energy and greenhouse emission.

The article will depart from the assumption that all people have the right to improve their standard of living. The economic growth that will be needed to realise this desire can be expressed, among others, in the need for energy and nutrients.

As a substitute for mineral fertiliser, the application of urine and faeces in agriculture will contribute to the reduction of greenhouse emissions (CO_2, CH_4 and N_2O). Illustrated with data of the Island on Tingloy in the Philippines, the article will present the argument that when human excreta are use as fertiliser, the standard of living of urban and rural farmers can be raised without an increase in the use of energy and exploitation of arable lands. The research will compare a develop strategy for a community in Tingloy based on the input of mineral fertilisers and of human nutrients. The model will distinguish between and based on the interrelated the C- and N cycle.

Results

The article wants to present a simple model through which one can start compare the effect of mineral fertiliser and human fertiliser on the global warming.

It is the intention of the authors that this *Tingloy model* can be used as tool by other communities to make strategic choices concerning the choice of sanitation approach.

With the application of the model one should be able to make a rough estimate of the impact of sanitation choices in specific local context on global warming.

The article will presents links between EcoSan and the Kyoto-protocol in the following sectors/source categories:

Energy; construction; transport; mineral products; agriculture; manure management; waste; wastewater handling.

Conclusions

The authors aspect to outline an argumentation and a supporting model that EcoSan practice must be certified under article 12 of the Kyoto-protocol, because it results in emission reduction as they are based on:

Voluntary participation

Real, measurable and long-term benefits related to the mitigation of climate change, and

Reduction in emissions that are additional to any that would occur in the absence of the certified project activity.

Rainwater harvesting, water re-utilisation and ecological sanitation – further developments

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Session A

Keywords

Greywater, rainwater harvesting, water re-utilisation

Introduction

Increasing anthropogenic environmental noxious, the change of soil exploitation and the climate change show a risk to the availability of water resources. Also the insufficient water resources in the single countries, various states of sophistication, social aspects and in many areas the low standard or a not even existing water and public sewage systems in different parts of the world are responsible for the mean supply of water. Experiences have shown that the water supply as well as the sewage water systems and clearings can not be treaten separately.

Even Germany with its high level of technology has to face many problems in this point.

The costs of preservation of the physical structures and systems for turning water into drinking water to such a standard which is requested in the German rules are very high. Main reason therefore is the increasing contamination of groundwater and the resulting efforts for the cleaning of "rohwasser".

The traditional water-carried waste disposal as a kind of transport medium for faeces- becomes a critical look in fact of the sustainability.

Comparing to the European countries which discuss the sanitary risk already at the point of using rainwater for toilet flushing and washing machine, most other countries will be content to dispose water in such a quality as the mentioned drinking water.

Based on these facts different technical innovations for a lasting water resource management and sewage systems have been developed.

Main aspects were the responsible commerce of water, which means a lower consumption and decrease of water contamination as well as a consistent partical flow management.

Whilst Europe focus mainly on technologies for saving water and efficiency of water recycling in all processes - biological, chemical and physical – different parts of the world are still in work for water and public sewage systems in general.

The constitution of new systems also means to renew all kinds of inspections and the modification to the already existing administrative guidelines. In Germany there exist e.g. the "Anschluss- und Benutzungszwang" for properties to the public infrastructure. Therefore many different administrative proceedings will have to be settled for any kind of technical innovations of the water resources management for communities.

So far main points in Germany were to reduce the consumption of drinking water. Technical installations as water saver fittings were a success in the sanitary area. A further important part is the rainwater harvesting and water re-utilisation. Through the substitution of drinking water by rainwater or different systems of grey water recycling, drinking water can be saved in one single household up to 50 %.

Rainwater harvesting – state of the technology

Systems of rainwater harvesting were used all around the world with different technical efforts. Reservoirs and transport of water in mainly used in the agricultural area. The utilization of rain-water in the domestic area constantly increases.

While in developing countries the rainwater in general is collected on a low-technical standard for domestic applications and on the regional level also as drinking water and for personal hygiene, in other countries the collection of rainwater, predominantly to the industrial countries, becomes a substitution of drinking water, which then will be used for various ranges of application as toilet flushing, washer and garden irrigation. The technology of the rainwater harvesting offers numerous products for different application cases and installation sizes. A wide range of products are manufactured and are offered in the mean time.

This installation is essentially based on 2 modules. The illustration shows a central rainwater system in a domestic area, combining a pump, a supplemental feed module and the system control unit. It also shows reservoir modul, which integrates the reservoir, quiescent supply, removal line, overflow and filter completely.

The modular construction enables complete, industrially prefabricated arrangements parts finished with connection in different equipment variants and price ranges to produce.

So far the possibility is given to combine different components which are to be started if necessary with alternative sanitary systems meaningfully. Numerous physical-chemical and hygienic examinations/tests prove that the quality of the rainwater from these kinds of installations is suitable according to the state of the technology to use the water for the toilet flushing, washing machine, the garden irrigation and for cleaning purposes.

Turning rainwater into drinking water

With water treatment systems as e.g. of Aqua Sure, The Netherlands rainwater can be proceeded into drinking water quality. Through the storage of rainwater and subsequent proceeding, these systems offer possibilities to construct public drinking water systems to smaller communities and villages or at least at the domestic area.

These systems are mainly designed for regions, which do not dispose of a drinking water infrastructure. The following pictures show a water treat system, which works with the usual process of drinking water recycling as pre-infiltration, adsorption, ion exchange and disinfection. The tool is build up on a modulare basis an works on a 40 l/h capacity. This is equal to satisfy the daily supply of a family.

Whilst countries with sufficient water resources the supply with drinking water does not show the main problem, regions with less water resources rainwater these becomes an important aspect referring to the daily water supply. By using the new developed, dezentral Wasseraufbereitungsgeräten rainwater can be turned into drinking water.

The use of rainwater in addition /as a supplement to process water, for cool systems and cleaning purposes and other applications in the commercial or industrial areas is already implemented in a lot of cases. Here, first of all, economic reasons were the clincher.

Dependent on the fees for drinking water and the connection on the public sewage water systems these investments amortize themselves in relatively short intervals.

Grey water-reuse – state of the technology

An increasingly more important role is ascribed to the grey water reuse by the development of a sustainable water resource management. Water recycling in the domestic area is not basically new, but the comfort claims and the lifetime habits concerning water and body hygiene have strongly changed compared to the past times. The water-consumption has risen in this area definitely.

Today water recycling means to grasp and to treat slightly loaded domestic sewage water (grey water) and sewage contaminated with faeces (black water) separately. Typically grey water is such water as the drain of bathes and shower sewage, washing table and the washing machine.

In a water-saving household in Europe approx. 50 to 55 l of grey water are consumpted per day and person.

In fact of the low nutrient content a simple biological cleaning will satisfy the expectations.

Based on the daily personal hygiene grey water continuous comes up not depending on any kind of weather influences.

The arisin grey water can be grabed to quality of process water, which gives the possibility to use this water for toilette flushing, washing machines as well as for watering demands.

Grey water systems can be implemented decentralized as well as centralized.

Decentralized grey water installations are, e.g. installations which process the grey water in the point of origin during central arrangements will bring the water from several housing units together and process them.

The grey water use assumes a functioning drinking water supply system to use the water by cycle guidance repeatedly.

The following image shows a grey water installation in a new built housing area with 120 units at Bejing, China.

Ecological sanitation

The ecosan concepts is based on a consistent separation of partical flow.

The recycling of nutrients taken from the sewage of domestic areas is most important. Analyses of partial flow show, that the nutrients are from the human excretions urine and faeces. For the further use of these nutrients special technologies are necessary to reduce and avoid the dilution of the partial flow. By the use of special sanitary systems as separation toilets, vacuum toilets and compost toilets the separation of the partial flow can be guaranteed. In an optimal case a complete recovery/retrieval of nutrients in the sewage water taken from the domestic area will happen.

A further combination of systems for solids und also power generation under assistance of biogas reactors is also possible and have successful happened.

Furter-oriented combinations of rainwater harvesting, grey water utilization and ecosan technologies

Systems of process water and rainwater harvesting and grey water recycling are already in use and proceeded in different countries. Similar systems are already in use for the ecosan technologies. It is recommendebal to avoid any kind of administrative restraints for the implementation and realisation of new and further oriented innovations in the denzentral solutions.

Actual there are multifaceted technologies, which can be accommodated to the individual financial situation of the particular country.

So far systems of rainwater and process water harvesting were successful used in main regions showing an existing drinking water infrastructure and public sewage system.

Possibilities of combinations of the suggested systems have to be proven accordingly to the different contraints. For countries with lower rainfall the question of the quantity of collected and stored rainwater has to be clarified. It will also be important to get further information about the annual spread of rainfall, roof and collecting areas/fields as well as about the possibilities to collect and store this water.

It has to be taken care in general that countries which will investigate ground for further communities or villages, especially the developing world with a low budget of water resources, should not work with any kind of Schwemmkanalistaion.

The combination of ecosan technologies and grey water recycling should be preferred. The grey water can be drained in a dezentral soil filter and be trickled down or can be drained into the Vorfluter.

It other regions with other constraints it has to be proven which kind of combination of the single systems will be the most effective. Additional it should be considered that the installations should only use as less energy as possible so this may guarantee that regions without any infrastructure can use this installtions dezentral by photovoltic or biogas installations.

It is also possible that in the sense of economical aspects and in view of an already existing infrastructure, the combination with rainwater harvesting and grey water recyclingshoul be continued. For the development of the responsible treat with water in municipales in general, the elements of ecosan technologies as well as rainwater harvesting and water re-utilisation systems will become more and more important. The combination of both strategies will be a new task field referring to the planning, installation, operation and maintenance. Therefore further research projects and model test are required.

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Session B

Social and economic aspects

Chairpersons

Jan Olof Drangert (Lingköping University, Sweden)

Katarzyna Kujawa-Roeleveld (Wageningen University, The Netherlands)

Richard Holden (The Mvula Trust, South Africa)

Judith Lienert (EAWAG, Switzerland)

Lectures

Requirements of sanitation systems - the flush toilet sets the standard for ecosan options*
Jan-Olof Drangert (Linköping University, Sweden)

The development and implementation of ecosan in the Netherlands: social opportunities and risks*
Bas van Vliet, Nanke Stein (Wageningen University, Netherlands)

Lessons learnt on ecosan in Southern Africa - towards closed-loop sanitation?
Catherine Wirbelauer (DED/IUCN , Botswana)

Experiences with ecosan in Danish allotment gardens and in development projects*
Henrik Bregnhøj, Ann Marie Eilersen, Martin Krayer von Kraus (Technical University of Denmark, Denmark)*, Arne Backlund*

Psychology and sanitation: a personal perspective
Isabella Wilke (South Africa)

Source separation - new toilets for Indian slums
Johannes Heeb (Seecon GmbH, Switzerland), Ken Gnanakan

A methodology combination to expose and assess water and sanitation related household behaviour
Helena Krantz (Linköping University, Sweden)

Factors which have influenced the acceptance of ecosan in South Afric a and development of a marketing strategy
Richard Holden (The Mvula Trust, South Africa)*, Riana Terreblanche, Mary Muller, Nawasan*

Integrated management of water resources in projects of German financial cooperation
Uwe Stoll, Bernd Schönewald (Kreditanstalt für Wiederaufbau, Germany)

Ecological sanitation in Mozambique: baseline data on acceptability, use and performance*
Rebecca J. van der Meulen, Christine L. Moe (Rollins School of Public Health of Emory University, USA)*, Edward D. Breslin*

Urban household perception of urine-excreta and solid waste source separation in urban areas of Ghana*
George Danso, Pay Drechsel, Lucy Gyiele (International Water Management Institute, Ghana)

This paper has been peer reviewed by the symposium scientific committee

Assessment of community knowledge attitudes, practice, behaviour and acceptance of ecological sanitation in peri-urban areas of Harare
Edward Guzha, Cleophas Musara (Mvuramanzi Trust, Zimbabwe)

Environmental alternative to sanitation and food sovereignity
Alberto Ysunza-Ogazón, Jaime Leyva S., Enriqueta Martínez M., Silvia Díez-Urdanivia, Laurencio López N. (Centro de Capacitación Integral para Promotores Comunitarios, Mexico)

Cost comparison of conventional and modern sanitation solutions*
Markus Lechner, Günter Langergraber (EcoSan Club, Austria)

Oral poster presentations

Application of ecosan principles through public private partnership projects -prospects and limitations
Hartlieb Euler, Pedro Aibéo (TBW GmbH, Germany)

Human urine from city to field - towards a sustainable co-operation?
Susanna Degaardt (Kretsloppskontoret Recycling Office, Sweden)

Poster presentations

Complexity of basic needs and the role of ecological sanitation in the rural region of Lake Victoria, Tanzania
M. Grottker, D. Grottker, D. Karrasch, V. Kleineidam (Fachhochschule Lübeck, Germany)

Preliminary survey based on community need leading to sustainable sanitation – an Indonesian case study
Suriptono (Merdeka University, Indonesia)

Rural Sanitation in Ghana
Michael Tsiagbey (Council for Scientific and Industrial Research, Ghana)

This paper has been peer reviewed by the symposium scientific committee

Requirements on sanitation systems – the flush toilet sets the standard for ecosan options*

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Session B

Keywords

Sanitation, sustainability, water conservation, urban agriculture, urban growth, systems analysis

Abstract

The urge for improved sanitation arises from our care about human health as well as the care about nature itself. Pit latrines represented a visible improvement over previous indiscriminate defecation. A variety of dry toilet systems have been and are being replaced by the flush toilet - a process that started almost two centuries ago. Soil and excreta management are inherently inter-linked and they are equal partners in ecological sanitation. The modern urine-diverting toilet is about conservation of resources and protection of nature and humans.

Today there is extensive experience of the various systems from many countries and urban areas. A holistic analysis of sanitation systems comprises aspects pertaining to the toilet in the home or yard and to aspects related to the rest of the community and to nature. In this paper three toilet systems are compared. The urine-diverting toilet compares quite favourably with the WC as for environmental sustainability. If installed indoors, this toilet can match the WC for socio-cultural features. A crucial comparison between the two systems deals with the household choice whether to take on the responsibility for operation or to hire someone to do it for them.

Introduction

The urge for improved sanitation arises from our care about human health as well as the care about nature itself. People no longer accept high mortality rates and ill health, nor do we want to rid the earth of fresh lakes and green forests. At the same time, most resources in the world are under severe stress due to rapid population growth, rapid urbanisation, and increased consumption levels. Together these trends call for assessing sanitation systems as to their sustainability.

An assessment comprises not only technical function and costs of systems but also management issues to ascertain its proper use and operation. The flush toilet connected to a sewer has been the undisputed technology for a long time. It is probably safe to say that most people in the world view the system as the best. However, the sustainability test of the flush system brings forward question marks that have to be addressed (Urban Water 2002). A variety of dry toilet systems have been and are being replaced by the flush toilet - a process that started almost two centuries ago. Today, therefore, we have extensive experience of the various systems in many countries and urban areas. This in turn allows for a comprehensive comparison and systems analysis.

The discussion about sustainability is appropriate at this time in history. We have lived through

*This paper has been peer reviewed by the symposium scientific committee

a century when the urban population of the world increased from a few hundred millions to 3 billion. In this process water scarcity and squalid conditions in our cities have appeared. By the year 2050 United Nations estimate that some 6 billion people will live in urban areas i.e. twice as many as today. How can we prepare for an urban infrastructure that avoids the drawbacks of water scarcity and low sustainability in the areas that will be converted to urban residential areas in the next 50 years?

Three sanitation options

Three systems will be reviewed in this presentation, represented by the flush toilet or WC, the pit latrine, and the urine-diverting toilet. These systems are not singular in character, but each of them displays a range of variations.

The flush toilet is attached to a cesspool or a grid of sewers that is managed by a utility. Inside the bathroom the flush toilet shows few variations. The pit latrine is always situated in the yard and managed by the household, but may look very differently. It may be a simple construction and superstructure. The floor may be a slab of cement or just logs put across the pit. The pit may be lined or not, and it may reach the groundwater part of the year.

The third system to be discussed is the *modern* urine-diverting toilet. Its principle is simple: urine and faecal matter are never mixed. The appearance of the toilet itself includes a range of materials and design (Figure 1). The management may involve only a single household, or may comprise several households connected to a communal system.

In Table 1 some principal features are summarised that will be discussed in some detail.

System	Toilet room	Maintenance	Potential reuse	Management
WC				
- sewerage	Porcelain chair or squatting pan	Sewer content to wastewater treatment plant	Sludge contains industrial waste-water compounds	Utility
- cesspool	Porcelain chair or squatting pan	Emptying of compartment	Sludge including greywater content	Utility
Pit latrine				
- permanent	Structure over pit outdoors	Emptying of pit	Manure	Household or utility
- temporary	Shed outdoors	Renewing pit	Plant tree on pit	Household
Urine-diverting toilet				
- indoors	Pre-fabricated chair or pan	Collection of urine and faeces	Urine and dried faeces to garden	Household or community org
- outdoors	Pre-fabricated chair or pan	Collection of urine and faeces	Urine and dried faeces to garden	Household or community org

Table 1: Principal features of three toilet systems

Pit latrines and WCs are well-known, while the urine-diverting toilet is less known. This toilet may use some water or be waterless. Urine is collected in a bowl or container, and the faecal matter and paper is collected in a net or bucket in a chamber below the floor. It has been installed also in two-storey buildings. Usually the collection chamber is ventilated with a pipe reaching well above the roof.

A major difference from the pit latrine and WC is that the householder or an employee has to empty the urine bowl and dried faeces. A benefit is that the stored urine and faeces constitute a good, hygienic, and relatively little contaminated fertiliser (Stockholm Water Company 2001). Simple storage is enough to sanitise the urine and faecal material (Schönning 2001). Reuse of sludge from a sewer system, on the other hand, has proven difficult because of its content of heavy metals and other contaminants.

Below is shown a South African urine-diverting pedestal and urinal (a) in plastic. A urine-diverting squatting pan in fibreglass (b) is promoted in China. Both kinds are installed indoors in the bathroom, and the content is being emptied from outside the house. The porcelain toilet chair (c) is marketed in Sweden and can be waterless or uses small amounts of water. In case of using water the collection, treatment, and reuse of nutrients require special arrangements. The wooden box with a bucket for faeces and a porcelain funnel and urine-collection bowl (d) was in use in Swedish towns a hundred years ago.

a) Urine-diverting pedestal from South Africa

b) Urine-diverting squatting pan from China

c) Swedish urine-diverting porcelain chair

d) Old urine-diverting toilet from Sweden

Figure 1: Indoor urine-diverting dry toilets from South Africa and China (upper) and Sweden

Environmental and socio-cultural sustainability and management

In the following we compare the WC and pit latrine with the *modern* urine-diverting toilet which is a technical development of the simpler version from the 1860s (Figure 1 d). A holistic analysis comprises aspects pertaining to the toilet in the home or yard and to aspects related to the rest of the community and to nature. In Tables 2 and 3 a number of important requirements are listed, associated with users, society and nature. The degree of fulfilment of each requirement by the WC, pit latrine, and urine-diverting systems is assessed.

a) User perceptions and socio-cultural sustainability

There are numerous reports on user appreciation of the various toilets in the house or yard. The eight features in Table 2 are a selection, based on the kind of requirements that seem to have crucial impact on users´ appreciation of the facility.

Features:	WC	Pit latrine	Urine-diverting toilet Outdoors	Indoors
- smell?	No	Yes	No, if well managed	No, if installed correctly
- flies and maggots?	No	Yes	No, if well managed	No, if installed correctly
- control and security?	Yes	No	No	Yes
- easy and safe to clean and maintain?	Yes	No	No, since outdoors	Yes, if properly built
- handwashing facility?	Yes	No	No	Yes
- hygienic handling of urine & faeces?	Yes	Yes, if covered	Yes, but unpleasant	Yes, if properly designed
- affordable to most residents?	Rarely	Yes	Yes	Yes, an alternative for every pocket
- space required indoor?	Yes	No	No	Yes

Table 2: Fulfilment of various user and socio-cultural sustainability requirements on a toilet system in the house or homestead

Some of the positive features of the WC include that it is easy to clean, is almost odourless, is indoors, and it benefits health. Odour appears only momentarily from gases and from the falling excreta. These are features that pit latrines do not have, and therefore make the latter substandard in comparison with the flush toilet. A comparison of column one (WC) and two (pit latrine) shows that the two systems are contrasting in every feature but one.

A urine-diverting toilet is odourless in the same sense as the WC and is therefore possible to install in the house. Therefore the household can control its use and who the user is, and keep it as clean as they want. It becomes as easy to clean as the WC and thus does not attract flies and maggots. Children are instructed how to use it and females can visit the toilet in the night with no fear. Handwashing after defecation will increase substantially if indoor, thanks to easy access to water and soap. These benefits will occur **only** where the toilet has its entrance inside the house or flat.

The urine-diverting toilet requires changes of a few practices, however. The handling of urine and faeces can be more or less repulsive depending on the design of the storage. In any case, it is quite different from the dirty work of emptying a latrine pit since the urine is in a container and the faeces are dry. The emptying is done from outside the house and causes no inconvenience for the residents. The frequency of emptying the urine may range from weekly to each year depending on the size of the container, and the same goes for the faeces.

It turns out that a urine-diverting toilet indoors has the same positive features as the WC when it comes to convenience and hygienic safety. A comparison of column one (WC) and four in Table 2 shows that the two systems are similar in all features except for affordability. The main difference is that the urine-diverting toilet is affordable for each pocket. The running cost is nil if the household takes care of the emptying, just like for the pit latrine, while the WC carries a cost both for the flush water and for the utility service for wastewater. Of course, the household with a urine-diverting toilet has to manage the greywater and there are simple ways for doing that.

In case the urine-diverting toilet is in the yard, the toilet has several features similar to those of the pit latrine (column two and three). Since the toilet is away from the house, a certain level of smell may be viewed as acceptable. Each time ash or water for handwashing is missing in the toilet room, someone has to walk to the house to fetch it. If a child has diarrhoea, the caretaker has to walk it to the toilet outdoors and also to come back afterwards to clean the slab. Female users encounter a security problem when visiting the toilet after dark. Also, if the toilet room is not locked, anyone may use or misuse the toilet, and it is a less inspiring chore to clean after unknown visitors. These examples show that it is likely that (any) toilet in the yard face operational and socio-cultural problems.

(b) Environmental sustainability

Any toilet system has an impact on the physical environment through the demand for water and even more so when disposing blackwater or greywater, urine, and faeces. The "foot prints" may be substantial or modest depending on how the system is managed. The assessment of what happens outside the house in an urban setting includes aspects such as the ones listed in Table 3. The urine-diverting system seems more environmentally sustainable than the WC and latrine.

Features:	**WC**	**Pit latrine**	**Urine-diversion toilet**	
			Outdoors	**Indoors**
- degradation of the environment?	Yes, sewer leaks to groundwater and may overflow, eutrofication if no treatment plant	Yes, may leak to groundwater and may overflow	No Greywater treated on site	No Greywater treated on site
- resource saving?	No, but wasteful use of water	Yes	Yes	Yes
- allow for reuse of nutrients?	No, due to accu-mulation of heavy metals in sludge	Yes, if pit is emptied or very shallow	Yes	Yes
- flexible system?	No	Yes, can be upgraded	Yes, can be moved	Yes, can be moved

Table 3: Fulfilment of environmental sustainability requirements on toilet systems in the community and in the natural environment

The WC requires water for flushing and treatment of the resulting blackwater. If water supply is intermittent, households are forced to store water for flushing. Two major reasons for questioning the sustainability of the WC system are that it requires water and that it does not conserve the quality of groundwater and surface water. En route from users to the wastewater treatment plant, sewers leak despite low pressure, and in some cases pipes are blocked and the content overflows into residential areas. Such events occur also for pit latrines. If groundwater levels are shallow or the soil is very permeable, leakages result in contamination of the groundwater (Barrett and Howard 2002). If the septic tank is well-built it must be emptied regularly. However, it often happens that the collection is delayed or non-operational and therefore the household has to empty the tank in unhygienic ways.

If sewers and emptying of septic tanks function well, there is still a need to treat the wastewater before discharge into a river or lake. Technically, it is possible to clean any kind of water, but it always carries a cost. The mixing of household water with industrial water and sometimes stormwater has worsened the situation, but in a growing number of treatment plants the industrial effluent is kept separate and treated separately. Still, the demand for extracting nutrients such as phosphorus, nitrogen, potassium, and sulphur from the blackwater requires a substantial investment (SNV 2003).

The modern urine-diverting toilet provides various possibilities to recover and reuse the nutrients in human waste both on site and by a communal organisation. Due to its transparency the urine-diverting toilet encourages, in contrast to the WC and pit latrine, good user behaviour and thus gives a fertiliser of higher quality, ready for reuse in the nutrient cycle. Users will not knowingly throw alien objects into a urine-diverting toilet, since they know that the content will be used for their own food production or in the vicinity (Drangert and Krantz 2002).

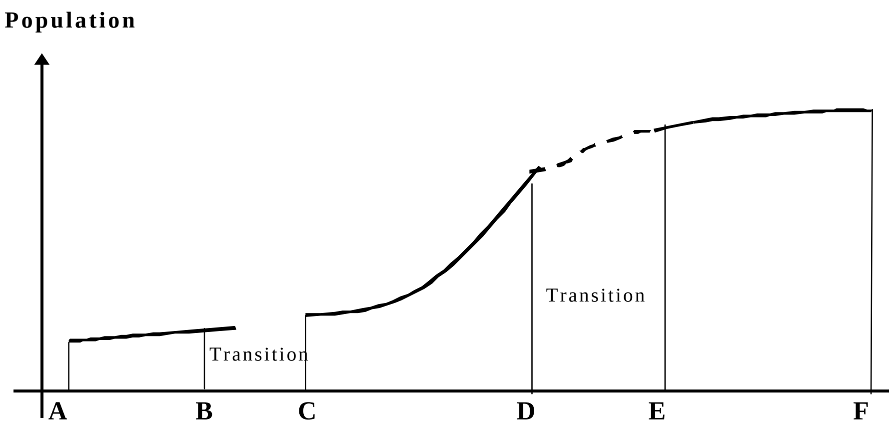
Greywater is produced also by households with a urine-diverting toilet, and it has to be treated. Again, this water can be treated in a simple biological step through sand and soil, where nutrients are taken up by plants instead of reaching the groundwater. The density of houses in the concerned area largely decides what treatment options are feasible.

c) Management and sustainability

Poor performance of a sanitation system may be caused by technical deficiencies, but often it boils down to managerial problems. A new framework for division of responsibilities requires new words and concepts. We introduce the term "*own-key*" to indicate activities and arrangements that are managed and controlled by local communities or individual households by employing locally available knowledge, skills and materials. The other end of the continuum consists of *"turn-key*" arrangements that are being utilised by the residents without them being involved in the development or running of the installation. The latter requires the extraction of financial resources from residents to the service provider either as fees or through taxation.

Generally, we note that demographic characteristics and hydrological conditions are factors of fundamental importance in selecting sanitation management solutions. So far we have dealt with sanitation management at household level, and now we analyse the relationship between demographic patterns and administrative capacity at community level. Figure 2 illustrates schematically a model for the link between the rate of population increase in a town or expanding urban area and the associated capacity to organise access to water and disposal of human and household waste. In order to emphasise that there is no simple cause-effect relationship involved, the figure includes transition periods when the population growth changes. The multi-dimensional causes for those changes are not dealt with in this paper.

When the urban population is small and stable or growing slowly (A to B in Fig. 2), a relatively large proportion of the population belongs to the economically active age group. Strong social links among kin and other groups contribute to a cohesive community where societal norms reign fairly uncontested. The hypothesis is that community leaders are fairly uninterested in major changes of the infrastructure. Although financial capability may be present, the leadership is often concentrating its efforts on managing low-budget services to the residents, rather than being entrepreneurs involved in a rapid "modernisation" process (Drangert et al. 2002). Free from external forces such as central government intervention, most of the water needs will normally be satisfied by the urban residents´ *own-key* arrangements.



Source: Drangert et al. 2002

Figure 2: Hypothetical relationship between urban population increase and infrastructure

On the other hand, during periods of rapid population growth (C to D in Figure 2), social cohesion tends to be low and public management, including tax collection, is often performed poorly. The hypothesis is that, under such conditions, existing infrastructure functions poorly and that little, if any, expansion of the public infrastructure takes place - a decline is more likely. Residents, especially newcomers to the town, are obliged to take *own-key* actions to solve, for instance, the provision of water and disposal of wastewater and human excreta. The chosen solutions may fall short of what is considered to be desirable by professional criteria. However, since the tax base and/or managerial set-up and other related functions are not adequate in this phase, the option to invest in conventional infrastructure is hardly present. Even if personnel are trained and installations rehabilitated, such measures soon fall into disrepair due to the demographic structural stress. Should this be the case, the search for improvements needs to focus on local solutions that do not require substantial inputs from the public sector. Such *own-key* arrangements are commonplace, but rarely appreciated by the formal sector. Although professionals hardly view these as appropriate, such arrangements are acceptable and, at times, sustainable and they do take into account the existing socio-cultural and economic circumstances.

The rapid urban population increase will sooner or later slow down, however, and as a result, the social cohesion will improve. The hypothesis is that authorities then will have the interest, capacity and financial strength to invest in and manage water and sanitation arrangements (E to F in Figure 2). Such a system may be a combination of turn-key and *own-key* arrangements.

Concluding discussion

The WC has had a strong impact on the general view of what is a good sanitation system, to the extent that it is perceived as the best. Only recently has the system been challenged on the ground of failing some of the sustainability criteria. However, any alternative has to be at least as good as the WC regarding all other favourable features if it is going to be accepted. Pit latrines, which have been popular in many urban areas over the last 50 years, represented a visible improvement over previous indiscriminate defecation. However, the excreta pits have contaminated local groundwater sources and proved deficient in several, but not all aspects.

Views on toilets have changed from "getting rid of excreta" to "what should we do with excreta?" In the earlier period engineers were requested to find solutions to its discharge, while at present biologists, agriculturists, medical professionals, are involved in reshaping the solution. Urine-diverting toilets is about conservation of resources and protection of nature and humans. Excreta management is inherently inter-linked with soil rather than water, and they are equal partners in ecological sanitation. This toilet system compares quite favourably with the WC as for environmental sustainability. If installed indoors, it can match the WC for socio-cultural features. A crucial comparison between the two systems deals with the affordability of investment and operation. The magnitude of savings of financial resources for the household depends on whether they prefer to handle the reuse of sanitised urine and faecal matter themselves or pay for the collection services.

Rapid urbanisation (Fig. 2) as well as difference in productivity rates between different sectors often push for a management shift from the public sector over to households and use of local resources. The urine-diverting toilet has the important characteristic that it can be managed by the household or by a group of households or even a utility. Therefore it can be adapted to the existing management capacity, unlike the case of the WC or pit latrine systems.

Poor sustainability challenges societies to improve the existing sewerage, but also to look for alternatives. The investment made in sewerage is enormous and there is no reason to abandon or dismantle existing ones. However, the long-term task up to the year 2050 is to house an additional 3 billion urban dwellers, and calls for many alternative solutions. Since conventional sewerage with treatment plants are costly and require efficient management, more affordable and resource-saving systems need to be developed. The leading idea should be to return nutrients to the soil, and improve and expand food production within the urban boundaries to secure the livelihood for additional urban dwellers.

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The development and implementation of ecosan in the Netherlands: social opportunities and risks*

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Session B

Keywords

Urban water management; eco-sanitation; transition management; consumer participation

Abstract

The diffusion of eco sanitation systems should be linked to the broader discourse about urban water management that is currently going on in the Netherlands. A shift from central sewer systems to de-central eco-sanitation systems involves a socio-technical transition and should therefore be initiated in socio-technical niches in order to change existing regimes of sewer management. The set-up of an ongoing social-scientific research project is discussed as well as two cases of eco-sanitation development in the Netherlands. For a successful niche development, much more emphasis should be laid upon consumer participation and societal embedding of new sanitation technologies.

Introduction

Sustainable urban water management is a hot issue these days in circles of water managers, city-planners, municipalities and builders both in the Netherlands and abroad. The implementation of eco-sanitation as one of the options for a more sustainable urban water management is however still lagging behind.

The present paper is reflecting our ongoing work within a project[1] set up by a consortium of environmental engineers, municipalities, utilities and housing developers to develop, study and implement several techniques of on-site anaerobic wastewater treatment in the built environment. The aim of the project is to enhance the diffusion of eco-sanitation within the Netherlands, by setting up niche projects in which researchers, municipalities, consumers and other actors can learn about the new technology. Although it is our objective to broaden the research to a European scope, in this paper we will focus on the situation in the Netherlands, where we have carried out two preliminary case studies.

The social scientific component in the project addresses social problems of implementation and societal acceptance of such eco-sanitation systems. We will first argue in the following section, that implementation of such systems should be connected to the ongoing debate on urban sustainable water management in order to enhance chances of success. Secondly, we will address the development of a special kind of eco-sanitation techniques (Desar systems) as our main study object, followed by a presentation of our methodology of research and case study selection. In order to address the opportunities and barriers to implement technologies in different spatial contexts, we argue that variables of management and consumer involvement

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should be added to the usually applied technical and environmental variables. In the penultimate section, we present the preliminary findings of some first (pilot) case studies before drawing some more general conclusions in the final section of this paper.

The societal context: some promising developments in urban water management in the Netherlands

The tradition in Dutch urban planning and building is to deal with water as an exogenous element in urban settings. Where there is an abundance of surface water in urban areas – which is almost everywhere in the Netherlands – one should get rid of it through lowering of water levels, digging canals and building huge storm water sewer systems. Most water infrastructures of the past centuries were designed to lead water away as quickly and efficiently as possible. In fact, the Netherlands, which for the largest part is a delta of 3 major European rivers (Schelde, Maas, Rhine) has become famous for its dealing with (and fighting against) water.

Although large technical systems, and especially the deeply economical, political and cultural rooted Dutch water management system, do not change overnight, there have been a number of developments that at least have made some bursts in the leading water management paradigm.

Since the 1980s the problem of desiccation has emerged on the political agenda. The few remaining natural wetlands in the Netherlands almost ceased to exist due to the severe lowering of ground water levels. On the local level, this may have been caused by ground water extraction for drinking water or industrial water production, but the general and most important threat is the core design of water infrastructure and -management: lowering water levels for agricultural or industrial purposes or to build new housing areas. To tackle this problem, policies have been developed from the 1990s onwards to cease ground water extraction at the most vulnerable sites, and to retain water in rural areas, by financially compensating farmers.

In urban planning, anti desiccation policies have led to some innovative methods to retain water in the area by lowering the percentage of hardened surface, and by substituting asphalt for metalled roads and parking plots. Separated sewer systems for storm water and wastewater have become the new standard. Rainwater from the roofs is increasingly disconnected from sewer systems to infiltrate the soil to fill up ground water levels. The implementation of such measures on ad hoc basis gradually evolved into more generic policies that put forward that water should be the leading principle in urban planning (Ministry of Environment, 2002). This means that existing ground water levels, water currents and flood are a given for new building projects.

While problems of desiccation have mainly been addressed by experts and policy makers, much more in the forefront of public debate is the - at first sight - opposite development of increased and more severe floods. After major the floods of Maas and Rhine in 1995 and 1997, the planning of housing and other building in the flood beds of these rivers have been cancelled or altered to meet the adapted flood risk assessments. Also the paradigm of building increasingly bigger and higher dikes to combat increasing flood-levels is slowly changing into seeking and appointing retention areas where high water volumes can temporarily be stored during floods. The consequence for urban planning and building firstly resulted in the reallocation of projects that were planned in flood beds but it now increasingly implies that housing and building are adapted to the occurrence of floods: floating homes, reservation of public space for watersheds etc.

Parallel to these developments is the increasing (re-) appreciation of surface water in urban public space. Living at the waterside has become very popular among house-owners and most new residential sites now include various smartly designed waters to border as much back-gardens as possible. Some urban planners sought and found gaps in regulations by which they could convert compulsory percentages of 'green areas' in their plans into 'blue space'. In addition, new residential sites experiment with more sustainable water management techniques such as reed-bed filters for on-site grey water treatment, rain water infiltration and dual water supply systems.

The culmination of these and other new water visions has been assembled in an influential advice to the government on Water Policy in the 21st Century (Commissie Waterbeheer 21e Eeuw, 2000). The Commission recommends a radically different approach to water management, in which water drainage as practiced in traditional water management should only be reverted to if retention and storage capacities have been utilised to their maximum. Space should be created and reserved for water storage and all spatial planning activities should be preceded by a 'water check': all qualitative and quantitative consequences for water systems should be assessed and compensated where needed.

These bursts in long existing water management paradigms seems also promising for the change of a major subject of urban water management: the sewer system. The Dutch sewer system belongs to the most advanced and probably the most dense sewer systems in the world. Increasing numbers of connections (now including rural areas) and increasing scales of treatment plants, together with institutional up-scaling through the merging of Water Boards, have contributed to a further centralisation of management and more sophisticated technologies of transport (pressure pipes), monitoring and treatment. However, these innovations did not alter the disputed design principles of sewer systems: diluting waste (nutrients) with drinking water, transporting it over long distances and treating it with the use of much energy, while generating environmentally problematic sludge. Therefore, we would argue that a thus-far underestimated aspect of sustainable urban water management is the development and implementation of alternatives to large-scale sewer and sewer treatment systems. To gain more public as well as institutional support for alternatives to sewer systems we would suggest that these alternatives should be developed and evaluated within the context of the promising trends in urban water management as have been sketched above.

From sewer to desar systems

In the afore mentioned EET research project, a specific type of eco-sanitation is considered; DeCentralised SAnitation and Reuse (Desar) systems. Desar systems () encompass a radical shift away from current technological systems of sewers and large-scale wastewater treatment. The main principles of Desar conflict with those of current sewer systems. In Desar systems waste is concentrated instead of diluted and it is treated on-site in compact mostly anaerobe systems. Its products will be reused for soil improvement and/or energy production (Zeeman and Lettinga, 1999). We are dealing here with more than just a next step in a well-defined trajectory of sewer technology development. It is a radical shift away from the basic principles of sewer technology. Such technological shifts, or *transitions,* encompass much more than a change of hardware. The new techniques require a different technological regime as well: the set of rules and regulations and institutional organisation are until now perfectly geared to manage sewer systems, not Desar systems. Equally radical are the changes that users, suppliers and service managers need to make in their daily practices. Collection, storage and discharge of human waste in Desar systems bears more resemblance to domestic waste management than to the current sewer system.

Our social scientific interest in such a transition deals with the changing practices of providers and consumers dealing with sanitation and the changing relations between them (see also Van Vliet, 2002, for similar studies of consumer-provider relations in drinking water and electricity networks). For this reason, we need to explore and compare not only the technical lay-out of Desar and sewer systems, but rather the changes in social practices around the building, use and management of these sanitation systems.

Social scientific research is rare in ‘technological niche’ projects like this. In most cases ex-post evaluations can be made: normally only after the development and implementation stages of technology development, one can make judgements about social implications of new technologies. In these cases, sociologists are left with hardly more than the study of acceptation of new technologies by its users. In the current project we are able to study technological development and implementation from *within*. The framework which we will use to do so is that of the management of technological transitions (Rotmans *et al*, 2001). Transitions encompass long term radical system innovations. The magnitude of change in technological transitions differs from only optimised versions of current systems in the following ways:

- In terms of eco-efficiency, a factor 20 improvement is envisaged in stead of factor 5 as in system optimisation
- The pattern of change follows an S-curve with a predevelopment, acceleration and consolidation phase (see figure 1 below)
- Transitions include changes in *regimes*: the rules and institutions shaping and enabling systems to develop

In order to enable regime changes, *technological niches* need to be developed: ‘protected’ spaces in which actors learn in various ways about new technologies and their uses. Protection is needed as regimes are configured as to support and to develop the technological trajectories that are currently in place, rather than to support or develop alternatives to these systems. Legal exemptions, subsidies or extra manpower may be needed to enable such niche projects to develop within current regimes.

Where technological niches are situated on the micro-level of socio-technical change, and regimes on the meso level, the macro level is that of a socio-technological landscape (see figure 1). The socio-technological landscape provides the broader context for regime and niches. The landscape metaphor refers to the structural character of its influence to technological development: the technological trajectories are guided by the gradients in a landscape of societal or cultural beliefs and practices. Changes in the landscape only occur gradually and slowly. A transition can now be defined as a gradual process of societal change, in which there is a structural change of characteristics of society (or a significant part of it) (Geels, 2002). Whether a regime shift will occur is dependent of a coincidence and coupling over time of successful processes within the niche, reinforced by changes at the regime level and at the level of socio-technical landscapes.

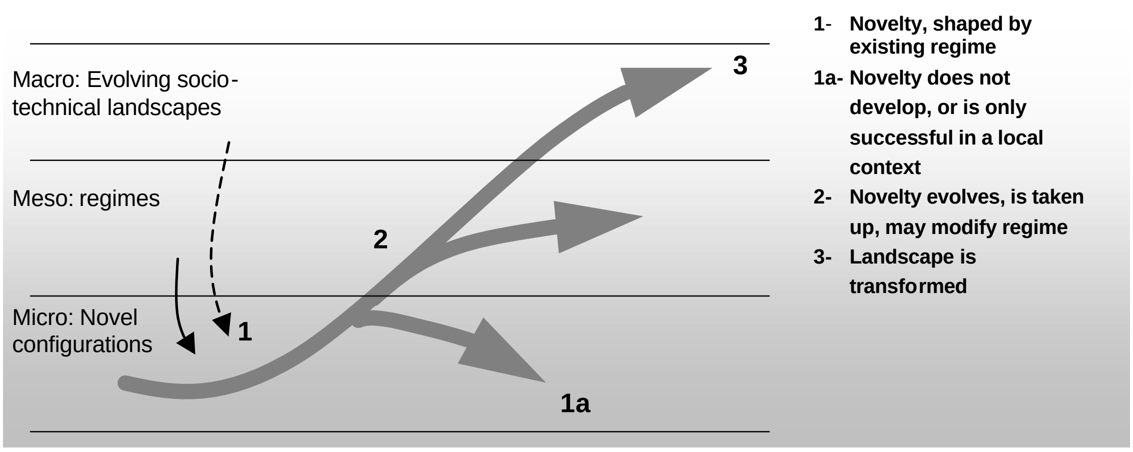

Figure 1: A dynamic multi-level view of regime shifts (Rip and Kemp, 1996)

Our study of implementation of eco-sanitation systems, of which Desar technologies are one example, and other alternatives to current urban water management is based on the idea that experimental projects may function as socio-technical niches to further regime and landscape changes in the practices (including technology uses) of urban water management and sanitation. The research includes case-studies of development and implementation of sustainable urban water management projects in different contexts of housing and utility building. . The selection of cases is derived from an initial inventory of environmental innovations in sanitation and urban water management, which is deliberately much broader than Desar technologies only. This inventory reveals a number of relevant variables to proceed our study (see figure 2). Three main clusters of variables can be made to categorise the cases of our study: conventional systems (a), alternative systems (b) and what we have called 'modernised mixtures' (c).

a) Conventional systems can be found in the clustering of values at the top of the diagram: central organisation, large-scaled systems and low user involvement.

b) Alternative systems are to be found at the opposite end of the diagram: small-scale systems, responsible users, de-centralised organisation.

c) Our research aims at combinations of these variable scores (modernised mixtures) in stead of deepening the dichotomy between 'modern' and 'alternative'.

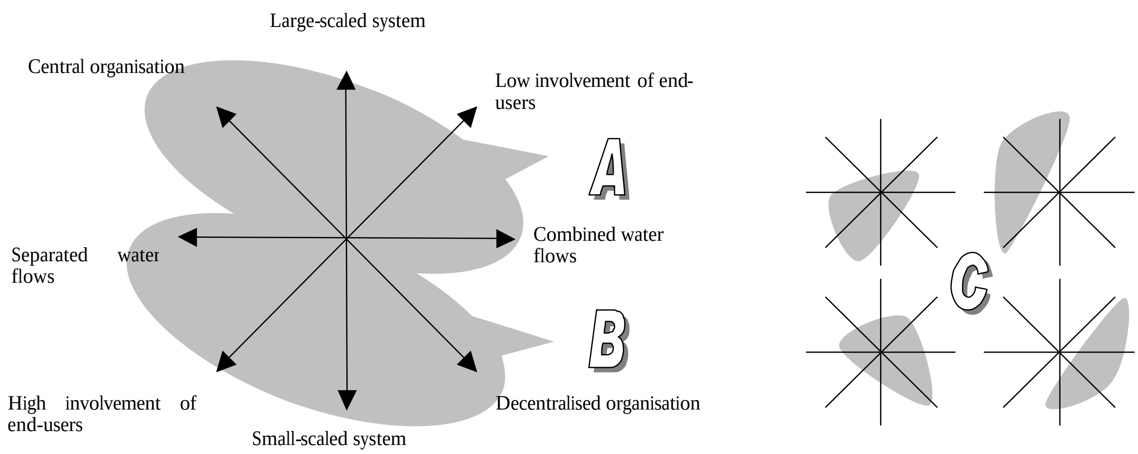

Figure 2: Variables for the inventory and selection of eco-sanitation cases

Conventional sanitation systems (a) are centralized systems designed for the treatment of single water flows. Large-scale sewer systems collecting all water flows are the extreme example of this category. The end-user involvement in these systems is low.

The category of alternative systems (b) has since the early seventies been propagated and developed by supporters of Schumacher's 'small is beautiful' thesis, encompassing consumers, technicians, philosophers and environmentalists. The idea is that not only the hard-ware of sanitation systems should be of a small, 'human' size, especially the social organisation around the design, implementation, use and maintenance should be kept as small or local as possible, to secure democratic control by the user of such systems. Besides, it is believed that such small systems are the most environmentally sound. Examples within such an alternative category are 'stand-alone' systems that do not need a connection to larger infrastructures, like composting toilets, rain water recycling systems, and reed-bed filters for waste water.

The category of 'modernised mixtures' (c) encompasses various score-sets on the four variables mentioned. Examples are centrally managed vacuum systems at the scale of a residential area with a high separation of flows and low consumer involvement; or small-scale but sewer-connected water systems based on the dual water flows and high consumer involvement. As these empirical examples illustrate, we are dealing here not only with a mixture of 'conventional' and 'alternative' technological aspects but with a mixture of social elements as well. The modernised mixtures bring together social and technical elements that used to be strictly separated and organised into ideological debates between the opponents and defenders of conventional, centralised and complex large technical systems.

Our case studies will be done at small and medium scaled systems, in which some waste streams are treated on-site and others transported and treated elsewhere for reasons of environmental efficiency. We will monitor in such cases of modernised mixtures the process of initiation, development and implementation of the new technology. From the side of providers (technology developers, municipalities, utilities, water managers) we assess which regime shifts are needed for a successful transition towards these new systems as well as their views about possible routes of diffusion and the role of end-users. Besides a particular emphasis is laid upon the involvement of end-users in design, diffusion, use and management and the consequences of these changes for current practices and standards of cleanliness, comfort and health.

Two pilot case studies

As the project is still in its initial phase, we can only present the most eye-catching elements of two pilot case studies, which will be followed through during the project. Although for the purpose of this paper we only look at the Dutch situation, we think that our findings will not only be of value in the Netherlands, but that they will be equally applicable in a wider European setting.

Therefore we will include cases in Germany and Sweden, where experience with eco-sanitation is already further developed. We expect that in these countries too, success or failure of eco-san experiments not only depends on technical adequacy, but just as much on the social environment in which the new technology is introduced. Below our first findings of two Dutch cases are presented.

The *first* case of Desar application we have followed from the start is the planned installation of an anaerobe treatment system of toilet and organic kitchen waste in a new urban residential site in the Netherlands. Although most parts of the system have been successfully applied in other settings (vacuum toilets in trains and aeroplanes, anaerobic treatment at various scales in industry), this would be the first application of Desar technology in domestic urban setting, in this case an apartment block, to be built in a larger residential site. The central idea was that if Desar infrastructures and techniques should be applied at household level, Desar technologists have to be involved in the earliest stages of urban planning.

The municipality, responsible for the planning of the site, had initially committed itself to support the experiment by allocating extra space within the requirements for the architect of the building. Besides, the municipality had to deal with the regional Water Board for all exemptions that are needed in standard procedures concerning sewer connection, and (human) waste management. Lastly the municipality should find a way to collect the remaining sludge from the Desar system and transport it to municipal waste facilities or farmers in the region, at least during the course of the experiment (scheduled for 2 years).

The technology can be characterised as medium to small-scale, based on a separation of waste water flows, a decentralised organisation and a thus far non-existent involvement of the still unknown end-users. The case resembles many aspects of a technological niche-project: the installation of a deviating technology for (human) waste treatment as well as its transport system (vacuum pipes and toilets) needs protection in the form of exemptions of sewer regulations, as well as subsidies to reserve space in the basement of the apartment block and to install a vacuum system and treatment tanks.

Although these measures of niche protection were more or less secured in advance of the project, it was certainly not enough to get the project started. Apart from technologists, municipality and water board professionals, there are many more actors involved in the planning, design and building of the site. Municipalities do not build houses, they commission private parties, (project developers, architects, building and installation companies, real estate agents) to execute the project from the initial design stages to the selling of the houses to individual consumers. In discussing the project with all these actors, it became apparent that both the municipality as well as project developers, proclaimed to be spokesman of the unknown end-consumers. As project developers and real estate agents are the risk takers in selling the apartments, one should not be surprised when they are the first to object to experiments that may affect either the price or the attractiveness of the apartment to the potential buyer. The municipality, although committed to the execution of the Desar project, also felt responsible for the well-being of its (future) citizens, and for the proper management of the system as well.

Because many crucial aspects of the experiment with vacuum toilets and Desar treatment systems were still unresolved - from seemingly trivial issues like the shape and colour of toilets to more intrusive aspects of management and transfer of technology after the experiments would come to an end - both the municipality and project developers have suspended their collaboration until these issues are clarified. One of the proposed solutions to start the project in time was to transfer the experiment to a block of *rental* houses, owned by the housing corporation in the municipality. This would ease the problem of managing and maintaining the system (the housing corporation would be the main actor here) as well as the issue of limited consumer choice over colour and shape of toilet systems (as consumers of rental houses are used to have no choice). However, this proposal has its shortcomings too and it is by now still unresolved as to whether and where the Desar installations can be built.

The lesson that can be drawn from this example of initiating a niche project is that apart from a commitment of the municipality and a subsidy for the installations, one has to deal with many more conditions under which such anomaly in the current system can be developed. Municipalities and Water Boards are legally responsible for a proper handling of human waste and they wish to have solid guarantees that alternative systems will work as well as, or even better than, the systems they are used to work with. As long as there are as many uncertainties as in the current project, their willingness to co-operate is limited. One of the other outstanding issues seems to be the representation of the end-consumer and his or her expected behaviour. As long as end-consumers are not known, other actors feel legitimised to act as their spokesman with an almost unavoidable caricature as a result. Project developers argued that consumers would renounce buying an apartment if they would find out that they do not have more than 2 models of toilets to choose from, or that they are linked up to a vacuum system in stead of a normal flush system. The problem with such claims is that they cannot be confirmed, nor refuted without consulting the consumer. This is exactly the reason why we have put consumer involvement as one of the factors alongside other characteristics of a water technology to take on board in the evaluation of niche projects.

Consumer involvement should not be caricaturised either. Our idea of consumer involvement stems not – or at least not only - from ideological considerations. We do think that generally speaking consumers are better off when they have a say in all matters that may influence their daily lives. But enabling and organising consumer involvement in technology design and service provision also serves more pragmatic purposes of proper functioning, prevention of misuse, cost reduction and many others. Moreover, in a time of liberalisation of the provision of water, waste and energy services, consumers have already become, willingly or not, much more active players in service provision than in the time that they were captive consumers without having any choice but to use the available networks.

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Another project that we have selected as a case study may illustrate what consumer involvement might encompass in sustainable urban water management. In this case, the waste water system formed an integral part of the initial design of a new housing area. The plan to integrate sustainable water management with energy saving, sustainable building principles and participation came from a group of potential inhabitants, who all had different but correlated professional backgrounds in the sustainability field. In the mid-nineties they found a positive response in the municipality of a medium-sized town in the centre of the Netherlands, which at that time was thinking of developing a site that used to be reserved for ground water extraction only. The municipality managed to obtain an additional building quota from the Province, with the condition that it would be spent on this sustainable housing project. In the initial planning phase the project partners included the core group of inhabitants, the municipality, several utility companies (water, gas and electricity), an architect and a representative body of the wider group of potential buyers of the houses. To cut down costs, the municipality decided not to delegate the project to a project developer, but to become the main commissioner itself. In combination with the security offered by the known group of future inhabitants, and the enthusiastic participation of the involved project partners a higher environmental ambition level was obtained than could be realised otherwise.

Another success factor lays in the philosophy behind the project. It encompasses a much broader vision on the outcome of the project then in our first case. It is a vision on sustainable living, that links quality of life with quality of the surrounding environment, in which the use of sustainable technology is just the means to an end, not the centre of the project itself. With this vision, potential inhabitants could be attracted in an early stage of the planning process, so that their wishes could be incorporated in the project before the plan became too definitive.

Not all went according to plan however. It is still not clear whether the biogas installation, that is scheduled to process the black water from the neighbourhood, will come into being. The water system as it exists today (2 years after the first 50 of a total of 200 houses have been built) only consists of the use of rain- and process water as second quality water in the houses. The reed bed filters that are designed to process the grey water of the neighbourhood will become functional when all houses and office buildings will be finalised, and a 'living machine'[2] might be added to process the water of an educational centre for which plans are made at the moment. When the wastewater system is functional, inhabitants will be expected to participate in the management of it. They are also legally responsible, if something goes wrong.

Due to time pressure, the level of inhabitant participation was much lower then envisaged beforehand. Although three workshops were held in which the wider group of inhabitants could ventilate their wishes, they were not able to modify their houses individually, as was planned. The professionals involved in the project were mainly responsible for the choice of sustainable technologies; inhabitants for example had no say in the choice for water saving toilets as opposed to a vacuum system or composting toilets. Inhabitants seem not to be too worried about this lack of participation; they do not mind the professionals to decide on the definite technology, as long as this technology meets their environmental and living standards.

When the system becomes fully operational, it will become clear if the standards of cleanliness, comfort and health of the inhabitants are met, and if these are compatible with a sufficient environmental standard. We will follow the developments closely in the coming years.

We see two major differences between the two cases that might give an explanation for the so far limited results in the first case and the initially successful course of the second case. One difference is that of the scope of the project: the first case is mainly about the implementation of a new technique. The 'hardware' was known, but problems emerged as soon as issues about the 'software' (management and maintenance issues) became apparent. The scope of the

[2] A 'Living machine' consists of a mini-ecosystem in which wastewater is treated naturally.

second case was much broader from the very start of the project: not the technology itself was put to the foreground, but the implementation of a sustainable way of building and living, for which new technologies should be developed and implemented.

The second major difference between the two projects concerns the involvement and representation of (future) inhabitants. They were not known in the first case so only assumptions could be made about their acceptance of new routines. Consumer participation in the design and principles behind the second case seems to have enhanced the willingness to change routines and to accept new responsibilities towards the use and management of new technologies.

Conclusions

We have argued in this paper that the implementation of decentralised eco-sanitation techniques encompasses nothing less than a socio-technical transition in wastewater management. Although we have witnessed some bursts in traditional water management, thus far a transition from sewer based sanitation towards eco-sanitation is lagging behind. However, the introduction of eco-sanitation would be much more accepted if it were linked to the now ongoing debate on water management rather than if eco-sanitation were only presented as a radical antagonist of sewer systems.

Successful transitions require strategic niches to be developed in order to alter contemporary regimes that are not supportive to eco-sanitation. The development of niches is a matter of careful selection of stakeholders and project preparation, as we have illustrated in our case studies. The involvement of end-consumers seems to be crucial as current conceptions of what consumers might do or need may be only a caricature of what consumers in practice can and are willing to do in eco-sanitation projects. In terms of project initiation it is important not to limit its scope to the hard-ware only. In many cases, the crucial barrier for social acceptance is not merely the technology, but rather its ‘software’: regulations, management, maintenance and use of technology. With this paper we have shown that when setting up eco-san projects, it is important that besides technical and economical factors, also social and institutional factors which influence the process of social embedding of the technology are considered.

Although the project is still in its initial phase, we already gained some important insights in socio-technical routes of design, diffusion, implementation and use of eco-sanitation technologies in the Netherlands. These insights will hopefully contribute to a better planning and execution of environmental innovation in sanitation technology in the Netherlands and abroad.

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Lessons learnt on ecosan in Southern Africa – towards closed-loop sanitation? [1]

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Closed-loop sanitation, lessons learnt, social acceptance, Southern Africa

Abstract

"Lessons learnt on Eco-San in Southern Africa – towards closed-loop sanitation?" is a short analysis of experiences gained in Ecological Sanitation with an emphasis on closed-loop systems. In Southern African countries the poorer segments amongst a rapidly growing population cannot afford conventional sewage systems and existing approaches to wastewater management and sanitation have become largely non-viable. In response to this, following the example of some Eco-San projects around the world the first compost latrines and Urine Diverting systems were introduced in the Region in the late nineties. Since then households are slowly starting to see the advantages of Eco-San and the systems are becoming more and more accepted despite users having to manipulate urine and faecal matter (often considered a taboo and dirty). However, the response to the different systems available in these countries has not been the same but was depending on household expectations, availability of space, living conditions etc.. Even though Eco-San is still very young in the Region it seems to be a suitable option to address sanitation and environmental concerns, but there is still a long way to go before the loops will be closing in Southern Africa.

Introduction

"Human excreta are composed of urine and faeces, which are produced in different quantities, have different qualities, and provide different benefits. Urine, faeces and the combination of urine and faeces can be processed in a number of ways. Regardless of how processing occurs, the goal is to return excreta to soils"[2]. The systems representing the approach of returning nutrients to the soil "are based on a systematic implementation of a material-flow-oriented recycling process"[3]: Closed-Loop Sanitation. When we talk about closing the loop we usually don't only think of by-products from the toilets but also combine the cycle with water

[1] With contributions from Aussie Austin (CSIR, South Africa) and Richard Holden (Mvula Trust, South Africa).

[2] SA Esrey, I Andersson, A Hillers, R Sawyer (2001)

[3] Ecosan-closing the loop in wastewater management and sanitation, Proceedings of the International Symposium, 30-31 October 2000, Bonn, Germany.

management, "as an hygienically safe, circular and holistic alternative to conventional solutions"[3]. The latter however will not be part of this analysis.

In the Southern African Region (mainly South Africa, Zimbabwe, Mozambique and lately Botswana) the priority of most Ecological Sanitation (Eco-San) projects that were initiated was to address sanitation and health problems. The developments have been manifold and results are very different. Only very few were directly linked to the idea of closed-loop sanitation. Why? Which processes are driving these projects? What are the aspects of a successful implementation of Eco-San projects in the Region? Is Eco-San a solution? Will the loops close? These are only some of the questions we have asked ourselves in analysing country case studies and compiling lessons learnt. The paper is subdivided in paragraphs containing information on general experiences in the different countries, whereas the boxes contain lessons learnt from a methodological point of view in each country. The paragraph on "Overall Lessons Learnt" is an analysis of both experiences and lessons learnt.

In the Region three main Eco-San systems were tested: the Fossa Alterna, the Urine Diverting (UD) systems and the Arbour Loo. The Fossa Alterna is a composting toilet with two vaults, when the first vault is full it is left unused for composting and the second vault is used. The UD-system is a dehydration system where urine is immediately diverted either into a container or a soak away and the faecal matter remains dry. The Arbour Loo is a composting system with a light superstructure based on a very shallow pit. Once the pit is full the superstructure is moved away and a tree can be planted into the full pit.

Experiences in Mozambique

In Mozambique, the introduction of Eco-San started after the collapse of the country's centralised slab-construction programme that had left the sanitation sector uncertain about the way forward. The Sanitation policy is unclear, particularly at Provincial level. In this context, since 2000/1 ESTAMOS, a Mozambican water supply, sanitation and HIV/Aids prevention/education NGO, and WaterAid, a British water supply and sanitation NGO, have been implementing Eco-San projects in the Niassa Province. Geographically the Niassa Province (Northern Mozambique) is the most sparsely populated province in the Country. The Province is characterised by poor infrastructure, a weak cash-based agricultural economy, and political and social isolation.

The initial idea was to implement water and sanitation activities in Lichinga in collaboration with the Municipality. During a participatory process water- and sanitation-related health problems (e.g. malaria and diarrhoea) emerged as being key concerns among local residents. During the same exercise residents realised that their latrines were contributing to these by being breading area for mosquitoes and by polluting the underground drinking water supply. Out of a number of options (Improved Pit Latrines, Two pit latrines, traditional latrines and Eco-San systems) the latter were identified as the most appropriate to solve the problems.

The concepts that underpin ecological sanitation were surprisingly well received and interest in Eco-San grew following the installation of demonstration models at leaders' houses. Households with the new latrines, mainly Fossa Alterna, spoke with their neighbours about these healthier and cleaner systems, that are odourless, fly-less, easy to build (shallow and stable), aesthetically pleasant and that can be combined with the washing area (often a tradition in the country). Aspects related to the re-use of by-products were also positively received and people were looking forward to use the compost to transform their yard. The enthusiasm increased especially after the first pits had been excavated, when users and authorities could see that the compost was of extremely high quality, thus assisting in the acceptance of a possible closed-loop use of the systems. A further advantage of Eco-San systems was that people perceived them as permanent solutions in contrast with pit latrines that once filled were relocated. In addition a few Arbour Loos were also constructed and fruit trees were tested including guava, mango, orange, avocado, as well as a range of local fruit trees. The latter system did not prove very popular in the villages because of lack of space around the houses, but was more popular and affordable at the fields where the systems could be built with local materials. Nevertheless, reasons for the acceptance of Eco-San can be very different and families were not only interested in sanitation for health reasons, but also for reasons of status and convenience. Many users referred to Eco-San systems as "modern toilets", given their recent introduction in the Province.

Lessons Learnt in Mozambique:

- ✓ Initiatives that allow families to choose between "Improved Latrines" and Eco-San systems proved to be more successful and people consistently prefer ecological sanitation over others.
- ✓ The acceptance of Eco-San systems is easier when people understand their problems and identify solutions by themselves.
- ✓ Interest in EcoSan and a closed-loop approach has subsequently grown as people have seen the contents of the pit and fears about excavating „unprocessed" faeces have diminished. People understand the concepts behind ecological sanitation, as they are simple, especially with demonstration models in place. (Learning by Seeing)
- ✓ Awareness raising and outreach programmes play an important role when introducing Eco-San (combination of participatory work and social marketing principles).
- ✓ The desire to build a "new", aesthetically pleasant and permanent latrine that eliminates problems of smell, flies and mosquito habitats while protecting groundwater is proving to be powerful enough to overcome cost considerations.

Monitoring and evaluation (M&E) also proved to be essential in providing critical information (especially at a technical level), thus strengthening the understanding of sanitation in Mozambique. Some of the more important observations made through M&E included that: people used too little soil/ash mixture because of the fear that the pit would fill too quickly; ash only is less effective against odours than the mixture; some kept their Pit Latrines for visitors because they were afraid of witchcraft and also wanted to keep the compost "clean"; during the rainy season Eco-San required greater management and care as the hole becomes quite damp and it becomes difficult to find dry soil to add to the mixture etc.

In Mozambique Eco-San seems to be a viable option both in peri-urban and rural areas, and evidence suggests that many people will invest in Eco-San systems over better promoted alternatives even if they already have a conventional pit latrine.

Looking at closed-loop Eco-San, Mozambicans recognise that the systems can have an added economic value. The closed-loop concept seems to be culturally acceptable as in the past many people in the Province planted trees and vegetables in disused latrines. The acceptance of Eco-San has been overwhelmingly positive in the Niassa Province and the use of the compost from the toilets for vegetable gardens has proven to be a considerable incentive for people who depend on farming. However, most of the new pits haven't filled-up yet and some questions still remain open: will people really excavate their pits once the faeces and urine have been converted to compost, and once the second pit is full? Will they really use the compost and fertilisers from the toilets for agricultural purposes and in their gardens? Those who have started applying the by-products to fields or home gardens have had positive results especially with maize and many are now testing on tobacco.[4]

Experiences in South Africa

In South Africa Eco-San was first piloted in 1997 through the CSIR (Council for Scientific and Industrial Research) and the ECATU (Eastern Cape Appropriate Technology Unit) in the Umtata area (Transkei). Since its very start it was directly associated with the UD-system, which was introduced as the only Eco-San option and was piloted as a new and better technology (compared to VIPs). Shortly after the start of the pilot project, the „National Sanitation

[4] Breslin and dos Santos (2001); Breslin (2002)

Programme“ that aimed to ensure that everyone had access to adequate sanitation systems [5], experienced problems of difficult geological conditions, precluding the construction of VIP. Eco-San was then introduced as an alternative solution[6] to VIPs for areas with these difficult conditions (e.g. rocky, sandy, high water table). The Mvula Trust, a local NGO, on behalf of the Department of Water Affairs and Forestry, started carrying out larger sanitation programmes and introduced UD-systems mainly in the Northern Cape.

As the UD-system was introduced following the Central American example, the “main research objectives” of the pilot project in the Transkei “were to test the basic acceptability of the technology and to determine the potential for resource reuse”[7] in the Southern African context. During the same pilot, issues related to the use and maintenance of UD-systems as well as cultural taboos and beliefs were also addressed. Community and Household involvement were immediately considered to be crucial and consultation processes were undertaken. Initial worries on how to store cleaning material or on the collection and re-use of urine for example were integrated into project implementation, thus not hindering the use of these new systems.

Lessons Learnt in South Africa:

- ✓ Sharing experiences with others around the world is crucial (the introduction of the UD “technology” was based on experiences from various countries including Central America, Mexico, Sweden and Vietnam).
- ✓ Political will and tensions within Communities/Areas can influence Eco-San.
- ✓ When introducing Eco-San social and cultural considerations are of utmost importance.
- ✓ Cash-subsidy stifle self-initiatives and continuous access to funding is required to maintain momentum on highly subsidised projects. A subsidy in kind (e.g. pedestal, some building material) could motivate households/communities to get on with improvements by themselves.
- ✓ In order to be successful and to increase rates of coverage a wide selection of methods and materials must be made available so as to meet the need and aspirations of different households/communities.
- ✓ Social interventions and health and hygiene awareness programmes should always accompany sanitation programmes, not only during the planning and implementation stage but also for a period of monitoring and follow-up.
- ✓ Sustainability is only achieved when the community wants and accepts the level of service provided, is able to pay for it and the skills are available locally to service the systems

Whilst introducing UD-systems some further cultural and technical aspects had to be covered: “men must sit down when urinating unless a separate urinal is provided; toilet paper does not decompose in the vault (because it is a dehydration and not a composting process); what do you do with the urine and with the faecal matter”[6], the system would only be appropriate if households were prepared to handle the by-products, etc. These questions were promptly addressed and the acceptance of UD-toilets was relatively positive.

During the implementation of the National Sanitation programme, it was noticed that Eco-San was accepted mainly because the system met people’s expectations around privacy, dignity, safety and convenience rather than health. Although the UD-toilets required more input in terms of maintenance, families appreciated the fact that the structure was permanent and could be built inside the house; that it required lower building, operation and maintenance costs, and that it was odourless. These perceived benefits meant for many households that the inconvenience of handling dry excreta was less disturbing than the inconvenience of moving a toilet or of using the bucket system.

Although the added value of high fertilisation and conditioning potential of the by-products had been recognised, the questions related to the re-use of these and a closed-loop approach were only promoted during the pilot project in the Transkei and not during the National Sanitation programme. In fact in South Africa there is not a culture of re-use and the UD-system was introduced solely to solve sanitation problems. The by-products of the toilets were not re-used

[5] Defined as a minimum of a Ventilated Improved Pit (VIP) toilet;

[6] Holden, R. and Austin, L.M (1999); [6] Austin, A and Duncker, L. (1999)

directly, the urine was led to a soak pit (and possibly taken up by adjacent trees) and the dehydrated faeces was simply thrown into the mealie fields, burned, in some cases buried or composted. The strategy of introducing Eco-San by emphasising on social aspects rather than on the added value of a closed-loop approach has been one of the success factors for the introduction of the systems in South Africa.

There is more to Eco-San than the acceptance by individual households. Community requirements to improve their sanitation systems, their willingness to be involved in sanitation processes as well as their ability to solve their problems themselves were felt to be extremely important aspects.

In South Africa the importance to adopt a holistic and multi-sectoral sanitation programme where successful implementation is linked to a "step-by-step" approach has been recognised and pursued. Toilet construction is seen as part of a bigger programme that includes: change of personal behaviour, improved water supply and storage, safe disposal of domestic waste and proper handling of food towards improved health and quality of life.

Although research on the safe use of urine and faecal matter for agricultural purposes has been undertaken, projects implemented have mainly been looking at improved sanitation, health and safe disposal of faeces. In South Africa there isn't a culture of re-use and some taboos are still alive. However, people are slowly becoming more receptive to re-using the by-products. Some pits are now being emptied and some people have thrown the faecal matter on the mealie fields and are now starting to realise that mealies grow better.

Experiences in Zimbabwe

The main reason for introducing Eco-San in Zimbabwe in 1997 was to address problems related to sanitation and health in peri-urban areas and soil impoverishment in rural areas. Since then, the Mvuramanzi Trust, a local NGO, has implemented projects in both informal peri-urban settlements around Harare (Porta Farm, Dzivarasekwa extension and Hatcliffe Extension), and in rural areas of the Country (Guruve and UMP district, Mashonaland, Central and Eastern province).

Eco-San started with the experimentation of Compost Pit latrines and at a later stage (since 1999) the Arbour Loo, the UD-system and the Fossa Alterna.

In the peri-urban context mainly sanitation and health problems had to be addressed as in some cases 1 toilet squat was used by more than 100 people. In these very needy areas Eco-San was positively appreciated mainly because of its private use, being user-friendly and easy to maintain. As Eco-San had the added value of providing compost, the systems were quickly considered to be a household asset. An evaluation study based on a 20% sample of the people with Eco-San toilets in the informal peri-urban areas near Harare was undertaken to assess the acceptance of these systems.

Generally Fossa Alterna systems were preferred to UD-bucket systems (people didn't want to carry the buckets with the faecal matter, they did have some problems with pipe blockages, and the toilets were smelling). Only 30% of the households did not use the by-products, mainly due to the lack of knowledge on how to use them safely. People did not know whether compost from others could be used or only own compost, whether urine would burn plants (although this only happens when directly poured onto the leaves) and whether it was generally safe to use the untreated by-products. Results also showed that whereas the majority of families used the compost (80%) most of the households didn't want to use the urine alone (61%). The use of faecal matter seemed to be acceptable on high-standing crops (maize, sunflowers, trees, flowers etc) but not on vegetables. There were fears that, because of lack of space for gardening, very quickly problems related to the disposal of the compost within the settlements would arise (the supply being greater than the demand for use).

Session B

In the rural areas of Zimbabwe the introduction of Eco-San systems was of a different nature. In fact, following the price increase of fertilisers and the poor over-cultivated soils some Eco-San projects started-off straight away with the major purpose of introducing cost-effective ways to restore/improve soil fertility in poor rural areas. In these areas UD-systems and Arbour Loos were tested.

Lessons Learnt in Zimbabwe:

- ✓ In very difficult situations (e.g. overpopulated poor peri-urban settlements; poor over-cultivated rural areas depending on agriculture) where people are desperate for solutions the introduction of new systems as Eco-San can be easier.
- ✓ The acceptance of a closed-loop approach is higher in rural areas where people depend on farming and easily recognise the added value of using the by-products.
- ✓ Proper training on Eco-San and a closed-loop approach need to be guaranteed but also a bigger involvement of all the family members pursued (too often only women carry the burden of sanitation, health and gardening, this should be avoided).
- ✓ Technical problems on the re-use of by-products can create confusion and jeopardise a process that is already difficult. This can be overcome with proper awareness raising and adequate research.
- ✓ The introduction of Eco-San and a closed-loop approach seem easier in countries where the culture of re-use has existed for a long time. In Zimbabwe most households traditionally have already composts for example.

After initial resistance to use the by-products, households finally started using urine for the production of a number of crops like rape, beans, peas, tomatoes, onions, maize, cotton and fruit-trees. Observations showed very quickly that results differed a lot depending on which crops urine was used on and many technical questions on the proper use of it were raised (concentration, application distance, timing, frequency and volumes of application). Further research on the improved use of urine and faecal matter for agricultural purposes had to be undertaken. Some rural communities that had seen the added value of using Eco-San systems in a closed-loop approach were prepared to start trials on the use of urine as fertiliser, provided they were given sufficient information and health safety assurance. In these rural areas both systems met with success: the Arbour Loo being easy and cheap to build and mobile (ideal for the fields and for planting fruit trees), the UD-system being also easy to maintain, cheaper to build and permanent.

Finally, through the generation of income at household level, Eco-San together with a closed-loop approach had an important economic impact that also contributed to the acceptance of these systems in Zimbabwe. The use of faecal matter and urine in crop production improved crop yields from backyards and fields, thereby improving household food security and increasing household income opportunities. It was quickly understood that a closed-loop approach could allow for an improved crop production with reduced inputs (especially on fertilisers) and thereby improve livelihoods in both rural and peri-urban areas.

Experiences in Botswana

Mid 2001 IUCN (The World Conservation Union) and PTB (Permaculture Trust Botswana), a local NGO, started an integrated resource management project in Botswana. The main aim was to pilot a household centred approach where the management of all natural resources used by the households would be integrated (water, waste, gardening, veld products). As part of the strategy, Eco-San was introduced in an attempt to close the loop. The start-off has been slow as proper awareness raising needed to be undertaken with participating households. Results are yet very little but from the experiences of the past 2 years households seem to accept Eco-San (they all chose UD-systems) mainly because: the toilets do not smell, the structures are not too expensive to build and local material can be used for it, little water is needed and the depth of the pit is shallow hence not dangerous. Households acknowledged the importance of a closed-loop approach for the improvement of soil fertility and are looking forward to use the by-products in their gardens. Will they really use them? A huge challenge is still ahead!

Overall lessons learnt

In the Southern African projects, Eco-San systems were positively received as appropriate sanitation systems. When people could chose between conventional and Eco-San systems they preferred Eco-San. People accepted the systems mainly because they are user friendly, permanent, aesthetically pleasant, odourless, easy to maintain, and "private".

However, the response to the different systems available in these countries varies. For example, in peri-urban areas of Zimbabwe and densely populated areas of Mozambique, the Fossa Alterna system was preferred to UD-systems, whereas in rural/rocky areas of South Africa the UD-system was preferred. In both Zimbabwe and Mozambique, Arbour Loo systems have been well received in rural areas (at the fields) but rejected in more populated areas. Generally the closed-loop approach was more acceptable in rural areas where people depend on farming and recognised the added value of using the by-products for agricultural purposes. Whereas in peri-urban areas people seemed more preoccupied in addressing sanitation and health problems first and were more reluctant in manipulating the by-products, thus choosing those systems where less handling was required. In all cases, it seems uppermost important that people are given the choice and that social as well as cultural aspects are considered.

The choice of Eco-San over other systems and eventually the choice of adopting the closed-loop approach were easier when people identified by themselves that sanitation was the main cause to their conditions (poor health and poverty). The use of participatory methods and social marketing tools seem to have provided a good basis of understanding in most of the projects. Successful Eco-San projects (whether looking at closed-loop or not) need also to be accompanied by proper awareness raising campaigns, adequate capacity building and intensive social interventions from their initial stage. One of the successful methods to do so has been the "learning-by-seeing/doing" approach whereby people accepted Eco-San and the idea of closing-the-loop when they could see the high quality of the compost, they were trained on how to safely handle the by-products, and when knowledge had been shared.

When projects were driven by government priorities of quickly addressing major health and sanitation issues (e.g. South Africa), the closed-loop approach was not promoted. As those governments respond to a critical situation that needs a fast solution the closed-loop approach is far too time consuming. It was noticed that projects that start with the sole idea of addressing sanitation and health issues have difficulties in integrating the closed-loop approach at a later stage. Experience has also shown that when the processes are driven and financed from outside the communities, thus increasing dependence on "others", they can be instable and fail once financial and institutional support weakens.

Was the added value of Eco-San really appreciated though; are the experiences in the Region pointing at a closed-loop approach? In Mozambique as well as in Zimbabwe, the closed-loop approach seems to be acceptable (especially in areas depending on farming). Generally, when users are made aware and sensitised about the added value of having an Eco-San system and using the closed-loop approach from the very start they have time to appreciate this advantage slowly. It also became evident that in Countries where there is already a culture of re-use of waste (e.g. Zimbabwe), it is easier to introduce the closed-loop approach. In these Countries the use of by-products (when accepted) was applied mainly to crops and trees and less to vegetables, indicating that although the concept is acceptable fears are still alive and efforts should go towards alleviating these fears by providing tangible results.

Conclusions

Since 1997, when the first compost latrines and dry systems were introduced in the Region, some progress towards closed-loop sanitation has been made. Research on safe handling and re-use of by-products has been undertaken and is already informing the projects in

Mozambique, South Africa, Zimbabwe and the pilot in Botswana. Although users have to manipulate urine and faecal matter, often considered a taboo and dirty, households are slowly starting to see the advantages of a closed-loop approach and the systems are becoming more and more accepted. In Southern Africa, the closed-loop approach seems to be generally more acceptable to poorer populations and farmers, who more easily recognise the added value of using Eco-San systems. In more populated areas people seem rather preoccupied by health and sanitation problems and do not recognise the immediate benefit of using the by-products. Even though Eco-San is still very young in the Region it seems to be a suitable option to address sanitation and environmental concerns, but there is still a long way to go before the loops will be closing in Southern Africa.

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Experiences with ecosan in Danish allotment gardens and in development projects*

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Session B

Keywords

Ecosan, dry no-mixing sanitation, urine collection, developing countries, allotment garden

Abstract

Experiences from four projects dealing with the implementation of ecosan toilets are presented. The projects took place in Denmark, Afghanistan, Burkina Faso and Guatemala. The approaches to implementation and the arguments that "sold" the idea are evaluated. The paper discusses how the experience gained in the four projects can be used in practise when implementing ecosan. In general, the main priority for end-users was to have an affordable and comfortable sanitation facility. In some places recycling of nutrients is already a priority, and in other places it seems to be possible to promote it. Whether or not people experience eco-san positively seems to be dependent on whether or not the eco-san toilets are used correctly. Demand must be created through information and mutual engagement in order to achieve a successful result. It is equally important to ensure involvement of the users in all aspects of the implementation and running of the toilet system. Communication, both before and after implementation, is paramount.

Introduction

The latest WHO/UNICEF assessment (Year 2000) indicates that in Africa, Asia and Latin America, the percentage of the urban population with access to sanitation is 84/78/87%, respectively, in urban areas, while in rural areas the percentage is 45/31/49%, respectively. There has been some improvement in Asia and Latin America since 1990, but in Africa the expansion of the sanitary infrastructure has barely kept up with the increase in population. The daily number of diarrhoea related deaths (mostly children under five), due to poor sanitation, hygiene and water supply, is equivalent to the crash of 20 jumbo jets.

There are also reasons to be concerned about the food production in some of the poor regions. Approximately 800 million people are affected by hunger according to the World Food Programme and approximately 250 million people are directly affected by desertification according to FAO. Exhaustion of land due to the insufficient addition of fertiliser is common in poor regions.

*This paper has been peer reviewed by the symposium scientific committee

The resolution from the Earth Summit in Johannesburg 2002 states that the number of people without access to sanitation facilities should be cut down to half before the year 2015. Although in principle the statement is positive and encouraging, implementation projects carried out in practice have faced severe problems in introducing sanitation. There is a great need for looking into better arguments and approaches to "selling" sanitation to local populations.

Dry No-mixing sanitation with urine collection provides a number of benefits that can be used as arguments for implementing sanitation. The hygienic collection of faeces and urine, the reduction of pathogenic organisms in the waste products during storage, the comfortable low-smell atmosphere, the protection of groundwater from contamination, the potential for reusing the nutrients in the fields, plus the resulting increased crop production are some of the main benefits associated with these sanitary systems. These benefits may lead to a higher interest from people without access to or with poor latrines.

The current paper discusses four eco-san implementation projects: one in Denmark, one in Afghanistan, one in Burkina Faso and one in Guatemala. The discussion will focus on the approaches to implementation and the arguments that "sold" the idea. On the basis of these four projects, the paper discusses how the experience gained can be used in the current practise of implementing ecosan.

Methods

The method used to evaluate the experiences with dry no-mixing sanitation with urine collection is implementation and interviews with the users. The extent of implementation and stakeholder participation varies between the projects. The specific conditions for each project will briefly be described in the following.

In Denmark dry toilets with urine collection were implemented in 89 allotment gardens, (Backlund et al., 2003). Eight different models of diverting/no-mixing sanitation systems without water flush for separate collection of human urine and human faeces were established in 1999-2000. The aim of the project was, through user participation in both planning and decision making, to find a more sustainable alternative to chemical and water flushing toilets and to gather the users experiences with the systems. The stakeholders that took part in the project were: the Danish Allotment Gardens Association, the municipalities, local allotment gardener organisations and voluntarily participating owners of allotment gardens. The incentive for the Danish Allotment Gardens Association to initiate the project was the fear that municipal authorities would demand the construction of sewers.

In rural areas of Herat Province, Western Afghanistan, a local modification of the Vietnamese two-chamber urine-collecting toilet was developed and a study of the inhabitants' sanitation habits was conducted in the year 2000. An interview investigation of 49 questions was made with 55 men and women about their perceptions and practise of hygiene and sanitation and their interest in using ecosan. 17 latrines were implemented in 2000 and evaluated the year after.

Figure 1: Moulding of slab and implemented result in Herat, Afghanistan *(Photo: Dorthe Eriksson)*

An interview investigation was carried out in Sabtinga, a rural community of 3000 inhabitants, 20 km North of Ouagadougou in Burkina Faso.10 male heads of families comprising a total of 160 people were interviewed regarding their habits and attitudes towards sanitation, hygienic practises and interest in ecological sanitation, using a questionnaire of 44 questions. The investigation was made in preparation for a possible pilot implementation program for UNICEF and a local organisation, CREPA.

In Guatemala three villages in Laguna Lachua National Park were briefly examined. 101 Ecosan latrines of the LASF type (Esrey et al. 1998) had been implemented in 1997-1999. The latrines were examined in 2000 by inspection and people were interviewed about their use of and experience with the latrines.

Results

Allotment gardens in Denmark

A successful implementation of diverting/no-mixing sanitation in the allotment gardens was achieved. Personal engagement on behalf of the project management and stakeholder participation in planning and decision making lead to the effective transfer of enthusiasm and knowledge about ecosan to participants, which was key to the success of the project. The majority of the 176 residents who took part in the project were within the age of 41-70 (typical for allotment gardens), and the distribution between sexes was fairly equal. Prior to the introduction of the diverting/no-mixing toilet systems, most of the residents had a chemical toilet.

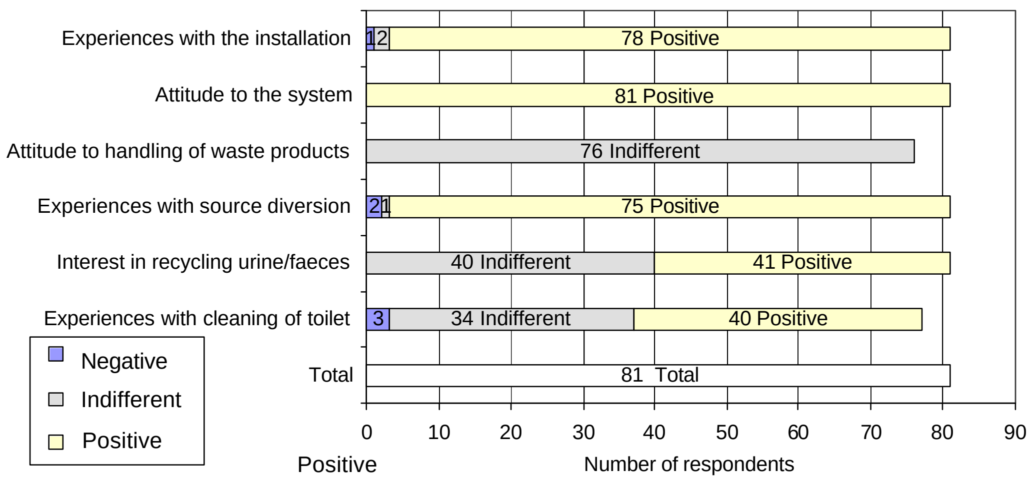

Figure 2: Attitudes towards and experiences with the ecosan systems in allotment gardens in Denmark. The answers have been lumped together in three groups to illustrate whether the attitude or experience was negative, indifferent or positive.

By interviews the participants were questioned about their attitude toward the toilet systems, see figure 2. The installation of the system went very well, there were some minor problems, which was solved with a help from the supplier. Some of the participants would have liked a manual in Danish instead of Swedish. In general the participants were rather indifferent towards the handling of the waste products urine and faeces. The general remark was that it could be a little smelly, but it was not a problem. The source diversion went well; there were two elderly women who had some problem with the urine collection, in that the urine went into the faeces container. Some minor children had to get used to the system. The interest for recycling the waste products to the garden was very high. However, it was not possible to obtain a permit to do so from the Danish authorities. People have therefore been instructed to bury it in the ground. Regarding cleaning of the toilet, the participants were either positive or indifferent. Only 3 participants found it more difficult to clean the present than the prior toilet, all 3 used to have water closets. The attitude towards the system in general was positive to very positive. Descriptions like clean, nice and brilliant, were used. A few participants mentioned that it could be a problem for visitors to use the system, others that the visitors would like to get one too. In general the participants were happy that they did not have to use chemicals as was the case with when they used a chemical toilet. They thought that it was a very good and cheap alternative to the installation of sewers. The price for the toilet systems varied from 200 to 1.200 US$. 72 % of the participants chose a solution in the price range of 700 – 770 US$. The estimated costs for implementation of sewers are around 7000 US$ per household. Aside from the higher cost, another disadvantage of sewer implementation is that it forces all families to use the same system, regardless of their preferences and lifestyle.

Figure 3: A+B: Backlund H1; C: Separett Villa 9000

Regarding implementation, it is very important to meet the expectations of the participants or, if it is possible, to go beyond their expectations. Good and continued communication can eliminate unrealistic expectations and secure that the more realistic expectations are fulfilled. Such extensive communication is very time consuming, but essential for success. The basis of the project was the free choice of the participants. Participation was voluntary, and a range of flexible solutions at different prices, was presented to fit individual needs. This promotes decision-making and self-management of the participants. It was often the woman who took the initiative to be part of this project. Here, as in many other countries, women often take the initiative to change the living conditions of the family. The participation of the woman in the family can, for many projects, be important in order to secure a new technology gets deeply rooted in the society.

The personal experiences of the users are of the greatest importance for the development of the technology. They contributed personally to the development of new technology by their evaluation of the systems and comments to sitting heights, design etc. The development of the new toilet "Separett Villa 9000" is partly based on the experiences of the participants of this project. "BACKLUND H1" is directly based on experiences from the project.

Overall, the response is that dry ecosan systems are excellent inexpensive alternatives to traditional systems. The advantages of establishing diverting toilets, as opposed to solutions with sewers, are among others water savings and recycling of nutrients. Furthermore, the economical advantages for the allotment gardens are considerable.

Vault latrines in rural areas in Afghanistan

The typical sanitation system in rural areas in Western Afghanistan is a raised single vault latrine, which can be emptied when full, or a pit latrine, which is not emptied. In this investigation 55 people were interviewed in 2000, before the implementation of ecosan systems started, hereof 29 males and 26 females. The people interviewed were chosen to cover the diversity within the community and they are representatives of >10% of all families in 9 villages in Herat

Province, Western Afghanistan. Males and females were interviewed by an interpreter of their own sex. 62 % of the respondents had a latrine, see figure 4. 65% of the latrines were of the vault type and 86% of families with vault latrines used the mixed excreta as fertiliser. Thus, approximately 35 % (62%*65%*86% = 35%) of the population in Herat are already applying excreta on the fields according to this investigation. After emptying the latrines the excreta is either buried (53%) or stored in a heap covered with earth (47%) for an extended period of time before it is applied on the field. The main risk of disease transmission is therefore on the men who empty the latrines, which contain some fresh excreta.

Out of the 21 families without latrine, 19 would be interested in having one, the two others were migrants who were not motivated to invest in property they didn't own. All 19 would contribute labour and 63% also materials, but cash payment is a problem among the poor people. All respondents were asked about their attitudes towards using urine collection and recycling of faeces and urine on agriculture. As it can be seen from figure 4 practically all of the respondents supported this method of recycling nutrients. However, for religious reasons, it was considered problematic to mix urine (considered unclean) with water (considered clean). The diverted urine could therefore not be applied by sprinkling on the fields.

The main reasons for having a latrine were that: It provides a visual shelter from the public (65%), it isolates the dirt in one place (58%), it is clean/hygienic (compared to bushes) (42%) and it yields fertilizer (16%). Vault latrines are usually used for depositing all kinds of dirt from e.g. sweeping (but not food waste) because it helps to keep smell reduced. 73% could not see any disadvantages of having a latrine, but 22% mentioned smell and 5% emptying as adverse effects.

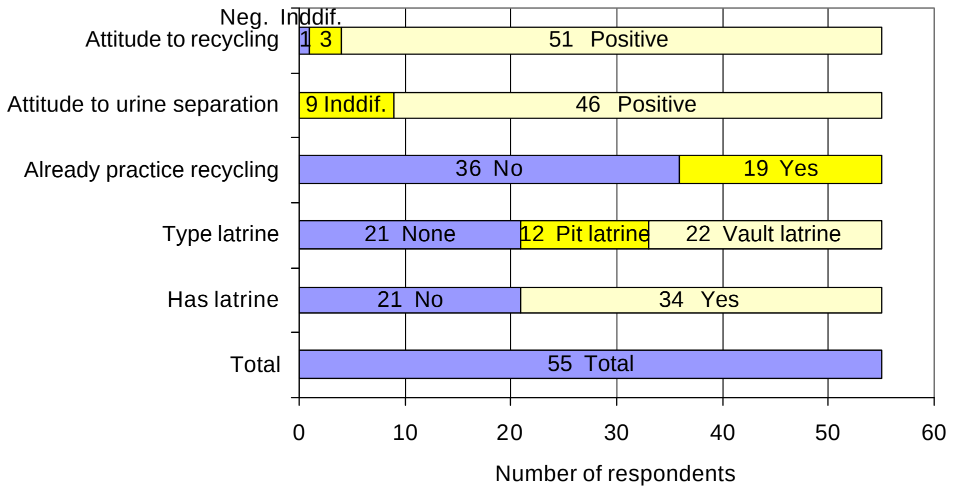

Figure 4: Latrine types and attitudes towards recycling of urine and faeces among 55 families in Herat, Western Afghanistan.

Based on the positive attitudes a design for a double vault latrine with urine collection was developed, inspired by the Vietnamese type (Polprasert et al. 1981). The design was developed together with the NGO Danish Committee for Aid to Afghan Refugees (DACAAR), and implemented by 17 families in 2000.

The latrine has a slab with two sets of holes and two vaults, to be used one at a time. The two units share a common urine collection system. Unlike the Vietnamese system, urine is led to a soak pit outside the latrine. The idea is that the soil in the soakpit could collect most of the nutrients from the urine and be used as fertiliser regularly.

In 2001 a follow-up survey was carried out. The main findings were that:

Latrines were being used by all household members and the users found them to be an improvement over their old type in terms of being of a good size, not as smelly as the old latrines, and the numbers of flies are less.

The separation of urine from faeces seemed to be working as it should.

The urine recycling method had not worked at all. It is not clear if it was because they did not receive sufficient instructions, if they did not understand the instructions, or if they are not willing to follow the instructions given.

The latrine was not replicated. This is exactly the same situation as with the DACAAR single vault type of improved latrine, which was also very seldom replicated. The problem seems primarily to be that the cost was found to be too high, but also that the latrine takes up too much space in the compound.

A lot of efforts have been stalled by the war and poor weather conditions, but the design is still being considered as an optional design in DACAAR's water supply, sanitation and health education program.

Interest for ecosan in Burkina Faso

Out of the 10 families interviewed in Sabtinga, Burkina Faso, 7 were Catholics, 2 Muslims and 1 animist. Only a few households in the whole village had pit latrines, but none of them were included in the interviewed sample. 90% of the interviewed were dissatisfied with not having a sanitation facility, and they argued that they lacked the money for constructing latrines. The reasons for wanting a latrine were 1) Improved health conditions, 2) privacy, 3) fear of snakes in the bushes and 4) the fact that certain animals eat faces and people later on eat the animals.

The family chiefs saw no conflict with their traditions in handling human excreta and using it as fertiliser. Their interest for ecosan was high, mainly because of the fertilizer it provides. People showed by words and by delivering building materials that they were interested and ready to participate in the construction, but they would not contribute money for it. A double vault latrine design was developed, and UNICEF Ouagadougou was interested to carry on with the idea.

Double vault latrines with urine collection in Guatemala

Our final investigation in Guatemala was an examination of previously implemented double vault latrines with urine collection of the LASF-type in villages in the Laguna Lachua National Park. It was found that the majority of the latrines were either not used or in a very poor state. Those in use were stinking, the faces vaults were wet and disgusting, and faeces ran out on the ground from open lids behind the latrine. According to the villagers, they did not receive proper information, or in some cases any information at all, about the use of the latrines when they were constructed. Some families did not participate in a capacitating course. Two single well functioning latrines showed that there were no fundamental technical or climate barriers for a proper functioning of the LASF-latrines. People were just not interested or did not know e.g. how to add soil and lime to keep them working.

Discussion

Motivation for procurement of ecosan

The most well-known arguments for procurement of ecosan toilets has to do with advantages of recycling nutrients to agriculture and avoidance of pollution of the environment with pathogenic organisms via wastewater. For people without sanitation or with very poor sanitation facilities these may however not be the "selling" arguments.

In Burkina Faso and Afghanistan, where many people have no sanitation facilities, shelter/privacy was the main argument for procuring a sanitation facility. Improved health/pathogen control and cleanliness also had high priority. These arguments may sound trivial to people who already use toilets, but should be included as prominent messages when selling Ecosan in these areas.

In Afghanistan recycling of nutrients in agriculture was also mentioned as an argument by 16% of the people, due to the fact that it already is a habit for some people in the area. Even though the fertiliser argument may not have the highest priority, it is still important to many people. In these countries the recycling aspects can be directly used as part of the selling argument to people without sanitation facilities and as a main argument in upgrading from e.g. a pit latrine.

The reduction in bad odour and flies due to the source diversion was another feature of ecosan that was appreciated in the Afghanistan implementation project, and this would presumably be a useful argument for people that are used to more smelly latrine types.

In the Danish project the selling arguments were different, although the main interests were similar. People saw the ecosan option as a cheap alternative to the very expensive solution with sewers.

The price argument is exactly opposite in Afghanistan and will be the same in other poor rural areas of the world; ecosan is generally more expensive than other options, such as various types of pit latrines. Here the additional arguments of less smell and flies and improved production in agriculture have to be conveyed carefully together with the arguments of health/pathogen control and privacy.

Generally the people of e.g. Denmark, Afghanistan, Burkina Faso and Guatemala seem to share the desire for an affordable and comfortable sanitation facility.

Implementation of ecosan

The experiences in implementation differ widely in the four examples we have looked into. This is natural because of the extreme differences in settings and cultures. However, one similarity is that whenever ecosan toilets were used properly, people perceived it as a good solution. In addition to this, there are also lessons to be learned from the ways the projects were promoted.

The importance of how the message is delivered is illustrated by the differences of success in Guatemala and Denmark. In Denmark the marketing of the ecosan toilets was combined with participation of the users and other related stakeholders in both the planning and decision making, and was followed up by continuous contact with the users after implementation. The project even resulted in development of a modified design based on user preferences. This is in total contrast to the Guatemalan project where the toilets were implemented without even explaining the daily operation procedures to all households.

Although ecosan is not too complicated, the daily operation is important for the well-functioning of the toilet and user satisfaction. In the simpler models for developing countries, operation involves adding an appropriate amount of dry material, while experience show that this is not necessary for odour removal in the Danish models furnished with ventilators. Follow-up after implementation makes it possible to correct mistakes and answer small and large questions, and will raise the satisfaction with the project.

Simple solutions adjusted to the needs and interests of the participants, based on a source diverting technology and local materials and manpower, should be developed and implemented. The point of departure could be based on already existing relations, and the establishment of local demonstration projects.

Cost recovery aspects of implementation also play an important role. Both the Danish and the Afghanistan project involved partial subsidisation of the facility. In Burkina Faso people stated that they were mainly able to provide labour and some materials for construction. It is in all cases motivating that prices are low or lowered and has contributed to the success. Considering the general difficulties in selling sanitation in rural areas of developing countries, it may in fact be necessary to subsidise in order to get implementation started. However, when the campaign

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is over, there is not necessarily a spreading effect. This was demonstrated in Afghanistan where people continue to construct pit latrines because they can be constructed for free. It will continue to be a problem among poor people, but when the benefits of ecosan for agriculture, and thereby income, have been more widely demonstrated in an area, it may result in larger demand.

The use of urine as fertiliser seems to be a difficult task in certain areas, even though most of the nutrients in the toilet waste are found in the urine. In Afghanistan people didn't use the urine, perhaps due to poor information, lack of tradition, or the labour involved in emptying the urine pit. The same rejection of the urine has generally been found in projects in Latin America (Esrey et al. 1998). More demonstration and information work should be done in this field, because of the high fertiliser value of urine.

Conclusions

The four different projects have illustrated that people can have a positive attitude toward the use of ecosan whether they are Danes, Guatemalans, Africans or Afghans. There is a lot to be learned from the successes and failures of these projects. Whenever the sanitation facility is used correctly, it has been shown that it can work in practise, and that people in general have a positive experience from, and attitude to, the use of ecosan. The success depends largely on whether or not the demand is created through information and mutual engagement, and on whether or not people are involved in the design of their own facility through a close communication. Involvement of relevant organisations and economic support in the establishment phase is important as well. More success stories and engagement from sanitation implementing agencies in ecosan solutions is needed for the continuous spreading of the system.

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Psychology and sanitation: a personal perspective

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Keywords

Psychology, constructs, change

Abstract

Promoting ecological sanitation involves confronting potential users on a psychological level. I illustrate this through my personal experience as a user of a dry urine diversion system. However, everyone's experience will be different. George Kelly's concept of 'personal construct' is a useful concept towards describing the multitude of attitudes, preferences and taboos people may have surrounding sanitation.

Asking people to change the sanitation system they're accustomed to, is asking a lot. It amounts to asking potential users to change their particular and ingrained personal construct regarding sanitation. How does one convert potential users to accept ecosan? From my experience I have crystallised four key concepts which played a major role in successfully changing my 'flush-loo' personal construct to incorporate ecosan. These are motivation, choice, supportive environment and experience.

Introduction

At a very early age, we learn our toilet habits from our parents. The way we use and experience our sanitation solutions are almost as old as we are.

Children are ready to be toilet trained, depending on their maturity, from the age of about eighteen months. In time we learn also, for instance, how to use a knife and fork, or how to independently perform many other small but important tasks essential to our daily living. But it's often our ability to use the toilet properly that comes first.

The rituals surrounding relieving ourselves are tied up with our parents views and habits plus our broader cultural and economic context. What we learn from these sources, become a 'personal construct'.

This term 'Personal construct' is a concept I borrowed from George Kelly's Cognitive Personality Theory.

George Kelly's cognitive theory of personality and personal constructs

George Kelly (1905 – 1967) was an engineer turned psychologist. He proposed a personality theory called the 'Cognitive Theory' in which he develops the concept of 'Personal Constructs'.

According to Kelly, a 'personal construct' is an attitude we acquire through experience. It's a bundle of habits, views, attitudes and preferences about issues such as work, retirement, marriage, family life. Anything and everything about our lives. This must then includes sanitation.

Should one confront an individual with sanitation systems other than what he/she is accustomed to, one is, broadly speaking, appealing to that person on two levels.

The first is the intellectual level, possibly involving understanding technical or environmental issues. The second very important issue is the psychological one. One would be confronting that individuals personal construct regarding sanitation.

The personal construct threatened

Kelly maintains that changing our core personal constructs create stress. We experience anxiety, even fear. The object of change presents a threat. It may even produce aggression.

This brings me to my personal journey with ecological sanitation. Initially, I experienced urine diversion as a threat to my personal flush-loo, non-involvement construct of sanitation. I wasn't exactly scared of it. And it most certainly didn't make me turn to violence! But I did experience some anxiety.

My story: a personal perspective

I have zero interest in toilets. I have zero interest in promoting ecological sanitation. Despite this, I use a dry urine diversion system on a daily basis, as a matter of course.

I am a middle class woman living in Africa. I explore and intellectualise about religion, socio-economic issues – just about everything. I find new ideas exciting. After all, I'm a South African. We live with change. It's routine for us. In short, I regard myself as being open minded.

So - when my husband suggested putting urine diversion into our home I was all for it. I intellectualised about it much as I would on any other issue. It was quite exciting. I'm always ready to try out something new. Besides, my husband is happy to go with all my mad-cap ideas. I might as well support him in his. Intellectually, I also accepted that urine diversion would work on a technical level. I simply assumed that all the good people promoting ecological sanitation know what they're talking about.

Despite my conscious acceptance of ecological sanitation, it still wasn't part of my long standing, deep seated personal construct of toilet behaviour. I didn't realise this. So when it came to the crunch, and out of the blue, urine diversion presented as something of a threat and cause me some anxiety.

This became clear only once I was confronted with a urine diversion pedestal in my own en suite bathroom.

The psychological journey: that 'uh-oh' feeling

In my journey with ecological sanitation, I had four hurdles to over come.

The first hurdle

That first 'uh-oh' feeling came when I was confronted by the new urine diversion pedestal in my comfortable, familiar bathroom. I felt mild anxiety. I was running scared.

In a subtle way, I tried to postpone using it. I told my husband I'd start using it in a few days, after he'd explained to me at length what the procedure was.

'It's simple', he said, and, to my dismay, outlined what I should do there and then. 'Just use it as normal,' he added.

I crossed my first hurdle, sat down and used the system. This was a big step.

It worked. I was beginning to break down my existing personal construct through experience.

The second hurdle

The next anxiety-inspired ‘uh-oh’ feeling surfaced. Much as I was assured that I could use the toilet ‘as normal’, I still didn’t trust the system. I made a point of urinating and defecating separately. That way I was guaranteed that everything went where it should go.

In time, and through experience I came to fully accept that I could really simply sit on the toilet, and let go. But it took a while, all of about eighteen months.

The third hurdle

I felt another vague, ‘uh-oh’ anxiety about having a bucket of yucky pooh only a few meters away from the bed where I sleep. Right in the inner sanctum of my home.

Through experience I learnt that it didn’t make any difference, because it was, in a sense, invisible. It didn’t smell. So that became okay as well.

The fourth hurdle

My final problem related to cleaning the toilet. An important part of my personal flush-loo kind of sanitation construct is that I will have nothing what so ever to do with faeces. That is non-negotiable.

My husband was the one who took the bucket from under the toilet and emptied it into the compost heap. That was *his* job.

By him doing it, I saw with my own eyes that it wasn’t the revolting job I expected it to be. It was no different to tipping a bucket of sand into our kitchen waste.

I am pleased to report that I can do it too! Through experience, I modified my attitude.

In each case, experience changed my personal construct regarding sanitation. What struck me was that even in an extremely supportive environment, I still had to confront anxieties. It showed me what a complex issue sanitation is.

Conclusion: summary and suggestions

One may say that people don’t jump at the chance of using ecological sanitation because ‘human beings resist change’, that ‘they’re stuck in a comfort zone’. Or they don’t care about saving the planet. There are all kinds of cliché’s one could drag up.

Statements such as these have negative overtones.

For me, Kelly’s theory explains in a more positive way what people go through when confronted with new or different ideas. People have deep seated core personal constructs about all aspects of their lives. Also about sanitation.

Don’t be fooled. Even a person like myself who is ecologically aware and overtly open-minded may have misgivings and anxieties.

George Kelly says that constructs aren’t finite. They can be modified. People can opt to choose alternative constructs.

Well - we don’t need Kelly to tell us that people can change their ideas about their world. We know it is the case.

The question is, how does one go about introducing new ideas to people successfully? How does one go about changing people’s sanitation constructs?

There is no definitive answer to this question. Instead, I’ve crystallised four key issues that may be useful since, in my case, it ensured my successful and sustained conversion to ecosan.

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1. Motivation

   I was motivated to use ecosan because I could see the ecological advantage (saving water) and I'm excited by new ideas.

   Inspire potential users. Talk their language. Show them why ecosan is a good idea.

2. Choice

   I was given a choice. If ecosan had been forced on me, I would probably have resisted using it. Potential users need to voluntarily buy into ecosan.

3. Supportive environment

   We've made some changes to our urine diversion system since it's installation. For instance, I insisted my husband remove the vent pipe since it caused an icy draft during winter. I couldn't make this modification myself. I needed someone I could rely on to listen to my complaints and act on it. That way I could make changes to suit my needs. If this wasn't the case, I would have removed the entire system and reverted to a flush toilet system.

   After installation of ecosan, listen to complaints and support users in any way possible.

4. Experience

   I learnt through experience that my misgivings about ecosan were unfounded. Where possible, give potential users the experience of using and cleaning a new sanitation system so they can see for themselves what it's like. At the very least, have an existing user tell his/her story to potential users.

In principle, all the above amount to on-going communication and support. Discuss psychological issues. Workshop psychological issues with potential users. Even where potential users have inferior technical solutions, one would still be challenging existing personal constructs. There would be existing comfort zones and ingrained habits and attitudes. Talk about it. And give support.

In essence, my point is this. Sanitation isn't a purely technical issue. Psychology kicks in – big time! Awareness and sensitivity to this are important when promoting any form of sanitation. Open dialogue between sanitation expert and potential users, as well as on-going support are essential.

Source separation - new toilets for Indian slums

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Keywords

Source separation toilets, slum toilets, urine utilization, fecal composting, closed loop concept

Abstract

A new toilet center has been constructed in a slum in Bangalore/India, which allows separated collection of urine and feces. Urine is used directly as a fertilizer on an agricultural education campus. The feces are professionally composted. The compost is used to grow medical plants on the campus as well as for banana production. A new sustainable development concept is being tested here, one which tackles the problems of sewage water and feces and creates an opportunity for one aspect of slum development: The income generated by the project (users fee, compost, bananas) can cover 50 % and more of the running cost of the toilet centers.

New toilets for Indian slums

Context

Rajendra Nagar is a large slum with inhabitants belonging to different caste, religion and race. The majority of households in the Rajendra Nagar Slum do not have their own toilet, and have access to only one functioning communal toilet. The establishment of numerous compost toilet centers is considered to be of a matter very great urgency. The lack of toilets is only one indication of the appalling living conditions for many thousands of slum residents, particularly women. They have so far been forced to defecate in the open field before dawn or after dusk. Sexual harassment and rape has been an associated problem. These toilets are aimed to bring about considerable improvement in such conditions for women and children.

Apart from addressing the plight of women, the project also deals with the cultural and religious context of India in which the handling of feces is a stigma. People who handle feces, in particular those who are "scavengers" and earn their low income through sewage-disposal are condemned to the lowest level of social ranking. This project aims to initiate a process of changing attitudes. Specially designed toilets, a carefully devised logistical system for the transport of the feces, as well as thorough composting (which minimizes handling of feces) serves to demonstrate that the handling of feces can be conducted professionally yet simply and cost effectively and need not be a social stigma. On the other hand, it can become an innovative income potential for the slum residents. The project therefore contributes to fighting scavenger's discrimination.

Project objectives

- Improving living conditions: establish toilet centers to improve living conditions in the slum and to minimize the risk of disease spreading during monsoon flood periods.

- Scavengers discrimination: The project shall open now income perspectives and generate a better social status for the scavengers community.
- Integrating faeces and urine into its appropriate environmental perspective: When faeces and urine are accepted to contain valuable nutrients which are otherwise lost. They will be seen to be integral to soil enrichment and a valuable part of the nutrient-chain.
- Compost and fertilizer production: collecting urine and faeces (by using urine separation toilets) for the production of compost and fertilizer.
- Generating income for slum development: the compost and urine can be used use in agriculture (mainly for non-food production but research into food production is also to be conducted). The income will be used for paying the running costs of the systems.
- Integrating slum dwellers and self-responsibility: the slum dwellers will be instructed to operate the toilet systems themselves. Representatives of the slum shall be involved in the project. The project will maintain an emphasis on women and children, but total participation from the whole community will be sought to ensure success of the program.
- Changing values in a long-term perspective: in the cultural context of India handling faeces is a social and cultural taboo. Since the sanitary problem is considered to be key problems of low-income settlement, solutions to solve these problems are urgently required. Resolving a cultural stigma is the key to solve this problem and therefore a long-term goal of this project.

Finding an appropriate solution

The following figure 1 shows the procedure of the participatory decision-making process carried out together with representatives of the slum population. Based on a need - demand evaluation as well as on considering economical and ecological aspects the decision was made to establish a toilet center with source separation toilets:

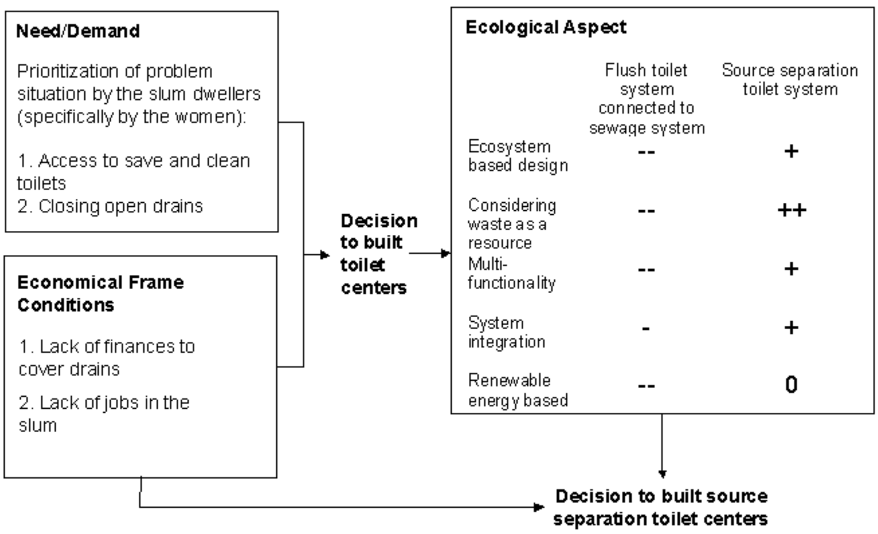

Figure 1: Decision making process

System design and system operation

The Bangalore project is based on implementing a closed loop concept (see Figure 2). A toilet center (with 4 toilet rooms for women and 4 toilet rooms for men) is serving 600 – 800 users per day. In the toilet center feces, urine and wash-water are collected separately (see figure 3 & 4).

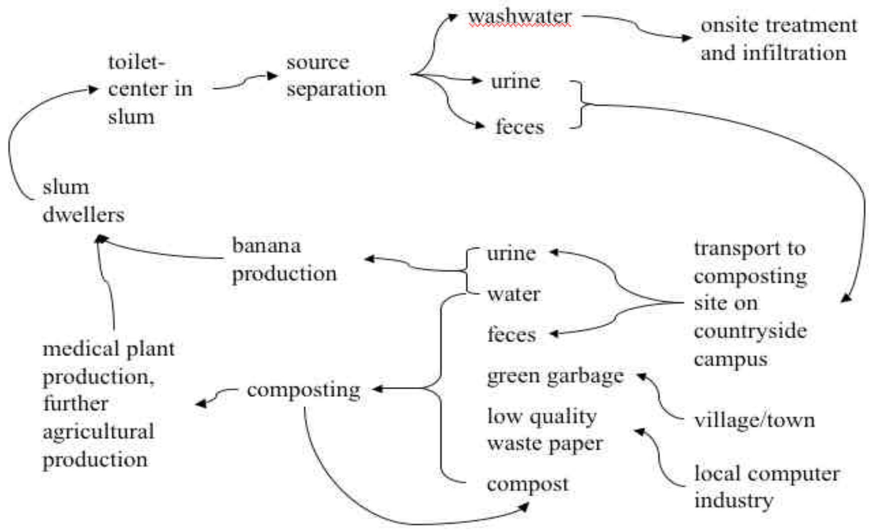

Figure 2: Closed loop design

The wash-water is being treated onsite in a small sand-filter system planted with Papayas and Bananas. The feces and the urine are separately collected in 120 l PE bins. Each day clean and empty bins replace the filled ones. One third of the volume of the clean fecal storage bins is filled with waste paper before it is placed in the service chamber. The paper soaks water from anal washing. No waste paper is filled into the urine storage bins! The full bins are transported to the composting site. It is realize that transport of the “resources - feces and urine” is needed to close nutrient cycles between urban and rural areas. On the composting site the feces is mixed with waste paper and biodegradeable garbage. The compost and the urine are used for agricultural production. The agricultural production can be sold on the local market.

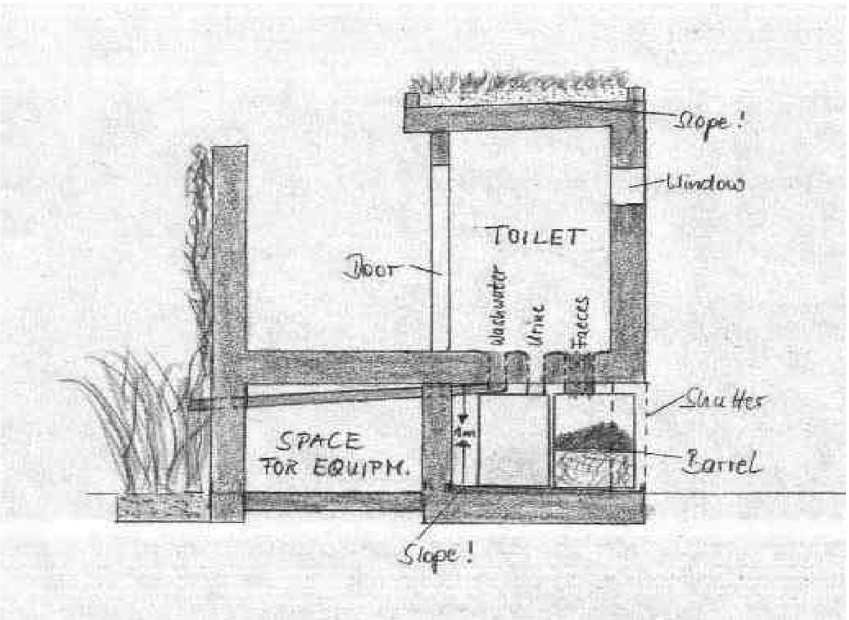

Figure 3: Cross section of the toilets

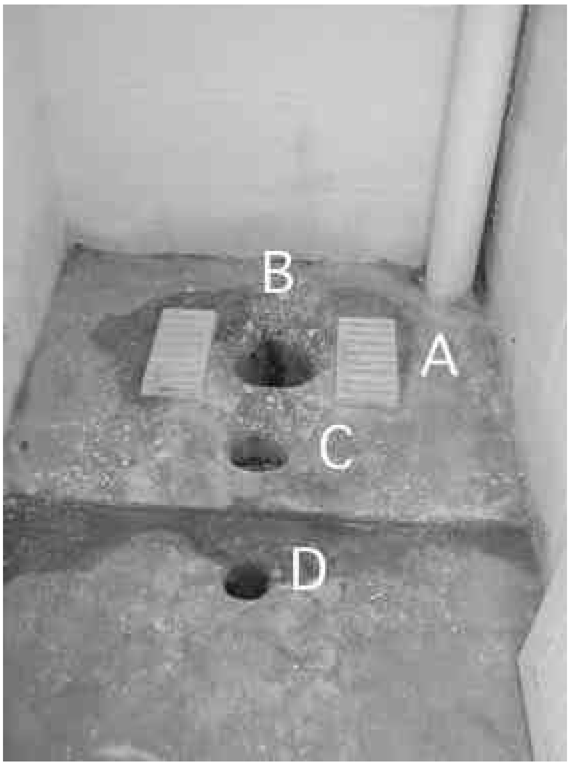

Figure 4: Squatting platform (same type for men and women). A: Footrest B: fecal hole, 20 cm Ø C: urine hole, 10 cm Ø D: wash-water hole, 10 cm Ø. Distance between holes: 25 cm.

On the composting site fresh feces is poured on a pre-prepared bed of compost and waste paper, when covered with green waste and compost (see figure 5). The first turning of the "compost sandwich" is done after 3-4 weeks. Further turning of the compost has do be done every 2-3 weeks.

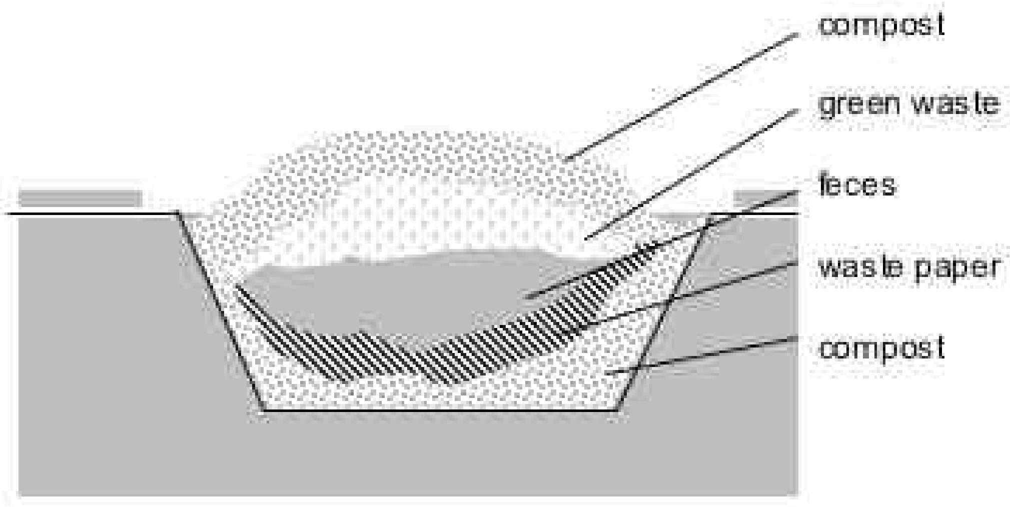

Figure 5: Composting process step 1

After 2-3 months the compost of the "Compost Sandwich" material is moved to the compost heaps (see figure 6). The heaps are covered with tarpaulin in order to avoid water loss caused by evaporation and in order to regulate the temperature in the compost heap in an optimal range of 45 and 55 °C. A digital rod thermometer is needed to control the temperature. From time to time the tarpaulin has to be removed for watering (e.g. during rainfall). The compost has to be kept humid but not wet. The compost has to be turned every 3-4 weeks. After 2-3 months the compost is ready for utilization.

Safety aspects

All work staff involved in the project was served with a comprehensive vaccination program. While working at the compost facility the work staff has to wear special working clothes (trousers, jacket, gloves, boots). It is strictly forbidden to smoke, eat or drink on the composting site. Working clothes and tools are kept separately. The working clothes are washed once per week. The tools are cleaned at the end of each working day. Injuries of the skin must immediately be disinfected and protected from further infection by dressing the wound.

Figure 6: Composting process step 2

Controlling the compost process

Among the most important controls is the daily check of the temperature in the compost heaps. This allows to be sure working within the safety zone for hygienization (45 and 55°C). The temperature is measured with a digital rod thermometer. While the composting process on the stacks lasts, humidity has to be controlled at least each time the material is restacked. If necessary it has to be corrected by adding liquid or by mixing with dry or wet compost.

Agronomic Parameters of Compost Sample			
Parameter	Result	Guide Number	Limit
pH	6,5		
dry matter (dm)	59,3 %	46 %	
org. matter	46,3 %	35 %	
total N	31,1 kg/t dm	13 kg/t dm	
P	10,7 kg/t dm		
P2O5	24,4 kg/t dm	7 kg/t dm	
K	7,8 kg/t dm		
K2O	9,4 kg/t dm	9 kg/t dm	
Mg	6,8 kg/t dm	8 kg/t dm	
Ca	32,1 kg/t dm	70 kg/t dm	
Pb	43,5 kg/t dm		120 kg/t dm
Cd	0,4 kg/t dm		1 kg/t dm
Cu	155,0 kg/t dm		100 kg/t dm
Hg	0,6 kg/t dm		1 kg/t dm

Figure 7: Compost analyses (sample taken in August 2002)

Urine and compost utilization

The urine has to be diluted (dilution rate: 1:20) before used as a liquid fertilizer. The urine can be used for all kinds of highly Nitrogen consuming agricultural crop.

Costs/economics

The 600 – 800 users produce 200t of urine and 100t of feces per year. This leads to a yearly production of 50t of compost and 50t of bananas. Figure 8 shows a first estimation of the economics of the system.

Investment			
Construction of Toilets	$7.000		
Construction of Compost site	$4.000		
Running costs per year		**Income per year**	
Salaries (8 Workers)	$8.000	Users Fee	$3.000
Transport	$2.220	Bananas and Medical Plants	$5.000
Administration	$1.600	Nutrient Value of compost and feces	
Maintenance and Depreciation	$3.250	($ 750)	
Total Running Costs	$15.070		$8.000
Net Costs	**$7.070**		
Cost per user and Year	**$12**		

Figure 8: Economics of Bangalore system

Further development

The project is still under development. The experiences of the first project phases prove the feasibility of the concept. The following aspect will be in the focus of the next years:

a) Process optimization:

- Optimization of urine utilization (e.g. for banana production), faeces composting and faecal compost utilization
- Optimization of process, operation and maintenance (in progress)
- Using new additives like dry leaves, etc.
- Monitoring (nutrient and hygiene aspects)

b) Knowledge transfer and assessment

Education and Information (workshops seminar with NGOs, governmental officials, etc.)

- Knowledge transfer to rural villagers and farmer, schools, etc.
- Comparative assessment of the system (nutrients, energy, environmental impact, economic viability)

c) Product utilization

d) Training programs for poor farmers

Scientific study

Scientists from the Indian Council of Agricultural Research (ICAR) have been contacted for a scientific study of the compost. A significant level of interest has been shown and plans are being worked out for a systematic study of the impacts of the compost on various kinds of agricultural produce. If successful, the project will only be established as one that will need to be implemented on larger scales by the Government bodies, but will also result in enormous economic benefits to farmers who are struggling with severe agricultural land related problems.

Results / impact / assessment

By S.S. Wilsson, local project manager "The toilet-center in the Rajendra Nagar slum was built with the objective of separating urine and feces and converting feces into compost rich in nitrogen content, a practice ignored or shunned over decades. Initially it was feared that reintroducing the practice of converting feces would be opposed due to prevailing culture observed and respected by the people. Considerable time and effort was made to convince the people that human feces are not a waste product, but a rich resource for production of compost. To this date the toilet-system is working satisfactorily and to our expectations. For improvement, further methods are being tested to bring about greater efficiency and to curtail expenditure. Labor is the main constraint and must be dealt with carefully as otherwise workers will put down their tools and quit without notice. Scavengers are not freely available for employment hence replacements are difficult. Thus every part of the project is of paramount importance and must be handled with personal and constant supervision. Undoubtedly there is immense appreciation from the people using these toilet-facilities since they were suffering without toilet facilities for a long period. More specifically, the women are very grateful for providing toilet facilities. The women in particular are very happy and content because this toilet provides them all facilities such as water, electricity and reliable wardens who keep the toilet in a very hygienic state all the time. Above all women using the toilet have the assurance of safety and security because the project is run by a responsible organization that pays personal attention to all aspects of this project. Conclusion: After two years we have achieved the desired objectives and it is noteworthy to mention that the public has cooperated well and has accepted that human feces and urine are a valuable resource. Although initially there were some constraints with regard to cultural practices we have comfortably overcome all negative thinking. It is hoped that this eco-friendly toilet will be replicated and the public will realize the value and benefits that could be derived from human waste and urine."

Conclusions - lessons learned

- Cultural and social aspects: Even working in a cultural context where handling faeces is considered to be very problematic, the project proved to be feasible. But referring communication is a key prerequisite to success.
- Technical aspects: The entire design of the project proves to be feasible. More work has to be done in up-scaling aspects: The existing projects serves toilet access to ca. 600 users. The entire project design has to be adjusted for bigger scale applications.
- Economical aspects: The target of the project was to cover all costs investment and running costs by the generated income. The experiences of the existing project show what this can not entirely be achieved. But the average annual net cost of the project of ca. USD 12 per persons proved the project to be economically feasible.
- Agricultural aspects: Having started with mainly an interest in toilet centers, the long term effects on improved agricultural production is a challenge.
- Safety aspects: The experiences prove that a save handling of the faeces as well as the production of a high quality compost is feasible.

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A methodology combination to expose and assess water and sanitation related household behaviour

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Session B

Keywords

Case study, ecological sanitation, everyday life, methodology, time -diaries, user perspective

Abstract

Replacement or alteration of water and sanitation systems motivated by ecological concern embrace transformation of three components: technology, organisation and user behaviour. The aim of this study is to develop a methodology to expose and assess households use of water and sanitation. A combination of methods, time -diaries, interviews and simple observations, was tried out in a case study with informants having a dry toilet system in Stockholm, Sweden. In the time-diaries the informants recorded water and sanitation use over five days. The simple observations provided information of the physical context, essential for the interpretation of the time-diaries. Used together they provided an image of informants' everyday life and how water and sanitation were integrated in everyday activities. The time-diary also increased the informants' awareness of own behaviour and habits. The methodological process, involving several contacts between informant and researcher, enhances the possibility to develop mutual trust. Hence, in the subsequent interview aspects otherwise hard to articulate could be discussed. Consequently, the triangulation is valuable in analysing various issues related to householders' interaction with and perspective on water and sanitation.

The problem

By a simple manoeuvre water is pouring from the tap, generally of desired amount, temperature and quality. The used water is easily discharged to sewers. About 50 % of the metals and chemicals in wastewater treatment sludge supposedly originate from household activities (Eksvärd 1999). The opaque conventional water and sanitation structure tends to make users' activities habitual and not in need of contemplation. Due to criticism in terms of lack of sustainability, modifications or replacements of conventional water and sanitation systems are locally taking place. Examples of such transformations are installations of toilets with separate handling of dry faeces and urine, and the introduction of individual metering and billing for warm and cold water. These seemingly technical changes also alter management issues and user behaviour. Hitherto, user aspects of water and sanitation have mainly been studied in terms of attitudes, acceptance and mapping of user experiences (e.g. Haglund and Olofsson 1997, Naturvårdsverket 1998). However, system development needs a more comprehensive analysis and methods to go with it.

The choice of methodology is intimately connected to the aim of the study, in my case to analyse household use and behaviour related to water and sanitation, associated with changes of the conventional system motivated by ecological concern. The main focus will be on household perception of risks and possibilities since it may be the decisive factor in implementing future system.

Studies of everyday life in households necessitate investigating a sphere considered as private. We also tend to view routine activities less rewarding to study since we all are well aquatinted with them. Interview methods are appropriate for collecting empirical data for qualitative social research, but have limited applicability for studies of habitual behaviour since people have difficulties articulating such activities (Ellegård and Wihlborg 2001). However, used simultaneously with other methods the prospect of getting sufficient information improves. The aim of this paper is to evaluate the appropriateness of a methodology using triangulation of time-diaries, interviews and simple observations, for answering questions of how, when, where and why water and sanitation is used in everyday life.

About the method

Time-diaries are developed as methodology in a time-geographical and interdisciplinary milieu. It is thought of being capable of visualising habits and routines and aims at identifying everyday contexts. The time-diary must however be combined with other methods if we want answers of why certain behaviour occurs. To use time-diaries prior to interviews makes it possible to approach values and standpoints otherwise difficult to articulate (Ellegård and Nordell 1997, Ellegård and Wihlborg 2001). Time-diaries and subsequent interviews have previously been used in studies concerning issues of everyday life (e.g. Friberg 1990, Östlund 1995, Sjöberg 2000). Everyday aspects essential to study depends on study focus, but generally it is what you do, why, where it takes place and with whom (Ellegård and Nordell 1997). The time-diary is structured accordingly with headlines like time, activity, locality and other persons involved, but it is also possible to add headlines covering issues of particular interest. What finally is included or excluded in the time-diary, is however entirely in the hands of the informants.

The time-diary is introduced in a meeting between the researcher and the informant, preferably in the home of the latter. At the same time some observations are made, like features in the kitchen and bathroom, distance to the faecal heap etc. The observations are important for the interpretation of the time-diary and the interview. Ideally, the informants write time-diaries for a week as activities could differ in character between weekdays and weekends. But, as the writing is demanding and time-consuming, the duration may be shortened, but still include both weekdays and weekends. The time-diaries are analysed in a computer program developed for this purpose. Various activities, places and relations are given individual codes. With this information the program creates graphs, giving an overview over the individual's projects and activities in space and time. This information is then used in composing the interview protocol.

Case study Stockholm

The most pronounced difference between a conventional WC and a dry toilet is the excreta management. What the WC flushes away to a distant place for treatment, are kept in the dry toilet. To be able to examine how this fact affects user behaviour, residents in a condominium with dry toilets were asked to participate in a study. They aim at living ecologically and consequently have chosen the dry system out of environmental reasons. The urine from all 32 households is collected in three tanks while each household takes care of its faecal matter. Out of the participating households, two were singles and two were households containing couples with children, one with younger kids and one with teenagers. All adults in the households participated and one of the teenagers also took part, thus in total the study involved seven informants in four households. They were asked to write a time-diary for five days, including three weekdays and one weekend. A minimum requirement was that all water-related activities were recorded as well as activities indicating the person's presence in the home.

Everyday life is made up of activities. Writing a time-diary becomes an additional task that disturbs the normal routines to some extent, and therefore it is often viewed as demanding and time-consuming. This study makes no exception. The informants believed that the diary affected everyday life to some degree, as the writing became an interruption in itself. Most of the informants thought it was demanding, especially after a couple of days when the interest diminished. Some found it hard to remember to bring the diary along and to keep writing. All informants tried to write continuously but some considered it difficult when many activities vied for restricted time. Occasionally reconstructions had to be made. Different strategies were adopted to enhance the writing, e.g. several water activities were clustered into one main activity and standards were set for frequent behaviours.

Even though the informants have full control over the information in the time-diary, the participating women felt ambivalent. They considered some water and sanitation related activities as too private to write down. Omitting these activities was considered but came in conflict with the wish to accomplish. Again, strategies were adopted, e.g. to record the activity but not in detail. Many believed that the time-diary made them more observant about their behaviour, but also that it did not affect their thoughts about water. Being a resident of the condominium involves continuous discussions about various environmental issues. Also, the residents have actively chosen systems for sanitation and waste handling that demands ecological awareness for being managed properly. This provides them with a line of thought somewhat different from what could be expected to find in conventional residential areas.

The time-diaries gave valuable information concerning when, where and what activities took place. However, they did not expose why certain activities were undertaken and the considerations affecting the decisions. Therefore interview questions were developed, of both common and exclusive character. Each interview lasted 1.5-2 hours. Interviews were transcribed and analysed along with the information in the diaries and the simple observations.

Each household has to empty the faecal bin regularly, varying between once a month to once every four months. How often depends mainly of family size and problems with flies. Some have noticed that a more frequent emptying partly eliminate the fly-problem, which incidentally is the most stressed drawback of the system. It seems like this is a job for adult men in households where this option is available. The most obvious argument is that the bin could be quite heavy conditional on amount of excreta and paper, in turn mainly determined by emptying frequency. Some households also have their bin in the basement with only an unwieldy manual elevator to their disposal. Another, not that evident cause, is that the women seem to rather not deal with this task at all. One believed it just occurred to become her husband's task, maybe a remnant from her latest pregnancy when she was not inclined to deal with faecal matter. She also asserted that her husband did not seem to mind. Another woman confirms the picture; her husband also did not bother. The biggest dilemma is she having difficulties standing the smell. Hence, in trying to avoid the faecal bin filling up too fast, and by that having to empty more often, she puts the urine paper in a basket next to the toilet.

Evaluation of methodology usefulness

The above is an example of information achieved from the study. The time-diary was only written for five days and no faecal bin was emptied during these days and consequently not displayed in the time-diaries. Despite this fact, aspects of faecal management could be fruitfully discussed. The time-diary together with the simple observations gives the researcher an image of the informants' everyday lives. Writing the time-diary also increases the informants' consciousness about their everyday routines and behaviour. The fact that habits and behaviour are displayed makes them feasible to discuss. In the interview all related questions could be addressed, even issues not present in the time-diary. The time-diary has narrowed the scope for the informants why all kinds of associated issues could be given some attention in the interview. Maybe the introspective effect was less pronounced in this particular study because of the informants' atypical environmental awareness. The process behind the triangulation also has positive side effects. Having contact on several occasions, over the phone making up appointments, personal meetings in introducing the time-diary and in making the interview, increases the possibilities to develop mutual trust between informant and researcher. Trust is important in studies touching upon personal issues as it may open some shut doors. The combination of the three methods also makes it possible in collaboration with the informant, to identify and disentangle inconsistencies between written and oral information. Thus discrepancies between narrated and actual behaviour could be reduced.

Finally, the method is sympathetic from an ethical point of view. The informant can control the empirical data, which is proper when dealing with private matters. It may also be an important aspect for the informants' willingness to participate. On the downside, albeit not an exclusive problem for this method, it allows the informants to leave possibly interesting activities aside. It makes it difficult to evaluate the comprehensiveness of the empirical material. The risk of omitted information could be somewhat reduced if the researcher succeeds in establishing trust.

Conclusions

Plain mapping of behaviour is not interesting without scrutinising the ideas and intentions behind certain actions, like risk reduction for personal as well as environmental protection. The three separate but interrelated data collecting methods makes it possible to expose and assess water- and sanitation related behaviour. The diary answers mainly the questions how, where and when, while the interview mainly answers the question why. The simple observations support the interpretation of the diary and subsequently the interview. Used together they could answer various research questions related to householder's everyday life. To better understand human everyday behaviour is an important factor in the making of a sustainable society.

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Factors which have influenced the acceptance of ecosan in South Africa and development of a marketing strategy

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Session B

Keywords

South Africa, social marketing, dry urine diversion

Abstract

This paper contends that the marketing of ecological sanitation is no different for any other sanitation technology. People are motivated by reasons other than health to improve their sanitation such as no smell, safety, security, comfort, privacy, convenience, minimum handling of excreta and the quality of pedestals and structures. At present many promoters of ecological sanitation focus on re-use, as the primary motivating factor for people to adopt the technology. The results of the South African Sanitation Programme, however, have shown that by marketing the product to people's aspirations ecological sanitation can be successfully introduced at a wide scale in a sustainable manner, whilst at the same time satisfying the Governments desire to provide access to sanitation to all. This paper sets out how ecological sanitation was introduced as an alternative technology into the Sanitation Programme in the Northern Cape Province, political support gained, and introduced subsequently into other Provinces.

Introduction

"It doesn't smell!" These are often the first words, which people utter, when literally faced with the mixture of soil, ash, faeces and toilet paper from a dry urine diversion toilet. No one mentions that it looks like good manure or that the separated urine can be used as fertiliser.

The lack of smell together with least handling of excreta; low capital and maintenance costs; security of an indoor toilet, privacy and comfort are the factors, which influence people's choice of sanitation technology. Health is rarely a motivating factor in choosing a toilet and the same holds true for ecological concerns.

The context, therefore, for your normal average householder, in which ecological sanitation is promoted is no different from any other sanitation technology. The contention of this paper is that from the experience in the South African, Department of Water Affairs and Forestry Sanitation Programme, householders do not primarily choose ecological sanitation from the point of closing the loop but from it being the technology that most ably satisfies their aspirations and physical requirements.

Until the proponents of ecological sanitation understand this and let people take informed choices, rather than insisting that it is ecological sanitation or nothing, ecological sanitation will remain an interesting side-show rather than a mainstream solution in the quest for sustainable sanitation.

Context

Ecological Sanitation was not introduced into South Africa as a distinct separate programme, but as part of the Department of Water Affairs and Forestry, Sanitation Programme. This programme is guided by the "White Paper on Basic Household Sanitation", September 2001, which contains the following 12 principles:

1. Sanitation improvement must be demand responsive, supported by an intensive Health and Hygiene Programme
2. Community participation
3. Integrated planning and development
4. Sanitation is about environment and health
5. Basic sanitation is a human right
6. The provision of access to sanitation services is a local government responsibility
7. "Health for All" rather than "all for some"
8. Equitable regional allocation of development resources
9. Water has an economic value
10. Polluter pays principle
11. Sanitation services must be financially sustainable.
12. Environmental integrity

The Sanitation Programme, which targets the poorest households, is based on a subsidy of R600 (recently raised to R900) per household, for materials and labour with the household contributing the remainder in cash, materials or labour. Since the people, whom this programme targets, do not have on-site water the programme promotes dry sanitation. Although the programme was supposed to promote technology choice the reality in most projects was the single pit Ventilated Improved Pit (VIP) toilet with a choice of top structures.

A central theme of the Sanitation Programme has been that good sanitation is required for improved health. Thereby educating people around the dangers of poor sanitation you will get households to construct toilets and alter their behaviour patterns [1]. The programme also made the assumption that people had poor behaviour, from an attitudinal point of view, and it needed to be changed. This attitude has persisted despite the evidence that people do not respond to these messages (Eales 2002[2]). At the same time the Department of Housing and Provincial and Local Government were also running sanitation programmes. These programmes frequently promoted waterborne sewage without considering the ability of people to pay for such a service.

It was thus in this context that ecological sanitation was introduced, at scale, in South Africa.

Introduction of ecological sanitation into the sanitation programme

Alternatives to the VIP were first sought in 1997 when in Namaqualand, Northern Cape, hard rock on the surface made it impractical to build VIPs. If jackhammers were brought in it would have been too costly and the community could not have replicated the toilets, when the programme finished.

Expert opinion promoted the use of double pit VIPs but this proved to be impractical, as a VIP

[1] "Water Supply and Sanitation Policy, White Paper", November 1994: South Africa

[2] Social Marketing and Behaviour Change in Rural household Sanitation Projects in South Africa" Kathy Eales, November 2 002

needs soil surrounding the substructure to allow the liquids to seep away. Also the households rejected them, as the floor was too high above the ground, making entry difficult and exposing them to the world when using the toilet.

In 1997 at the workshop on Ecological Sanitation, held at Ballingsholm, Stockholm, Sweden it was realised that the dry urine diversion toilet, as used in Mexico, might provide the solution. In 1998 a number of moulds were purchased from Mexico and the first units installed[3]. Given the geological conditions the option the community had was either to try the dry urine diversion toilet out or carry on using the bucket system until collection stopped and revert to using the veld. Initially this was the main marketing strategy to the communities, that the urine diversion toilet was the only affordable option available to them given the geology of the area.

The first dry urine diversion toilets installed were generally double pits (either next to each with a moveable pedestal or one pit behind the other with a fixed pedestal) with capacity for several years and the urine was led to a soakaway. Households were encouraged to plant trees around the soakaway to take up the nutrients and moisture. By doing this it was hoped that people would see the effectiveness of the urine as a fertiliser and be encouraged to experiment further (In Namaqualand there is a high degree of mineralisation in the soil and groundwater and plants are naturally salt tolerant). The question of dealing with the faecal matter was left to a later stage when the pits required emptying.

Two methods of dealing with the toilet contents have emerged:

1. To burn the contents: This has been successful due to the very dry climate and the use of hard instead of soft toilet paper; and
2. Composting/burying: This has only been recently introduced as the 1st pits have required emptying. On opening the pits people have realised how innocuous the contents are and have had no problem in emptying the pits. Generally households buried the contents. However after a year people realised that a transformation of the contents had taken place and have been planting pumpkins, potatoes and onions. This step did not take place naturally but occurred due to the strong support and encouragement of one of the fieldworkers, Maria Wildschutte. As a result of the 981 households who have accepted the dry urine diversion technology in the Kammiesberg Municipality, Namaqualand, 50 are now practising ecological sanitation.

An interesting development in Namaqualand was the construction of double VIP toilets against the houses with access from the inside. These have proved very successful. On opening them, however, it was realised that due to the dryness of the area the pits had remained dry and there was in fact very little difference between them and the operation of dry urine diversion toilets. This again made the marketing of dry urine diversion easier as people saw very little difference with what they were accustomed to and what was being promoted.

Another significant event was the construction of social housing in the villages with all the fittings for waterborne sewage but no water connection nor treatment facility for the sewage, either on or off site. A local woman, Maritjie Meyer, after seeing the pictures of Cesar Anorve's bathroom in Mexico, reckoned she had nothing to lose by installing a dry to urine diversion toilet in her bathroom. This inspired all residents with similar houses to install dry urine diversion in their houses, and the National Sanitation Operations Manager of the Mvula Trust to convert his house. This served to demonstrate that a dry urine diversion toilet is a permanent installation inside a house unlike a VIP toilet, which is outside the house and needs to be moved when full (if a pit emptying service is not available, as is generally the case).

All of this was happening at a local level with support from the local politicians (total population of the municipality 11,000). However, for the programme to be implemented on a wider scale it

[3] **"**Introduction Of Urine Diversion In South Africa**"** R D Holden & L M Austin, South Africa. 25th WEDC Conference Addis Ababa, Ethiopia, 1999

needed to overcome opposition to dry sanitation at provincial level.

Gaining of political support

Any sanitation programme cannot function without political support. In the Northern Cape the sanitation programme was well supported at local level. The Premier of the Northern Cape, Manne Dipico, however, went on record stating that his objective was to eliminate the 25,000 buckets in the Northern Cape and replace it with waterborne sanitation. He also stated that dry sanitation was a second class technology, which would continue to deprive the historically disadvantaged people of an acceptable standard of living. The Premier was not alone in this view, which was supported by many local government councillors.

This presented a few problems since the communities where buckets were prevalent could not afford to maintain waterborne sewage and often there were not the water resources as well.

A twin strategy was conceived to overcome this:

1. To gain the Premiers support for dry sanitation; and
2. To demonstrate that dry ecological sanitation provides exactly the same level of convenience and service in a middle income house.

To overcome the first obstacle, in July 2000, the African National Congress caucus in the Leliefontein Transitional Local Council (TLC) invited the Premier to an Open day in Nourivier, Namaqualand to demonstrate to him the success of dry sanitation and request his endorsement and support. Councillors and officials from other municipalities were also invited to share the experience. At the start of the Open Day the Chairperson of the Leliefontein TLC, Gert Maarman stood up and stated that in Namaqualand, where there is little water and little money dry sanitation, is the ONLY solution.This statement might not sound much, but it was made 5 months before local government elections in a climate where everything was being promised free to residents (such as free basic water). After seeing the village and listening to the people the Premier not only reversed his stance but also allocated significant sums of money to dry sanitation. Gert Maarman went on to become the Mayor of Kammiesberg, the new, and very much bigger, local municipality.

The second obstacle was overcome by the National Sanitation Operations Manager of the Mvula Trust installing a dry urine diversion toilet into his own home in central Johannesburg. This installation was coupled with greywater recycling and served to demonstrate that with minimal intervention from the household dry ecological sanitation produces the same level of convenience coupled with significant cost servings. It also demonstrated that on a stand with a garden area of 200m^2 no form of off site treatment is required[4]. Due to the central location of this house it has been visited by over 300 national and international visitors, been shown on national television 4 times and has served as a central point of the advocacy campaign for the acceptance of ecological sanitation in South Africa. An interesting point was at the same time, October 2000, the house was converted another two influential players in the Northern Cape Water Services programme agreed to convert their houses but to date have not. The main reason appears to be psychological (Wilke 2003)[5] and this needs to be noted in any marketing campaign.

Introduction of ecological sanitation to other rural and urban areas

It was recognised from the beginning of the Sanitation Programme that people would not readily

[4] "The use of Dry Sanitation in the Urban Environment" Case Study No.7, 2002: Mvula Trust

[5] "Sanitation And Psychology : A Personal Perspective" Isabella Wilke 2003

accept a new technology and they would need to see the physical toilet, not a model or pictures, before committing themselves[6]. One way of overcoming this is to take people to communities where the technology is already in use and this has been used very successfully in the Northern Cape to spread knowledge about dry ecological sanitation and in other parts of the country, around VIP toilets. Also the technology needed to be introduced to urban as well as other rural areas.

Unfortunately Namaqualand is far from most areas of habitation being 600km from Cape Town and 1200 km from Johannesburg and without any adequate air links. It, therefore, has proved extremely difficult to get people to visit the villages in terms of both time and cost to experience ecological sanitation.

Since it has not been possible to take people to ecological sanitation the focus has been on taking ecological sanitation to the people. Five strategies have been developed:

1. By taking politicians, officials, community members etc. to the house in Johannesburg it has enabled them to gain firsthand experience of ecological sanitation in an upmarket house. Over 300 people have now visited the house, some returning with colleagues for a second visit;

2. By consistently raising, with municipalities, the issue of sustainability of water services, and highlighting the every rising incidence of the failure of waterborne sewage systems, it has encouraged municipalities to look at alternatives. The most notable success has been with Ethikewni (Durban) and Majareng (Warrenton). In Ethekweni the officials came to the conclusion that they could not extend waterborne sewage to all areas and that they did not have the means to empty VIPs. Their conclusion was that outside a set boundary, households would either have to provide and run their own treatment works or accept the dry urine diversion system provided by the municipality. Although their logic in choosing dry urine diversion is impeccable doubts have been expressed about the method of introduction in that households are given no choice about a technology, which many might feel offensive. The test will come in 2 years when the pits will need to be emptied. If the household empties the pits, or they are prepared to pay someone to empty them then it will be successful. If not the technology could easily be discredited. In Majareng there was initially great opposition to anything but waterborne sewage. Officials and councillors, were in fact, some of the first visitors to the house in March 2001 and at stage they were not convinced. They continued to submit applications to Provincial and National Departments for grant funding to expand the reticulation and build a new treatment works. In the Northern Cape, however, the departments have an integrated approach to water services and unless the municipalities can prove, through current payment for services, that they can sustain a waterborne system, capital finance is not granted. After having their application turned down they then started to look at alternatives and now fully support the programme. Their most recent initiative was to convert 2 municipal houses from a flush to dry urine diversion to reduce service costs to the occupants who could not afford the cost of emptying the conservancy tank.

3. When difficult ground conditions, or dense settlements, preclude the construction of VIPs, using the opportunity to introduce dry ecological sanitation. Using this strategy ecological sanitation has been introduced in 5 of the 9 Provinces in South Africa (KwaZulu-Natal, Limpopo, Western Cape, North West, and Gauteng)

4. Marketing dry ecological sanitation around the issues of as no smell, safety, security, comfort, privacy, convenience, quality, minimum handling of excreta and low capital and operation and maintenance costs. This in fact appeals most to households and the difference between a cheap plastic toilet seat and a wooden toilet seat has been used to successfully market ecological sanitation.

[6] "Guidelines Implementation Manual for DWAF Funded Household Sanitation Projects" July 1997: Mvula Trust

5. Introducing the concept gradually and allowing for people to change back. Where people are already on waterborne sewage the first step is to introduce greywater re-cycling and garden composting. This has an immediate financial benefit and they see how the soil is improved. The next stage is to introduce the dry urine diversion toilet. It is, however, imperative to allow for conversion back to a flush toilet so that the resale value of the house is not affected and people do not feel forced into a corner (a re-conversion takes 8 hours).

In Northern Cape all 5 strategies were successful mainly due to the financial support of the Department of Water Affairs and Forestry and the focus on integration and sustainable services with other Departments. Dry sanitation is now no longer an issue and it is estimated that 80% of households choose dry urine diversion over VIP toilets. In other provinces similar success has not yet been achieved for a combination of reasons, the main one being the reluctance of professional staff to accept and promote the technology.

Social marketing to households

Once a sufficient number of dry urine diversion toilets had been installed, including a number inside houses, the principle of how the toilet works can be demonstrated to a wider audience. The technology is then marketed around the advantages of being inside the house and a permanent structure, compared to a VIP.

A dry urine diversion toilet inside the house offers:

1. No smell: To ensure there is no smell from a dry urine diversion toilet the faecal matter must not start decomposing whilst in the chamber underneath. The addition of soil and ash and the use of a bucket to prevent external moisture reaching the faeces ensure this.
2. Safety: Pits are very much smaller than VIPs and children do not have the fear of falling into the sewage;
3. Security: Going to an outside toilet can be dangerous. In rural areas people have a fear of snakes and in urban areas fear of attack (so much so that even where the toilet is flush they will use a chamber pot at night rather than risk visiting the toilet);
4. Comfort: An inside toilet is generally well lit and warm compared to an outside toilet, which in winter is cold and draughty. To ensure that a dry urine diversion toilet offers the same level of comfort the pits have been reduced in size so that the bucket used to catch the faeces just fits and there is no ventilation pipe to produce cold draughts.
5. Privacy: An inside toilet means that no-one sees you going to the toilet and can comment on your habits;
6. Convenience: At night the convenience of an inside toilet is immeasurable. No getting dressed, getting wet if it is raining etc. The only negative aspect of the dry urine diversion toilet, from a male convenience point of view is that a male must sit to urinate unless a separate urinal is provided. The fixed subsidy of the Sanitation Programme overcomes this by simply saying that if a separate urinal is required then the owner must pay for it. For example in the house in Johannesburg a separate waterless urinal of a comparable quality to the rest of the bathroom fittings would have cost R1500. This prodded the males in the household to drop their trousers and now it has become so natural that no more thought has been given to installing one.
7. Quality: In South Africa, it has been demonstrated as has by Cesar Anorve in Mexico, that the quality of installation of a dry urine diversion toilet, is equal to that of a flush toilet. This is a major selling point and is often overlooked when promoting ecological sanitation.
8. Minimum handling of excreta by the household: One of the reasons for preference for VIP and flush toilets is that the household does not handle any excreta. It either drops in a pit,

and the pit filled in hen full, or is flushed away for someone else to deal with. To gain acceptance of dry urine diversion systems have been developed whereby the urine and excreta is handled as little as possible in its raw form, thereby increasing acceptability. To this end the programme now promotes the use of a 45-litre bucket underneath the toilet. This has sufficient capacity for a month and can be easily lifted out compared to using a rake and shovel. In communities where use of chamber pots is prevalent the reality is that they are already handling excreta once a day, generally without thinking about it. Once this is pointed out the resistance to handling faecal matter once a month drops away.

9. Low capital costs. Of all the systems urine diversion has found to have the lowest capital cost R1500 compared with R2000 for a VIP and R10,000 for waterborne; and

10. Low operation and maintenance costs. The external costs of a dry urine diversion system, if a householder is practising ecological sanitation is R0 per annum compared with R200 for a VIP and R1200 for waterborne systems.

The marketing of the toilets has been around giving households information about the different technologies and allowing them to make a choice depending on their individual circumstances and preferences[7]. When presenting the different sanitation technologies the most frequently asked question around the dry urine diversion toilet is around smell and the handling of the faeces. This is understandable given the desire of people to handle excreta as little as The most effective way to answer this is to have samples from the toilet and the compost heap available so that people can physically smell (or not) the faeces and see how it decomposes. Once they are satisfied that there is no smell and the job of emptying the toilet will not be unpleasant then they are willing to accept the technology on the basis of the above points rather than marketing it around the reuse of excreta.

Impact on health

The emphasis on social marketing has lead many people to ask if the programme has lost sight of the main objective of the Sanitation Programme, that is improvement in health.

The question on how to measure the impact of the Sanitation Programme on health has bedevilled it since its inception since no reliable statistics have been available at project level, nor in many cases at hospital level. In many settlements people do not visit the public health system but use traditional healers for reasons of proximity and respect. Also to carry out detailed epidemiological studies per settlement are not achievable nor cost beneficial.

By taking a leaf out of the water industries book, where multiple treatments, (barriers) are used to prevent transmission of disease, a simple survey has been developed which measures the number of barriers to transmission of disease in a household. The more barriers the more difficult for disease to be transmitted. This survey can be administered at the beginning, during and at the end of the project to assess the impact of the project. The information is valuable for the communities in deciding what interventions to target in order to improve their situation.

The findings have been remarkable:

1. The survey is simple to administer. In Thukela 18,000 households were surveyed in 3 weeks and in Jo'burg 4,000 households in 4 days with the community members themselves conducting the survey and capturing the data.

2. In many cases the survey showed that households were already doing the maximum they could, given the conditions they lived under. To improve health required an infrastructure intervention rather than a behaviour change. The results below are from the baseline survey, Baldaskraal, KwaZulu-Natal. They show that BEFORE any project intervention over

[7] "Position Paper On Sustainable Sanitation", R D Holden, Appropriate Technology Conference, Johannesburg, 2001

72% had an acceptable score (more than 8) indicating that with the majority of people hygiene awareness was not a problem. This allows the intervention to be focused on the households at greatest risk rather than scattering a broad message, which would be rejected by most as patronising, across the community.

Score	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
No. of HH	0	2	5	6	12	12	22	23	57	51	51	33	16	5	10	0	0
Distrib.	0%	1%	2%	2%	4%	4%	7%	8%	19%	17%	17%	11%	5%	2%	3%	0%	0%

Table 1: Results of Household Survey, Baldaskraal, KwaZulu-Natal

Results

Since 1994, in the various sanitation programmes, in South Africa, approximately 170,00 dry toilets have been installed of which 160,000 are Ventilated Improved Pit toilets, and the remainder various proprietary and dry urine diversion (approximately 4,000) systems. Most of the dry urine diversion toilets have been installed in the Northern Cape where there has been strong political support for the programme.

Although the initial marketing approach was offering dry urine diversion as the only alternative in difficult geological conditions households are now choosing it for other reasons, mainly because it can be built inside a house. Very few of the households intentionally practice ecological sanitation, that is the reuse of the excreta to close the loop. Where reuse does occur it is by default during the disposal of the excreta rather than a deliberate act. However since the decomposed faeces are returned to the soil and the urine disposed of in the root zone where it can be taken up by plants the same effect is achieved. This success has been achieved by marketing to people’s aspirations rather than promoting reuse of excreta, which is a major turnoff to most people.

Conclusion

The introduction of ecological sanitation, in the form of the dry urine diversion toilet, has been achieved on a large scale in South Africa by marketing it around social factors rather than the benefits of the reuse of the excreta. The wide scale acceptance is attributed to the fact that householders were given a choice of technologies and because ecological sanitation satisfied the social requirements the best, given the water, geological and cost constraints. A further factor, in its acceptance, has been the long-term support (4-5 years) provided by the programme to ensure the cycle is completed before households are left to their own devices.

Although the programme has been largely in rural areas the concept is now being introduced into the urban areas and it is found that the same factors influence its acceptance. To gain wider acceptance a broad marketing campaign is required promoting its social advantages rather than the ecological advantages.

Although it is difficult to compare the South African Sanitation Programme to individual projects in other countries, it is believed it is significant that a technology, only introduced at a large scale in 2000 has captured 2.4% of the market, with people choosing the technology, rather than be told what to accept.

The recommendation from the South African Sanitation Programme would be to market ecological sanitation through its social advantages rather than reuse. This experience mirrors the Bangladesh sanitation programme, which achieved a high rate of coverage through social marketing[8] rather than health promotion.

[8] “Private Sector-just a new (hope)?” Report on the 15th AGUASAN Workshop. June 1999

Integrated management of water resources in projects of German financial cooperation

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Abstract

This presentation reflects KfW's past and present experience in the field of Integrated Water Resources Management and lessons learned, to be further considered in future actions, thus embedding them in the framework of the Millenium Development Goals. We will highlight a few examples from our current project portfolio, which demonstrate concepts for water and nutrient reuse at different levels with regard to decentralisation and technological standards, including the relevant framework conditions necessary to implement sustainable projects. Projects to be presented are on rural water supply and sanitation, wastewater reuse in North African and Middle East Countries, sewage sludge reuse in agriculture, reuse of effluent for potable water and anaerobic treatment of municipal sewage.

Introduction

As part of the German Official Development Assistance , KfW, commits investment loans and grants of some EUR 260 Million per annum for water supply and wastewater and sanitation projects in more than 25 developing countries. This is about one fifth of our total commitments within German Financial Cooperation, which is thus one of the world's largest bilateral sources of financing for this sector.

We have been active in the area of urban and rural water supply, wastewater and sanitation for many decades. In line with the Millenium Development Goals adapted solutions which account for the access of the population, especially poor income groups to safe drinking water and basic sanitation are a top priority. As postulated in the Agenda 21 a holistic approach taking into account the ecological sustainability (integrated water resources management), financial viability (ability and willigness to pay by consumers), the participation and acceptance of user groups for adapted solutions are key elements for the successful implementation of projects. Therefore, such investments are usually accompanied by campaigns to build capacities, raise awareness for water as a scarce resource and encourage hygiene. Following sectoral reforms, to which we contribute in cooperation with GTZ and the donor dialogue, new operating concepts have been established and tested recently in many countries.

In our present work we note that the following aspects are increasingly gaining importance:

- the availability of water resources and their management (i.e. groundwater mining, desalination),
- the increasing competition over the use of water resources among private, industrial and agricultural users,

- the need to develop integrated approaches strongly emphasising on the economic and the social framework in the planning and the implementation of appropriate technological solutions,
- the weak legal and institutional framework in many countries,
- rising water quality problems, and
- the need for considering water and nutrient cycles (i.e. effluent and sludge reuse).

Comprehensive project concepts are being developed and implemente d in accordance with the specific demand and needs of the population to be served and the specific circumstances of the project area. These include water and nutrient reuse schemes with different levels of decentralisation and technological standards. For example:

- In our rural water supply and sanitation projects, predominantly in Africa, we promote traditional **on-site sanitation systems** using feaces in agriculrure.
- A number of wastewater projects are under preparation which fulfil the requirements for the **re-use of treated wastewater**, among others in Tunisia, in Jordan and in Yemen. In the latter two countries, comprehensive studies of the possibilities of re-using treated wastewater in agriculture are being carried out.
- In Turkey, concepts for **using sewage sludge in agriculture** have been successfully developed. Thus far the practical implementation of these concepts has generated satisfactory results.
- In Namibia a plant for purifying pre-treated **wastewater to produce drinking water** went into operation in 2001. In coming years this plant will supply up to 40% of the capital's requirements. In the case of Namibia we linked our financing to significant improvements in demand management by way of price increases and water conservation campaigns, the results of which have proven highly successful.
- New innovative and cost-saving technologies are being tested, such as **anaerobic processes to treat municipal sewage** in Ecuador and in Egypt.

With regard to new wastewater and sanitation concepts and the use of "appropria te or adapted" technologies in general, where ECOSAN plays an important role, we would like to point to the following lessons learned so far:

- Conventional wastewater treatment systems do have their merits both in ecological and financial terms, particularly where sewerage systems already exist. And this is frequently the case in the Middle East and North African countries, for example. By expanding these options, significant results may be achieved with limited funds.
- We will not conceal the fact that the delimitation of centralized vs. decentralized solutions in city outskirts, slums and scattered settlements can be very difficult. The same holds true for design parameters and for treatment standards. The wishes of our partners as well as suggestions made by consulting engineers sometimes exceed the limits of ecological and economic viability. Frequently, we have to adjust expectations and apply concepts for gradual expansion. Therefore, in most of our projects central sewerage is limited to high-density settlement areas whereas in the remaining areas on-site systems are promoted.
- Solutions for re-using treated wastewater and sewage sludge to close water and nutrient cycles are gaining priority, specifically in very densely populated arid regions. However, based on our first experience this undertaking can be highly complex and challenging from a technical, socio-economic, legal and institutional point of view.
- In our view promoting "appropriate technology" implies that we focus on the very problems to be solved: thus, depending on local conditions, in principle a wide range of technical

solutions from simple latrines to sophisticated treatment facilities may emerge as being "appropriate". In any case, there are no universal solutions.

In urban and periurban areas conventional sewerage continues to be the appropriate concept which is therefore being applied internationally by all DC institutions. A major reason for this is certainly that there are still no proven alternatives that could be implemented on a wide scale, for instance according to the ECOSAN concept. Incidentally, the industrialised countries also have a lot to catch up on in this respect as well because it is here that it must be demonstrated first whether these concepts work before we can get our partners in the developing countries to accept them.

KfW is participating and collaborating in the efforts towards more effective and efficient wastewater and sanitation projects and is actively supporting the GTZ-ECOSAN project in preparing and implementing pilot schemes in order to gather practical experience in our partner countries.

Examples of KfW-financed projects

1. Lesotho, Sewage disposal in 13 villages (Phase II), latrine programme

The purpose of the project was to build latrines in all 13 urban centres of Lesotho with the exception of Maseru, the capital, for which there was a parallel programme financed by British development cooperation. Around 160,000 people live in these towns in total. The construction of central sewage disposal facilities was financed under a parallel sewage disposal project in 11 of these small towns which was also financed under German FC, and here the systems were put in place only in selected parts of the towns, where central sewerage is applicable.

The funds from the Latrine Programme were used to finance: a) the work of the Urban Sanitation Improvement Team (USIT), which headed the campaign to spread the construction of latrines in Lesotho's urban settlements and b) financial support for the construction of latrines and the measures necessary for the treatment of pit contents.

The USIT advised the buyers of latrines on the selection of the latrine site, on the suitable latrine type, on the purchase of suitable materials and in the search for qualified craftsmen whose training was also imparted by USIT. In this context the strong and continuous participation of the user groups was a key element to guarantee acceptance and effective operation of the latrines. During the eight years of its implementation the project contributed towards the construction of more than 12,000 VIP latrines (ventilated improved pit latrine) in private households and around 1000 school latrines. This means that around half the population in the project locations has access to this form of sanitation. After the latrines are emptied the contents of the pits are dried, making them suitable for application on farmland, for which they are being at least partly utilized.

In some cases private companies have now been commissioned to empty the latrines with cesspool cleaners. The cost of emptying a latrine, which is done about every seven years, is roughly EUR 25.

The total cost of the project was around EUR 1.5 million.

2. Tunisia, use of treated effluent

The reutilization of treated effluent is increasingly gaining importance because of the growing water scarcity in the arid regions of central and southern Tunisia. According to ONAS (Office National de Assainissement) statistics between 25% and 28% (1997: 21%) of treated effluent is currently being used for irrigation of around 35 irrigation perimeters with a total area of 6,900 ha, mainly for tree crops and cereals.

To increase the share of effluent use in agriculture the ONAS in 1998 began to implement a programme for the re-utilisation of treated effluent which was initiated by Tunisia's President. This programme provides for around 20,000 hectares of farmland to be irrigated with treated effluent by the year 2010. ONAS argues that for this programme to be implemented under the current legal framework it will be necessary to have an additional treatment stage for disinfection the effluent. ONAS has devised a programme to retrofit the existing sewage treatment plants with additional treatment stages, and new treatment plants should already be equipped with such treatment stages when they go into operation.

KfW is supporting the ONAS and the Ministry for Agriculture, Environment and Water Resources in the following priority aspects, starting in the framework of the sector dialogue:

c) In order to promote the reutilization of treated effluent in agriculture and to justify investment in additional treatment stages the legal framework in Tunisia will have to be reviewed for consistency and completeness and adapted to international standards.

d) In addition, given the limited financial capability of ONAS the financing of operating costs for additional treatment stages for disinfection of the wastewater, which usually lead to a 10% increase of operating costs, will have to be defined. The financial contribution of the users of the treated effluent will have to be agreed with the Ministry for Agriculture, Environment and Water Resources.

One important aspect in the discussion on the use of treated effluent in agriculture is the problem that the farmers have difficulty accepting it, which has been observed in the past. For one thing, farmers and local authorities have socio-cultural misgivings against using treated effluent in irrigated farming, and for another there is often fresh water available for irrigation at a low price, particularly in the northern parts of the country. In addition, the Ministry for Agriculture, Environment and Water Resources and the regional departments of agriculture so far do not appear to have much interest in treated effluent.

3. Jordan, re-use of treated wastewater in irrigated agriculture in the Jordan Valley

Jordan is one of the most water-stressed countries in the world. At present, around 70% of total water consumption is used for irrigation purposes. Since the total water consumption has exceeded the renewable resources the agreed Jordanian-German co-operation aims at the protection and efficient use of the existing ground and surface water resources by, among others, substitution of fresh water for agricultural irrigation by using treated effluent. The present and future co-operation is based on the "Joint Approach of Jordanian-German Co-operation in the Water Sector and Related Environmental Aspects" dated November 2001, which includes aspects of irrigated agriculture with the overall objective of improving the water balance of the country.

Within the framework of Financial Co-operation (FC), the German Government has committed around EUR 89 million for the extension of the sewerage system of the Greater Irbid Area in the northern uplands of the Kingdom. The investment programme includes the implementation of three sewerage networks with advanced-technology wastewater treatment plants (WWTP) for densely populated urban areas and is supposed to be completed by the year 2005. These three wastewater collection and treatment systems supplement the Central Irbid sewerage system and treatment plant that started operations in 1987. Based on the mid-term projections, towards the year 2015 the daily volumes of treated effluents from the WWTPs would come to some 550-600 l/s.

The overall objective of the programme currently at feasibility stage is to define and implement measures for the re-use of treated wastewater on existing agricultural irrigation perimeters, in order to substitute the use of freshwater in irrigated agriculture and thus improve the water balance of the country. As a consequence, the use of treated effluent on additional or new perimeters is excluded. This shall be supported by an integrated irrigation and water use programme for the Jordan Valley North Area, considering the available treated effluents, a reduced use of fresh water resources and natural rainfall.

Because of a number of negative experiences in recent years, when water supply for irrigation was affected uncontrolled by effluents from wastewater treatment plants in certain regions, a low acceptance rate by farmers and markets is said to dominate. This is why the project concept is to be supported by professional guidance and control and, most important, by an official public awareness campaign confirming product qualities and health standards. It is to motivate the farmers, the markets, and the public to understand and accept the reuse of treated effluents for irrigated crop production. On the other side, in order to improve the farmers' acceptance of the use of reclaimed water, the monitoring and quality control of the outflow from the WWTPs must be permanently guaranteed by the responsible authority i.e. operator of the plants, and the respective laws and regulations must be enforced, leading to countermeasures and/or sanctions in case the standards are not fulfilled. Further, the Jordanian Government has to adapt its legislation concerning treatment standards in order to allow an efficient and safe use of treated wastewater in irrigation.

4. Namibia, water reclamation plant Windhoek

The population of Windhoek has grown strongly particularly in the years after independence and today totals around 300,000 inhabitants. Until the end of the 1950s the drilled wells utilised since 1928 and the Avis Dam which was built in 1933 and has been dry for quite some time were sufficient to supply the population of about 36,000 inhabitants with water. After 1959 the water supply came not only from the drilled wells but, initially, from the Goreangab Dam, the water of which was treated in a treatment plant. The water supply was later expanded into a central Namibian integrated water supply scheme. To that end three new dams were constructed by the Namibian government. The water resources thus available to the city of Windhoek are not sufficient to secure the water supply in the future, especially because long periods of drought, erratic precipitation and high evaporation lead to great fluctuations in the available quantities. The additional supply of Windhoek by an extended long distance bulk water trunk line from the area of Otjozondjopa (200 km distance) or the Okawango river (500 km distance) is not feasible from economical and ecological point of view.

Since 1968 the world's first water reclamation plant for converting wastewater into drinking water has been in operation in Windhoek. Over the years this plant was gradually expanded by the city of Windkoek and modernised (14,000 m³/d, treatment stages with flotation/sedimentation/filtration/activated carbon filtration/final chlorination). The rehabilitation and enlargement of this plant to a capacity of 21,000 m³/d was supported by an FC project.

According to the overall concept, the treated effluent from the existing municipal treatment plant (18,000 m³/d, 6.5 mn m³/a), which possesses treatment stages of nitrogen removal, phosphorous removal and maturation ponds, is blended with water from the Goreangab Dam (secured available water 1.5 mn m³/a). This way almost one third of the entire water consumption can be covered by wastewater for reclamation.

The total cost of the treatment plant amounted to EUR 13 million and was three-quarters financed from FC funds. In return the city of Windhoek was obligated to a) introduce tariff increases and a stronger consumption-related progression, b) make efforts towards a substantial reduction of specific water consumption and c) significantly reduce water losses. As a result of the tariff increases, surplus revenue on basis of operation costs is already being achieved and the collection efficiency is around 87%. Technical losses are being reported at 8% and the commercial losses (for instance from water meters not read) are estimated at 10%.

The wastewater reclamation plant of Goreangab was put into operation in 2002 and is being operated by the private operator WINGOC. In the preparation of the management agreement the city of Windhoek was supported by a transaction adviser financed from FC funds.

However, this solution has to be considered as an exemption, taking into account the difficult framework conditions and the specific capacities with regard to wastewater reclamation of the city Windhoek. The high conversion costs per cbm, the strong institutional framework needed - in the case of Windhoek a private manager will operate the plant -, the sophisticated operation of the plant and the need for a secure water quality monitoring system are risks which are difficult to handle, especially when considering the general framework in developing countries.

5. Egypt, wastewater disposal Amriya/Alexandria

The district of Amriya, located in the western part of Greater Alexandria, experienced strong population growth over the last 20 years without adequate water and sanitation infrastructure development. In the entire district, but mainly in the densely populated settlement areas where housing standards are mostly low, large portions of the population are exposed to health hazards from numerous sources of contamination, particularly from the sewage and faeces stagnating in the streets. The discharge of untreated sewage into the canals and the wild waste dumps alongside the canal embankments also cause severe pollution which leads to considerable mephitis originating from anaerobic processes in the waters. The planned project, in which the densely populated settlement areas have been chosen as a priority for the construction of a sewerage system and connection to a central sewage treatment plant, represents the first expansion stage in the planned development of the sanitation infrastructure in the Amriya district and currently can make the most effective contribution to improving the health and environmental situation in the district. Furthermore, the capacity of the sewage treatment plant will be large enough to accommodate the sewage produced by the new settlements already connected to sewers.

The project will assume a pioneer role with the planned mechanical-biological treatment plant for 300,000 PU in the first expansion stage. A combined anaerobic-aerobic treatment process will be applied – initially for only a portion of the sewage, however. In a first anaerobic stage around 70% of the organic waste will be eliminated without aeration while the second aerobic stage will serve as secondary treatment for compliance with the prescribed effluent standards. Operating costs are estimated to be around 50% lower a) as a result of lower energy consumption for aeration and b) as a result of lower costs for sludge treatment because the excess sludge quantity obtained from the anaerobic process will be only around 10% of the quantity of the aerobic process which will accrue already in a stabilized form. Savings can also be achieved in the cost of the investment.

The sewage sludge produced by the sewage treatment plant is to be composted following mechanical dewatering and then used in agriculture for farming purposes. Positive experience has already been gained in this respect from the treatment and utilization of sludge in two sewage treatment plants already in place.

The overall investment cost of the project is estimated at EUR 55 million, of which EUR 33 million will be financed from FC funds. The project is to be implemented in the next two to three years. A management agreement with a private operator is to be concluded for the operation of the sewage treatment plant.

A sewage treatment plant financed by FC funds with an anaerobic first stage and downstream settling ponds for 65,000 PU went into operation in Babahoyo, Ecuador, in 2002. The first operating results reported from there confirm the above data concerning sewage treatment performance and costs.

Conclusions

The application of ECOSAN concepts, which are per definition highly decentralized and apply high-level separation and reuse of water and nutrients, needs further demonstration in developed as well as in developing countries, especially in urban areas, to gather practical experience and prepare for large-scale implementation. This is still a challenge because the following questions, among others, have to be answered:

- What particular technical and operational concepts are most appropriate?
- What socio-cultural considerations have to be made?
- How to secure reliable operation and thus manage potential health risks?
- How to proceed with a restrictive legal framework and standards for re-use elements?
- How strong is the ownership of local partners and their willigness to support appropriate technologies?

KfW is participating and collaborating in the efforts towards more effective and efficient wastewater and sanitation projects and is actively supporting the GTZ-ECOSAN project in preparing and implementing demonstration projects in order to gather practical experience in our partner countries.

Ecological sanitation in Mozambique: baseline data on acceptability, use and performance*

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Abstract

Households using ecological sanitation ("ecosan") latrines in Niassa province, Mozambique, (n=76) were surveyed regarding the factors contributing to the adoption, acceptability, use, and maintenance of these latrines. Neighbors without ecological sanitation latrines were also surveyed, for comparison. Biosolid samples taken from in-use latrine pits had a mean temperature of 23°C (16.1°C–30.4°C), pH of 8.3 (5.7–10.2) and moisture content of 48% (13-88%). Most users learned of ecological sanitation through the non-governmental organization (NGO) WaterAid and its partner organizations. Households chose ecological sanitation for a variety of reasons, including the design, construction, maintenance, and health benefit of the latrines. Users found ecosan latrines very satisfactory, and were following maintenance directions. Based on the low average temperature and varying moisture contents of the latrine samples, we recommend prolonged storage (1-2 years) and that precautions be taken when using the biosolids for agriculture.

Introduction

Prompted by the educational outreach work of the international NGO WaterAid and its Mozambican partner organizations, households in the province of Niassa, Mozambique, are rapidly adopting ecological sanitation ("ecosan") technology in which human wastes are stored until safe and then reused as fertilizer for agriculture. ESTAMOS, a community organization that promotes food security, HIV/AIDS prevention, and safe water and sanitation, is the partner organization that works in the districts of Lichinga and Mandimba, where this study was conducted. Lichinga is the provincial capital of Niassa, Mozambique's poorest and most remote province, and Mandimba is a large district capital within the province.

The primary ecosan design promoted by WaterAid through ESTAMOS is the "fossa alterna," which consists of two permanent, partially lined, shallow (1.25 – 1.75 meter) pits and a movable concrete latrine slab. This slab covers the pit that is in use, and a wooden cover protects the pit that is not in use. Thatched straw walls surround the two pits and a private bathing area, which is attached (fig. 1). Fresh excreta are covered with a mixture of ash and soil. When the first pit is full-after approximately one year of use-it is covered and its contents are allowed to decompose. The second pit is then used until it is full, at which point the first pit is prepared for reuse: its

*This paper has been peer reviewed by the symposium scientific committee

contents are removed and are further decomposed or used immediately as fertilizer. Since the spring of 2001, communities throughout Niassa have requested assistance with constructing more than one thousand fossa alterna ecosan latrines, and more than three hundred of these have already been built.

This study highlights the attitudes and behaviors of ecosan users as they begin to use ecological sanitation. At the time of the study, few households had begun using the second pit. This study therefore does not address the impact of ecosan latrines after the decomposed excreta have been removed. Instead, building on Water-Aid's regular monitoring and evaluation of Niassa's fossa alterna latrines, this study documents baseline information on 1) latrine preference and ecosan acceptability, 2) the use and maintenance practices of ecosan latrines, and 3) selected physical and chemical characteristics of the biosolids in the latrines.

Figure 1: Fossa Alterna Latrine

Methods

Eligible population

This June 2002 to July 2002 study investigated all households known to have fossa alterna latrines in the peri-urban towns of Lichinga and Mandimba and in the surrounding rural communities. Latrines that had been completely built but which were not in use because they lacked a concrete slab were included in the study. Also included in the study were the one or two closest households neighboring each household with an ecosan latrine. Eligible respondents in all households were people who were over 18 and were responsible for latrine maintenance (if applicable).

Field survey

In June and July 2002, interviewers fluent in local languages (Portuguese, Nyanja, Macua, and Yao) conducted surveys of households with fossa alterna latrines (n=76) and of their closest neighbors (n=110). The in-depth surveys asked up to 338 questions. The type of latrine owned (if any), the number of latrines owned, and whether the owned latrines were in use determined which questions were asked in each household.

The research team visually inspected latrine construction and maintenance and noted evidence of use. Using PVC pipe of 3.8 cm diameter, the team took core biosolids samples from 48 in-use and two full (dormant) pits. Ambient and sample temperatures were taken on-site, and the samples were taken to the lab in plastic bags.

Physical and chemical measurements

Moisture content of the core samples was determined by comparing the initial weight of a 20-60 gram sample with the weight of the same sample after the sample was dried. Samples were dried in the sun in metal weighing dishes, on a concrete slab covered with black plastic. Samples were covered with plastic overnight and during inclement weather. The pH of the sample was measured with a standard pH probe. If necessary, the sample was diluted with small amounts of neutral water until the pH could be measured.

Analysis

Two households with ecosan latrines are omitted from analysis because their respondents were younger than 18 years. In order to reduce the potential bias of a varying sample size, direct comparisons between households with ecosan latrines and their neighbors used only one comparison neighbor, even if two comparison neighbors were surveyed.

Results

Background demographics

Communities that are farther than a 30 minute walk from the administrative centers of Lichinga and Mandimba were classified as rural (n=32); others are classified as peri-urban (n=42). Thirty study households were in Lichinga, and 44 in Mandimba. The mean household size was 5.5 people in houses with ecosan latrines and 5.1 in houses without ecosan latrines. About 61% of households were Muslim, and 39% were Christian. The materials used to construct houses indicate poor economic status: 79% of ecosan households had roofs made of straw, 81% had walls made by free hand, and 81% had dirt floors. Regarding property, 55% had bikes, 56% had radios, 4% had televisions, and 15% had access to electricity. Households with ecosan latrines did not differ significantly from their neighbors by socio-economic indicators.

Seventy-six percent of households with ecosan latrines grow food in machambas (agricultural fields that are away from the home) or in home gardens. Research on agricultural practice, conducted in Mandimba only, found that all of the ecosan households that grew food used fertilizer, thought that their land was not fertile, or thought that fertilizer would help their land.

In terms of health, 18% of respondents from households with ecosan latrines thought they had worms, 18% thought that their youngest child had worms, and 24% reported that their youngest child had had diarrhea in the past week.

Knowledge, preference and acceptability

When asked how they heard of ecosan, 63% of people with ecosan latrines identified ESTAMOS as the source of their introduction to ecological sanitation. Ten percent reported having heard of ecological sanitation from a community leader (such as a chief, secretary, or sanitation activist), and 10% reported having heard of ecosan on the radio. When asked directly regarding whether they had heard about ecosan on the radio, 36% of households with ecosan latrines and 35% of their neighbors responded affirmatively.

Among owners of fossa alterna latrines, 23% chose this type of latrine for its structural aspects (design and construction), and 14% chose ecosan for aspects relating to its use or outcome (maintenance, health, or fertilizer, for example). A substantial proportion of all ecosan owners, 41%, reported not having chosen this type of latrine for themselves (table1).

Why ecosan owners chose ecosan latrines (n=70)	%
design	17
construction	5.7
maintenance	7.1
health	5.7
fertilizer	1.4
generally attractive/other	19
did not choose ecosan latrine	41
don't know	2.9

Table 1: Factors in latrine choice

The majority of ecosan owners reported that their hands felt dirty after defecating (88%), that they were accustomed to washing their hands when they didn't feel dirty (95%), that feces were dangerous (85%), and that latrines improve health (82%). For these attitudes, there were no significant differences between ecosan owners and their neighbors. Ecosan owners were significantly more likely to think that using composted feces and urine from a latrine on agriculture would improve health ($p = 0.0098$).

Ecosan users, but not their neighbors, most commonly identify fossa alterna latrines as the healthiest type of latrine and as the type of latrine they hoped to have in two years (fig.2). Both households with ecosan latrines and their neighbors viewed traditional pit latrines as the hardest to maintain. Improved pit latrines are defined by their concrete slabs, whereas traditional pit latrines have platforms made of poles.

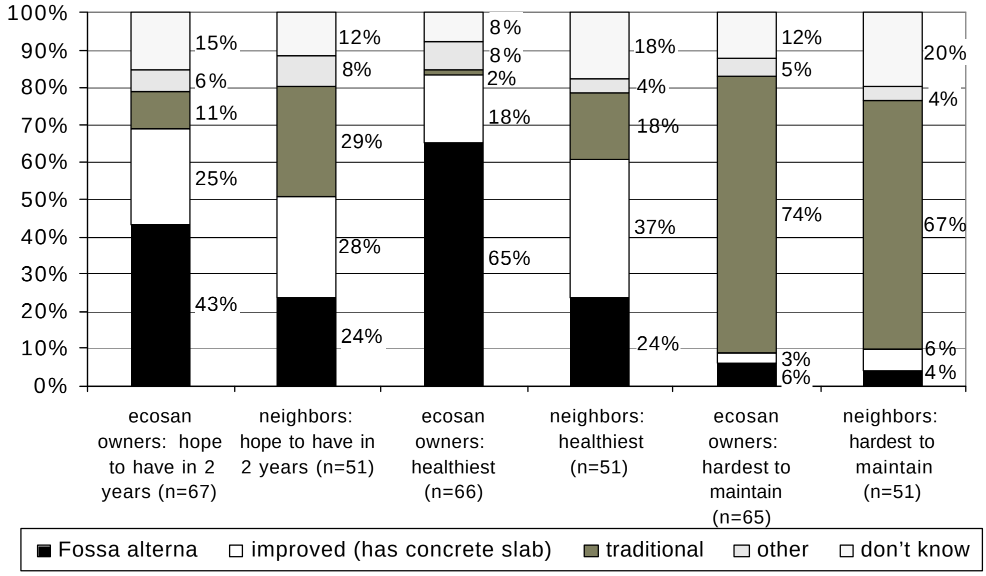

Figure 2: Perceptions of latrine types

All respondents reported receiving assistance in ecosan latrine construction, but only 18 percent of households with ecosan latrines reported that they would have built the same latrine without assistance. Ninety-one percent reported having received help with materials, 83% with construction advice, and 61% with construction labor, and none reported having received monetary assistance. In contrast, although the sample size was smaller, no owners of other types of latrines reported having received any construction assistance. Few people knew the cost of constructing their latrine (table 2)[1].

	ecosan latrines	non-ecosan latrines
received assistance in building latrine	95% (69/73)	0% (0/23)
would have built the same latrine without assistance	18% (12/66)	not applicable
know cost of constructing latrine	0% (0/72)	15% (4/26)

Table 2: Assistance in constructing latrines

Ecosan users nearly universally reported satisfaction with their ecosan latrines, and many reported that they would recommend this type of latrine to someone else (tab.3)[2]. Comparing ecosan users in Lichinga with their neighbors who had functional latrines, ecosan users were significantly more likely to report latrine satisfaction ($p<.0001$) and willingness to recommend their type of latrine ($p<.0001$). When given the response options of improved health, worsened health, and health that has not changed, 86% of ecosan latrine users reported that their family

[1] The numbers in brackets indicate the number of positive responses divided by the total number of households interviewed."

[2] "The numbers in brackets indicate the number of positive responses divided by the total number of households interviewed."

had experienced improved health since the construction of their latrine. Upon probing, people elaborated with comments like, “we do not have diarrhea problems” and “we are not frequently sick.” Users of non-ecosan latrines also reported similar improved family health since latrine construction.

When asked to identify latrine aspects they liked, 56% of ecosan users mentioned construction in general or some specific construction aspect, such as the walls, the concrete latrine slab, or the roof. Thirty-one percent of users also specifically noted liking the latrine’s two pits. When specifically asked to identify what they disliked, 43% declined and responded simply that they liked the latrine. Despite the overall affinity towards ecosan latrine construction and design, 11% of ecosan owners disliked the depth of the pits, and 14% identified the walls as problematic. They described the walls as weak, and some explained that they would prefer walls of brick.

	ecosan latrines	non-ecosan latrine
satisfied with latrine	98% (65/66)	80% (33/41)
would recommend this type of latrine to someone else	88% (53/60)	51% (18/35)
problem with smell*	17% (10/59)	33% (5/15)
problem with flies*	16% (9/58)	71% (39/55)
health improved since latrine construction*	86% (51/59)	87% (13/15)
more flies before construction of latrine*	13% (7/56)	40% (6/15)

*among households whose latrines are in use

Table 3: Acceptability of ecosan latrines

Use and maintenance practices

Ecosan users most frequently reported reducing latrine-related smell and flies by adding ash and dirt and by covering the latrine. Users of other types of latrines also reported adding hot or boiling water and hot ash. Although users of other types of latrines reported adding ash to reduce smell, only ecosan users reported adding a mixture of ash and dirt.[3]

The majority of ecosan users follow the instructions given by WaterAid to regularly add dirt, ash, or a mixture of ash and dirt: 83% reported doing so (tab.4)[4]. Upon inspection, 85% of all in-use latrines had ash, dirt, or a mixture available inside the latrine. 82% of all ecosan owners thought they should add dirt, ash, or a mixture. Only 3.4% of ecosan users add grass, straw, and/or kitchen scraps to their latrines, and 2.7% of all ecosan owners thought that these substances should be added to a fossa alterna latrine. No ecosan users reported adding trash to their latrine, and only 1.6% of all ecosan owners thought that trash should be added. 91% of ecosan users had handwashing sites with evidence of use.

	ecosan latrines
add dirt, ash, or mixture*	83% (49/59)
think dirt, ash, or mixture should be added	82% (61/74)
add trash*	0% (0/39)
think trash should be added	1.6% (1/64)
add grass, straw, or kitchen scraps*	3.4% (2/59)
think grass, straw, or kitchen scraps should be added	2.7% (2/74)
has hand washing site with evidence of use	91% (50/55)

*among households whose latrines are in use

Table 4: Maintenance attitudes and actions

Physical and chemical characteristics

Samples taken from the in-use pits of fossa alterna latrines had temperatures similar to the ambient temperature, with a mean

[3] On average, 3.2 adults and 1.8 children use each ecosan latrine, and all household members use the ecosan latrine in 89% of ecosan households. Among ecosan households, 26% have more than one latrine. Before constructing ecosan latrines, 6% reported defecating in the open; others reported using their neighbors’ latrines.

[4] “The numbers in brackets indicate the number of positive responses divided by the total number of households interviewed.”

temperature of 22.8°C (standard deviation 3.28°C). Mean moisture content was 47.6% (standard deviation 21.3%) and mean pH was 8.28 (standard deviation .88) (table 5)[5].

	temperature (in °C)	moisture content (%)	pH	depth (in cm)
n	47	47	48	52
mean	22.8	48	8.28	113
std deviation	3.28	21	0.88	37
minimum	16.1	13	5.68	20
maximum	30.5	88	10.22	180
	temp≤18°C: 4.3% (2/47)	moist≤25%: 13% (6/47)	pH≤8: 23% (11/48)	depth≤60: 9.6% (5/52)
	18°C <temp<24°C: 62% (29/47)	25%<moist<65%: 62% (29/47)	8<pH<10: 75% (36/48)	60<depth<120: 42% (22/52)
	temp≥24°C: 34% (16/47)	moist≥65%: 26% (12/47)	pH≥10: 2.1% (1/48)	depth≥120: 48% (25/52)

Table 5: Physical and chemical characteristics of contents of in-use latrine pits

Discussion

Knowledge, preference and acceptability

In these communities, there were no clear associations between the adoption of ecosan latrines and economic factors or attitudes towards sanitation. There is insufficient information in this study to determine if the association between ecosan latrine ownership and the belief that putting composted feces and urine on agriculture would improve health preceded and helped predict ecosan adoption, or was a product of ecosan adoption. Compelling reasons for adoption varied from household to household, pointing to the need for further ecological sanitation promotional efforts to be correspondingly diverse.

To questions about what types of latrines are the healthiest, easiest to maintain, and would be most desired in the future, fewer than 4% responded with the answer of flush toilets. Although the question asked refers specifically to "latrines" (not to "latrines or toilets") it is notable that flush toilets are not widely perceived as the best sanitation options.

A large proportion of households with ecosan latrines reported not having chosen their type of latrine. Noting that those closest to the problem of inadequate sanitation are best able to diagnose its solution, and that long-term project sustainability is associated with a household's actively having chosen that project, WaterAid is committed to having communities, and even individual households, make their own informed decision about what type of sanitation technology is best for them. This apparent lack of user choice is not in line with the WaterAid's policy that users should make their own decisions regarding water and sanitation. In the past, WaterAid has recognized that in Mandimba, for example, fossa alterna latrines are the only latrines being built, and has flagged the need to ensure that "communities are getting the chance to really choose, and not simply being given a list of choices but being guided into a pre-determined choice made by government, activista or NGO staff" (Breslin 2001). WaterAid is leading participatory workshops in which the benefits and drawbacks of various types of sanitation-not just ecological sanitation-are discussed. In December 2002, the District Directorate of Public Works had over 700 applications for latrines, of which 59% were for fossa alterna latrines; the other applications were for improved latrines or for minor improvements to existing latrines, solicited by people who intend to convert to fossa alterna latrines when old

[5] "The numbers in brackets indicate the number of positive responses divided by the total number of households interviewed."

latrines are full.

Although some households reported not having chosen fossa alterna latrines, the choice was also not made by WaterAid, but by local community leaders. In some communities, for example, leaders targeted the elderly to be the first beneficiaries of ecosan latrines. In this study sample, a user who had not actively chosen the latrine was no more or less likely to recommend the latrine or to care for the latrine by adding ash and dirt. Those who did not choose this latrine were, however, less likely than ecosan owners who chose their own latrine to report satisfaction with their latrine ($p=0.04$).

While household ownership may be important for sustainability, committed NGO involvement seems to be crucial in the introduction and implementation of ecological sanitation: the majority of ecosan owners cited ESTAMOS as their source of introduction to ecosan, and nearly all reported that they would not have built their latrine without assistance. WaterAid's mass education through the radio seems to have been heard widely throughout the study communities, both by ecosan owners and their neighbors.

Use and maintenance practices

Ecosan users are instructed to add a mixture of dirt and ash to their latrines, and to wash their hands after using the latrine. The evidence of addition of dirt and ash to the pit and use of handwashing sites therefore serve as proxies for compliance with NGO advice. Compliance with the instruction to add ash and dirt may be prompted by the tangible outcome: users perceive adding ash and dirt as a way to reduce smell and flies, and even users of traditional latrines reported this action.

Physical and chemical characteristics of latrine biosolids

For latrine biosolids to be useful in agriculture, they must be safe to handle and not contaminate food crops with human pathogens. Microbiological analyses of biosolids were not performed in this study, but the measured physical and chemical characteristics of samples taken from in-use latrine pits can help predict the likelihood of pathogen inactivation. Previous studies have described the range of conditions associated with microbial die-off, but their application to this study is somewhat limited because they focus on storage conditions, not on in-use conditions.

In general, high temperatures (55-65^{o}C) are associated with rapid microbial die-off, and are generally indicative of thermophilc aerobic composting. The maximum temperature observed in these samples was 30.5^{o}C, indicating that aerobic composting is not occuring. Most fundamentally, aerobic composting requires oxygen. Regular turning of the pile contents allows each part of the pile to have access to oxygen. Manipulation of the contents of a fossa alterna ecosan latrine, however, is not practical. Although the free air space of a pile (and its oxygen content) are often inversely related to moisture content, moisture content alone does not determine free air space levels. Strong fibrous materials, such as straw, allow free air space to be maintained in spite of high moisture content, while granular substances like ash and soil cause the material to become compact with increased moisture (Gotaas 1956). Although large-scale aerobic composting is unlikely in the fossa alterna latrine, appropriate additives could facilitate pockets of aerobic composting.

If the moisture content is low enough, cells lack the water necessary for metabolism (Redlinger 2001) and die through desiccation. Desiccation may be occurring in Niassa in six ecosan latrines that had moisture content less than 25%. However, because the moisture level in the pits is sensitive to environmental humidity and these samples were taken during the driest season of the year, the average moisture content in the latrine pits is probably higher than these observed values. When pits are in use, they also regularly gain extra moisture through the addition of urine. We predict that these latrines are able to attain lower moisture levels when they are full, left dormant, and are not subject to further urination.

Other studies have shown a strong association between very high pH and pathogen die off (Moe and Izurieta 2003). At pH levels greater than 10, faecal coliforms die much more rapidly than at lower pH levels. Three-quarters of the fossa alterna samples had pH values between 8 and 10, but only one of the 48 latrines sampled in this study reached a pH of more than 10.

The most likely mechanism for pathogen destruction in fossa alterna latrines is anaerobic composting. Anaerobic composting occurs when a solid is tightly packed, with 40-75% moisture, or is surrounded by liquid, with 80-99% moisture (Gotaas 17). Successful pathogen die-off through anaerobic composting depends largely on time. Because fossa alternae have two pits, waste products in the first pit are able to compost as that pit fills, and are also able to compost for the entire duration of the filling of the second pit. This extended period of time (perhaps as long as two years) is critical for substantial pathogen die-off in anaerobic composting conditions, but may not be sufficient.

Conclusion

Ecological sanitation in Niassa is off to a promising start: users are choosing ecological sanitation, are using ecological sanitation, and are satisfied with ecological sanitation. WaterAid's work demonstrates that household sanitation can succeed in a very poor population. Ecological sanitation is especially relevant agriculturally-driven economies like this one.

Although the self-reported worm infections in the study population have not been confirmed by lab diagnoses, they suggest the possibility of widespread helminth infection and alert researchers to the importance of thorough pathogen destruction in composting excreta. Further studies should be done to compare the physical and chemical characteristics of the materials from in-use and stored latrine pits, and microbiological analyses would provide information on which conditions best promote pathogen die-off and result in a safe endproduct. Because the microbiological safety of the end product of these pits remains unknown, the storage should be as prolonged as possible, and precautions should be taken when handling the biosolids and using it in fields. Potential precautions include letting the biosolids sit on the top of the field, exposed to the sun, before planting occurs; applying the biosolids to land only before planting occurs (instead of as an added fertilizer after growth has begun); and using it with crops whose edible portions do not touch the ground. Ecological sanitation is being promoted well and implemented well, with the support of WaterAid and its partner organizations. Public health education about the safe use of excavated biosolids will enable the end product also to be used well, strengthening the health of both agricultural crops and people.

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Urban household perception of urine-excreta and solid waste source separation in urban areas of Ghana*

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Urine excreta separation, solid waste source separation, resource recovery, urban household perception, urban agriculture, Ghana

Abstract

Attaching resource recovery and reuse options to the sanitation system could create win-win situations for urban and peri-urban farmers and city authorities. In a study carried out in different Ghanaian cities (Accra, Kumasi, Tamale), the level of interest of urban households to separate organic from inorganic solid waste as well as their attitude towards toilet facilities, which separate urine from excreta, was explored. 2500 households were interviewed with focus on source separation, and about 650 households to assess perception, knowledge and interest in reuse of human excreta and urine.

Approximately 70-80% of the sampled households showed no objection to source separation. Despite the generally positive attitude, actual waste separation trials in Kumasi showed that its efficiency is declining after some weeks independent of living standard. This was attributed to lack of follow-up after an initial training.

With respect to toilets separating human excreta and urine, 70% of the household had a positive perception. Most households suggested that urine could be used as medicine while dried excreta are good manure. Although only a few households were interested to sell their new resources, about 60-80% believed that there should be a market. Current pilot trials with eco-toilets in Kumasi do unfortunately not consider this potential.

In general, household interest and perception is **not** the limiting factor for resource recovery but any technology has to be tested in close collaboration with the households concerned.

Introduction

Urban and peri-urban areas in developing countries are among the most polluted and disease-ridden habitats of the world. Much of this pollution is caused by inadequate and inappropriate urban sanitation infrastructure and services. As cities expand and urban populations increase, the situation is growing worse and the need for safe, sustainable and affordable sanitation systems is becoming even more critical. The challenge that this growth presents to decision-makers and planners in meeting the needs for food, shelter and waste management is complex. The waste challenge can best be described by the fact, that in all Ghanaian cities, 50-75% of the municipal budget is used to tackle the ever-increasing waste generation. And the waste

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problem is increasing the deficit of the communities. While in Kumasi the total costs of waste collection and transport (without salaries) sum up to 18 billion cedis[1] per year, the revenue from related fees is not exceeding 7 billion cedis (KMA, unpubl. Data, 2002).

In view of the importance of urban and peri-urban agriculture and the need for affordable fertilizer, it appears appropriate to explore options of nutrient recycling from municipal waste (Drechsel and Kunze, 2001). However, although resource recovery and reuse are desirable options, they are still the big exception in developing countries (Furedy, 2002; Drechsel et al., 2002).

According to the Environmental Sanitation Policy, ''sanitation in Ghana leaves much to be desired'' (Government of Ghana, 1999). Indeed, less than 40% of urban residents are served by solid waste collection services and less than 30% by an acceptable household toilet facility. Insufficient financial, technical, and institutional capacity of the municipal authorities to collect, transport, treat and/or dispose solid and liquid wastes is one of the major urban problems. There are for instance three human waste treatment facilities in Accra, with a new one running below capacity due to the short innercity sewerage system, and two stabilization pond systems which are broken down (but still used) since years. As a result, at least 30% of the municipal excreta are dumped into the ocean after collection (GTZ - AMA, unpubl.)

Approach and rationale

In view of the general high potential for municipal waste composting in the study area (Leitzinger, 2001; Salifu, 2001; Fobil et al., 2000), the *International Board for Soil Research and Management* (IBSRAM)[2] targeted in a corresponding study three cities in Ghana to develop decision support on waste composting. The study received support from IDRC/IWMI and the French Government. The overall project aims at developing recycling strategies to close the rural-urban nutrient cycle.

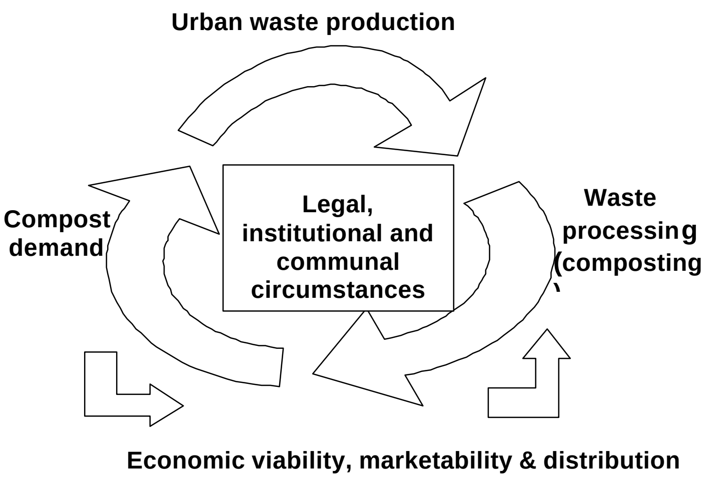

Figure 1: The recycling loop (Drechsel et al., 2001).

In this project a general model has been proposed (Drechsel et al., 2001) which follows the "Recycling Loop" (Fig.1) with the following five study segments: 1) waste or raw material supply, 2) recycling/composting process, 3)compost demand, 4) legal, institutional and communal settings, and 5) economics and marketing.

The model thus tries to qualify and quantity: organic waste supply by households, agro-industries, markets, etc, (1), waste collection, transport and processing on composting stations (2), the demand and willingness to pay by farmers, estate developers etc. for the product (3), and all this under consideration of the legal, institutional and communal settings (4) and the viability of any recommendation (5). It becomes obvious that such a project requires a multidisciplinary approach going far beyond a simple technical "composting" one. Some results from the different segments have been presented elsewhere (e.g. Danso et al., 2002; Vazquez et al., 2002).

[1] 8500 cedis = 1 USD (2002/3)

[2] In April 2001, IBSRAM became incorporated into the International Water Management Institute (IWMI).

The issue we tried to address in this paper is the public perception of Resource Recovery and Reuse, especially the level of interest of urban households to separate organic from inorganic solid waste to support municipal compost stations and their attitude towards toilet facilities which separate urine from excreta.

Study area and methodology

The study was conducted in and around three cities in ecological zones of Ghana. These are Accra (Coastal savannah zone), Kumasi (Humid Forest Zone), and Tamale (Guinea Savannah zone). Accra is the capital with about 1.7 million inhabitants. Population growth rate of Accra is 3.4% per year. Kumasi is the capital town of Ashanti Region and the second largest city in Ghana with a population of 1,170,000 and annual growth rate of about 6% (Ghana Statistical Services, 2002). This figure refers to Kumasi's night population since its famous and gigantic market attracts an additional 0.5 to 1.0 million people per day. Tamale is the administrative/regional capital of the Northern Region and has a population of about 200,000 with a growth rate of 2.5 % (Ghana Statistical Services, 2002).

Each city area is divided into different sub-metros which were used as base for household interviews and data recording via schoolchildren (age 13-16). About 60 schools were randomly selected from the different sub-metros in the three cities under consideration of local population density. The school pupils received questionnaires to be filled at home with their parents. Care was taken to keep the study representative in terms of different social and religious groups. In southern Ghana, the proportion of Muslims is about 20%, in Tamale around 70%. In all, the pupils represented 2500 households in the three cities. Additional surveys through interviewers were carried out in 658 households within different communities in Kumasi to assess household perception, knowledge and interest in separation and reuse of human excreta and urine, for example, as soil conditioner for urban and peri-urban agriculture (UPA). Communities were differentiated according to their toilet systems.

Results and discussions

Source separation and co-compost

It was explained to the households that organic waste can be turned into compost for urban and peri-urban agriculture (UPA), especially if source separation could be realized. About 70-80% of the sampled households showed no objection to separate their refuse into an organic and an inorganic fraction to help to make better compost. Only few households were not willing to separate their waste and about 10% would only separate it if it would be requested with extra fees for those who would not participate (Table 1). There was no significant difference between Christians and Moslems or households with different educational or occupational background.

Source separation	Kumasi		Accra		Tamale	
	Frequency	%	Frequency	%	Frequency	%
Yes	498	84	414	77	229	81
No	70	12	28	5	18	6
Only if law	24	4	94	18	37	13

Source: IWMI Ghana data, 2001/02

Table 1: Willingness in source separation in the three cities

The survey also asked whether or not the households would buy food that has been grown using co-compost, i.e. compost made from solid waste and human excreta. Table 2 shows that approximately 65-82% of the households would buy crops that have been grown using co-compost, while almost 15% would not buy such products and mentioned culture and possible diseases as their main constraints. About 10% of the sampled households could not express their concern on the issue. Sixty-five percent of household stated that if it is well treated the compost could be applied to any crop including vegetables.

Answer	Kumasi (%)	Accra (%)	Tamale (%)
Yes, I would buy	79	65	82
No, I wouldn't buy	13	17	15
Indifferent	8	18	3
Total	100	100	100

Source: IWMI Ghana data, 2001/02

Table 2: Willingness to buy crops that have been grown using co-compost

The survey further asked who could be the most appropriate body to work with in waste management. About 65% of the households considered their assemblymen as most appropriate to coordinate waste related activities, followed by churches and private companies. This means that people at the grassroots level believe more in the assemblyman's effectiveness and capacity to organise community initiatives than in their city authorities or private companies, currently in charge of waste management. These results provide a first guide of the type of solutions that would be 'socially acceptable'. Interventions via the 'Assemblyman' imply participation at the grassroots level, good leadership, and a strong sense of self-reliance. This picture confirms the assertion that waste interventions need a strong linkage with the local municipal representative to be accepted, understood and successful (Vazquez et al., 2002).

The Institute of Mining and Mineral Engineering of the Kumasi University carried out a pilot study on household source separation in selected suburbs of Kumasi. A total of 90 households were selected with 30 per category from low, middle and high-income communities. Major criterion used in grouping the household was monthly accommodation rent, which ranges from up to ¢70,000 (low), 71-150,000 (middle) and above 150,000 (high income) at year 2000 prices[3]. Households waste characterisation analysis revealed that across all income areas waste consisted to 78-85% of food waste and 4 to 13% sand and wood ash amongst others. All households were provided with five containers with different labels describing what type of waste should be put in for a period of at least 8 weeks. Households were educated and sensitised before the commencement of the project on the need for source separation and the associated benefits.

All the necessary logistics for source separation were provided and the wastes in the containers were collected and disposed on daily basis. The containers were big enough for the households to fill them but none of them were fully filled at the time of collection.

Low income (n = 30)		Middle income (= 30)		High income (=30)	
Weeks	Rate (%)	Weeks	Rate (%)	Weeks	Rate (%)
2-3	40-50	2-5	30-50	3	20-40
7-8	Less 10	6-8	20	6-8	25

Source: Asiama, 2002.

Table 3: Household sorting efficiency over 8 weeks.

The results indicate that, sorting rate was relatively high (40-50%) among all households in week 2-3 and even continuing up to 5 weeks in the middle-income group (Table 3). However, there was a general decline in commitment to 10-20% from about week 6 on. This implies that any sensitisation campaign has to continue also after introduction of the system. Households mentioned as difficulty the lack of motivation in comparison with their normal daily tasks and challenges, such as gaining their daily income. It was also realised that in most cases house waste collection and disposal was not done by the head or leaders of the household but the children and/or house helpers. Moreover, five containers might have been too much for this pilot

3 4000-6700 cedis = 1 USD (Jan-Dec. 2000)

trial.

Sanitation facilities and re-use of urine and excreta

In urban low-income areas, the use of the Kumasi Ventilated Improved Pit (KVIP) latrine, other public pit latrines and free range (i.e. open defecation) is most common, while in the middle and high-income areas water closets are dominant. About 60% of the sludge produced in the 658 households interviewed is disposed off by the Kumasi Metropolitan Assembly (KMA) and subcontracted private companies, whilst 30% of households do not know how the sludge is disposed and 10% mention private conservancy workers. Three months is the modal period for the dissludging in low income areas and one year or more in the middle and high income areas. Fifty-five to sixty percent of households in the low and middle income areas mentioned problems with the sanitation facilities they are using. Most notable in low income areas is the method of dissludging, long queuing, and bad scent while leakage of septic tank was often reported in middle income areas (see also Frantzen and Post, 2001; Van der Geest and Obirih-Opareh, 2001). On the other hand, only 35% of the households in the high income areas experienced problems which were mainly due to water shortage affecting flashing of the toilet.

The survey further showed that 90% of household interviewed knew that excreta (i.e. animal manure) can be a valuable source of nutrients in agriculture. Only 10% of the households were concerned about health implications. Concerning the use of human excreta, still in average 72% had a positive perception (Table 4) again with regard to its use as manure. In fact, 80% also believed that there should be a market for dried excreta. About 60% also believed that there should be a market for urine especially as medicine.

Household perception	Low income		Middle income		High income	
	Frequency	%	Frequency	%	Frequency	%
Positive	185	72.5	167	69	119	74
Negative	70	27.5	75	31	42	26
Total	255	100	242	100	161	100

Source: IWMI Ghana data, 2002

Table 4: Perception on the use of composted dried human excreta in farming

The positive perception of urine separation might have been stimulated by a recent media debate about the pros and cons of a urine therapy. In general, nearly all household (94%) were interested in a toilet system which allows the separation of human excreta and urine, giving that it is provided for free. However, only 17% of the households were interested in selling dried excreta or urine themselves.

The strong public association of excreta with manure for soil fertility improvement supports those initiatives on ecological sanitation which emphasise the nutrient value of our faeces and urine (Esrey and Andersson, 2001). On the other hand, it contradicts a now two-year-old KMA initiative where about 70 “enviro-loo” toilets (with in total 210 seats) from South Africa have been installed in certain basic schools and as public toilets in some low-income communities. Here, the toilets are disslugged without the equipment which allows excreta-urine separation. Moreover, the users are not aware of the design of the system, thus ignore the flap lever which is used to push faeces in the right location for decomposition. The result is a mix of urine and excreta instead of their separation, unnecessary heat generation and many complains of bad smell and genital diseases affecting mostly women.

Conclusion

The majority of the Ghanaian households asked had no objection to either source separation or the separation of urine and excreta and were willing to test such systems if the facilities needed are given out for free. This shows that also in low-income countries, resource recovery and reuse might work if appropriate technologies are tested and further developed in close and continuous collaboration with the concerned households. Source separation trials might have to address education also at the school level as children are mostly in charge of household waste collection, transport and disposal.

Appropriate ecological toilet systems might best fit into middle- and high-income households with backyard farming. This might facilitate the use of excreta while market opportunities for the use of urine (in the medical sector) will have to be explored before systems are put in place.

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Assessment of community knowledge attitudes, practice, behaviour and acceptance of ecological sanitation in peri-urban areas of Harare.

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Session B

Keywords

Urine diversion toilets, participatory ecological sanitation education, acceptance of ecological sanitation, over-cultivation, mono-cropping

Abstract

Ecological sanitation was introduced in the peri-urban areas around Harare the for different reasons depending on the geophysical and socio-economic persuasion of the environment where it was being implemented. In the densely populated informal settlement ecological sanitation was introduced for purely for technological convenience. The informal settlements did not have any form of sanitation whatsoever, the settlement did not have reticulated water system to facilitate water borne sewage.

In the peri-urban informal settlements near Harare ecological sanitation was accepted purely on technological advantage and was mostly for family convenience, privacy and easy maintenance. In the rural areas ecological sanitation was readily welcome because it made nutrients urine and faeces accessible for use in agriculture. They were however concerns with respect to the user friendliness of the technology to women especially as it relates to sanitary pads change and disposal. Gender roles and burdens with respect to operation and maintenance of the ecological sanitation toilets were also other interesting findings of this study.

Using participatory approaches such participatory evaluation process (PEP), participatory rural appraisal PRA and Focus Group Discussions (FGD) any assessment was carried out to determine ecological sanitation knowledge, attitudes, practices and behaviour (KAPB) of communities in the peri-urban informal settlements and peri-urban rural areas in and around Zimbabwe. In order to quantify group responses with respect to specific issues such as reasons for preferring ecological sanitation toilets, preparedness to use human excreta for crop production and whether they would eat crops and fruits grown using human excreta secret ballot charts was employed. Cross tabulation and comparison was achieved by using household structured questionnaire for some of the issues discussed during participatory approaches. Data validation was done using the triangulation methods through comparison of the findings of the three approaches mentioned above. The findings obtained using the above approaches quiet comparable and some of them are outlined below.

76.5% of the respondents said they like the ecological sanitation toilets because they are convenient and private to the household. It is easy to supervise the use of the toilet by household members and ensure it is clean at all times. 6.7% of the people felt that there is little work involved in the maintenance of the ecological sanitation toilets. 6.7% of the people in Dzivarasekwa Extension said the toilet provided manure, and was a household asset.

What they like (by %)	Hatcliffe Extension	Dzivarasekwa Extension	Total for two settlements
Privacy / Convenience	80.3	60	76.5
Little labour	13.3	1.5	6.7
Ease to construct / maintain	7.6	0	6.2
Health	4.5	13.3	6.2
Household asset	0	6.7	1.2
Source of manure	0	6.7	1.2

Table 2: What communities like about ecological sanitation toilets

In Hatcliffe extension 83.3% of the households said the toilet was all right and 60% in Dzivarasekwa extension said the toilet was all right. However the community did not like the following on the ecological sanitation toilets:

In Hatcliffe extension

- 7.6% said the pit was too shallow
- 3% said rain comes in
- 3% said the toilet smells
- 1.5% said the squat hole was too big (because it was not fitted with a pedestal seat)

In Dzivarasekwa extension

- 20% did not like carrying the faecal bucket
- 13.3% did not like blockages of the urinary pipe
- 6.7% said the toilets smell

20% of people in Dzivarasekwa extension said they did not like carrying the faecal bucket for fear of ridicule by neighbours. They said the perforations on the bucket had grown big so faecal matter drops through the perforations onto their heads and shoulders. Because they have no protective clothing, they feel it's a dirty job. Communities suggested that the faecal bucket should have a lid so that contents do not spill during transportation. Emptying faecal buckets is done at night to avoid other people noticing.

In Hatcliffe extension 84.6% of the households said they allow lodgers to use the toilet while only 12.5% of the households in Dzivarasekwa extension allow lodgers to use the toilet. The situation is different for neighbours. In Hatcliffe extension 50% of the households said they allow neighbours to use the toilet while in Dzivarasekwa extension only 13.3% said they allow neighbours to use the toilet. The table below summarises attitudes towards the use of toilets by neighbours:

Attitude	Hatcliffe Extension	Dzivarasekwa Extension	Total sample
They mess the toilet	21.2	60.0	28.4
Good neighbourliness	0	18.5	18.5
Only when passing through	16.7	0	13.6
Should get one from the project	7.6	20	9.9
They will contaminate the environment	12.1	0	9.9
Do not want to handle other people's faeces	3	13.3	4.9

Table 3: Attitudes towards sharing ecological sanitation toilets

The study sought to find what the community members know about ecological sanitation toilets. The following were the findings:

- 90% of people with ecological sanitation toilets have received instructions on their care and maintenance
- 54.3% knew how to use soil, ash or sawdust
- 25.9% said they knew about human manure
- 9.1% knew about alternating the pit
- 3.7% said the pit should always be dry
- 1.2% said deep pit toilets contaminate ground water

The communities in Dzivarasekwa extension felt that every household member could easily use the toilet. 92.8% of the people felt that men, women and boys could use the toilet with ease while 85.6% felt girls could use the toilet with ease and 71.4 felt the disabled could easily use the toilet. They however felt that the chamber needed modification to avoid the mixing of urine and faeces when girls are using the toilet.

The management of the toilet weighs heavily on women as the following table shows:

Management activity	Mother	Father	Boy	Girl	Other (employee or both)
Refills ash/ soil/ saw dust container	92.9	7.1	0	7.1	0
Cleans toilet	84	4.9	1.2	0	2.5
Puts faecal bucket in place	78.6	7.1	7.1	0	7.1
Cleans faecal bucket	78.6	7.1	7.1	0	0
Empties faecal bucket	71.5	14.3	7.1	0	7.1
Responsible for the plot / garden	64.2	18.5	1.2	3.7	3.7
Attends meetings	59.3	27.2	1.2	0	0
Contributes labour during construction	51.5	21	27	27	0
Pays for construction	42	50	3.8	0	3.8

Table 4: Gender roles in toilet management

The community said mothers are generally responsible for the family hygiene hence they do most of the maintenance work on the toilet. The health and hygiene programme should target women.

More than men because they handle excreta more frequently than any other member of the family do. Interestingly is the fact that mothers are responsible for cleaning and when they are away the duty falls on girl children and the fathers with boy child having the least responsibility.

While there is knowledge on the different uses of excreta, there was limited evidence of the actual use in Dzivarasekwa extension. Some members indicated that they prefer to buy vegetables from other people but would not eat their own vegetables in which they have re - used excreta. In Hatcliffe extension, the toilets are still new and have not yet filled up so communities have not really experienced re- using their excreta.

In Dzivarasekwa extension, the community said they would use excreta for the following:

- Planting flowers, maize and fruit trees
- Urine is used as fertiliser

Most people in Dzivarasekwa extension said they cannot use for growing vegetables as they are uncomfortable eating vegetables knowing that they were fertilised from human manure. At the moment options for disposing have been limited to throwing the faecal matter on open ground or rubbish pits. Isolated cases were reported of faecal disposal on the road or in neighbour's yard. The community noted that they have limited space for gardening so in the long run the supply would be greater than demand.

In Hatcliffe extension there was no experience in handling (through excavating of old pits) and using through planting crops, as most pits have not yet filled up. During a voting session, women indicated that they would plant "things" or place the manure in the gardens. The feeling was that there is nothing embarrassing about handling of the faecal matter (23 women saw no problem). However two women in the group said they would not handle pit manure as it was dirty.

Some community members said they ate sweet potatoes planted where people used to dispose of their faecal matter and these did not test as good as those planted with ordinary manure. This finding is not conclusive since other factors may influence the taste. However 66.3% of the households interviewed said they put the faecal manure in their fields or gardens, 13.8% said they use it for tree planting and only 8.8 % said they throw away the manure. They throw away the manure because they either do not want to use it or they had no plot in which to apply the manure. 24 households (out of 80) were not using faecal manure for the following reasons:

- 11 said the manure was not treated.
- 6 because they had no knowledge on safe use.
- 4 said they did not want to handle faeces.
- 2 said they had no garden.
- 1 felt the manure might cause disease.

61.3% of the households said they would not use urine as a fertiliser because they said it would burn crops, 17.5% said it had a bad smell while 55% said they did not know that it could be used. 11.3% said urine is a good fertiliser and 12.5% said they would use urine because fertiliser was expensive.

The buying and selling of faecal manure is not taking place in the two settlements. Nurseries have bought manure from households. When asked if they could use manure from neighbours the response indicated that communities are uncomfortable doing that. (17 voted that they could not, 3 said they did not know while 2 said yes). However during the household interviews, 67.5% said they would sale their faecal manure. 35 households said they would sale to generate income, 24 households said they would sale if they have no need for it while 5 households said they would sale because they do not want to use it.

7.5% of the households felt it was a health hazard to buy faecal manure and 32.5% would not buy because they did not want to handle other people's faeces. However, 56.3% of the households said they would buy faecal manure from other people because:

- 23 said they would buy if the did not have enough.
- 22 households said it was good manure.
- 3 households felt it was cheaper than fertiliser.

The first reaction to ecological sanitation ideas was scepticism. In Hatcliffe extension, households indicated that their initial reaction was that there would be too many holes, too many flies and high incidence of cholera. Demonstration toilets, peer education and pressure brought about attitude change. Communities indicated that demonstration creates awareness and improved understanding. Visual aids enhanced understanding. Another motivating factor was that communal toilets were unbearable to use. During the rainy season, the toilets flooded and faecal matter started flowing out of toilets. This and the education given promoted some members to try the Fossa Alterna toilet. Women in Hatcliffe extension indicated that hygiene education is best given during weekdays. In Dzivarasekwa extension, the initial reaction was one of discomfort at the thought of carrying faecal matter in buckets for disposal.

The motivation for change of attitude was demonstration toilets at the school supported by booklets. The community felt that demonstration works best. 55.6% of the respondents said Mvuramanzi Trust did the mobilisation, 23.5% got the idea from other people while 6.2% got the idea from Ministry of Health staff. Community meetings provided information to 14.8% of the respondents.

In 59.3% of the cases the mothers attended meetings on ecological sanitation which explains why mothers were the first to know about ecological sanitation in 60.5% of the cases. The father attended meetings in 27.2% of the cases and male children attended in 1.2% of the cases. The girls did not attend meetings and have therefore limited knowledge on ecological sanitation.

What was evident in both communities is that there has been sufficient marketing of the toilets to an extension where demand has outstripped supply.

One woman had this to say" Well I thought they were giving us these toilets because we stay in Dzivarasekwa Extension and are a forgotten community"

Priority areas for hygiene awareness were:

- Hand - washing after changing baby napkin, before handling food, after using the toilet and after greeting people.
- Personal hygiene (including washing private parts when waking up).
- Cleaning the toilet.

During the focussed group discussion, women said generally people do not practice good hygiene behaviours even when these are known. The Fossa Alterna toilet does not have hand-washing facilities making it difficult to wash after using the toilet. There was also an emphasis on body- washing.

In both communities the decision to construct the toilet is usually made by women. Children who request for improved sanitary facilities also influence this decision. It is logical that women make the decisions about the toilets as they attend meetings, are inconvenienced by lack of privacy. They also manage the disposal of faeces of the young children. However the investment into the toilet is shared among men and women depending on the breadwinner.

The ecological sanitation toilets have been well received and clearly the communities prefer them to communal toilets. However there are problems in the use of the toilets. Some households in Dzivarasekwa extension were not using the toilet during the time of the study. They said they did not have ash or dry soil to use in the toilet. The study was undertaken during the rainy season. The following table summarises the findings:

Observation (%)	Dzivarasekwa Exten ion
Clean pedestal	93.3
Back slab in position	85.7
Faecal bucket in place	64.3
Faecal bucket in use	64.3
Tight back slab	50
Solids in the chamber	21.4
Blocked pipe	14.3

Table 5: Condition of toilet

To validate findings from oral discussions we administered a checklist on a sample household toilets and the following were our the results:

- In 82.5% of the toilets there was evidence of soil /ash / sawdust.
- 73.8% of the toilets had soil / ash/ or sawdust containers.
- 71.3% of the containers had soil / ash / sawdust.
- 12.5% of the toilets had a bad smell.
- 12.3% of the toilets had evidence of fly breeding.

In conclusion we have seen that community attitudes have been influenced by practical demonstrations at schools. Attitudes towards excreta use need to be reinforced with practical demonstrations on the safe use of human manure. Production of human manure should be matched with safe use of the manure. Currently the project has not adequately demonstrated the advantages of using human excreta. There is therefore no concerted effort to harvest and use the manure. The manure is harvested to clean the bucket or to empty the pit not for its value.

Excreta management the project assumed that every household had a plot/ garden in which to use the manure. 10% of the households in the sample interviews did not have gardens or plots in which to apply the manure. Households with no gardens did not have alternatives but to throw the faecal manure away in the bush. The households should be encouraged to donate or sell their manure to the school or interested persons.

The project should build upon the ecological sanitation project to improve solid waste management in the two settlements. At present there is no refuse collection system. Households dump their refuse in rubbish heaps. The dumping site promoted the breeding of rodents. The abundance of rodents led to increase in snakes and fleas feeding on the rodents. People should be encouraged to separate waste and use the degradable matter in composites. This effectively reduces the amount of waste in the environment. If waste is properly managed, the rodents will be reduced because they have no food.

Contrary to popular belief the health and hygiene education encourages toilet use, in the two settlements the main reason was convenience. The health and hygiene benefits became incidental. The project has demonstrated that social reasons can promote the use of toilets. The project should now focus at other issues and not stick to health and hygiene education to promote the safe use of toilets.

According to the community in DZ, rubbish is thrown at the edges of the settlement and this includes faecal matter. This is seen as posing a health hazard since children often play in those rubbish dumps. The rubbish encourages fly breeding. The community indicated that it is their social responsibility to clean the surrounding on and off site. The problems being faced are related to poor community organisation and lack of hygiene education.

Environmental alternative to sanitation and food sovereignity

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Keywords

Ecosystem, education, environment, evaluation, didactic, sanitation.

Abstract

The present research is part of a larger project related to Primary Health Care, based on the ecosystem approach to environmental sanitation. The project is based in a highly marginalized rural area, located on the Pacific Coast of the State of Oaxaca, Mexico. In this context, the ecological principles of sanitation are the most suitable alternative to dealt with health problems derived from environmental pollution, such as malnutrition and diarrhoeal diseases. The present paper emphasizes the high priority given to the implementation of a social sensitization-education process, supported by an education program oriented to the protection of the environment that may ensure the participation of the community in an interactive fashion.

The information presented here is still preliminary in the sense that the project is still on going. This report includes results of a 3-year long community program focused on the correct construction and adequate use and maintenance of Eco-San toilets, where three different sets of educational materials have been instrumented at the community level and evaluated in three different population groups.

The results show that the three interventions proved to be a good means to promote environmental education, and that, even though the level of knowledge acquired by the three population groups differed, the level of community sensitization was positive and significant in all three.

Introduction

The Training Center for Community Promoters (CECIPROC after its name in Spanish) is a Mexican NGO, whose main objective is to embody the high-priority importance for community programs related to health and nutrition, particularly in the context of rural development. Specifically, this work is inscribed under Rural Sustainable Development Projects, which have as top premises Nutrition and Community Health activities carried out through the development of training programs for community health workers (Promoters) and the implementation of community development projects (Ysunza, et. Al. 2002).

The work reported here is part of a broader CECIPROC project, based in the Mexican state of Oaxaca, specifically in the southern coast of the Pacific Ocean. The region has a mixture of indigenous (Mixtec, Chatino) and Afro-Mexican Mestizo origin, and has the highest infantile and maternal mortality rate in the country. This is basically due to problems related to malnutrition and infectious diseases like diarrhoea. In other words, the health problems are derived form a mixture of an inadequate food intake affecting both quality and quantity and inadequate environmental sanitation due to a lack of hygiene infrastructure in a highly polluted environment. To make the matters even worse, the state of Oaxaca has the highest household water supply deficit in the country, as only 46% of families have access to piped water. (Ysunza, 1996)

In terms of the underlying causes and direct consequences of marginalization, the conditions found in the state of Oaxaca are not different from what happens in other underdeveloped regions of the world: lack of financial resources, problems of water shortage, lack of institutional capacity to respond to these needs, among others, lead us to point out that the conventional solutions to environmental sanitation, such as "flush and discharge" or "drop and store", are not applicable in view of their high costs. The serious threats of water shortage throughout the world, including Mexico, and the severe problems of environmental pollution in sewer systems without adequate treatment have caused several problems, particularly in coastal regions such as those found in the Pacific Ocean coast of Oaxaca, where bacteriological contamination pollute tourist beach resorts, sometimes causing the presence of the "red tide" and other problems, which are increasingly present. (Esrey, et. al., 1998)

Hence, the ecological principle of sanitation, or Eco-San, in which human feces are safely recycled to fertilize the soil without using or contaminating the water, are potentially a suitable answer to the problem.

However, adoption of such practices is not spontaneous. For them to be properly used, it is necessary to carry out a reliable sensitization education process, aimed at people with low schooling and little or no previous exposure to previous use of such ecological alternatives, in such a way that the use of them may result attractive and understandable, and may lead to a high acceptance and adoption rate.

The main objective of the present research was to evaluate the educational material specifically designed for this purpose, as a pre-requisite to extend its use and be able to measure the health and nutrition impact at the community level.

Methodology

Characteristic of the study

One of the most important characteristics of the methodology used was the **interactive community participation**. This involved all the social actors who participated in the different phases of the process, and included sensitizing the participants, the design and elaboration of the teaching material, the community diagnoses, the evaluation workshops, the construction of the Eco-San, as well as the follow-up and evaluation phases related to their use and maintenance. A second characteristic, which follows from the previous one, is the **longitudinal** design, by which we intend to measure the impact of our intervention throughout time. Lastly, the design called for a **comparison** between different communities as well as between beneficiaries and non-beneficiaries, based on the length of time Eco-San was used as well as the ethnic characteristic of the recipients of the intervention.

Objectives

To elaborate and spread out didactic material for environmental education that promotes the construction, use and proper maintenance of the Eco-San.

To measure the impact on health and nutrition at the community level of the appropriate use and maintenance of the Eco-San, comparing the different communities participating in the study.

To carry out an ethno-anthropological study on the community's perception about the management and disposal of human feces.

To increase family availability of food grown in the backyard based on the recycle of human waste.

Working strategies

- Selection of communities and organization of Community Assemblies.

  Six communities from two ethnic groups were selected for the study, based on two indicators:

  1. Time of use of the Eco-San.
  2. Predominant ethnic group in the community.

  Two control communities, consisting of no intervention, were included in the design.

The characteristics of the six participating communities are shown in table 1:

Name of Community	Time of use of Eco-San		Predominant ethnic group
	< one year	three or more years	
Palma Sola		X	Mestizo
Charco Redondo		X	Afro-Mexican
Cuauhtemoc	X		Afro-Mexican
Loma Bonita	X		Mestizo
Chacalapa	No use		Mestizo
La Luz	No use		Mestizo

Table 1: Selected communities

In each community, we called for a local Assembly with the participation of local authorities and households, in order to explain the objectives of the program, its economic limitations, ant to organize an **environmental sanitation committee** who would be in charge of selecting the **beneficiary families**, as well as establishing the agreements related to the construction, use and maintenance of the Eco-San.

- Elaboration and dissemination of didactic materials

Videotape. A videotape was filmed using locations and characters that reflected the reality of the communities, in order to facilitate the identification of the participating people with the environment and images shown on it. The script focused on the general problems related to environmental sanitation and its ecological impact, from a health perspective. Other items were included, such as local food production and the importance of **community participation** for the appropriate construction, use and maintenance of the Eco-San. A major advantage of a videotape as an educational tool is that it does not require people to know how to read or write.

Comics. Comics are a well-spread means of communication among the Mexican population, particularly in people with little schooling, as the colorful pictures and popular characters result physically attractive. Comics usually tell a love story or address a topic of popular interest. The comic produced to promote the Eco-San told a story of an imaginary Mexican rural town, where a schoolgirl who suffered from frequent intestinal infections went to visit a traditional doctor and a health promoter (as usually happens in real life). As the story develops, the health promoter participates in a community assembly and shows how the Eco-San is built, how it is used, and how the ecological sanitarian was properly maintained. The story ends with the girl, healthy once more after building and using the Eco-San, returning to school, and the family using the re-cycled feces to fertilize the backyard garden to produce food. While the use of the comic required people to know how to read, in many cases the images were self-explanatory and the comic was well accepted even by illiterate people.

Poster. Posters made out of plastic material were printed, containing pictures and text that explained the proper use and maintenance of the Eco-San; do's and do-not's were clearly explained. The posters were permanently placed inside each Eco-San built in the communities. While users were expected to read the instructions, the images were self-explanatory.

- Design of the evaluation workshops.

The **beneficiary families** included 494 people, who participated in evaluation workshops carried out with the purpose of making them aware of the community health problems related with basic sanitation, as well as the benefits that Eco-San offered. Seventeen workshops were carried out in the six participating communities, involving three population groups: school-age children, adolescents and adult women.

The didactic materials previously described were evaluated according to the following scheme:

Community	Women > 18 years old		Adolescents (15-18 years old)		School-age children (5-14 years old)	
	Intervention	N° of participants	Intervention	N° of participants	Intervention	N° of participants
Palma Sola	Poster	13	Comic	21	Video	12
Charco Redondo	Comic	35	Poster	29	All	38
Cuauhtemoc	Video	25	All	20	Poster	45
Loma Bonita	All	26	Video	23	Comic	32
Chacalapa	All	32	Video	18	Comic	38
La Luz	Video	20	NO	NO	Video	41
Subtotal:		150		111		206
Subtotal:	Beneficiaries participants					318
	Non beneficiaries participants					149

Table 2: Population groups and didactic materials evaluated.

Two qualitative evaluations were carried out at the group level, one before and the second one after the workshop. The evaluation was based on two types of questions health: related to environmental sanitation; and the construction, use and maintenance of the Eco-San toilets. Responses classified knowledge of the participants as: 1) Very low, 2) Low, 3) Basic, 4) Good and 5) Excellent.

Detailed activities of each workshop are described in technical specification cards, previously elaborated. As an example, one of the objectives was to develop different group dynamics, both to establish coexistence relationships correct answers, after the presentation of the corresponding didactic material. This way, five quantitative evaluation categories were settled down: Very poor (0-<50%); Poor, (50-<60%); Fair (60-<80%); Good (80-<90%) and Excellent (90-100%).

- Construction, use and maintenance of the Eco-San

The Community Committee of Environmental Sanitation and the beneficiaries had the responsibility of the organization and construction of the Eco-San, as well as the follow-up related to its use and maintenance.

After the workshops, the technical team of CECIPROC was in charge of follow up related to the use and maintenance of Eco-San, through home visits in which a questionnaire was applied to beneficiaries.

Outcomes

The evaluation of the knowledge related to the didactic material by the different population groups after the workshop is presented in table 3.

Although all groups of women showed improvement, the greatest improvements (from low to good knowledge) were observed in communities B_1 i.3. after 1 year of use of Eco-San.

Adolescents who had good knowledge about the system after 3 years of using Eco-San showed no improvement, while those who used it for 1 year showed improvements from low of very low to basic.

School children showed improvements in all communities, the greatest increments were seen in those communities which had 1 year of use of the sanitation system, closely followed by those which had 3 years of use.

It is interesting to note that all population groups living in control communities showed improvements in their knowledge of the Eco-San system, though moderate and lower than intervention groups. However, their knowledge was generally lower than intervention groups at baseline.

Type of community	Group of women		Group of adolescents		Group of school children	
	Pre-evaluation	Post-evaluation	Pre-evaluation	Post-evaluation	Pre-evaluation	Post-evaluation
A_1* Palma Sola	4 Good	5 Excellent	4 Good	4 Good	3 Basic	4 Good
A_2* Charco Redondo	4 Good	5 Excellent	4 Good	4 Good	4 Good	5 Excellent
B_1** Cuauhtemoc	2 Low	4 Good	2 Low	3 Basic	3 Basic	5 Excellent
B_2** Loma Bonita	2 Low	4 Good	1 Very low	3 Basic	3 Basic	4 Good
C_1*** Chacalapa	3 Basic	4 Good	3 Basic	4 Good	3 Basic	4 Good
C_2*** La Luz	2 Low	3 Basic	---	---	1 Very low	2 Low

Categories or levels of knowledge

A*	3 years of use	5	Excellent
B**	1 year of use	4	Good
C***	0 years of use	3	Basic
		2	Low
		1	Very low

Table 3: Evaluation of the knowledge about Eco-San after the workshops according to years of use and population groups.

Quantitative evaluation of didactic materials

Tables 4-7 show the evaluation of didactic materials. In general, adolescents showed the lowest level of correct answers, except for those communities in which the three didactic materials were evaluated, where adult women showed the lowest percent of correct answers (Table 7). The situation in Loma Bonita (B_2), where the three didactic materials were evaluated simultaneously, contrasted with that found in all other communities, where adult women usually

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ranked highest in their percentage of correct answers to the evaluation applied.

School children ranked high in the evaluation of the videotape; low in the evaluation of the comic; and excellent in the evaluation of the poster and in the three materials evaluated simultaneously.

In relation to the didactic materials, the **videotape** showed the higher percentages of correct answers, followed by all the didactic materials evaluated at the same time, then by the poster, and lastly by the comic.

Population Group	Community	Videotape: level of benefit	Correct answers
Women	B_1 Cuauhtemoc	Excellent	100%
Adolescents	B_2 Loma Bonita	Poor	50%
School children	A_1 Palma Sola	Good	90%
Adolescents	C_1 Chacalapa	Good	80%

Table 4: Evaluation of the videotape

Population Group	Community	Comic: level of benefit	Correct answers
Women	A_2 Charco Redondo	Good	80%
Adolescents	B_2 Loma Bonita	Poor	50%
School children	A_1 Palma Sola	Fair	70%
School children	A_1 Chacalapa	Good	80%

Table 5: Evaluation of the comic

Population Group	Community	Poster: level of benefit	Correct answers
Women	A_1 Palma Sola	Good	80%
Adolescents	A_2 Charco Redondo	Very Poor	30%
School children	B_1 Cuauhtemoc	Excellent	100%
School children	C_2 La Luz	Good	80%

Table 6: Evaluation of the poster

Population Group	Community	All level of benefit	Correct answers
Women	B_2 Loma Bonita	Poor	50%
Adolescents	B_1 Cuauhtemoc	Good	80%
School children	A_2 Charco Redondo	Excellent	100%
Women	C2 La Luz	Fair	70%
Women	C1 Chacalapa	Good	80%

Table 7: Evaluation of the videotape, poster and comic

Discussion and conclusions

One aspect that has to be taken into account when interpreting the quantitative evaluations applied is that 70% of the participating women referred to be illiterate, and even among those who were not, there is a great difficulty in obtaining a fluid and correct reading, as well as to express ideas in writing among the three population groups. Therefore, the use of a qualitative evaluation complemented the quantitative interpretation of the results.

According to the **qualitative evaluation at a global level** there was an expected positive change as far as the level of knowledge before and after the workshops among all groups and in most of the communities, in particular the school age children from community B_1, who showed the highest level of acquired knowledge (Table 3).

In contrast the groups of adolescents from communities A_1 y A_2 (3 years of usage of Eco-San) did not modify the level of knowledge, as may have been expected. In all cases there was a higher level of acquired knowledge in relation to Eco-San years of use, specifically the construction, use and maintenance knowledge, as may have been expected (Table 3).

According to the acquired knowledge by population groups, school children got the highest records followed by women, and in the last place, by adolescents (Table 3)

Focusing on the **quantitative** results, there were two important results that were consistent with the qualitative ones: The school children obtained the highest number of correct answers (86.6) followed by women (76.6%) and adolescents (58%). Community B_1 obtained the highest percentage (93.3%) (Tables 4 to 7).

These consistencies may be explained by the fact that children have a higher level of schooling than adults, who have a greater "educational lag". On the other hand, the school children represent a group that has the greatest capacity to learn in recreational conditions such as the ones the workshops were designed after.

The low values showed by the adolescent groups reflected the low participation they had throughout the project, including one group that never showed up at the workshop. This may probably be related to the nature of the adolescents psycho-biological conditions. Some of them felt shy during the workshops dynamics or were very reluctant to participate (Table 3, 4, 5, 6).

The women's group even when they had more potential disadvantages (i.e. older, illiterate, broken-spanish speaking, etc). Were capable to overcome these limitations and showed motivation and participation during the whole intervention.

In relation to the best didactic material used, the videotape had the highest percentage of correct answers. In fact, we expected this result, based on the fact that the video offers more communication possibilities in predominantly illiterate populations.

Lastly, I want to highlight the importance of including in this paper the social component according to the ecosystem approach components (nature, society, process and device), that was present through the production, dissemination and evaluation of the educational materials presented. In other Eco-San projects, these materials are practically non-existing, and their successful implementation and encouraging results point out to the importance of considering the use of the four of them together (Esrey, et. al. 1998)

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Cost comparison of conventional and modern sanitation solutions*

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Keywords

Comparative study, cost efficiency, investment costs, operational costs, ecosan concepts

Abstract

The objective of the study is to investigate the cost effectiveness of Ecosan-solutions for rural villages in Austria. Three different scenarios have been compared, ranging from conventional to modern, reuse-oriented, solutions. For comparison a precondition for all solutions was the compliance with the applicable legislation. In the comparison a “model village”, resembling a typical village in rural areas was used. Based on legal requirements due to small recipients – typical for these areas – higher then normal standards for effluents were assumed.

Three scenarios were compared, scenario A representing a conventional solution comprising sewer and treatment plant, scenario B considering urine diversion, separate storage and discharge to the treatment plant for reuse, and scenario C assuming in house measures for quantity reduction, storage and reuse respectively dry toilets and decentralised grey water treatment followed by infiltration. The cost estimations are based on actual costs of comparable systems and offers of suppliers. Necessary changes in the houses have been considered.

The results demonstrate clearly that, both with regard to construction and operation and maintenance, conventional systems for rural areas are the most expensive option but still encouraged through subsidising systems. It becomes clear that in addition to their sustainability reuse oriented systems are also definitely economically advantageous.

Introduction

The existence and enforcement of strict environmental legislation in Austria achieved significant improvements of the environmental situation; at least as far as the water compartment is concerned. Approximately 85 % of the population are connected to public sewers and consequently treated in biological treatment plants (BMLFUW, 2003a) with, depending on the size, advanced biological nutrient removal. Transferring this high tech end of pipe approach to less densely populated settlements resulted in the past in exorbitant increases both in investment and operational costs. Future trends regarding the possible developments of the water/wastewater industry (PWC, 2001) all focus on economic efficiency, mostly neglecting

*This paper has been peer reviewed by the symposium scientific committee

presently un-served regions for cost reasons (BMLFUW, 2003b). All of these arguments assume the traditional non-prevention oriented strategy to be the only possible option to tackle the existing problems and could possibly result in a reduction of environmental standards for economic reasons.

For this study it is assumed that modern sanitation solutions, which focus on reduction of energy and material flows can assure the high environmental standards of Austria at acceptable cost for the population. The objective of this study therefore was to compare investment and operational costs for different solutions taking into account varying degrees of preventive measures in order to prove that applying different models of technical solutions for different settlement structures can be the option to achieve the requested environmental standards for rural and more remote locations at acceptable costs.

In addition such solutions are better suited to fulfil the legal requirements of Austria according to which reduction, prevention and recycling of wastewater and its compounds are prioritised against treatment of wastewater.

Frame conditions and problem description

The background of the study was the discussion in three rural villages on the solution of their immediate problems concerning wastewater. For the purpose of the study a “model-village” was created in order to objectify the discussion. The “model-village” is app. the average of the three villages in question and resembles a typical village of this region. It consists of 25 houses with a total of 100 inhabitants. The share of agriculture is still 30% meaning that 8 houses out of the total are active farms. Presently wastewater produced in these households is collected in septic tanks. Theoretically this would mean that wastewater is stored and reused in agriculture due to the fact that these septic tanks normally have an illegal overflow - in order to reduce the emptying frequency - mechanically treated wastewater (sedimentation only) is discharged either by an existing rainwater sewer or by means of drain pipes directly to the recipient.

The particular region is additionally marked by small receiving streams. Under certain circumstances this requires a significantly higher reduction of an emitted pollution load compared to the general standards. Therefore it is assumed that the pollution load of any water discharged from the households has to be less then 15mg/l BOD_5 and less then 5mg/l NH_4-N at an effluent temperature of 10°C.

Proposed scenarios

Three scenarios were considered only having one basic principle to fulfil was the legal compliance. This means that each technical solution has to fulfil the legal standards presently in force. Other criteria like for example whether one scenario would result in higher environmental benefits then requested were neglected.

<u>Scenario A</u> solves the problem in a conventional way by constructing a separate sewer system and a conventional biological treatment plant (Figure 1). Due to the strict standards a tertiary treatment step, e.g. a constructed wetland, is required.

<u>Scenario B</u> (Figure 2) assumes a conventional separate sewer system and treatment plant but toilets with urine separation and decentralised storage in each household. Automatically urine is collected separately by using the sewer system during night times with near to zero wastewater flow, stored separately and used as a fertilizer in agriculture (e.g. Lens *et al*., 2001). A tertiary treatment step is not necessary since no access of nitrogen has to be removed. The reason for including this scenario was that compared to Scenario C, which is presented below, still most of the responsibility for operation and maintenance of the whole system lies with the community and not the single households.

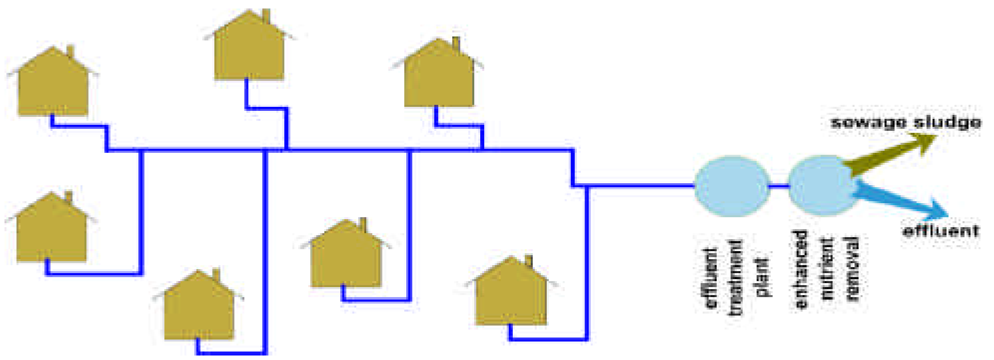

Figure 1: Schematic sketch of Scenario A.

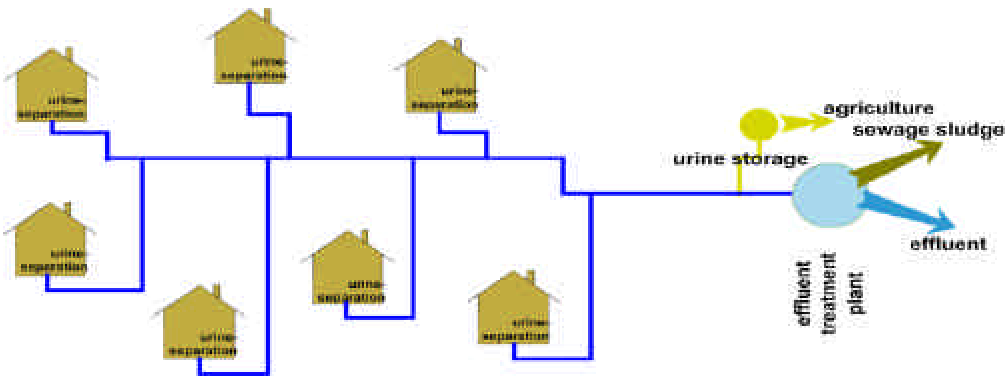

Figure 2: Schematic sketch of Scenario B.

<u>Scenario C</u> is assumed to be the option which fulfils the requirements of Ecosan-solutions best under the given conditions, i.e. to further sustainable development by closing nutrient and water cycles with as little loss of material (nutrients) and energy as possible. For those households which are active farms, in house measures for quantity reduction are assumed (i.e. low flush toilets), followed by storage in order to bridge those periods when use in agriculture is not allowed, e.g. during periods of frozen ground or snow, and subsequent use in agriculture together with manure.

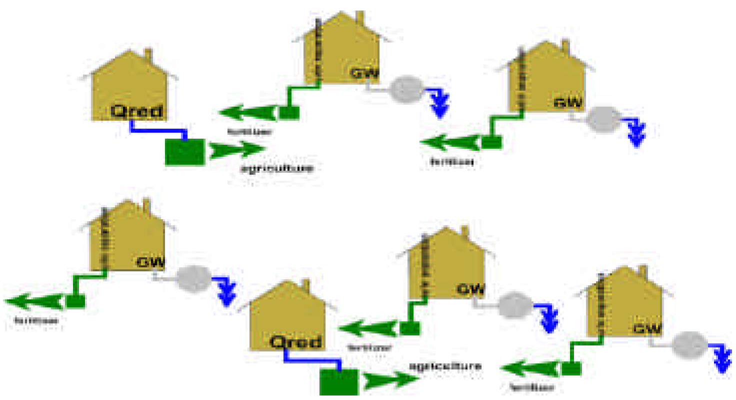

Figure 3: Schematic sketch of Scenario C.

For the remaining households reduction in wastewater quantity and quality is proposed by the application of dry toilets was foreseen. For the remaining greywater for each household a constructed wetland for treatment followed by infiltration is considered (Figure 3). It has to be stated that due to the particular situation in Austria regarding groundwater protection infiltration to the ground(water) is not forbidden as such but very strictly regulated. Nevertheless on the basis of average greywater quality (Laber and Haberl, 1999) after treatme nt no problems are assumed for the sage of this study.

Investment costs

The investment costs are based on the frame conditions described above, current data published (e.g. BMLFUW 2001, 2003c), information from suppliers (in particular regarding separation toilets, dry toilets, etc.) and own practical experiences from implementation of both conventional and alternative sanitation projects.

For Scenario A cost it is assumed that for the construction of the sewer lines no major hindrances due to underground conditions occur and costs are therefore comparatively low. The same applies for the treatment plant. Nevertheless due to the small size average costs of 1.000€ have been assumed per person equivalent. For tertiary treatment a vertical subsurface flow constructed wetland is assumed with relative cost – including all necessary pumps, structures and pipings – of approximately 125,-€ per person equivalent. The average length of the sewer line per house connection is based on an average length of the network in the village of 30m and a transport line to the nearest receiving stream of app. 1.000m. Table 1 summarises the assumptions and resulting total costs and costs per house connection respectively. The total investment costs are 14.650,-€ for each house connection.

Unit	Assumptions	Costs	Costs/house
sewer line	25 houses á 70m at 145 €/m	€ 253.750,00	€ 10.150,00
treatment plant	100pe at 1000€/pe	€ 100.000,00	€ 4.000,00
3rd step	100pe at 125€/pe	€ 12.500,00	€ 500,00
Total Scenario A		**€ 366.250,00**	**€ 14.650,00**

Table 1: Investment costs for Scenario A

Costs for the sewer line in Scenario B naturally have to be same as in scenario A while the cost of the treatment plant is assumed to be reduced significantly since enhanced nitrogen elimination is not required due to separate collection and storage of the urine. Operational problems of the treatment plant caused by a lack of nutrients could be solved by controlled dosage of urine from the storage tank. The storage tank was designed for a storage period sufficient to bridge the period during which no agricultural application of fertilizer is allowed. In addition to these costs also costs for the urine diversion toilet which is vital for the system to function are considered. It was assumed that on average two new toilets were required for each household.

Table 2 summarises the assumptions and the resulting total costs and costs per house connection respectively. The total investment costs of Scenario B (14.694,-€) are basically the same as for Scenario A. The advantage of reduced cost for the treatment plant is consumed by the urine storage tank and the urine diversion toilets.

Unit	Assumptions	Costs	Costs/house
sewer line	25 houses á 70m at 145€/m	€ 253.750,00	€ 10.150,00
treatment plant	100 pe at 500€/pe	€ 50.000,00	€ 2.000,00
urine diversion toilets	25x2 at 1.200€	€ 60.000,00	€ 2.400,00
urine storage	18m³ at 100€/m³	€ 3.600,00	€ 144,00
Total Scenario B		**€ 367.350,00**	**€ 14.694,00**

Table 2: Investment costs for Scenario B

Costs for Scenario C (Table 3), being the most "decentralised" solution, consider the different solutions for farmers and other households respectively. Cost for dry toilets for quantitative and qualitative prevention are calculated for 2/3 of all houses including cost not only for the toilet seat but also the required changes within the houses. For these houses treatment of greywater in constructed wetland systems followed by infiltration is calculated.

It is assumed that by application of vertical flow constructed wetland system a surface area of 2m² per person equivalent is sufficient at relative cost of 250,-€/m². For the remaining 1/3 of households use of the total wastewater in agriculture is assumed. Due to the unsatisfying state of most of the existing septic tanks costs for renovation (50% of new septic tanks) were considered. Since the required size of the tanks depends directly on the wastewater production reduction by installation of low flush toilets is included (2 new toilets per house). Thus a size of 58m³ for each tank is sufficient to achieve a six months storage period. The total investment costs for Scenario C per house connection is only app. 4.450,-€. The main difference compared to the other scenarios is the non-existence of a sewer line.

Unit	Assumptions	Costs	Costs/house
greywater treatment	17 houses at 500€/pe	€ 34.000,00	€ 1.360,00
dry toilets	17x2 at 1.500€	€ 51.000,00	€ 2.040,00
low flush toilets	8x2 at 600€	€ 9.600,00	€ 384,00
renovation septic tanks	50% of 58m³ per house	€ 16.240,00	€ 649,60
Total Scenario C		**€ 110.840,00**	**€ 4.433,60**

Table 3: Investment costs for Scenario C

Operational costs

The operational costs are based on the frame conditions described above, current data published (e.g. BMLFUW 2001, 2003c and own practical experiences from implementation of both conventional and alternative sanitation projects.

Operational costs can only be assumed with a higher degree of uncertainty compared to the investment costs. One main reason is that only insufficient information on actual operational costs of sewer lines are available. In addition costs depend on the strategy applied in operation and maintenance of sewer lines, whether it is prevention or cure oriented. For the purpose of this study costs for a proper operation of sewer lines is assumed to be 1% of the investment costs annually. Another source of uncertainty is the cost for disposal of sewage sludge produced in Scenarios A and B and in a lesser extent in Scenario C. Depending on the chosen path of reuse respectively disposal the costs vary significantly. It was assumed that the quality of sewage sludge allows application in agriculture. In addition the idealistic value of work by all households in Scenario C regarding the emptying of the dry toilets and operation of the grey water treatment plants was neglected as well.

Depreciation of investment is considered on the bases of a fixed interest rate of 5% annually. The average life span of the mechanical equipment is assumed with 10 years while the average life span of all other investment is calculated with 50 years. Inflation is considered with 2% per year. For the purpose of this study a constant repayment rate was assumed. These assumptions are the same for all scenarios.

Table 4 shows the operational costs for Scenario A. For the treatment plant the costs comprise mainly costs for energy, material, personal and external supervision. Annual cost in Scenario A calculates to 1.300,-€ per house connection.

Unit	Assumptions	Costs	Costs/house
sewer line	1 % of investment annually	€ 2.500,00	€ 100,00
treatment plant	energy, material, personal, supervision	€ 10.000,00	€ 400,00
	sewage sludge (not considered)	€ 0,00	€ 0,00
depreciation	5 % over 10-50 a	€ 20.000,00	€ 800,00
Total operational costs Scenario A		**€ 32.500,00**	**€ 1.300,00**

Table 4: Operational costs for Scenario A

For Scenario B (Table 5) operational costs are nearly the same. A slight reduction in treatment plant operational costs – since the highest share in the cost is the personal – is compensated by the slightly higher investment costs of this option. The value of approximately 360kg of collected nitrogen per year is not calculated.

Unit	Assumptions	Costs	Costs/house
sewer line	1%	€ 2.500,00	€ 100,00
treatment plant	energy, material, personal, supervision	€ 9.000,00	€ 360,00
	sewage sludge (not considered)	€ 0,00	€ 0,00
depreciation	5 % over 10-50 a	€ 21.000,00	€ 840,00
Total operational costs Scenario B		**€ 32.500,00**	**€ 1.300,00**

Table 5: Operational costs for Scenario B

Operational costs for Scenario C are summarised in Table 6. In addition to the general assumptions the lifespan for dry toilets and low flush toilets was assumed to be 25 years in average. Therefore depreciation costs are high compared to the investment. As mentioned above both the idealistic value of work carried out by the households for operation of the units as well as the fertilizer value of the separately collected material are not included in the calculation. The total cost per household is with app. 410,-€ annually less then one third of the operation and maintenance cost of the first two scenarios.

Unit	Assumptions	Costs	Costs/house
grey water treatment	17x energy, supervision, etc.	€ 3.000,00	€ 120,00
	sewage sludge (not considered)	€ 0,00	€ 0,00
depreciation	5 % over 10-50 a	€ 7.293,17	€ 291,73
Total operational costs Scenario B		**€ 10.293,17**	**€ 411,73**

Table 6: Operational costs for Scenario C

Cost comparison

As mentioned above the main underlying principle of all scenarios presented was their compliance with the present legal situation with regard to discharge of wastewater to the environment. This means that the three solutions are comparable with regard to their performance in this sense.

In Figure 4 (left) the investment costs of the three options are compared. While the investment costs for Scenario A and B are similar, costs for Scenario C are significantly lower (app. 30%). The difference is mainly caused by the high costs of the sewer system.

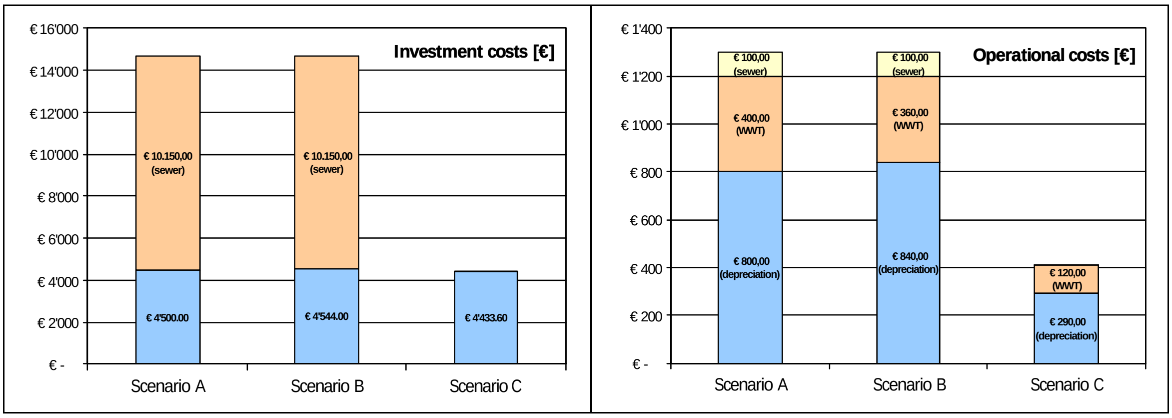

Figure 4: Comparison of investment costs (left) and operational costs (right) (wwt wastewater treatment).

Figure 4 (right) shows basically the same picture for the operational costs. In addition to the high depreciation costs, caused mainly by the high investment for the sewer lines also the operation of the wastewater treatment plants in Scenarios A and B is higher. The latter has to be qualified since, as mentioned above, the value of work carried out by the households themselves in Scenario C was not included. Nevertheless it is again obvious that both options with sewers cause approximately 3 times higher costs for operation and maintenance. Although if additionally the value of the nitrogen collected in Scenario B were considered still the level of costs achieved by Scenario C – were the same value is recovered – could not be reached.

Figure 4 compares absolute costs, not taking into account the present system of subsidising wastewater infrastructure in Austria. Generally all installations on private property (with the exception of long connecting sewers and main sewer lines) can not be subsidised. Taking into account average subsidy rates the pictures looks differently.

Figure 5 summarise both investment and operational costs taking into account present subsidising practices. Due to the nature of the subsidising system – normally only the minor part is a direct contribution to the investment but the rest contributes to the repayment of a loan – the effect becomes most obvious for the operation and maintenance costs which have to be financed by the households directly. Scenario B becomes the most expensive since the investment costs are nearly the same as for Scenario A but partly, since in house installations, not supported. Although Scenario A is still 50% more expensive then Scenario C it is obvious that an important incentive for alternative solutions is lost.

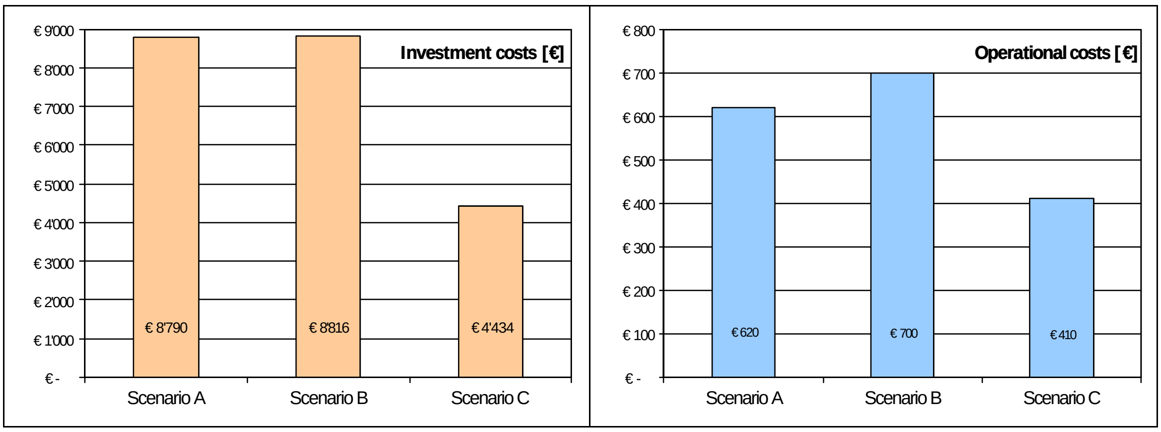

Figure 5: Investment costs (left) and operational costs (right) without subsidy.

Conclusions

The comparison of investment and operational costs of three different scenarios clearly shows that conventional systems for rural areas are the most expensive option (mainly due to the sewer lines needed) but still encouraged through the subsidising system. Neglecting subsidising issues the advantage of alternative sanitation solutions under the frame conditions described above becomes obvious. In addition to their sustainability reuse oriented systems are therefore also definitely economically advantageous.

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Application of ecosan principles through public private partnership projects-prospects and limitations

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Session B

Keywords

Appropriate technology transfer, public-private partnership, sanitation concepts, framework

Abstract

Inadequate or even lack of sanitation is a key social, health and environmental problem in the majority of countries. Public programs are insufficient and do not reach the majority of the population. Private initiative alone often only serves a few, who then however mostly remain affected by those without suitable sanitation and do not get their co-operation. Lack of finance for investment and operation, lack of integration into dwelling and economic activity, resulting often in unsuitable technical and environmental approaches, and a lack of participation can sometimes be overcome if public and private actors manage to co-operate and agree upon a suitable division of labour and framework of responsibilities and thus turn sanitation into a joint development priority, which can then help as well to save and reuse valuable water, nutrient and energy resources.

Introduction

Traditional central sanitation and waste disposal, as dominant in industrialised countries, used to be and still is rather publicly planned and supervised by responsible and specialised Government agencies, traditionally built and mostly operated publicly or through public supervision and public financing.

These central systems involve a full sewer system or leading to a waste water treatment plant, or a collection and transport chain to a landfill out of town, with petrol for solid wastes or water being the means of transport, for toilets, grey water, often for rainwater and industrial effluents as well. Here resulting garbage and treated sewage sludge becomes a costly problem, since it is mixed with toxic substances and heavy metals and thus the organic substance and nutrients need to be disposed of instead of being reused in agriculture; the treated water is going into a river or polluting ground water as seapage, instead of contributing to plant growth and water table refilling. These concepts as well fully separate sanitation issues from solid waste management, agricultural and energy production. But they do not separate the waste streams, which would be so much more important for a future reuse.

More recent and sometimes fiercely debated, by some just considered as modern and up-to-date concepts, involve a larger private involvement, sometimes even a full private responsibility and ownership of urban water supply, waste and waste water disposal and treatment. However, for a long time these more private sector oriented approaches followed the same technical planning and underlying principles.

Figure 1: Appropriate decentral waste water treatment through a UASB-System in Lima.

Figure 2: Canal and treatment for distribution of nutrients and treated waste water, Lesotho.

Regardless of the technical concept of sanitation, there is a common understanding that publicly owned and operated systems, mixed ownership and/or operation as well as private models can all the same be efficient and satisfactory models for all stakeholders involved in sanitation, as long as adequate public control, supervision and regulation for this basic needs requirement can be fully and sustainably secured. However, mostly an appropriate mix of different public and private responsibilities have proven to be the more efficient organisation model to secure appropriate and sustainable sanitation.

Increasingly, central systems are refinanced through consumer or household fees, on waste, water and waste water treatment, sometimes based on actual consumption, sometimes only on a per capita or household basis, which often further increases spoilage, in particular of water. In most developing countries central waste disposal, water supply, sewer and waste water treatment systems are not or only partially in place due to the high investment and operation costs needed and lower household and tax incomes. Development strategies for a long time were mostly copied concepts from industrialised countries, with water supply installations being the first priority. Planning of sanitation took place quite often in a second step often regardless of climatic and economic differences in these countries, with blue prints and equipment from industrialised countries sometimes being transferred regardless of climate and economic potential in a one to one pattern.

Figure 3: Vacuum-system reduces water use for Toilet Flushing in apartment building; before anaerobic treatment, Freiburg, Germany.

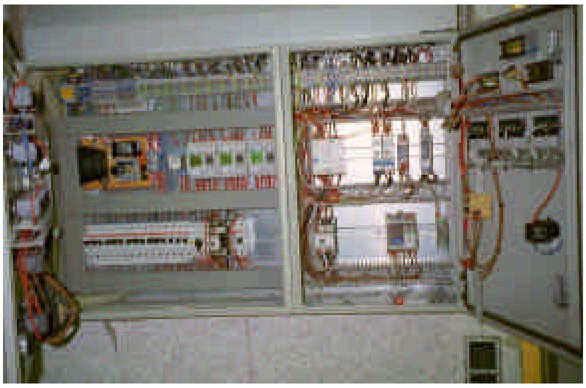

Figure 4: Recycling and energy optimisation sometimes ask for sophisticated control panels even in Ecosan projects.

A direct transfer of the "European" or "industrialised" type of sanitation approach, regardless whether privately or publicly organised or financed to developing countries can create the following problems:

1. The systems developed and applied in industrialised countries are proving to be only sometimes sustainable, here in particular in terms of long-term water and energy balance
2. The need for capital investment and operation requirements are too high for many developing countries
3. Public administrations are mostly less well organised and equipped in developing countries than in industrialised countries, with countless standstills of these systems as a result
4. Clean water is even more scarce in many developing country environments than in industrialised countries
5. Nutrients and their balanced mix as available in organic sludge and waste have a higher economic value and are more needed for sustainable agricultural production and soil conservation
6. Higher temperatures lead to higher evaporation and activity (in landfill, sewer, canals, ponds and other treatment plants), thus changing the optimal waste and water management pattern
7. they lead to a faster biological activity, decomposition and green-house gas production and thus different treatment, transport and storage behaviour and needs for sewage and sanitation
8. Higher temperatures increase the production of biogas as a potential decentral energy supply, which is often crucial, where firewood, dung and charcoal use are a main reason for ecological damage and poverty; here as well climatic issues need to be considered
9. Labour is often abundantly available in developing countries, asking for labour intensive sanitation, recycling and reuse approaches
10. There is often a shortage of qualified labour, management capacities and funds for operation, maintenance and repair of sophisticated installations under public control and responsibility, thus leaving a majority of installations idle after a short period
11. The organic share of municipal and industrial solid waste is larger asking for a different approach to their management; for example their joint treatment with industrial or agricultural waste or municipal sludge
12. High transport cost (roads, vehicles, fuel) for solid waste disposal at far-out centralised dumps and related ground water pollution problems ask for a different approach
13. Soil conservation, the water balance, biomass, forestry, agricultural and nutrient production and related energy and hygienic issues are considerably more important within the overall economy and environmental balance of developing countries
14. Overall public and private economic and financial parameters, costs and benefits and their distribution in most developing countries are considerably different and need to be respected as a base for planning, participation and implementation
15. This transfer approach is even less suitable for city outskirts, rural settings and smaller towns, where the contradictions and restrictions of central sanitation become more obvious

Figure 5: Nutrient recycling wants suitable marketing of waste compost Talcuahano, Chile.

Figure 6: Recycling of municipal solid waste through composting , Addis Ababa, Ethiopia.

Public private partnership in eco-sanitation

Actual discussion on Public Private Partnership Projects within the German Development Co-operation focus the dominant public character of Development Co-operation, which is financed from Public funds (Ministry of Co-operation – BMZ) and channelled for implementation through state-owned organisations like GTZ for technical co-operation, KFW for public loan financing, DEG for private loan financing or for example InWent for financing of training issues.

The overall goal is to have the German Private Sector, so far mainly used as a subcontractor, stronger and earlier integrated into development co-operation, to use its know-how and capital and to help these companies to enter the markets of developing countries. As well to reduce the financial burden of public development co-operation and to use efficiencies and experiences of the private sector through these "partnerships". Commonly in these co-operations the private portion is meant to be focusing and used for private business interests and a public portion is added to secure the development goals. PPP-Projects can either be separate projects or they become increasingly an early and integrated part in the planning and implementation of development co-operation projects.

Figure 7: TBW-InWaSia-System for water, nutrients, energy production, recycling and reuse from industrial waste water in Cuba.

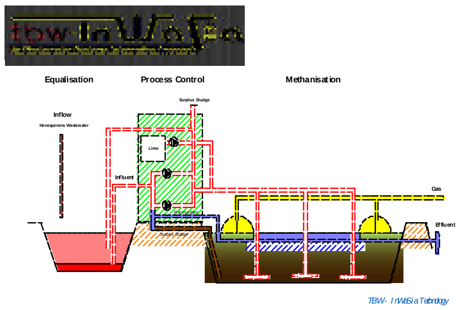

Figure 8: UASB-Recycling scheme; waste water treatment plant at sugar cane factory in Jamaica

Ecological sanitation and thus development co-operation focussing ecological sanitation anyhow has to secure a broader involvement of households, the private sector, and different government and non-governmental actors. Ecological sanitation thus is likely to need a major private share involved in implementation from “developing” and “industrial” countries for a number of reasons, for example:

1. The public sector is rather designed and dimensioned to oversee central issues, installations and projects, which involve long-term planning, budgets and personnel
2. Ecological sanitation asks for a larger share of individual varieties of sanitation concepts for different types of situations and thus a larger individual involvement and flexibility
3. Since ecological sanitation tries to reverse the somewhat unconscient “private disposal – public responsibility and care” concept, it asks for broader sensibilisation and responsibility of private and decentral actors
4. The public sector has less experience and capacities to operate the benefit and reuse side of ecological sanitation in gardening, horticulture, pesciculture and agriculture
5. Ecological sanitation tries to mobilise private interest and investment through more decentral or individual benefits from water, nutrients and energy within reach and touch of the population
6. Ecological sanitation builds on technical concepts which are easier to plan, build, copy and manage for local technicians, households and decentral organisational units

Since larger public co-operation projects of industrialised countries are – at least used to be - often rather designed to support central sanitation structures and their administration in developing countries, an increase of private involvement through the PPP approach in ecosan projects seems to some extent only logical and consequent to allow major elements of ecoson to materialise.

Figure 9: Waste-reuse research for simultaneous treatment of liquid, sludge and solid waste from municipalities and industries; in transportable containers, Hanau, Germany.

Figure 10: Agro-industrial wastes contain a large nutrient and energy potential; central-decentral treatment plant for municipal and industrial wastes in Rothenburg, Germany.

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Figure 11: After washing and shredding different plastic fractions can be reused; Lima.

Figure 12: Digesters; treatment plant for municipal, agricultural and industrial wastes.

On the other hand, sanitation and waste management are not per se a profitable business for the private sector, and will not become profitable in the near future; if funds are not mobilised for related services, this applies, even if some costs can be reduced, just as well for ecosan projects.

However, the private sector involvement will help to increase focussing the monetary side of sanitation, like water reuse, nutrient reuse, replenishing soils, energy production, climatic issues, other recycling materials and their productive use in urban construction, horticulture, agriculture and other areas.

As well the private sector involvement helps to identify or develop appropriate individual solutions with the optimal cost-benefit relation, a prime driving force of private sector activity.

Figure 13: eco-san seminar in the municipality of Yang Song near Beijing, China; here the water table drops 1 m per year.

Figure 14: Integrated waste treatment and fertilizer distribution plant, use of toilet and green biomass energy, Thomassin, Haiti.

Figure 15: Anaerob-aerob waste separation, treatment and recycling plant in Canete, Peru.

Figure 16: Compost preparation from municipal solid waste in Canete, Peru.

Quite obviously there are some risks involved in privatising eco-sanitation and turn them into "PPP Projects":

1. public administrations want to get rid of the overall responsibility for waste and waste water disposal by giving it to privately owned companies without a clear framework of duties, control or without providing or allowing to raise the necessary investment and operational funds;
2. this is occurring for example in some states in the solid waste sector in India at present, where the Government, by focussing recycling and energy values of solid wastes, tries to hand over collection and disposal duties to private companies without securing adequate income with the consequence of poor disposal and treatment practices
3. the private sector might want to "pick the raisins", the valuable portion, out of the sanitation and disposal business (for example only affluent quarters), thus leaving the public sector with the most expensive and least attractive portions of this obligation
4. the private sector, by taking over public sewer and treatment installations and even water sources, can get out of control; as a result, installations and operation sometimes deteriorate; cost increases become unacceptable for households; qualification of the public sector to supervise activities get lost

A good and comprehensive contractual framework, with a long-term sustainability and investment plan, with cheques and balances and constant independent controls is thus crucial for a fruitful co-operation between private and public sector in this field.

More decentralised eco-sanitation leaves more room for local planners, builders, contractors, operators, since the level of investment and securities needed is more within the reach of these companies. Since eco-sanitation concepts are meant to be more close to sight and interest of the households and local community and to existing local know-how levels, a more direct control and intervention can be expected for eco-sanitation approaches; on the other hand, eco-sanitation with a major private involvement can be even more demanding for a public municipal control and supervision.

Figure 17: Engineers and supervision team of municipality discuss progress of integrated waste treatment plant in Chonburi, Thailand.

Figure 18: Bottom sealing for 6 ha landfill of integrated waste recycling and disposal plant in Chonburi, Thailand.

Just like private and public partner will have to balance their interest through a good framework and communication within a PPP-approach of a development project, this applies as well for the whole sanitation sector in the developing country. So PPP-projects in eco-sanitation mirror perhaps better a sustainable implementation model in a given urban setting. However, no prime concept has been developed yet that secures an optimum organisational structure for all parties and interests involved;

A good mix and co-operation of the different private and public stakeholders and the establishment of clear frameworks is undoubtedly the direction to be taken: and this applies even more for eco-sanitation approaches.

Figure 19: Most important is the attitude of the young people towards eco-sanitation; here is an example of sensitisation for sustainable waste management in Imperial, Peru.

Figure 20: Even the black and yellow water from train toilets is a valuable nutrient for plant growth and soil improvement if treated sufficiently.

Conclusions

There are uncountable hindrances of Public-Private Partnerships for truly cost-efficient sanitation. However there is little alternative. TBW has, within a number of projects, made some substantial progress on that rocky road to combine private initiative and public responsibility and participation with more sustainable sanitation and recycling strategies. Just like private and public partner will have to balance their interest through a go od framework.

Human urine from city to field - towards sustainable co-operation?

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Keywords

Fertilizer, nutrients, urine, recycling, resources

Abstract

Possibilities and problems connected with the establishment of a well-functioning recycling system for source separated human urine from a Swedish city to productive land were investigated. Via literature and interviews with people with experience of similar recycling, potential urine users and other stakeholders, the current position was determined. The results show that a potential market exists for source separated human urine as a fertiliser around cities, especially in agriculture. However certain critical issues must be resolved for the desired degree of consumer confidence and knowledge to be achieved regarding human urine and its recycling system within the entire recycling chain. This is possible with good information and quality-assurance measures. There is urgent need for a risk assessment of pharmaceutical residues in the product, not least to enhance end-user and public confidence. Quality assurance systems have been developed for segments of the chain but an overall approach is lacking. One party, e.g. the urban authority or its contractors, must be appointed to a coordinating role. Society should have the final responsibility for the development and function of the recycling system and should be the driving and supporting force when necessary in the development of these new systems.

Source separation of human urine – why and how?

The conventional sewage treatment systems of Swedish cities today do not allow a high level of nutrient recycling back to agriculture. Only a small percentage of the total amount of nutrients is captured in the sludge of the sewage treatment plant, still polluted by compounds not wanted in agricultural fields. Many of the nutrients are instead discharged to recipient waters, causing eutrophication and nitrate poisoning of the groundwater. The Swedish Environmental Protection Agency has recently proposed as a national goal that in 2015 at least 60 % of the phosphorus in sewage must be recycled to productive land, of which at least 50 % should be agricultural land (Naturvårdsverket, 2002).

In recent years, research on source separation of human urine has been carried out on a broad front. The results show that this system opens up for a high level of nutrient recirculation in an environmentally advantageous way, where the hygiene risks can be minimized to an insignificant level (Jönsson et.al., 2000). Although urine represents only 1 % of the volume flow in household wastewater, it contributes 80% of the nitrogen, >50 % of the phosphorus and 80-90 % of the potassium (Vinnerås, 2002). By separating the urine at source, a large proportion of the nutrients can be captured in a small and very clean fraction, which functions well as a fertiliser. A urine separating toilet has a special bowl for urine at the front and another for faeces and paper at the back. The urine and a small amount of flushwater flow separately into a collecting tank in the housing area, from where they are later emptied and transported by a tanker to a storage tank. It is common that the urine is stored in an unused slurry tank at the farm before application. During storage, the urine is sanitised and after this, it is used as a fertiliser for cereals or other crops.

Increased knowledge of the system has prompted a growing political interest in Sweden for source separation of urine, as one of many ways to achieve a greater recycling of plant nutrients. While in the beginning mainly installed in eco-villages, source separation systems are becoming more frequent in villas, blocks of flats, schools and other institutions. About 2-3000 urine separating porcelain toilets have been sold in Sweden, and in addition to that a large number of plastic ones for summer cottages (Johansson et.al., 1998). According to Swedish law, local municipalities must provide for appropriate collection and treatment, e.g. recirculation, of source separated urine and other sewage fractions kept in a closed tank. There is a need to investigate forms for a well-functioning retrieval system all the way from city buildings to the field. To achieve the political vision of recirculation of nutrients, local planning authorities have to pay attention to the kinds of products and recycling management required by the end-consumers for fertilisers, for example farmers. There are also many other stakeholders along the nutrient recycling path and it is important to investigate how they view co-operation.

Source separation of human urine in the city of Gothenburg and the aim of the study

In Gothenburg, the second largest city in Sweden, there are currently four larger buildings with urine diverting systems installed, together producing some 300 cubic metres of urine-flushwater mixture per year. The city of Gothenburg wishes to create a co-operation with fertiliser consumers for recirculation of this and for an expected increased fraction in future. To achieve this, a feasibility study was initiated, performed as an MSc thesis at the Swedish University of Agricultural Sciences (SLU). The overall questions at issue were:

What are the possibilities and problems in finding an outlet in agriculture or other productive land; and

How can we solve the problems?

Problems and possibilities – views of different stakeholders

Literature studies and conversation with a great number of actors and scientists were performed to explore issues like urine as a plant nutrient; economic and technical aspects of the retrieval system; legal issues of importance; health- and environmental risks; and actor acceptance. Below follows a brief compilation of the information gained from some of the most important stakeholders.

Present and potential urine users in agriculture

Some of the farmers interviewed were interested in using human urine. This interest mainly arose from the need for fertiliser on the farm, the crops grown, the equipment available and the environmental awareness of the farmer. If suitable equipment was not available it could be hired from a contractor but large amounts of urine were required for this to be economically viable. There appeared to be a great need for readily available N fertiliser in organic farming, so if the use of human urine were approved within EU subsidised organic farming, the demand would increase. The international associations for organic farming (IFOAM) can permit human urine that on crops for human consumption, if the urine is sufficiently sanitised. Most farmers are demanding that the nutrient content be assured by analyses etc. Many are sceptical to that the fertilising effect will be as good as stated and potential participants wanted to test the product before agreeing to co-operation. One urine-using farmer questioned was considering stopping because of the poor nutrient concentration in the product when it reaches his farm. There was a fear of being sanctioned by consumers if confidence in urine were to be lost in the future. This has already happened to farmers fertilising with sewage sludge in 1999, when the mass media raised concerns about the presence of brominated flame-retardants in the sludge. End-users wanted a guarantee that this would not happen and were very interested in the position taken by branch organisations and consumers.

Potential uses in municipal parks and sports fields

It was shown that there is a certain need for fertilisers, which could theoretically be replaced by human urine on e.g. lawns and flowerbeds. Application of human urine by an injection technique in combination with soil spiking has been shown to work well on golf areas (compared to conventional spraying). This method should in principle also work on a park or football pitch but it was not known whether the injection equipment required was available. Acceptance issues are very important for all these areas. What would be the reaction of visitors and of grounds staff? Would there be an undesirable smell? A desire was expressed for much more information and for precise details of the urine composition. Staff and sports players would be exposed to the fertilised soil – is there a risk of infection in cuts etc.? Football attracts the mass media, so a massive information campaign would be needed to prevent scandal stories at a later date. If directives came from above and a good level of co-operation was established, most interviewees would be willing to test the system. Small-scale testing would be an accessible route. There is a pedagogic potential in using urine in parks and at the same time informing the public, provided negative effects can be eliminated. One park was discussing using urine in its compost instead of artificial urea.

The food industry, the Union of Swedish Farmers (LRF) and consumer organisations

Most of the large food and feed companies policies encourage recycling of plant nutrients from town to country. However, during questioning it became clear that the feed industry and the mills will not permit fertilisation with human urine until more tests are carried out on pharmaceutical residues and until there is quality assurance of the product. There is a fear of negative press coverage being associated with brand names. The general opinion was that the Government should devote more funding to this issue, as it is a social problem. The meat industry currently permits the use of human urine, as does the leading dairy in the area under certain circumstances. The target of the LRF is for the majority of all nutrients to be recycled from town to country within a generation. They permit both urine and blackwater but not sewage sludge. Leading food companies, national organisations for the environment and sewage and urban councils are working together within the ReVAQ project, which allows monitoring of e.g. heavy metals, organic poisons and salmonella in recycling. Consumer organisations are generally positive to source separated toilet waste as opposed to sludge.

Urban authorities and housing companies

In many areas there is a lack of procedures to ensure that urine separation systems are correctly installed in buildings and then maintained. This has led to nutrient losses in the form of ammonia, and to rain and soil water leaking in. It is the responsibility of the urban council to supervise when granting permits for such systems and to collect the urine. Today, there is in practice inadequate or non-existent supervision of such systems.

Recycling companies for organic waste

One company that had the business concept of recycling urine for urban councils claimed that the amounts recycled were far too small to create a financial incentive for recycling. A lot of money has been invested in conventional systems, which have been developed over 50 years. If urine separation is allowed an equally long period of development, it will probably function and be financially viable. Initial funding was often readily available, as politicians wanted to improve their environmental profile, but there was a perception that difficulties arose in transferring recycling to general practice while trying to cut costs. It is not good for society to go in and pay all the recycling costs because of the high degree of unreliability in the initial phase. It is often hard to withdraw this support at a later stage. It would be better to find a buyer who valued the nutrients. A computer system has been developed that allows traceability of every batch from the production source, to the storage sites, to the field on which it is applied and the time of application, to the crop grown etc.

Conclusions

There are users who are very positive to the use of human urine but one condition for this is that the quality of the urine as regards concentrations of plant nutrients and its freedom from harmful substances must be assured.

A well-functioning quality assurance system must be coordinated across the entire chain. Urban authorities bear the main responsibility for such coordination. The work in ReVAQ could perhaps act as an example.

The health and environmental risks of pharmaceutical residues have not been investigated. An analysis of the health and environmental risks of pharmaceutical residues in relation to recycling of human urine needs to be carried out.

The benefits of nutrient recirculation mainly belong to society as a whole and society should therefore support the development of these systems to the extent necessary. E.g. agreements regarding compensation for any losses suffered by individual farmers could be introduced.

Farmers and their customers within the food and feed industries are not very knowledgeable about human urine as a product and many believe the risks are as great as for sewage sludge. Since the general public has little information about the issues involved, press stories can have a great impact. We must provide extensive and accurate information to the market and change opinions. A public debate about the importance of recycling nutrients would be ideal. It might then transpire that the public will want us to await the results of testing for pharmaceutical residues, despite many believing that both the health and environmental risks in this regard are greater with the conventional waste systems of today.

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Complexity of basic needs and the role of ecological sanitation in the rural region of Lake Victoria, Tanzania

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Session B

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Basic needs, ecological sanitation, cybernetics, health and hygiene, education, infrastructure

Abstract

Living condition and standard in the rural region of Lake Victoria, Tanzania, is very poor compared to central Europe. Deficits in basic needs are obvious and development is slow due to a high population growth rate and difficult due to the complexity of basic needs. In this paper the interactions of basic needs and the role of ecological sanitation shall be described in a cybernetic approach. By this the technology of ecological sanitation is less described in particular, but the complexity of interactions which make the implementation of a technology successful or not, is discussed.

Introduction

During a more than ten-year partnership between a Tanzanian (Mwanza, Lake Victoria) and a German NGO (Lübeck) the basic needs in the rural region of Lake Victoria were investigated. Several visits of members of both NGO's took place in order to learn and understand living conditions in the different countries. However, rapprochement of both NGO's was slow due to the different sociological, cultural and technological background in the two countries. But both NGO's stated: The slower the cooperation was growing, the more stable development took place. On this background the complexity of basic needs and the role of ecological sanitation is discussed in the NGO's and reported in this paper.

Basic needs

The investigations of the paper's authors during the last 3 years were focussing on the basic needs in Tanzania, defined and roughly explained below. They are dominant regarding the development of rural areas by technical measures in order to improve living conditions in the villages and small towns in Tanzania. The interactions among these basic needs are very complex which makes a non-linear, cybernetic thinking in improving living conditions necessary. Each of the following basic needs is influencing all the others significantly; all measures of development have to be taken into account in parallel. The relevant basic needs, requirements on it and its state in Lake Victoria region can be very brief summarized as follows (Karrasch et al., 2002; Grottker, T., 1989):

<u>Health prevention</u> is very poor in the Lake Victoria region, since all 5 dominant infectious diseases as Malaria, Pneumonia, diarrhoea, tuberculosis and HIV were among the top 10 diseases in the investigated hospitals and dispensaries. Poor hygienic living condition, water supply, wastewater drainage / treatment, waste management as well as very little knowledge

about the interaction of hygiene and health are reasons for this state.

Medical treatment of diseases is fairly good in big cities like Mwanza, where many hospitals and dispensaries are located. In rural regions few dispensaries with little medical and pharmaceutically resources are available. Long walking-distances, treatment-fees and opening hours make the medical treatment very difficult. Basic medical service is required in each village.

Drinking water supply is mainly basing on shallow wells, which can fall dry during summer season and a few deep wells, which belong for example to private schools. Clean drinking water supply with more than 10 l/(P•d) and less than 2 hours to walk is required in every village.

Ecological sanitation could be easily implemented in the rural region, because in general no drainage and/or treatment system is in use. Safe wastewater collection and storm water drainage is necessary in order to dam infectious diseases and limit energy and material resources.

No waste management exists in rural villages. Since only few wastes are produced in rural regions, it looks uncritical. Nevertheless, consumer goods like batteries, electronic devices or chemicals might cause a high risk for the villagers. Organic material should be reused and inorganic or toxic wastes should be dumped at a “safe” location.

The nutritional conditions are specific to the topographic, climatic and agricultural conditions in the Lake Victoria region. Although the annual precipitation is about 1500 mm/a nutritional supply during dry seasons is sometimes very serious. Consequently starchy nutrients, which are resistant to long dry periods, are dominant in the nourishment. Diversity in agricultural production is required in order to sufficiently supply villagers with carbohydrates, proteins, vitamins and minerals. Further, conservation techniques are required, using a minimum of energy and material resources.

Housing conditions are adequate to rural village structures. Nevertheless infrastructure and hygiene is poor (see above/below), but most serious is the lack of mosquito nets, too little space in the houses and poor water / wastewater conditions, which increase the risk of infectious diseases.

Traffic system is typical to the east African communities. Villagers are walking on foot or riding by bike. Public (mini-) buses are available, but very expansive and in case of heavy illness or pregnancy people will often not be transported to hospital. Rural development is necessary to make people more independent of the traffic system.

Communication takes place at local markets and/or social meeting points. During dry seasons trade is far less than during rainy seasons. Consequently less communication and less information exchange is possible.

Electric power supply is available only along the main traffic roads. It is necessary for public (and private) services as medical services, water supply, sanitation and conservation of nutrients.

Firewood supply is necessary for cooking and preparation of hygienic drinking water if no water supply is available. In savannah around Lake Victoria some regions are seriously lacking in firewood. Reforestation is necessary immediately in order to protect from dramatically firewood shortage in the next decades.

The Tanzanian government offers basic school education. However, many families have no money for school fees and children have to work for the family income. This problem increases if parents died by HIV or other infectious diseases or inadequate medical services. The understanding of the interactions with all other basic needs increases step by step the longer children go to school. Because many children start primary school not before the age of 9 years, about 10% finish primary school (reach the 6th class) only.

Continuing education is offered by private (church) or public services. Mainly women take part in the education programmes, which are focussing on health prevention, hygiene and environmental problems. The role of women in Africa differs significantly from the role of European women. Development in technology has to take this requirement into account if education programmes are carried out in order to improve basic needs.

Complexity of interactions among basic needs and role of ecological sanitation

The complexity of interactions among basic needs is very high. The improvement of living conditions by changing only one or the other basic need will fail, except development takes place very slow. A more efficient and quick way to find a developed and stable system needs a cybernetic approach (introduced e.g. by Vester, 1990), which is carried out as follows.

In table 1 all thirteen basic needs mentioned above are listed on the x- and y-axis of the table. For each basic need the effect on every other basic need is evaluated and reverse. Each basic need is once observed in its active role and on the other hand in its reactive (passive) role. The evaluation is basing on the intensity but not on the kind of the interactions. Values from 0 to 3 are weighing this intensity.

Effects of ⇩ on ⇨		1	2	3	4	5	6	7	8	9	10	11	12	13	AS	Q	P
health prevention	1		3	2	3	3	2	1		2		1	2	3	22	76	638
medical treatment	2	3		2	2	2	3	1		2			3	3	21	78	567
drinking water supply	3	3	3		3		2	1		3		2	1	1	19	83	437
ecological sanitation	4	3	2	3		1	2	3					1		15	71	315
waste management	5	3	2	2	1		1	3	1			1	1	1	16	67	384
nutritional conditions	6	3	2			2				3			3	3	16	57	448
housing conditions	7	2	2	1	3	3	2		1	2			2	1	19	106	342
traffic system	8		3	2	1	3	3	1		3	2	2	1	1	22	440	110
communication	9	3	2	2	2	3	3	1	1			1	2	2	22	110	440
electric power supply	10	2	3	1	1		1	2		1			1		12	400	36
fire wood supply	11	1	1	2		1	3	2	1						11	100	121
basic school education	12	3	2	3	2	3	3	1		2		2		3	24	120	480
continuing education	13	3	2	3	3	3	3	2	1	2	1	2	3		28	156	504
	PS	29	27	23	21	24	28	18	5	20	3	11	20	18	247		

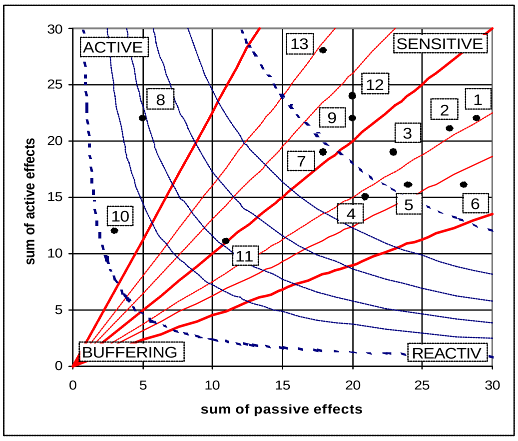
Table 1: Evaluation of interactions and their effects among basic needs and interpretation of the role of each basic need: Either active or reactive, either sensitive or buffering.
0 = no interaction, 1 = small interaction, 2 = medium interaction, 3 = high interaction
AS = sum of active effects, PS = sum of passive effects
Quotient Q = AS / PS x 100, Product P = AS x PS

The results of this evaluation are shown in figure 1 and can be interpreted as follows. Basic needs as *traffic system* (8) and *electric power supply* (10) are highly active on other basic needs, but on the other hand buffering, because their reactive role is marginal. They play a minor role in the development of living condition in the Lake Victoria region, as well as the *firewood supply* (11), which is neutral in both dimensions.

Living conditions in the region of Lake Victoria are very instable, because 8 of 13 basic needs are highly sensitive and two more are sensitive. They are effecting other basic needs as well as they are effected by them on a high to very high level. This graph make obvious, how serious development in this region is. A wrong, a too intensive or extensive, a too fast or slow development may cause dramatically changes in other basic needs and loss of living condition may be the consequence.

Development without the slightly active to neutral, but highly sensitive basic needs as *continuing education* (13) or *basic school education* (12) and *communication* (9) no stable living conditions are possible. *Housing conditions* (7) play a minor role, because they are neutral and less sensitive. On the other hand basic needs as *health prevention* (1), *medical treatment* (2) and *drinking water supply* (3) are highly sensitive but more or less neutral. *Ecological sanitation* (4), *waste management* (5) and *nutritional conditions* (6) are slightly reactive to reactive, but *ecological sanitation* (4) is less sensitive.

Interpretation and Conclusions



1. Health prevention
2. Medical treatment
3. Drinking water supply
4. Ecological sanitation
5. Waste management
6. Nutritional conditions
7. Housing conditions
8. Traffic system
9. Communication
10. Electric power supply
11. Firewood supply
12. Basic school education
13. Continuing education

Figure 1: Evaluation of interactions and their effects among basic needs and interpretation of the role of each basic need: Either active or reactive, either sensitive or buffering

The implementation of ecological sanitation technology is significantly improving living conditions in the Lake Victoria region, Tanzania. But no stability in living conditions can be reached if changes go too fast or interactions among basic needs are ignored. Consequently the following concept to improve living conditions by ecological sanitation systems is suggested.

<u>1. Preparation.</u> Ecological sanitation projects should be prepared by continuing education (adults/women), basic school education (children) and communication (markets/seminars/ meetings). Information exchange and education on the interactions among basic needs and between technology, environment and society with respect to ecological sanitation systems is necessary. Without education no success in the long term can be expected.

<u>2. Implementation of technology.</u> The implementation of ecological sanitation technology shall follow after specific education step by step. Interactions where either basic needs are highly or medium affected by ecological sanitation (No. 1,2,3,6,7 of table 1) or ecological sanitation is highly or medium affected by other basic needs (No. 1,2,3,7,9,12,13 of table 1) have to be observed carefully and control procedures have to carried out, if necessary. Sometimes other basic needs have to be improved in parallel (e.g. drinking water supply) to guarantee the systems functioning in the long term.

<u>3. Operation concept.</u> Stable operation of ecological sanitation systems is guaranteed only, if an operation concept is developed during step 1 and 2. Therefore operation committees have to be established by the community, mainly composed of the users of the system. Further, the continuing interaction between the different committees of the concerned basic needs has to be established.

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Preliminary survey based on community need leading to sustainable sanitation - an Indonesian case study

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Session B

Keywords

Community participation, preliminary survey, small-scale community technology, small-scale technology, sustainable sanitation.

Abstract

The preliminary survey based on local community need as a preparation of a project is essential in order to build 'sustainable sanitation' in the local community level. The 'Small-Scale Community Technology concept' that is produced by the survey, and the small-scale sustainable sanitation technology: the Ecomax, have been a significant part of the success of the Embong Brantas Project – the small-scale based sanitation technology project.

Introduction

Most community development projects have a strong social dimension that is critical to its success. It is a matter of fact that many community development projects including sanitation projects in Indonesia funded by World Bank and others have failed tragically due to ignoring social aspects in their project's preparation. As a result most people remain disposing of human waste directly into rivers and canals. Considering the importance of social dimension in community development projects, the Embong Brantas Project in the squatter area in Malang Municipality, East Java, Indonesia, as a small-scale community sanitation project, has carried out a preliminary survey before implementing its sanitation programs.

The preliminary survey

The survey was intended to answer questions such as: what were the expectations of the community?; how was the community prepared for the project?; how has the community been organized to manage the technology and does this work?; and how can it be improved from community perspective? The survey was conducted in Embong Brantas area, involving professionals from Malang Municipality, Surabaya (the capital city of East Java), and Jakarta (the capital city of Indonesia), in order to assess the attitude of the community towards the project proposal. The preliminary survey aims not only to stimulate and encourage the local community at Embong Brantas to be aware of the need of sustainable sanitation for their benefit towards healthy living, but also to design an integrated programme which is culturally acceptable, and to study how to approach the local community and how to effectively implement the project. Further, the survey is also used to unite local community will to fully participate in this project in order to create a sense of ownership. Moreover, the survey is an excellent opportunity to obtain information directly from all stakeholders who have ever been involved in the delivery of sanitation services in the past. Their inputs that have come from real experience would provide invaluable information to prepare and secure the sustainability of the project.

The survey's questionnaires

The questionnaires of the survey are as follows:

1. What is your occupation?
2. Have you heard about the Embong Brantas Project?
3. How important is it to clean up the Brantas River?
4. How important is it to have sewage treated? Why?
5. How important is it to have clean water supply in/near every house?
6. Sewerage can be done with a large pipe that takes it all away (at great cost) or it can be done with small pipes and managed locally.
   a. Is it important enough to do the treatment locally despite the extra work for local people?
   b. Is it an opportunity for local people to be more involved in their *Kampung*?
   c. Will there be resentment at having to help manage the treatment?
   d. Is it likely to be seen as second-best technology?
7. What kind of management system would be required to establish an effective local wastewater management system?
8. Would women be involved in this process?
9. What kind of problems do you envisage? Can they be managed?
10. In your opinion, does the local community need a 'public environmental education programme' (PEEP) before they begin to operate and maintaining the project? Is it 'essential' or just 'important'?
11. What is the best way of performing PEEP to the local community in the project?
12. What kind of education system would best be performed so that the local community has a sense of belonging to the project?
13. Who should deliver PEEP to the local community on the project?
14. Who should fund this PEEP?
15. Does the local community need 'technical training' for operation & maintenance of the project?
16. Who should give the 'technical training' for the local community involved in the project?
17. Who should fund this training programme?
18. Do you agree that *PKK* will have an important role in disseminating information on domestic wastewater disposal issues?
19. What is your opinion on the efforts of the head of *RT/RW* in encouraging the local community to maintain a healthy environment especially in domestic wastewater area?
20. How should 'CEMT' perform their role in order to achieve their goal?
21. How should 'CEMT' perform their role in order to be a good partner of the local government in improving the environment?
22. How should 'CEMT' perform their role in order to be a good partner of the local community in improving our environment?

Note/Abbreviation:

PEEP : Public Environmental Education Programme
PKK : *Pendidikan Kesejahteraan Keluarga* – Literally means: Family Welfare Education. PKK is women's association.
RT / RW : *Rukun Tetangga* (harmonious neighbourhood) / *Rukun Warga* (harmonious community).
CEMT : Centre for Environmental Management and Technology. Merdeka University, Malang, East Java, Indonesia.

The survey's respondents

The people interviewed who have had an experience in carrying out or being involved in sanitation projects previously are listed below, showing their occupation.

Ministry of Public Works, Directorate General Cipta Karya	: 4 respondents
The Jakarta Wastewater Management Enterprise (*P.D. PAL JAYA*)	: 2 respondents
Jakarta City and Environmental Planning	: 2 respondents
National Research Council	: 1 respondent
Provincial Government in Surabaya	: 4 respondents
Regional Planning Board in Malang	: 2 respondents
Environmental Agency	: 2 respondents
Department Public Works in Malang	: 3 respondents
Malang Water Supply Management Enterprise	: 1 respondent
The Sanitation & Waste Agency of Malang	: 2 respondent
The Public Health Agency of Malang	: 5 respondents
Jasa Tirta Public Corporation	: 1 respondent
Head of Blimbing Borough in Malang	: 1 respondent
Head of Precincts in Malang	: 4 respondents
The Institution of Family Welfare	: 4 respondents
NGO's	: 6 respondents

The survey's results

1. Although there is very little experience in small scale sewerage technology and domestic wastewater management, the government and community representatives can see immediately that it would be important to do this project.
2. Although there are competing priorities, people can see that the project will improve health, give a greater sense of human dignity, and improve the appearance of the area.
3. Cleaning up water is fundamental to people not only for health reasons but also for cultural and religious reasons.
4. The small scale technology approach has immediate appeal to everyone as it is seen to be a part of the community and it can help build the community.
5. To manage a small scale 'village' system' such as the one proposed should involve the community and the lowest level of the local government (*Kelurahan*/Precint), *i.e.* a 'bottom-up' management approach will work best.
6. Women should centrally be involved in this process as they are the most closely affected and can influence families.
7. The key problems envisaged are mostly to do with the maintenance of the technology.
8. A 'Public Environmental Education Programme' (PEEP) is needed before the project begins and should be conducted through the community organizations (*RT/RW and PKK*) by way of regular meetings and should be run by the local government and Centre for Environmental Management and Technology (CEMT). Funding for this program should come from a combination of the government, CEMT and the community.
9. Technical training for operating and maintaining the system will be required and needs to be conducted by CEMT (with the local government's help); and funds for this should be from the government, CEMT and the community.
10. The involvement of CEMT with the government and the community provides many opportunities for developing a model project.

The survey's results are then analysed to produce an innovative 'sanitation development concept' that contains social, environmental and economic aspects of sustainable development principles which is called 'small scale community technology' (**SSCT**). Socially, the SSCT fits with the traditional Indonesian community principle of *'Gotong Royong'* and enables the local community to own and manage the technology by themselves. Environmentally, the SSCT will treat domestic wastewater more effectively and has more potential for water reuse. Economically, the SSCT will be cost-effective because, unlike large-systems, small-scale systems require proportionally smaller on-going maintenance budgets. Moreover, the SSCT will not cause major disruption to the densely populated cities. The large saving is very important for developing countries like Indonesia where funds are scarce and tend to be used to meet priority needs. SSCT is a system designed to help develop 'small-scale technology' and build 'community participation.

The Ecomax technology – small-scale technology

AusAID/Australian Aid, through the Pollution Control Implementation (PCI) project, funded a small-scale Australian technology – Ecomax – for testing the benefits of small-scale technology in the Indonesian context. Ecomax is an innovative, high-performance sewage treatment system developed in Western Australia. A typical household system is generally positioned adjacent to the house and grassed over to blend into the garden landscape and requires about 100 square meters of leaching space. The system has the following notable features: very high phosphorus and nitrogen removal, high removal of BOD and suspended solids, disinfection without chemical addition, heavy metal removal, gravity driven process, very long life, negligible maintenance, and there is no moving parts (Bowman, 1997). The technology is able to reach the 20:30 BOD:SS requirements set by PCI. More importantly, it is small enough to fit in to a site in the community and it is not too complex for the local community to manage.

Conclusion

The preliminary survey based on community need that has produced 'Small-scale community technology' system has shown that the delivery of sustainability is always going to involve technical and social dimensions. The fact that sustainability is not being delivered is not because of the lack of the technical innovation but the lack of social innovation.

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Rural sanitation in Ghana

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Introduction

Rural water and sanitation in Ghana is considered and seen as a social issue and not merely a technical or financial one. Sanitation, in general has always been an afterthought in past water and sanitation programmes in Ghana until the launch of the country's Community Water and Sanitation Programme (CWSP) in 1994 when situation reversed. Sanitation programmes in the country could be described as ambitious since they involve fundamental behavioural and attitudinal changes at the household level.

The decade of 1970-80 may be described as the lost decade for sanitation in Ghana since there was no mention of sanitation in water and sanitation programmes. In the ensuing decade of 1980-90, water and sanitation projects were considered but not seriously and this decade may be described as the decade of awareness to start recognizing sanitation in its own right within water and sanitation programmes. The national communal Ventilated Improved Pit (VIP) latrines programme implemented from 1980 to1987 on the initiatives of the Ministry of Local Government and Rural Development was unsustainable due to constraints in funding. Except for a UNDP assisted project in two regions (Volta and Central) of the country in 1984-87 and a project implemented under a Programme of Actions to Mitigate the Social Cost of Adjustment (PAMSCAD) which made the building of five (5) demonstration latrines for each hand dug well provided in a community, sanitation programmes in rural Ghana in the past was almost nonexistent. Most water and sanitation projects in the past considered and assumed that sanitation is part of hygiene education on water component.

The situation changed considerably in the early part of 1990. Local experiences and lessons from re-designed UNDP pilot water and sanitation projects in two regions (Volta and Eastern) and successful sanitation programmes from other parts of the world paved the way for what is today the rural sanitation of Ghana. In deed, the national community water and sanitation policy and strategy for sanitation promotion was formulated in 1994.

National community water and sanitation programme

The Community Water and Sanitation Agency (CWSA) was established by an act of Parliament in December 1998 as Act 564. This Agency is mandated to be responsible for the coordination and management of the country's rural water and sanitation programme. The objectives, policies and strategies of the CWSP have been defined through a long process of dialogue between government, funding agencies, service providers and users and other stakeholder representatives.

The vision of the CWSA is the development of capacity in District Assemblies to be able to plan and facilitate water and sanitation services using the private sector and community management groups to ensure sustainability of facilities. This requires the transfer of high quality skills to District Assembly staff, community management group members, associations and private sector firms.

It is envisaged that by the creation of this capacity, it will become possible to achieve the provision of sustainable community water and household sanitation facilities in 83% of communities and small towns by year 2008 and in all communities and small towns in the country by year 2020.

The mission of CWSA is to manage Ghana's Community Water and Sanitation Program (CWSP) for accelerated and equitable delivery of potable water and sanitation facilities as well as promote hygiene education benefits to rural communities and small towns in Ghana.

The objectives of the CWSP are summarized as:

- Provide the basic water and sanitation services to communities that will contribute towards the capital cost and pay the normal operations, maintenance and repair costs of their facilities;
- Ensure sustainability of these facilities through community ownership and management, community decision-making in their design and active involvement of women at all stages of individual projects;
- Promote efficient, cost effective and sustainable delivery of improved water supply and sanitation facilities through private sector promotion and support;
- Maximize health benefits by integrating water, sanitation and hygiene education interventions, including the establishment of hygiene education and latrine construction capabilities at village level.

The strategy of the rural water and sanitation launched in 1994, assigns to the public sector, the role of facilitation and the private sector the role of implementation. District Assemblies are the centres for the application of the strategy whilst Community Water and Sanitation Agency (CWSA) offers technical assistance and overall monitoring of the strategy. The strategy for rural water and sanitation delivery has changed from the former supply driven approach to a demand driven approach with emphasis on sustainability.

The strategies of the programme include the following key elements:

- Demand responsive approach to delivery of facilities;
- Public sector facilitation, with CWSP as the lead government agency;
- Private sector provision of goods and services;
- Community ownership and management;
- Integration of hygiene education with the provision of water and sanitation facilities;
- Gender mainstreaming at all levels of sector activities.

Demand responsive approach to delivery of facilities

The national strategy stipulates that development interventions are directed at communities that actually desire to own and manage the water and sanitation facilities. Experience has shown that supply driven approach to water delivery has not ensured sustainability of the systems, which were put in place. Consequently, the demand responsive approach is being applied with the implementation of the strategy. However, the strategy also provides some degree of flexibility to enable the CWSA address or respond to emergency situations.

Public sector facilitation

The strategy provides for the public sector institutions to create the enabling environment for the private sector and other stakeholders to operate. The CWSA is expected also to ensure capacity building for key sector players, especially the District Assemblies by providing technical assistance and specialist support in the implementation of NCWSP. Furthermore, CWSA ensures equity and widespread coverage of safe water and improved sanitation facilities through subsidies.

Private sector provision of goods and services

In line with Ghana's development goal of using the private sector as the engine of growth, private sector institutions are to provide goods and services required for the effective implementation of the NCWSP. Direct and actual implementation activities are contracted to private sector or NGO organizations to carry out.

Community ownership and management

It has been observed that sustainability of facilities is higher where communities perceive the facilities to be their own. Hence, ownership and management of the water and sanitation facilities are key elements in the national strategy. The community ownership element of the strategy is facilitated and rationalized by requesting the communities to contribute towards the capital cost of construction of the facilities.

Integration of Hygiene Education with the Provision of Water and Sanitation Facilities

The intended health benefits from the provision of the water and sanitation facilities can only be realised through the integration of hygiene education into all rural community water and sanitation projects. The hygiene education is of importance in ensuring the acquisition of knowledge and skills in the proper use and maintenance of water and sanitation facilities. The promotion of hygiene education creates the necessary awareness and change in attitudes and behaviours at the levels of individual, household and community towards the use of water and sanitation facilities.

Gender mainstreaming at all levels of sector activities

The national community water and sanitation strategy advocates awareness creation of the roles of men and women with respect to the delivery of water and sanitation facilities. It is believed that such measures enhance the sustainability of the facilities, especially as women are more affected by the availability and non-availability of water and sanitation services.

Status of implementation of community water and sanitation programme

Region	**Population**			**Communities**	**Rural Households with Sanitation Facility**	**Sanitation Coverage %**
	Total	**Rural**	**Urban**			
Ashanti	3,187,601	2,273,953	913,648	2,387	23230	8.16
B. Ahafo	1,824,822	1,665,821	159,001	2,435	32,870	15.76
Central	1,580,047	1,475,783	104,264	2,586	74,430	40.32
Eastern	2,108,852	1,440,155	668,697	3,972	26,500	14.72
G. Accra	2,909,643	393,244	2,516,399	714	-	0.00
Northern	1,854,994	1,602,028	252,966	3,727	7,000	3.52
U. East	917,251	870,394	46,875	2,165	-	0.00
U. West	642,223	575,579	66,644	1,018	-	0.00
Volta	1,612,299	1,302,093	310,206	2,643	39,040	24.00
Western	1,842,878	1,550,169	292,709	1,815	8,410	4.32
TOTAL	18,480,610	13,149,219	5,331,391	23,462	211,480	12.87

Source: Community Water and Sanitation Agency, Coverage data on potable water and sanitation facilities in rural communities and small towns in Ghana, December 2001. A household sanitation facility serves 8 people.

Table 1: Distribution and percentage coverage of household latrines provided under CWSP

The limitation of the data in Table 1 is that the sanitation component of the CWSP was implemented mainly on pilot basis and was geared towards sensitizing households to use

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latrines. This accounts for the low count of sanitation facilities.

However, there exist sanitation facilities, which were provided by other agencies but the data on the coverage of sanitation facilities by these other agencies are not immediately available. Therefore, the data shown in the table represent only households served with sanitation facilities by the support of Community Water and Sanitation Agency. The water and sanitation sector assessment carried out in the African Region revealed that the overall rural sanitation coverage status for Ghana in 1999 was 64% (WHO, 2000)

At the community level, the involvement of the private sector in the provision of sanitation facilities has mainly been through project-trained latrine artisans. The community-based artisans have been trained in the construction of various types of improved sanitation facilities suitable and affordable to rural communities. The trained artisans are then relied upon to construct new sanitation facilities for consumers on demand, some with project assistance.

The use of locally trained artisans as providers of sanitation facilities has been quite successful in the promotion of sustainable sanitation (Doku, 1996). Communities have resident artisans who are well trained in the construction of various types of Ventilated Improved Pit (VIP) latrines and some are promoting latrine construction through direct marketing. Latrines are now being built in some communities without project subsidies and once this catches up, the country is bound to attain the primary goal of sustainability.

Key-lessons

- The prevailing poverty in the rural areas and the low priority consideration of sanitation does not encourage household ownership of latrines;
- Any low-cost sanitation project that did not promote a technically, socially acceptable or generally affordable sanitation facilities, was likely to fail;
- Low cost intervention for provision of latrines is difficult to implement in unstable soils;
- User education related to cleanliness, disposal of cleansing materials and use of latrine by all members of the family including children needs to be intensified;
- The private sector lacks the entrepreneurial skills, marketing techniques and the promotional tools to be able to sell their product to potential consumers;
- Too much emphasis on the promotion of household latrines with the total neglect of communal facilities even in areas where they are more feasible.

The way forward

Constraints such as difficult ground conditions, high groundwater table, limited availability of space due to dense settlement patterns and high poverty levels in the rural areas point to the fact that Ecological Sanitation (Ecosan) latrines will be a better option and must be promoted in Ghana. There should be adequate experimentation and pilot studies for the selection of options of Ecosan latrines for the communities in Ghana.

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Rural and peri – urban case studies

Chairpersons

Grietje Zeeman (Wageningen University, The Netherlands)

Paul Calvert (EcoSolutions, India)

Håkan Jönsson (Swedish University of Agricultural Sciences, Sweden)

Rose Kaggwa (National Water and Sewerage Cooperation, Uganda)

Lectures

Acceptance of ecosan concepts in Tanzania - a case study of "piloting ecological sanitation Majumbasita Dar Es Salaam" *
Alfred J. Shayo (EEPCO, Tanzania)

National strategy to promote ecological sanitation in Uganda
Austin Tushabe (Ministry of Lands, Uganda)*, Elke Müllegger, Andreas Knapp*

An effective dry sanitation system - the Enviro Loo
Brian La Trobe, Gavin La Trobe (Enviro Options (Pty) Ltd., South Africa)

Nutrient utilization by urine separation - experience from the Lambertsmühle project*
Martin Oldenburg (Otterwasser GmbH, Germany)*, Jutta Niederste-Hollenberg, Andreas Bastian, Gitta Schirmer*

Ecosan in past and present effort in Nepal
Nawal Kishor Mishra (Department of Water Supply and Sewerage, Nepal)

Holistic ecosan small-town planning: the TepozEco pilot program
Ron Sawyer, Anne Delmaire (Sarar Transformación SC, Mexico)*, Andrés A. Buenfil*

Ecosan: an unsuccessful sanitation scheme at a rural school: lessons learnt from the project failure
Aussie Austin (CSIR Building and Construction Technology, South Africa)

Longitudinal study of double vault urine diverting toilets and solar toilets in El Salvador*
Christine L. Moe, Ricardo Izurieta (Rollins School of Public Health of Emory University, USA)

Skaneateles lake watershed composting toilet project
Richard Abbott (Department of Water, City of Syracuse, USA)

Experiences in setting up ecosan toilets in shoreline settlements in Uganda
Rose Kaggwa (National Water and Sewerage Corporation, Uganda)*, Sonko Kiwanuka, Tom Okurut Okia, Farouk Bagambe, Chris Kanyesigye*

Results in the use and practise of composting toilets in multi-story houses in Bielefeld and Rostock, Germany
Wolfgang Berger (Berger Biotechnik GmbH, Germany)

Bringing ecosan to South Asia
Paul Calvert (EcoSolutions, India)

This paper has been peer reviewed by the symposium scientific committee

Oral poster presentations

Community led sanitation blocks systems in Kenya
David Kuria (Intermediate Technology Development Group, Kenya)

Economical and ecological benefits of decentralised, small-scale human excreta management system in Nepal
Govind R. Pokharel (University of Flensburg, Germany)*, Deepak R. Gajurel*

Eco-toilet: a sustainable approach of sanitation in the lowland eco region of Nepal
Krishna Mani Lamichhane (Department of Water Supply & Sewerage, Nepal)

Owner-built composting toilets in Lismore, Australia: meeting the needs of users and regulators
Sam Walker, Leigh Davison (Southern Cross University, Australia) *

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Poster presentations

Waste separation and composting at the household level: peri-urban interface, Kumasi, Ghana
Andrew Bradford, Duncan McGregor, David Simon (Centre for Developing Areas Research, University of London, UK)*, Korsi Ashong*

Water development and sanitation improvement activates development
James Mwami (Busoga Trust, Uganda)

The SUSSAN project: strategies towards sustainable sanitation - presentation of an Austrian applied research project
Markus Starkl, Raimund Haberl (University of Natural Resources and Applied Life Sciences, Austria)

The integrated water management system at the "Kulturfabrik Mittelherwigsdorf"
Annekathrin Kluttig, Gernot Kayser, Gerlinde Liepelt, Heike Heidenreich (Germany)

This paper has been peer reviewed by the Symposium Scientific Committee

Acceptance of ecosan concepts in Tanzania - a case study of "piloting ecological sanitation Majumbasita Dar Es Salaam"*

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Keywords

Household, groundwater pollution, urine diversion, unplanned settlements

Abstract

Piloting Ecological Sanitation at Majumbasita Dar Es Salaam Tanzania particularly aimed to adapt Ecological Sanitation (EcoSan) as an option in combating sanitation problems in the country by recovering and recycling to the maximum extent the resources present in human excreta. EcoSan technology has drawn attention to many Majumbasita dwellers, international organizations, government line ministries, individuals and other stakeholders following construction of 95 EcoSan Latrine units in household level and 6 stances School latrine in the project area. Two types of urine diversion toilets have been applied, the seat pan and squatting pan, the later being more preferred to the community.

This paper provides insights and lessons learned from a piloting ecological sanitation project in Tanzania since November 2000. It includes findings of review as conducted to assess the operation and socio cultural pertaining the technology. It shows to what extent the EcoSan is accepted in Tanzania. In addition, the paper explored community reactions towards the recycle of nutrients from human excreta and research on the recyclable nutrients. Public acceptability is promising following the PHAST (Participatory Hygiene and Sanitation Transformation) methodology carried out at all stages of project implementation.

Introduction

Unplanned settlements have kept increasing in many Tanzanian towns, and there is no immediate plan to improve them. The problems of diarrhea and other faecal – related diseases remain highly endemic despite enormous efforts over the past few decades to control them. The situation is even worse than sanitation coverage statistics depicts. Coverage of sanitation facilities in Dar es Salaam (with 2,497,940 million inhabitants, which is 7.2% of the total National population) revealed that 79% of the inhabitant's uses pit latrines, 9% septic tanks and 12% uses conventional system Mato (2002).

Although a bigger number of people have access to some form of latrine, vast amounts of improperly managed faeces and untreated sewage contaminate the living environment. According to Haskoning and M Consult (1998) 50% of the pollution produced at domestic level per capita per day in Dar es Salaam was estimated to be received by pit latrines that have a pollution load to groundwater in kg/day estimated to be Biological Oxygen Demand (BOD_5) 15,282; Chemical Oxygen Demand (COD) 16,131; Suspended Solids (SS) 6,116; Dissolved Solids (DS) 97,857; Total Nitrogen 4,829 and total Potassium 915. The groundwater finally is a

*This paper has been peer reviewed by the symposium scientific committee

source of water supply for domestic and industrial uses. The water users may suffer the consequences from the pollution.

Conventional forms of centralized and individual sanitation systems are not sustainable solution to sanitation problems in the country. In Dar Es Salaam City domestic sewage is collected by a sewerage system that was first constructed in the 1950's. The system serves only about 12% of the residents. The major part of the Dar es Salaam residents about 88% use on-site sanitation allowing its effluent to percolate into the soil representing a potential source of groundwater contamination, which is an alternative source of water supply for the residents. According to Mato (2002) Piped water system in Dar es Salaam supplies only about 50% of the demand and groundwater is the alternative source. The groundwater is used to augment piped supply and more than 36 deep boreholes drilled in the city are directly (without treatment) connected to the main water system. In addition, residents in the city dugs and drills shallow and deep wells respectively to supplement the water supply in their respective residences.

Environmental Engineering and Pollution Control Organization (EEPCO) a Tanzanian Non Governmental organization recognized an urgent need to look for human excreta disposal option in the country that will protect the environment.

EEPCO supported by UNICEF Tanzania pioneered and implemented a piloting project for ecological sanitation at Majumbasita Peri-urban area in Tanzania since November 2000.

Ecological Sanitation is a system that makes use of human waste and turns it into something useful and valuable, with minimum pollution of the Environment. In essence it consists of using latrines, which are safe and ecologically sound and designed in such a way the end products can be easily transferred into agriculture or forestry (Morgan, 1999).

Pilot area

The piloting Ecological Sanitation Project in Tanzania have been implemented by EEPCO in unplanned settlements at the Peri-urban part of Dar Es Salaam called Majumbasita in Kipawa ward in Ilala District. 23,000 people inhabit the area.

The piped water supply from the city network suppliers only a small proportion of the inhabitants, and the supply is intermittent. Many people (85%). depend on well water. The quality of the well water is doubtful. According to Chaggu and John (2002), E-Coli count for samples from boreholes with depths 1.8metres and 6.5metres were 3000 FC/100mil and 178FC/100mil respectively. The pollution is definitely due to seepage from pit latrines and septic tanks. These conditions have resulted into breakout of cholera and other faecal related diseases mostly during rain seasons.

Sanitation prospects

- The communities in the project area keep their home environment clean, use water for anal cleansing and use the latrines.
- Latrine coverage in the area is high. However, most of the latrines are traditional pit latrines lacking privacy, door, and roof, and characterized with poor dirty squatting slabs. In addition are characterized with high water table, worst during rain seasons.
- Latrines are dug mostly shallow, because of: high water table and sandy/collapsible soil. The pits are mostly lined by sand: cement blocks.
- The community uses ground water/well water as a reliable source of water supply in the area.

Community reactions [1]

- EcoSan concept has attracted many people. This is because, they found it to have positive elements for their living environment, and people proved it to be permanent latrine by having a durable vault and a standby one (being a double vault is an added advantage to the users) for use when the fist one is full.
- The community welcomed the EcoSan as a solution to latrines construction in their premises because of permanency, simplicity, durable, affordable, environmentally friendly and hygienically safe relative to traditional normal pit latrine.
- Reuse of nutrients was also a positive element of the facilities.

Project activities

Main activities inputs to the piloting project include, community awareness creation and sensitization regarding sanitation improvement and introduction of EcoSan concept. This was achieved mostly by using Participatory Hygiene and Sanitation Transformation (PHAST) methodology. Another activity was recruitment of local masons to be well acquainted with theoretical and practical aspects of EcoSan latrine technology, so that they will be resource persons in the community to sustain the project. Construction of EcoSan latrines was another major activity where by 95 units (double vault, urine diversion) were constructed in household (hh) level and 6 stances in school. Monitoring and evaluation is the other major and important activity in this project to measure project acceptability and sustainability.

To accomplish the activities some stakeholders were involved from the start of the project including the implementing agency (IA) EEPCO, UNICEF, local governments, community etc. Main activities of the project, and achievements are discussed in the following sections.

PHAST training for CORPs (Community Owned Resource personnel)

PHAST is one of the best working Participatory approach methodologies to address water, sanitation, hygiene, behavior and attitude change (PHAST training guidelines, 1998). The hygiene and sanitation promotion processes focuses on the linkages between water, sanitation, hygiene and health in the areas of personal hygiene and its related water uses; safe and unsafe water; waterborne and excreta related diseases; environmental cleanliness; food handling and storage; specific behaviors such as hand washing practices; and latrine use and maintenance.

The project IA recognized the importance of applying PHAST methodology in implementing the project. To make sure the PHAST methodology is equipped to the community in a sustainable manner, some members of the community were trained to be PHAST CORPs in their area; and expected to train other people in the area. National PHAST trainers for a period of 10 days trained 22 PHAST CORPs equipping them with capacity to impart PHAST knowledge to other inhabitants in the area. Furthermore, the CORPs had one month in job training supervised by national PHAST Trainers. The PHAST CORPs has formed a community group aiming in facilitating community PHAST meetings in the area.

Training of masons/artisans

During the training the exercise of recruiting and imparting EcoSan concepts to local masons was successfully done.12 masons have acquired EcoSan technical skills, and participate in

[1] These reactions of communities were collected during PHAST facilitation in community level. They are important towards the successes of the lessons learned because it will help in spreading the technology to reach and benefit more people quicker.

building the mentioned 95 EcoSan units in hh level and 6 stances in school. Methods used were lectures and lot of practices.

EcoSan construction activities

Construction activities for the 95hh units were carried out successfully and in time. Generally the community acceptability of the project, their contribution and commitment in the construction activities was high and encouraging. This is due to the learnt positive benefits of EcoSan toilet including conserving the environment and water.

Construction materials

The design criteria for selecting construction materials for EcoSan were suggested which takes into consideration the following: - Locally available, easily applied, Affordable and durable.

With these in mind it was suggested that sand: cement blocks to be used in building the substructure. For superstructure the following materials were suggested to be appropriate for making the walls: sand: cement blocks, new or used/old iron sheets/tins, timber, thatch etc depending on what the household can afford, and provide privacy for the latrine users. For roofing, new or used/old iron sheets/tins and thatch were suggested. Timber, new or used/old iron sheets/tins and thatch were suggested for making a latrine door (figure 1.).

Masonry **Thatch** **Used/old iron sheets**

Figure 1: EcoSan latrines - superstructures by different construction materials – Majumbasita DSM. (Photos by EEPCO 2002)

Estimate cost for EcoSan latrine

Constructions of EcoSan latrines in hh level were done in cost sharing between project and hh as indicated in the table below.

Item	Project contribution US$	HH/community contribution US$	Total US$
All materials for Substructure	80		80
Skilled Labor costs for substructure	12		12
Casual Labor costs for substructure		3	3
Construction site and water		Not valued	
Materials for Superstructure- walls and door		Variable. Maximum[2] 70	70
Roofing materials	15		15
Vent pipe	6		6
All Labor costs for superstructure		15	15
Total	113	88	201
Percentage %	56.2	43.8	100

Table 1: Cost for one unit double vault HH EcoSan latrine

EcoSan Pans - types and user's choices [3]

A Survey conducted in the 43 households with EcoSan latrines 19(44.2%) prefers seating pan (figure 2b.) in their toilet and 24(55.8%) prefer squatting pan (figure 2a.).

Among 95 households using EcoSan latrines 34 (35.8%) have seating EcoSan pans while 61(64.2%) has squatting EcoSan pans. Choices by families reveal that more people in the project area prefer squatting pans than seating ones.

Figure 2a: EcoSan latrine installed with squatting pan (EEPCO 2002)

Figure 2b: EcoSan latrine installed with seating pan (EEPCO 2002)

Ecological gardens

Study gardens have been established at Karakata primary school field and at individual households for trial purposes of recycling nutrients from EcoSan latrines. The plants in the gardens include eggplants, banana trees, cassava plants etc. For comparison purposes the gardens have been divided into two similar portions. Urine was applied to only one portion to

[2] Costs for superstructure varies depending on the materials used for construction. The maximum cost in the project area is where sand: cement blocks were used for superstructure construction.

[3] EcoSan Pans are locally prefabricated using sand and cement for seating pan and aggregate for squatting pan, to be installed in EcoSan latrines.

determine the efficiency of urine as a fertilizer.

Ecosan toilets - users practice

The project management assisted by community PHAST group has carried a survey to the first constructed EcoSan latrines in 44 households in the project area. The survey took place between 27 November 2001 and 30 November 2001, to study users practice and behaviour change among EcoSan latrine users and find some problems encountered in using the latrines. Below are the results and discussions.

	HH with EcoSan latrine surveyed	Latrines in use	Latrines not in use[4]	Latrines used in very good practice	Latrines used in good practice	Latrines used in poor/bad practice
No	44	28	16	18	9	1
%	100	63.6	36.4	64.3	32.1	3.6

Table 2: HH survey results for EcoSan latrine - users practice (source: EEPCO final report for pilot project 2002)

Among the 28 hh using EcoSan latrines 21 hh (75%) said there is no problems in using the latrine. The remaining 9 hh (25%) has reported some problems such as smell, difficulty in urine separation, dislike of seating pan (especially houses with many user including tenants) and difficulties in washing seating pan. The project management with the users has solved the problems through participatory leaning and experiences from earliest users.

It was evident from experience that after people have become familiar with these systems, no flies or smells occur, and others opt to install them inside or adjacent their homes, and most of their initial reservations have gone. As a result, the number of EcoSan latrine users increases, and many has left their old pit latrine, and many have started reusing urine in gardens/plants as soil conditioner. (Charts below)

Table below illustrate the number and percentage of EcoSan latrine users reusing urine in gardens/plants.

	HH with EcoSan latrine surveyed	Latrines in use	Latrines not in use	HH using urine in gardens/plants	HH not using urine in gardens/plants
No	44	28	16	13	15
%	100	63.6	36.4	46.4	53.6

Table 3: HH survey results - urine use in gardens/plants (source: EEPCO final report for pilot project 2002)

Figure 4 reveals 76% of the total residents in the hhs with EcoSan latrines has left their old latrines, and start using EcoSan latrine. The number of EcoSan latrine users in the hhs increases with time, depending on the experiences and knowledge given to the hhs occupants by the project management and earliest users.

[4] Latrines that are not in use were still under construction in the time of the survey.

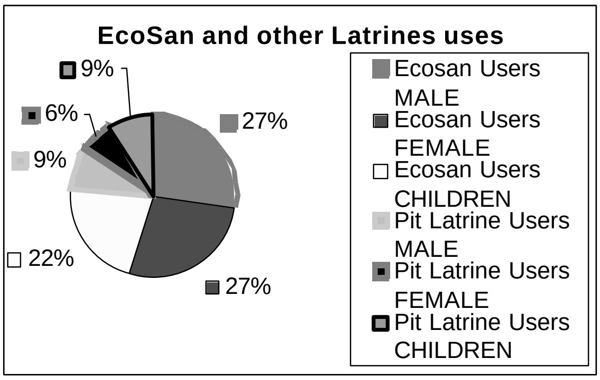

Figure 4: EcoSan and other latrines usage

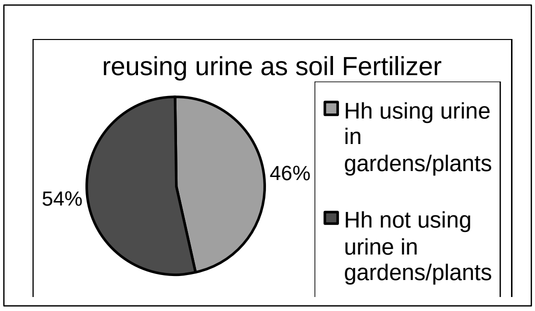

Figure 5: Using urine as soil fertilizer

Figure 5 Shows that 46% of hhs using EcoSan latrine has ongoing reusing urine as a soluble fertilizer in their gardens/plants, and the number is increasing with time depending on the experiences and knowledge given to the hhs occupants by the project management and earliest users.

Research & laboratory analyses [5]

A research that included Laboratory analyses and field-testing of urine and dry sludge were carried in the department of Civil Engineering department, Water Section in the University of Dar Es Salaam. Analyses were supposed to be done in both urine and faeces for nutrient levels faecal pollution and heavy metal contents. The main reason being to observe that the excreta had or had no any nutrient to support plant life as fertilizer or soil conditioner and to check the level of contamination by both faecal and/or heavy metals.

Due to time and resources constraints only few Solid Faeces samples were taken on 4th December 2001 for analysis to obtain baseline data that will be compared with the data to be obtained from Sanitized faecal matter, to be analyzed when the latrines are filled and covered to allow complete sanitized. In addition analysis for heavy metals was dropped.

Enough urine samples were taken and analyzed from 4th December 2001 to 26th February 2002. The summary of results is given n the table below.

[5] Research was very important to determine levels of nutrients in both urine and sanitize d faecal matter.

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Sampling pt	pH	COD (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TKN[6] (mg/L)	Phos-phorus (mg/L)	Potassium (mg/L)	Faecal Coliform (No/100 ml)	Total Coliform (No/100 ml)
1	8.8	3850	2060	180.5	7.04	616	6.72	173.4	70	180
2	8.76	3620	1980	141	9.12	319.2	5.14	71.6	60	150
3	8.88	3300	1660	165.8	5.42	442.4	10.93	85.6	90	210
4	8.85	3580	1950	170.4	8.53	302.5	10.54	167.3	70	180
5	8.82	3560	1900	168.2	5.4	285.6	7.03	49.5	60	170
6	8.9	3780	2010	195	10.12	518	15.74	54	80	140
7	8.47	3300	3300	160.4	5.26	228.5	6.82	180.2	60	140
8	8.78	3520	3520	175	7.44	320.1	3.24	65.8	60	130
9	8.8	3450	3450	170.5	6.35	298.2	3.67	78.5	80	180
10	8.66	3380	3380	186.2	6.24	314.5	9.12	143.6	70	160
11	8.84	3420	3420	165.8	5.46	298.6	8.54	98.2	90	200
12	8.74	3550	3550	186.5	6.93	386.2	10.22	63.4	70	190
13	9	4200	2400	125.6	4.75	596.4	24.5	330.8	60	160
14	9.23	5350	2680	208.5	26.815	1760	75.65	176.5	70	180
15	9.2	4830	1960	185.2	11.44	1366	47.8	184.3	40	120
16	8.52	3680	2100	190.4	13.1	967	28.4	104.6	20	100
17	8.98	5600	2900	235.3	26.25	1580.6	92.3	392.8	190	340
18	9,02	4950	2460	195.8	10.56	1220.2	67.5	204.4	130	310
19	9.05	3860	1350	148.3	9.76	783.7	52.9	192.5	170	370
20	8.93	4800	2160	180.5	15.62	1670.5	70.3	187.9	110	350
21	8.88	4500	1990	173.9	11.18	982.1	85.6	195.2	150	390
22	9,21	4150	2080	210.5	16.43	976.5	69.7	148.9	170	390

Table 4: Table of results for urine samples (Source: EEPCO & University of Dar es Salaam research report 2002) [7]

Faecal & total coliform levels in urine

Research results revealed that, the urine samples contained a few number of faecal coliform and total coliforms. The microorganisms' definitely originates from faecal matter, and is caused by the latrine users unexpectedly. However, the highest number of faecal coliforms found in one sample was 190 No/100ml is allowable for irrigation when compared to receiving water standards category 3 (maximum permissible concentration is 250 No/100ml). However, effort is required to prevent any possible ways, which allows the microorganisms to emerge and contaminate the urine. There is need of continued advocacy to assist the users on how to use the latrines better for improved health. In addition further research is require to see improvements in controlling the cross contamination.

[6] TNK = Total Kjeldahl Nitrogen (Sum of Organic Nitrogen and Ammonium and Ammonia Nitrogen). Total Nitrogen (TN) = TKN +Nitrite (N)+Nitrate (N)

[7] Source: Joint research report between EEPCO and University of Dar Es Salaam

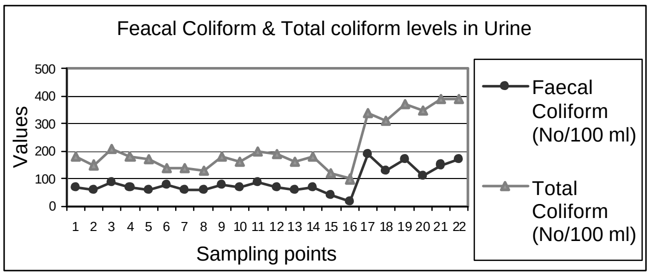

Figure 6: Faecal Coliform & Total Coliform levels in urine

NPK values

According to Johnson (2002), 25-50 kg of faeces is produced per person per year; which contain up to 0.55 kg of Nitrogen, 0.18 kg of Phosphorus and 0.37 kg of Potassium. Furthermore, an adult may produce ~400 liters of urine per year containing 4.0 kg of nitrogen, 0.4 kg of phosphorus and 0.9 kg of potassium. Taking these figures into consideration, it means that, in Majumbasita per annum, they will produce 550 x 10^3 - 1100 x 10^3 kg of faeces with 88 x 10^3 kg of N, 8.8 x 10^3 kg of phosphorus and 19.8 x 10^3 kg of potassium. Comparing to the data obtained it is suggested that there is a great potential in "human waste".

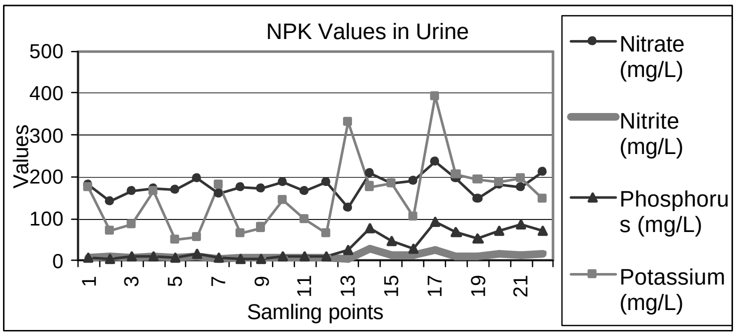

Figure 7: NPK Values in urine[8]

Future plan

EEPCO is aiming to spread of the technology in Tanzania. Initially, EEPCO in its action plan has included EcoSan promotion activities in Tanzania including: Follow up activity for the piloting project in Majumbasita Dar Es Salaam, promotion in schools, Organize National Workshop on Ecological Sanitation, Continuation of research on urine and sanitized faecal matter and promotion activities Mara region, Mwanza City (lake zone) and Hai District in Kilimanjaro region.

[8] NPK = Nitrogen + Phosphorus + Ammonium

Conclusion

Ecological Sanitation toilets are very suitable for the Tanzanian environment especially in urban and peri-urban areas experiencing high water table problems, rocky and collapsible soil. Acceptability of the technology in Majumbasita Dar Es Salaam is promising, and people's uncertainties about EcoSan toilets faded away when they observe workable EcoSan latrines in their area. The pilot project was therefore vital in introducing EcoSan technology in Tanzania.

Communal acceptability, affordability, and political determination are very important in promoting EcoSan technology in Tanzania. Community involvement from the beginning onwards using Participatory approaches such, as PHAST methodology is fundamental for the success of EcoSan technology.

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National strategy to promote ecological sanitation in Uganda

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Session C

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Abstract

The national strategy to promote Ecological Sanitation in Uganda has been developed by DWD and Environmental Health Division (EHD) in collaboration with the Water and Sanitation Program, Africa (WSP-AF). The over-all objective of the strategy is to improve the living conditions of the population in Uganda by ensuring better sanitation practices, personal hygiene and food security through better management of human excrements. More specifically its purpose is to offer as an alternative, a sanitation technology option to perennially difficult areas of pit toilet construction as well as to create demand and introduce an environmentally friendly sanitation technology option that eliminates the pollution of our surface and groundwater resources.

The strategy is based on the following main principles:

- Targeted interventions at different levels - from household to the national level.
- Build on ongoing successful experiences (South Western Towns Water and Sanitation Project).
- Integrated approach to problem management – getting new stakeholders on board and attempts to get many institutions buying into the EcoSan concept.
- Marketing strategies for creating demand tailored to local conditions.
- Focus on tangible larger-scale successful applications as opposed to scattered ones.
- Use of small masons as agents of change and promoters.
- Ecological sanitation as a business – stimulation of cooperation with private sector producers and collection service providers.

Introduction and background

Figure 1: Institutional toilet at Kisoro teacher training college (Kisoro, Uganda)

Figure 2: EcoSan facility for households (Ishasha, Uganda)

Approximately 87% of the Ugandan population are living in rural areas, in villages and small trading centres, where only 50% have access to safe drinking water and even less to adequate sanitation facilities. The traditional means of human excreta management have failed in some parts of the country. The sewerage systems are beyond the reach of most of the population and pit toilets contaminate the ground water resources and at times are hard to construct especially in difficult areas like in rocky, sandy, water logged and congested places.

As a response to this unsatisfactory situation the South Western Towns Water and Sanitation Programme (swTws-I) funded by the Austrian Development Cooperation (ADC) was launched in 1996. The project was designed to cover 19 small towns and rural growth centres in the South-west of Uganda with the aim to provide safe water and improved sanitation facilities. Meanwhile the second project phase (swTws-II) is in the starting period, which will support additionally 30 towns within the next six years. The Directorate for Water Development (DWD) has the overall responsibility for project implementation. The above mentioned deficiencies with conventional approaches and solutions in a way forced the responsible project staff to think in alternatives. That is why DWD started promoting Ecological Sanitation as a method of human excreta management. The idea was to promote a cost effective alternative that can address the ever-increasing land shortage (for sanitation activities) in urban and peri-urban areas, avoid contamination of water resources, and use the nutrients for agriculture.

After a series of practical experiences in implementation in the South-western region, workshops, discussions, seminars with Swedish experts (like Uno Winbald) the outcome was an agreement that Ecological Sanitation concepts would be beneficial for the entire country and especially in difficult areas like in rocky, sandy, water logged and congested places. During 2001, DWD and Environmental Health Division (EHD) in collaboration with the Water and Sanitation Program, Africa (WSP-AF) began the process of establishing a National Advisory committee on Ecological Sanitation, drawing members from relevant line ministries and stakeholders. During the last year the national strategy to promote EcoSan in Uganda has been developed, approved and adopted. In a further step a one-year EcoSan operational Plan was developed based on the national strategy.

Objectives of the national ecosan strategy

The overall objective of the national EcoSan strategy is **to improve the living conditions of the population in Uganda by ensuring better sanitation practices, personal hygiene and food security through better management of human excrements.**

To finally reach this objective the following intermediate targets will have to be achieved:

- Equip the national and district technical staff with capacity to advocate for, plan, construct, operate, maintain, promote and sensitize the communities on the health benefits of Ecological Sanitation.
- Build the private sector capacity in the planning, construction, operation and maintenance of Ecological Sanitation facilities through practical training for construction, operation and maintenance.
- Sensitize the user communities through the district based technical teams on the resourcefulness of human excrements towards food security through the recycling of sanitized faeces and urine in agriculture as soil conditioners and source of plant nutrients.
- Offer as an alternative, a sanitation technology option to perennially difficult areas of pit toilet construction and promotion with high water table, soft formations and/or rocky grounds.
- Create demand and introduce an environmentally friendly sanitation technology option that eliminates the pollution of our surface and groundwater resources.

Main strategic considerations

Building on ongoing activities and experiences

At very beginning of the process of developing an EcoSan strategy it was found to be imperative to take stock of the available experience in and outside Uganda as well as to build on these valuable experiences.

On international level these were mainly the “Household centred environmental sanitation (HCES) approach” with the Bellagio Principles:

- People at the centre
- Stakeholder involvement
- Closing cycles
- Decentralised solutions;

and the recommendations of the Nanning conference (First International Conference on Ecological Sanitation, 5 – 8 November 2001, Nanning, China):

- The systematic incorporation if ecological principles in the overall sanitation debate.
- Forging stronger links with (new) stakeholders as agriculture, energy or urban planning.
- Need for further research in the fields of hygienic aspects, economics, agricultural reuse and behaviour.

These principles and recommendations were guiding the strategy development. On national level it were mainly the lessons learnt of the „south western Towns water and sanitation project (swTws)“ in Uganda and recommendation of various workshops and seminars influencing the shaping of the strategy.

The national lessons learnt can best be summarized as follows

- Much more efforts have to go into public sensitisation and promotion campaigns.

- Subsidized household sanitation should be implemented, if at all, with caution.
- There is need for a follow up and monitoring program. Especially during the first year of operation of new EcoSan systems users need certain advice on how best to maintain and operate their EcoSan facility.
- The aspect of safe agricultural reuse and getting farmers to appreciate the nutrient value of excreta needs more attention.
- The Double vault dehydrating toilet is an appropriate technology for small towns. Keeping them dry is crucial for their proper functioning (mainly for sanitization).
- Demand drivers for households to opt for EcoSan are: permanence of structures, little odour, construction above ground is possible. This is especially an advantage in case of rocky grounds or high water tables.
- There is a demand for a communal collection service (dry faeces & urine) and construction and thus a need to offer these services to the users to ensure a similar level of convenience like a flush and discharge system.
- Local masons can serve as “agents of change” and promoters.

Coordinated and targeted interventions at various levels

The recognition of the need for targeted and coordinated interventions at various levels - starting form the household level up to the national and international levels (refer to figure 1) – is the heart of the strategy and should:

- Ensure an integrated approach to problem management – getting new stakeholders on board and attempts to get as many institutions buying into the EcoSan concept as possible.
- Avoid isolated and fragmented pilots with limited impact towards influencing the national policies and regulations.

Figure 3: Targeted and coordinated interventions as various levels (WSP-AF, 2002)

Focus on 2 pilot implementation areas and national EcoSan fund

The rational for focusing human and financial resources in this early stage of EcoSan development in Uganda to 2 pilot areas – the South West of Uganda for a rural and rural growing centres and the Sida funded program within part of Kampala City Council - was as follows:

- At present there is limited human capacity to ensure close follow up at household level. Therefore it was decide to focus on resources, where close monitoring of the process can be ensured.
- Priority to get successful pilots (urban - Kampala, rural growing centers – South West) on a larger scale rather than (isolated) demonstration toilets spread over the country. This was also to ensure successful demonstrations to convince local decision makers that EcoSan can work also on larger scale ("seeing is convincing").
- The implementation activities in the pilot areas provide enough scale for the private sector to get attracted and to develop a supply chain for EcoSan products.
- There is capacity in the pilot areas to ensure that information, marketing and advocacy campaigns are carried out parallel to the "hardware" interventions.

However to ensure successful promotion countrywide and not just strictly limited to the pilot areas it is foreseen to establish an EcoSan fund to stimulate NGOs, institutions, private sector and individuals to come up with innovative proposals. The funding modalities and administrative requirements for this fund have yet to be established.

Bundling the support around 4 main components for intervention

Figure 4: 4 main components for intervention at the various levels (WSP-AF, 2002)

Information dissemination, awareness creation and advocacy play a major part to reach out to the communities and users. Activities and means will be manifold. Starting with the production of information leaflet, dealing with general sanitation and hygiene education as well as a proper use of the EcoSan facilities (adding dehydration agent, cleaning activities) to videos, exhibitions, to the establishment of contacts with national and local media (TV, radio, print media) - they all aim at making the EcoSan concept known and to raise the demand for investing in such an alternative solution. Additionally the award of an EcoSan innovation price is meant to be both an advocacy tool to raise the profile of the EcoSan concept within the sanitation sector and a tool to stimulate innovation. To get decision makers on district and sub county level buying into the concept advocacy workshops will be held. To provide a proper framework for all the mobilisation and promotion activities professional support will be given to develop a communication strategy for different target groups.

Technology and system development as well as applied research are one of the basics for a project or programme implementation. The acceptance of EcoSan systems depends mainly on the consideration of the stakeholders' needs and interests. Workshops and thematic round tables bringing producers, experts and users together to share a common understanding on possible shortcomings of existing technical solutions and pave the way for further improvement. There is need for designs to cater for different conditions and costs. The range of solutions should make facilities affordable for the poor but also make them attractive for the upper classes. Further steps forward are the construction of demonstration toilets including agricultural demonstration plots. These activities should go along with research activities on agricultural reuse, economic (cost-benefit analysis) and legal aspects. Eventually all these interventions will most likely be more sustainable once operation systems with farmers and operators can be established (e.g. through loans, micro credits, trainings) to allow the to make a living out of it ("EcoSan as a business).

Demand responsive training and follow up support can be guaranteed with "mobile" EcoSan trainers who are providing courses and workshops in the field and give monitoring support. The development of training courses for implementers in the region combined with seminars for farmers, local small scale entrepreneurs and operators as well as the training of trainers are additional activities. The development of special programmes for schools (like education programmes in hygiene behaviour and sanitation topics) and of curricula for universities and technical colleges are aimed at increasing the awareness and interest of the pupils and students and thus motivating them to play the role of "agents of change".

Networking, mutual learning and experience sharing should help to develop the most efficient approach to introduce and promote Ecological Sanitation as well as to identify defective developments within a project and to learn from others experiences. At such an early stage of the introduction of a new sanitation concept it is important that implementers share their hands on experience very closely in order to avoid "reinventing the wheel" many times. It is planned to establish an national "EcoSan fund" for exchange visits, thematic seminars, staff-exchange programmes, short term expert missions, training, and technology experiments. For an extended knowledge base the cooperation with resource centres and UWASNET (a Ugandan national umbrella organisation for NGOs in the water sector) is vital. These organisations are seen to be instrumental in providing services like producing an EcoSan newsletter, conducting annual EcoSan workshops and seminars. The establishment of an "anchor" secretariat for networking and coordination at MoH and officers at MLWE as well a the national advisory committee on EcoSan.

Conclusions

Coordinated and concerted efforts are needed to promote Ecological Sanitation at a larger scale. The proposed strategy to develop and promote Ecological Sanitation in Uganda is a coordinated effort to both create a critical mass of stakeholders and institutions involved to promote EcoSan and focus limited resources (human financial) to develop EcoSan systems at a certain scale. The future challenge is operationalize some of the proposed strategic interventions like national EcoSan fund an price as well as to link the strategy and operational plan which still has more the character of a project approach to the national implementation framework within the Sector Wide Approach in Uganda.

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An effective dry sanitation system – the Enviro Loo

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Abstract

The Enviro Loo is a waterless dehydration / evaporation toilet system that provides a non-polluting, environmentally friendly, cost-effective and low maintenance solution to the sanitation crisis. It offers a standard of respectability and convenience, comparable to a waterborne system, yet without the prohibitive costs and obvious strain on precious water resources.

The Enviro Loo is a sealed, zero-discharge unit that is driven by radiant heat and wind power. The human solid waste entering the tank is quickly separated from the urine which is evaporated to atmosphere. The solids, by a process of dehydration and aerobic bacterial action, dramatically reduce in volume which results in the removal of an odor and pathogen free compost-like material, every two to three years, depending on number of users.

The system was developed in South Africa where it has been operating since 1994 with over 18,000 installations worldwide. In 1997 the Enviro Loo was awarded the first prize by the World Intellectual Property Organization Award (Swiss based) for a significant contribution to African innovation in the field of Health Care.

Introduction

Many developing countries face an acute crisis in the provision of safe, respectable, economical and convenient sanitation facilities. The World Health Organization (1996) estimates that approximately 3000 million people lack even the most basic sanitation- nearly half of humanity. Statistics from the United Nations indicate that approximately 380 million of these are urban dwellers.

The risk of disease posed to communities due to a lack of adequate sanitation is well documented. Poor environmental conditions caused by inadequate sanitation give rise to high rates of diarrhoeal diseases and Helminth infections like Ascaris and hookworm, as well as exposing the population to the threat of hepatitis, polio, cholera, typhoid fever, methaemoglobinaemia, and numerous carcinogens.

The lack of sanitation alone is responsible for more than two million deaths per year. Added to this are the high levels of contamination of water resources from inadequate sanitation sources.

The findings of a South African Water Research Commission study reports that approximately 46% of South Africa's groundwater resources are contaminated above the internationally acceptable limit.

Pit Latrines and other sanitation systems that rely on "seepage" into the surrounding soil have been identified as a contributing factor to this widespread contamination. Surface water sources and living environments are contaminated through spillage from bucket toilets, discharge from pit latrines that can be flooded by storm water during high rainfall periods and exposure of raw sewage where waterborne systems have been incorrectly maintained.

It is these conditions that have resulted in over 80% of the diseases in developing countries being related to poor drinking water and inadequate sanitation. Approximately 34 000 people die every day due to water related diseases – more than 100 jumbo jets crashing daily!!

The threat of inadequate sanitation to our water resources and communities couldn't be clearer.

The dry sanitation system – a unique solution

The Dry Sanitation System provides a unique solution to the sanitation crisis. It neither taps into precious water resources nor causes environmental pollution, while producing a stabilized, compost-like material that is five percent it's original volume and safe to handle.

The system was developed in South Africa as a response to the critical problem in the provision of safe, respectable, economical and convenient sanitation solutions.

Till then, the alternatives had been limited.

Waterborne sanitation is often seen as the normal method for the disposal of human waste. Due to it's "flush and forget" nature, it is seen as the ideal solution. But the strain on precious water resources should not be underestimated. To flush away the 550 liters of human waste in a waterborne system, each person requires approximately 15000 liters per annum. Added to this is the high cost of, and need for, maintenance of the treatment plants and reticulation systems. 95% of all sewage produced in developing countries is discharged completely untreated into the surrounding water resources. The health risks posed extend beyond those city dwellers exposed to the waste, but also results in polluted water resources and a resultant high disease burden on the surrounding population.

The alternatives to waterborne at that stage were either Ventilated Improved Pit Latrines, Chemical or Bucket Toilets. The obvious disadvantages from smell and the flies that they attract are well known, and those with experience of these systems are well aware of the high maintenance costs. Perhaps most importantly though, are the associated health risks created. Exposure to raw sewage through spills, overflows and flooding, as well as pollution of groundwater resources, results in numerous illnesses and a large number of deaths each year.

Development of the system

The research and development of this Dry Sanitation System was initiated by Dr La Trobe in 1988. Knowledge gained through over twenty years experience in the field of Waste Management was harnessed and applied to the development of a system that would provide a cost-effective sanitation solution that could operate without a high level of institutional support.

Various prototypes were tested and evaluated over a four year period. Based on the initial positive test results of the process, and after researching various manufacturing materials, it was evident that low density polyethylene plastic offered the best structural properties with regard to structural strength, flexibility, material lifespan and its inert properties.

The first plastic molded units were manufactured and installed during February 1993.

The developers of the system committed the product to a five year evaluation period to ensure that the Dry Sanitation System could provide a long term solution. This was achieved by installing the units on a widespread basis and monitoring the performance, social acceptance and structural integrity of the system.

These field trials have proved invaluable for the development of the system and have resulted in numerous modifications and improvements over the years.

Biological operating principles

Liquid and solid separation

Faeces and urine drops directly through the toilet pan onto a sloping reception area. The urine proceeds by gravity, to the liquid trap at the bottom of the tank, via drainage holes through the front portion of the plate. Any faeces that enters the system at the same time, are later swept onto the drying plate by a flat scoop attached below the toilet flap.

Migration of the solid waste down the drying plate

The initial push of the solid waste via the scoop onto the drying plate pushes the faeces onto a bed of organic and enzymes material that is loaded on commissioning of the toilet. This organic additive helps kick-start the decomposition process.

Any foreign material such as sanitary pads, and various forms of anal cleansing material, is pushed along with the solid waste. Toilet paper ultimately breaks down, newspaper and other foreign materials merely dehydrate and are easily removed from the collection area, in the fullness of time.

The solid waste slowly, but progressively, moves down the sloped drying plate. This movement is aided by the scraping / pushing action of the flat scoop attached below the flap.

The surface of the drying plate has a number of ridges across the width of the plate designed to retard the progress of the solid waste. This ensures the waste is constantly aerated thereby stimulating a reduction in volume via the subsequent evaporation of liquid.

In order to avoid contamination of the dried waste, the waste material is periodically removed from the drying plate collection area and deposited into a hanging bag. This waste then remains in the bag for an approximate period of eighteen months to two years prior to removal from the system.

The waste contains a myriad of organisms contributed from the faeces itself and the starter organic material, in a symbiotic arrangement of survival of aerobic mechanisms, bacteria, protozoa, helminths, yeast cells, other commensals plus, of course, a high volume of dead cellular waste.

At various times the waste might contain evidence of maggots, larvae and grubs, which are all part of the breakdown and stabilization process. As the dehydrating material gradually moves towards the collection area, the microbiological activity will begin to slow down due to a lack of moisture.

The time frame (retention period) from entry of the solid waste, until the waste is removed from the collection area, depends on the number of users per day and according to the local climatic conditions namely average wind velocity, ambient temperature and humidity levels.

After widespread utilization of the system in South Africa, it has been the experience of the developers that some of the dried humus like material need only be removed approximately every eighteen to twenty four months.

Aeration of the waste

The ventilation through the system is such that during the period that the waste moves down the drying plate it is constantly subjected to a large airflow.

For example with a relatively low wind speed of 4 kilometers per hour we can estimate an airflow of approximately 100 to 150 cubic meters per hour through the system.

This continual airflow has the following effect on the solid waste:

A reduction in volume through evaporation of the high moisture content.

The oxygen devitalizes the pathogenic organisms.

The oxygen acts as a deodorizing agent.

Biological heat within the solid mass

It is a well known fact that in the course of the composting process, there is a build-up of heat within the mass of the composting material. Temperatures of sixty five to seventy degrees Celsius are not uncommon, particularly with "forced aeration composting".

This sort of scenario would never be achieved within the solid mass in such a Dry Sanitation System. Temperatures of 55 degrees Celsius and above can be reached directly underneath the sealed manhole cover.

Within the solid mass on the drying plate it is doubtful if the internal temperature would ever go above thirty five to forty degrees Celsius for the following reasons:

- The solid mass on the drying plate is too small to retain heat.
- Any heat build-up, no matter how small, is quickly dissipated by the incoming air.
- To reduce the in-flow of air could result in anaerobic conditions within the system.

"Radiant heat" therefore contributes to the operation of the system, via the heat build-up underneath the manhole cover and through the approximate ten degree increase in temperature, above ambient, within the ventilation pipe causing a convection current, which assists operation of the ventilation extractor and thereby positive ventilation extraction through the system. This creates a negative pressure within the container.

The other important aspect of the stabilization process is the prolonged dehydration process, thereby retention period, resulting in subsequent bacteria attenuation and devitalisation.

The following graph by *Feachem at al (1983*) depicts the elimination of pathogens related to temperature and time.

This demonstrates that at a temperature of approximately 35 degrees Celsius most pathogens would be reduced below hazardous level within a retention period of one year. It is therefore self explanatory, that if the waste has a retention period of between 18 to 24 months, it is very unlikely that disease causing pathogens would survive at infective concentrations, apart from helminths.

Viruses from human waste will not survive outside the host body for longer than three month periods.

The eggs of Ascaris worm cysts and other helminths are however capable of extended periods of survival at temperature below 65 degrees Celsius. In order for the stabilized waste to be free of worm cysts, it should be subjected to the process of "Forced Aeration Composting" which will ensure the desired temperature levels of 65 degrees Celsius or more.

Evaluation and scientific studies

Baralink, South Africa

In April 1996, the Johannesburg Transitional Metropolitan Council conducted a study of thirty Enviro Loo Dry Sanitation Systems installed in the Soweto community of Baralink. The study was sponsored by the South African Water Research Commission and monitored by the independent firm of consulting engineers, Stewart Scott. The monitoring team consisted of officials of the Council's Department of Health and Social Welfare, Cydna Laboratories (Water & Waste Directorate) and Stewart Scott. The quarterly progress and follow up meetings were attended with additional observers from the Department of Water Affairs and Forestry, Mvulu Trust, representatives from Enviro Options, members of the Baralink community and representatives from the SAWRC.

The project continued over a period of a full calendar year in order that the toilets are subjected to the conditions of the four seasons of the year.

The thirty families using the Enviro Loo System, and an equal number for the control group consisting of adjoining neighbours, were visited by the monitoring team twice a month for the full year.

The two significant results of this study demonstrated that:

- Those families using the Enviro Loo had a dramatic decrease in gastroenteritic diseases
- The system gained community acceptance

Cydna Laboratories then continued to monitor and analyze the waste. The following details their findings.

Date of sample test	Moisture content	E.Coli count*	Coliform*	Salmonella
8 Dec 1998	15.82%	-ve nil	Nil	-ve
8 Dec 1998	12.49%	+ve 30	30	-ve
14 May 1999	15.7%	-ve <10/g	<10/g	-ve
14 May 1999	11.8%	-ve <10/g	<10/g	-ve
10 August 1999	N/A	-ve <10/g	<10/g	-ve
10 August 1999	N/A	-ve <10/g	<10/g	-ve

*Bacterial count measured as number of bacterial units per gram of sludge material

Figure 1: Cydna laboratory results

Botswana survey

An assessment of the Enviro Loo dry sanitation system was conducted by the Technical Unit of the Department of Local Government and Development, for the Ministry of Local Government Lands and Housing – Botswana, in April 1997.

The final recommendations stated "In the final analysis the task force came to the conclusion that in view of the present sanitation situation in our country some recommendations should be made in favor of adopting this Non-Flush Dry Sanitation System in Botswana."

Northern province task team

The Enviro Loo dry sanitation system was evaluated in October 1995 by a task team that was appointed to conduct research for the Department of Education into cost-effective schools for the Northern Province, South Africa. Numerous systems were evaluated and the conclusions stated "If either a main sewer line or a sewage farm or enough water were not available then the tested Enviro Loo dry sanitation system should be installed and be given preference above the other alternative sanitation systems"

Evaluation by S. Bannister et al

The Enviro Loo dry sanitation system was evaluated by S.Bannister et al, South Africa. The findings were published as a scientific paper at the 23rd WEDC International Conference in Durban 1997. This was an interim report based on the first six months of the Baralink study.

Locations and applications

To date, over 18,000 units have been installed throughout South Africa, neighbouring countries, namely Botswana, Namibia, Mozambique, Zambia, Zimbabwe and countries further a field, such as Australia, Brazil, Cameroon, Cyprus, Gabon, Ghana, Greece, Kenya, Nigeria, and Uganda . Some test units are on trial in Kuwait, New Mexico – USA and

Papua New Guinea. The system has been patented in some 69 Countries.

The Enviro Loo can be utilized in a variety of applications, including:

- Domestic / Residential, urban, peri-urban and rural housing
- Schools and Clinics
- National Parks, Game Farms and Farms
- Holiday Cottages
- High water table and rocky areas
- Underground – Mines
- Roadside toilets
- Particularly effective where water resources are not freely available

Conclusions

This unique dry sanitation system does not totally fall into the category of a composting sanitation system. Nor was it designed as such, but as with a compost sanitation unit, the final product is a dry humus-like material.

When ultimately ready for removal from the unit, which might be only two to three years after commissioning, it is relatively safe to handle. As a result, it does not require the expensive services of a vacuum tanker but can be transported on an open truck, as it is odorless. It should, however, be subjected to a process of "Forced Aeration Composting" to devitalise any remaining Helminths.

This technique of handling and treating primary sewage is capable of being a major contender in the field as an alternative sanitation solution to waterborne systems, while providing an innovative technique to stabilize and safely dispose of human waste products in a manner that the end products will pose no threat to the environment or the users.

The technique was scientifically developed and well tried and tested in the field in a number of countries before finally being offered as an alternative sanitation solution.

The design and manufacture is robust and has proved to withstand abuse. It is a completely sealed, zero-discharge system which requires little maintenance and is relatively inexpensive to manufacture.

It is capable of fulfilling the sanitation requirements of rural, peri-urban and urban large scale communities under divers climatic conditions.

Nutrient utilization by urine separation - experiences from the Lambertsmühle project*

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Keywords

Decentralised wastewater systems, urine separation, greywater, separation toilet, constructed wetland

Abstract

The wastewater concept for the Lambertsmühle with urine separation, the greywater and brownwater selection is described. The installed sanitation technology is one of the prerequisites for the source separation; here different types of toilets are in use. In a one and a half year investigation program the affectivity of the separation was checked. No nitrogen losses did occur in the urine storage, neither in normal nor in acid storage conditions. Most of the persistent organic pollutants from hormones or pharmaceutical residues were found in the urine. Some of them could be degraded under acid storage conditions. The urine worked as a fertilizer like normal mineral fertilizer, but it is recommended to mix the urine with animal manure by using on the farmlands.

Introduction

The "Lambertsmühle" is an ancient watermill, which is nowadays operates as a museum. In connection with the restoration of the building a progressive sanitation concept has been developed for the museum. The mill building has a public area for visitors, guests etc. and a flat in the first floor, which is rented to a family. Due to the local conditions a connection to a sewer network system was not possible. Therefore an own wastewater treatment is also necessary in the future and it was decided to install a source-separating concept.

The separate collection of urine (with or without flush water named as yellow water), faeces (brownwater) and greywater from the kitchen, bathrooms is the prerequisite for the concept. For the separation of urine and faeces different toilets are installed.

*This paper has been peer reviewed by the symposium scientific committee

The different types of separating toilets are shown in figure 1. Two toilets separate the urine from the faeces by a small wall in the toilet bowl, but they mix the urine with flushing water. This dilution of the urine is very important for the volume of the urine storage and its transport, because the daily input volume controls this. Therefore a low – or better – no dilution is recommended. Especially the toilet shown in the centre of figure 1 can cause problems if used by children. The faeces can be placed in the front part of the bowl and must be removed and cleaned manually from the toilet bowl.

The toilet on the right side is a toilet with a special mechanism for urine diversion. While sitting on the toilet a valve opens under the users weight and the urine can pass the small outlet in the front area. By leaving the toilet seat, the valve closes and the flushing water is able to clean the whole bowl and leaves the toilet bowl by the faecal outlet. The advantage of this toilet is the undiluted urine separation and the hygienic proper cleaning of the whole toilet bowl by the flushing water.

Figure 1: Separating toilets installed at the Lambertsmühle, left: BB-Innovation, Sweden, centre: WostMan, Sweden, right: Roediger, Germany

The urine of these toilets is collected in a special tank and is used by a farmer as fertilizer on his farmland.

Faeces and greywater are flushed normally to the wastewater treatment plant. The solids are removed in a special separation unit, collected and dewatered. After composting these solids can be used also as a soil conditioner. The liquid phase from the separation unit contains only a small amount of nutrients and can be treated easily. In the Lambertsmühle project the biological treatment is done in a constructed wetland. After this process the water is given to the receiving water.

A scheme of the sanitation concept regarding to the water and the nutrient cycle is shown in the following figure.

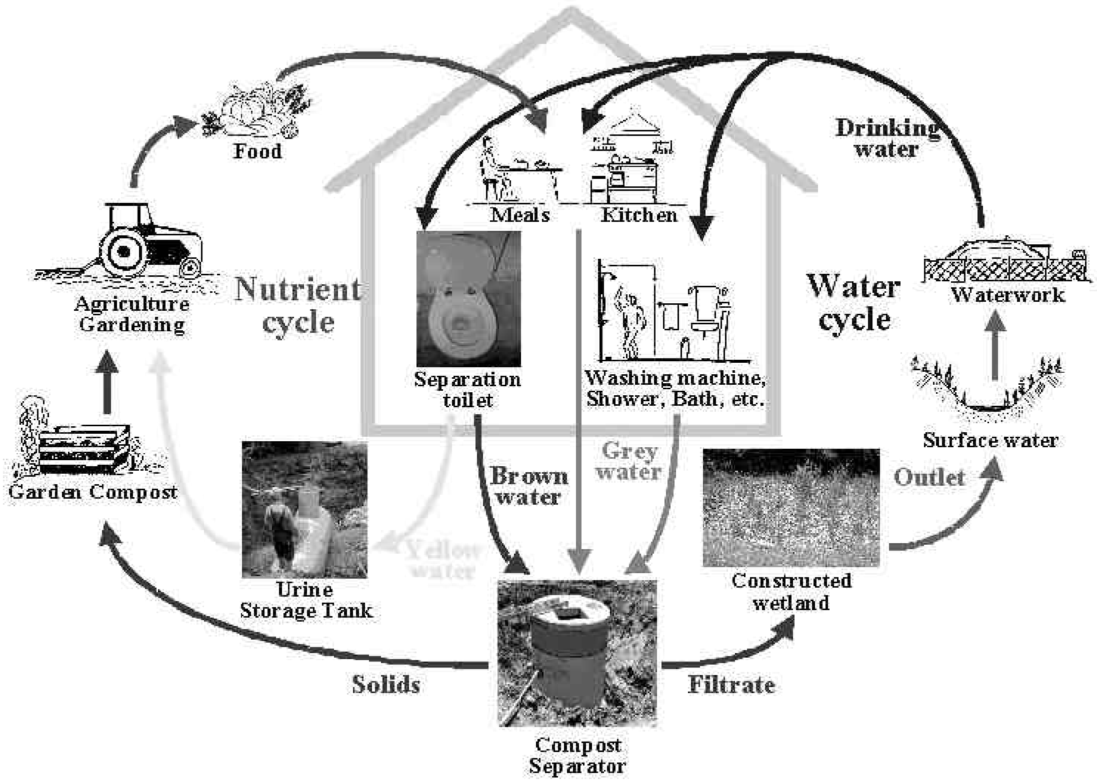

Figure 2: Sanitation concept Lambertsmühle

This is one of the first urine separation projects in Germany, which is inspired by project in Sweden (Hellström and Johansson, 1999), which successfully collecte d urine and reused it as fertilizer after a storage time. The results, experience and recommendations of the various projects are published in various publications (Johansson, 2001, Höglund 1998,2001) and can be shared by this project.

Methods

For the project described above an investigation program has been running for 18 months. Different partners are involved with various task, which are described in the listing:

- Efficiency of source separation and of each stage on the basic of concentrations and mass balances
- Increasing of the knowledge of such systems and ideas for further developments
- Experiences with storage, treatment and utilization of the nutrients from the urine
- Investigations concerning operation of the various compounds (toilets, treatment, uti lization)
- Investigations of the nutrient utilization in the agriculture by lab scale experiments and on-site on small scale fields nearby
- Investigations of hygienic issues
- Measurement of persistent organic pollutants (pharmaceuticals, hormones etc.) in the different flows and the influence of storage and treatment especially of the urine on these pollutants

- Recommendations for optimisation of source separation systems

For fulfilling the tasks above various campaigns with measurements took place. In this campaigns the water volume of the different flows were measured and samples were taken for analyzing. A methodology for the identifications of 17 persistent organic pollutants (pharmaceutical residues and hormones) was developed for the urine with its high salinity. All flows were analyzed on these substances and on hygienic parameters. The collected urine was used as fertilizer either on lab scale or on farmlands with grassland nearby the mill

Basing on this values mass balances and various calculations were made.

Results and Discussion

The ratio of the volume of grey- and brownwater is varying during the different measuring campaigns (figure 3). A mean ratio of 40 % brownwater and 60 % greywater can be measured. The flushing water causes the high value of the brownwater volume from the toilets.

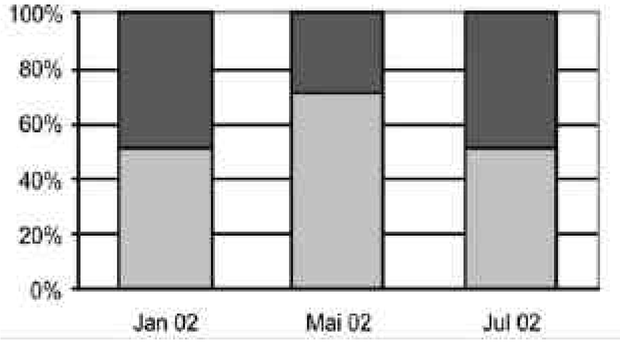

Figure 3: Volume distribution of brownwater (dark) and greywater (bright)

The comparison of the nitrogen loads from the different sources show the main fraction in the brownwater, greywater contains only a small load of 22 – 45 % of the total load:

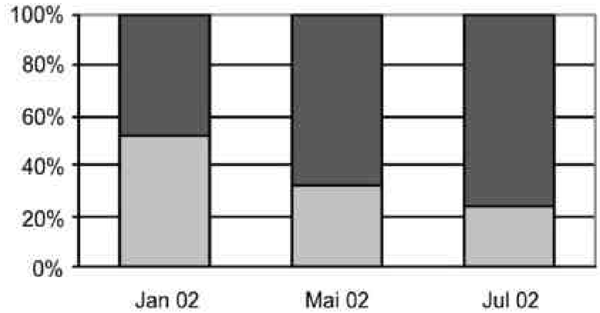

Figure 4: Nitrogen distribution of brownwater (dark) and greywater (bright)

The concentrations of the organic parameters in the flow into the constructed wetland in the terms of COD and BOD_5 have shown concentrations, which are comparable to normal domestic wastewater. Here 250 – 800 mg/l COD did occur in the influent of the constructed wetland.

The demands for the wastewater treatment, given by the authorities, can be fulfilled without any problems by the constructed wetland as treatment plant. The separation of the urine results in much lower nitrogen concentrations into the constructed wetland compared to normal treatment plants. Elimination rates for nitrogen of the constructed wetland have been always nearly 95 % and increased with ongoing operation time.

Although one conventional toilet of the flat, which is one of 5 installed toilets, could not be replaced by a toilet with separation technique and the urine from this toilet was not separated, the influent nitrogen concentration to the constructed wetland was less than 20 mg/l and could be degraded down to 5 mg/l in the effluent of the constructed wetland.

Because of the operation as a museum the user frequency can vary very wide. Especially during visiting times the loading of the wastewater treatment plant increased significantly. For these days the buffer capacity of the constructed wetland worked very proper and no higher concentrations in the effluent did occur.

The separator was constructed as a filter-bag, in which the solid material was retained, the liquid drained off. Organic material like woodchips or wood shavings was added as additional carbon source and for a better dewatering. This unit worked with the processes of separation, collection and thickening of the solid from brown- and greywater. The solid separation in the compost separator was very effective, but the dewatering processes didn't work very proper. It was assumed, that the diameter of the filter-bags was too large, furthermore the handling of the bags was very uncomfortable due to the large size. Therefore replacing of a smaller one to increase the dewatering capability by increasing of the total surface should optimize the bag. Results of this replacement are still missing, because it is in operation for a few weeks.

Samples taken from the urine tank have had ammonia concentrations about 1.200 mg/l and a COD with more than 10.000 mg/l. These concentrations were in accordance with the calculations made with the theoretical dilution of the urine by water for flushing purposes. Calculations made with the assumption of 85 % nitrogen originated from the urine showed a capture rate of approx. 50 %. The one toilet in the flat, which is not separating urine and collects all wastewater from the toilet together, caused this low rate. Taking this into account the values are in accordance with the experience in Sweden, where a nitrogen capture rate by urine separation of 60 – 70 % was measured (Jönsson et al., 1998).

The urine was stored under different conditions. In a first period sulphuric acid was added to keep a pH < 3 for many months. In this time no pathogens were measured in the urine. In a second phase no acid was added and the urine was stored without any condition. Then a pH value of 8,3 – 9 occurred in the storage. Although under these conditions ammonia occurs, no smell could be noticed by the owners. Only after opening the tank a light smell was noticed from the tank. During the storing a sludge settled on the top of the tank was noticed. Therefore the mixing, e.g. with a pump is necessary before emptying the storage tank.

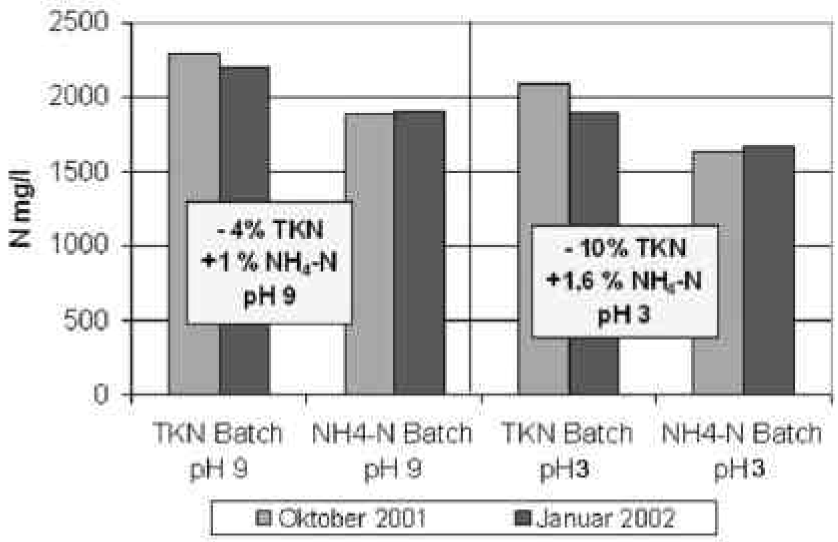

Figure 5: Nitrogen losses of urine during storage

For the estimation of possible losses during the storage specific measurements were made (figure 5). Neither without any acid conditioning nor under acid storage conditions the losses of nitrogen could be noticed over a period of four months.

These results were supported by the opinion of the museum staff, which never noticed any disturbances by smell of the wastewater treatment plant. Therefore they were very satisfied by the separation concept. These results are in accordance with the Swedish experience, in which only the occasional adding of caustic soda for the avoidance of sewer clogging was recommended (Johansson, 2001). Clogging of pipes, mainly of the urine pipes was not noticed in the sewer system of the Lambertsmühle.

One of the main project's tasks was the determination of residuals from pharmaceuticals and hormones in the urine. Until the start of the project experiences with analysing these compounds didn't exist. So one the main task was the development of analytical techniques for the urine matrix.

Residuals from pharmaceuticals were mainly found in the urine, only very small concentrations could be found in the greywater or in the brownwater. Hormones were also found, mainly as the natural hormones, in the greywater. In the end the sum of indicated substances was very low. The spectrum of identified substances was the same known from normal wastewater effluents. The degradation of these substances in the urine increased with decreasing pH-value. When some substances could be degraded in an acidic environment, this didn't occur under neutral conditions.

The urine was used for fertilizer experiments in greenhouse and free-range environmental conditions. The nutrient utilizations have been excellent for the tested plants. Either under realistic conditions or in the greenhouse investigations the growth rates of the plants fertiled with urine was slightly better than with mineral fertilizer or manure. The very low concentration of heavy metals in the urine could be recognized as a significant advantage versus other mineral fertilizers. The acidification of the urine prevents ammonia stripping and the urine is an additional input of sulphur into the soil. Nutrient balances of the small-scale experiments show a better utilization of the nutrients from urine compared to other mineral fertilizers.

For the use of the nutrients from urine enough agricultural space was available. Rough estimations show that for the use of 25 % of the total nitrogen from the wastewater only 2,5 % of all fields used for agricultural use is necessary.

Conclusion

The results of the first year of operation of the urine separation system can be named as:

- Not every separation toilet can be recommended, esp. for children.
- Nitrogen loss by urine collection and storage is unelectable in neutral conditions as well as in acid conditions.
- Urine storage in acid conditions destroys pathogens and affects a hygienic harmless fertilizer.
- Persistent organic pollutants are mainly concentrated on the urine. Specific components can be degraded by storage in acid conditions.
- The solid removal in the compost separator is very effective. The unit is responsible for collection, separation and dewatering processes; the composting effect can be neglected.
- Due to the source separation the effluent values of the constructed wetland are very low concerning the nitrogen concentration.

- The first results of the agriculture investigations are demonstrating a good efficiency of the fertilizer on special plants. Further investigations are under progress.

The increasing focus on persistent organic pollutants, which are distributed by human wastewater in the surface waters, is supporting the installation of the source separation. With separation of the urine the wide spreading of these components in the natural environment can be avoided. Additionally the emission of nutrients in the receiving waters can be reduced and artificial fertilizer can be replaced.

The first results of this project are very promising and are showing a lot of benefits of the source separation concept. The efficiency of the treatment can be increased by the source separation. Urine can act as a very good fertilizer and can be hygienically harmless by specific storage conditions.

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Ecosan in past and present effort in Nepal

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Abstract

Nepal is a landlocked country and its three sides are surrounded by India while big mountains towards China segregate the north side. It has an area of 1,47,181 sq.m. with a population of 23.1 million (Census report 2001) with significant human and geographical diversity. Still 84% of the people live in rural areas. The population growth rate is 2.2%. Agriculture has an important role in the economy of nation. Various governmental as well as non-governmental reports say that more than 80% of the economically active population is employed in the agricultural sector. Still more than 40% of the population falls below poverty line with per capita income of only US$ 249.

Since past many decades, Nepal continues to suffer high mortality and morbidity rate tolls about 28000 deaths of children per year nation bears the damage of about Rs. 4 to 10 billion each year which is 1.5 to 4% of the GDP. Recent census report (2001) shows that 46% of the population has access to latrines where more than 50% of them are temporary. 80% diseases are caused by insanitary condition.

Ecosan has been practised for the past many generations in Nepal in different forms. The author has visited many places where farmers have used excreta and urine separately for feeding pigs and for growing crops and vegetables since last many years. Average people have "Feco-phobia" i.e. they do not like to hear the word "excreta", but few farmers take even raw (fresh) excreta from latrines to their vegetable gardens and grow good quality of vegetables which are tasteful and highly demanded.

In Bhaktpur district of the Kathmandu valley, an interesting event happened in past when the government of Nepal with the support from donor agency constructed a sewerage system there. The farmers had broken the sewers of the project and taken the raw sewage to their farm-lands with buckets. Even these days, farmers use direct fresh sewage from sewers to their farms in different places.

Recent report of one of the village development committees (VDCs) in Gorkha district, 150 km. away from Kathmandu, says that some of communities of the VDCs defecate in open pit (1' X 1' X 1') in a corner of a room of the house for feeding pig. They beat their kids in case they defecate elsewhere. An appropriate example of ecosan has been observed by the author in Sidhipur VDC of Lalitpur district in Kathmandu valley. The farmers have constructed small water-seal pit for collection of urine in their house. They pour ash after each urination and use them as fertilizer for kitchen gardens. They have pit latrines away from their houses where they put leaves or other organic materials to cover the faeces. This system of sanitation have been practised for the past many generations. These are few examples of the uses of excreta and urine in Nepal.

The author after participating the 1st International Symposium, 2000 in Bonn, Germany, discussed the outcomes of the symposium in National Sanitation Action Steering Committee comprising of members from donors, NGO, INGO and developed a proposal to launch a pilot project on ecosan with technical and financial support from WHO, Nepal.

The pilot project has been approved and launched in Sidhipur Village Development Committee located 3.2km East of Lalitpur Sub-Metropolis and 7 km away from Kathmandu. It is situated 1372 meter above sea level and has a population of about 5685. It has 99.8% Newar ethnic population. Among these Newars, there are 80% Jyapus (farmers) and rest are others.

The main objective of this project is to have a pilot project on ecosan toilet installed and amalgamate the sanitation and agriculture for better environment and health of the people.

Most of the houses in this village do not have sanitary toilets. They go to river side for defecation. In this village, most of the farmers use animal manure and raw human excreta as fertilizer for crops and vegetables. They have been practising since ancient days although it is unhygienic. Thus, the village is a right place to launch this ecosan project to reduce the environment the health hazard and to train them in proper way of using the human excreta free from pathogenic germs as safe fertilizer.

The construction of ecosan toilet would be started in order of individual houses who prefers to invest having the ecosan toilets. The phases have been designed as follow:

- Community consultation and designing
- Construction and orientation
- Lab testing, monitoring

The community consultation and designing phase is on-going and the construction work will be stared in few days. The detail of these will be included in the paper.

A proper monitoring system is designed to promote the construction, the operation & maintenance of toilet and the uses of excreta & urine as fertilizer. The study is also focused to develop the uses of the fertilizer for different crop-pattern, to access NPK value in excreta & urine and the presence of pathogens in different stages of excreta & urine. The Environmental Sanitation Project is going to develop a plan based on the experience learned in the pilot project for implementation of ecosan program through country.

Holistic ecosan small-town planning: The TepozEco pilot program

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Session C

Keywords

Adaptive planning, ecological sanitation, integrated approach, TepozEco, Tepoztlán, Mexico

Abstract

The main objective of this paper is to share our preliminary experience in planning and developing an urban ecosan pilot program in (Tepoztlán) Mexico, which includes ecological toilet promotion, water demand and graywater management, rainwater harvesting, organic residue recycling, urban agriculture, and environmental education. The promising start of this project (named ***TepozEco***) has been based, primarily, on its iterative, flexible, responsive design process -*adaptive planning*- and a strong network of partners and collaborators. Even though the local context is to some extent unique, particularly in regards to the institutional resource base, local environmental awareness and the local government commitment, the social economic conditions in the municipality in many ways reflect those in much of Latin America. Thus, the *TepozEco* project could serve as a good ecological sanitation example for much of Mexico, central and South America.

Introduction

This paper presents the principal characteristics of the planning and start-up phases of a holistic ecosan district program in Tepoztlán, a small urban center 70 km south of Mexico City. The ecosan program, named *TepozEco,* encompasses a population of approximately 33,000 and includes ecological toilet promotion, water supply and graywater management, organic residue recycling for urban agriculture and public gardens, and environmental education.

Tepoztlán has a rich institutional base, a dynamic society with a special history of environmental activism, and strong local government leadership and commitment. The socio-economic situation –including poor indigenous rural villages, a transitional middleclass, as well as wealthy weekend homes – are, in many ways, a microcosm of conditions and contrasts prevalent in much of Latin America. At the top of a watershed, within a national park and important biological corridor, and as a tourist destination, the municipality is both politically and environmentally strategic.

The case study will attempt to highlight the following elements:

- The local socio-cultural and environmental characteristics of the district that make Tepoztlán an ideal place for an ecosan pilot program.
- The importance of having a strong network of partners.
- The advantages of developing an iterative, flexible, adaptive planning process.
- Implementation strategies and future plans.

Background information on Tepoztlán, RedSeco and *TepozEco* Pilot Project

Tepoztlán is a municipality with enormous contrasts, ranging from poor indigenous villages, through a dynamic urban center of approximately 18,000 inhabitants, to luxurious suburban homes for some of the most influential people in Mexico. The town is deeply rooted in its distinctive blend of indigenous and Hispanic cultures and traditions, as well as a special history of environmental activism. For example, largely due to pressure from the local population and leaders, in 1937 the entire area was declared, by presidential decree, the *El Tepozteco* National Park; and in 1988 was included in the environmentally strategic Biological Corridor *Chichinautzin*. Then, as recently as 1994, the town went through a lengthy and sometimes violent struggle where the people and their leaders, motivated primarily by their concern to preserve the natural beauty and integrity of the local environment, opposed and managed to back down an international consortium that had initiated a major "golf resort" venture. In order to keep the corrupt state officials at bay, Tepoztlán declared itself a "free municipality" and had to survive through almost two years with virtually no support from the state or federal governments. The same environmentalist municipal president (or mayor), who had stood against these external interests, was reelected to serve for the present 3-year term from 2001 through 2003.

Recently, Tepoztlán has been included in a comprehensive district development program, coordinated by the Ministry of Tourism, which aims at conserving the natural and cultural heritage of 12 distinctive Mexican towns, as the cornerstone of sustainable tourism. A key element of the approach has been the establishment of a representative non-profit association, "*Tepoztlán Valle Sagrado*" (**TVS** -"Tepoztlán Sacred Valley"), to guide multisectoral development activities in partnership with local, state, and federal governments. This community-based organization promises to be an important vehicle for promoting ecological approaches and for insuring the continuity of the *TepozEco* program beyond the 3-year municipal government timeframe.

Because of its location at the top of the watershed, Tepoztlán does not receive waters flowing from upstream villages. The seat of the municipality is thus responsible for water pollution in streams and wells in the valley –and further downstream. The clean water that flows down the mountains, after passing through various villages, gets polluted with gray and black waters, as well as garbage that are dumped into the ravines and rivers. In addition, an estimated 70% of the urban population uses waterborne systems emptying into septic tanks that seldom conform to adequate standards. Therefore the untreated contents filter down into the soil and underground fissures presumably contaminating unconfined and confined aquifers, which supply water to most of the population.

The **RedSeco,** an Ecological Sanitation Network in Mexico, has had a central role in the multidisciplinary planning process and will be a key mechanism for implementing the program. The Network is made up primarily by NGOs, academic and research institutions, as well as members of the local government, who share a common concern for the progressive deterioration of public health and the environment due to unsafe and unsustainable conventional sanitation approaches. During the past several years, members of the Mexican RedSeco have made significant gains in demonstrating that eco-sanitation approaches can and should be an integral part of government programs.

In partnership with the local government, the RedSeco initiated a series of preliminary studies and trial experiences in Tepoztlán, during 2002, leading to a combination of program components and strategies that have a high promise of introducing a sustainable urban ecosan system. Moreover, the flexible, responsive design process has established an open and creative working environment and solid interinstitutional and intersectoral relationships.

The special social, political and environmental characteristics of Tepoztlán facilitated the development of the ***TepozEco*** ecosan project. In response to an invitation from the Swedish EcoSanRes program, Sarar Transformación SC (**Sarar-T**), with support from the United Nations Development Program / Environmentally Sustainable Development Group (**UNDP**/BDP/ESDG), submitted a preliminary project proposal in mid-2002; organized a study visit to China with local government officials in November; and negotiated a tripartite Project Agreement between the Local Government of Tepoztlán, the Stockholm Environment Institute (**SEI**) and Sarar-T beginning in January 2003. The main objective of this initial one-year pilot project, financed by EcoSanRes/Sida, is to carry out the research and development demonstration phase of the *TepozEco* program, leading to a full scale implementation program involving ecological toilet promotion, water demand management, graywater management, rainwater harvesting, organic waste management to produce compost for urban agriculture and public gardens, one or more eco-stations for secondary treatment of toilet output, and environmental education. The overall 5-year goal of the program is to create a fully functioning example of urban ecological sanitation in at least one peri-urban neighbourhood and an outlying village of the Municipality. This model ecological town of 33,000 inhabitants will be a living example for the Latin American region to study and learn from, and to generate further global interest and capacity.

Session C

Methods

Whereas Tepoztlán offers unusually favorable conditions for establishing an ecological sanitation demonstration site within an urban-to-rural spectrum, the program designers are aware that positioning ecosan into the mainstream of infrastructure planning and procedures will probably not happen through the standard linear interventions. Traditional sanitation has never been a high development priority, and it will probably be the same for ecosan, no matter how appropriate it may seem. The 1-year program planning approach has been holistic, incremental and iterative, where the distinctions between small demonstration activities, applied research and participatory planning are frequently blurred. Key elements process include:

- Integrated approach
- Partnerships
- Adaptive planning

Intergrated approach

The program has been designed with five complementary components, which share the common aim of creating an environment that will be conducive to the emergence of ecologically sustainable sanitation practices. On the one hand the strategy intends to reinforce those conditions or "drivers" which will help motivate the families to assume eco-sanitation practices, while, on the other, discourage conventional systems by highlighting their social, economic and environmental costs. The following diagram illustrates the key elements of the approach:

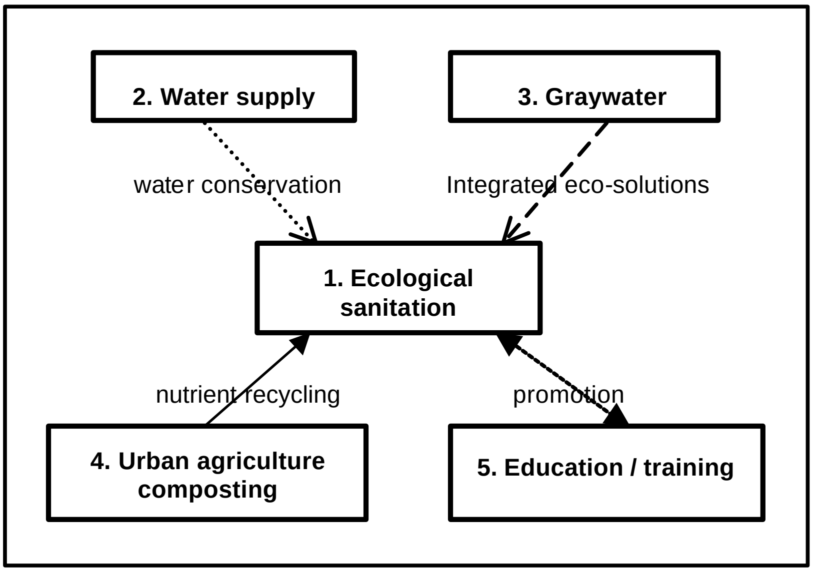

Figure 1: Diagram of the principal components and interactions of the *TepozEco* ecosan program

Partnerships

The project foundation has been built upon a strong network of partners at local, regi onal and international levels:

1. Local

In addition to the municipal authorities, who have demonstrated an unusually high level of competence and commitment, the project implementers have made special efforts to include a range of local NGOs and civic groups, which have experience in various related disciplines including:

- Micro-watershed conservation
- Nutrition, family vegetable gardens, and school programs
- Micro-enterprise development, training for masons and plumbers
- Environmental education
- Integrated district development and tourism

A particular strategy of the *TepozEco* is to contribute to the social capital of the community and thus have spin off effects in other development spheres.

2. Technical and academic

The RedSeco is constituted by the a number of Mexica n and Latin American associates, with specialization in a number of fields, for example:

- Environmental education and dissemination of alternative waste management techniques.
- Promotion of water-saving practices by popularizing alternative technologies: dry ecological sanitation, graywater filters and rainwater harvesting;
- Agro-ecology, urban agriculture, and organoponics;
- Research into organic residue treatment and disposal to ensure pathogen' risk reduction and the safeguarding of public health;
- Crop research, applying human urine to fertilize vegetable gardens and improve soils;
- Human development, environmental health and participatory training.

3. International –EcoSanRes/SEI and UNDP

The *TepozEco* program in Mexico is among the projects that EcoSanRes supports. Ron Sawyer of Sarar-T is also one of the core consultants of this project. In addition to the support in capacity development, methods development and evaluation, the EcoSanRes program gives the *TepozEco* project access to a broad range of international specialists. The *TepozEco* project continues to count on the support of the UNDP/ESDP, which played an essential role in nurturing the project during the trial phase in 2002.

Adaptive planning process

Another key aspect for the relatively successful start of the project has been the iterative, flexible, responsive design process, which we have termed adaptive planning. In Mexico, as in much of the developing world, rigid plans are destined to failure because, among other things, the people, government and institutions often lack the "rationality" and "progress" ideals of western culture. In fact, due to certain cultural hurdles (e.g. institutionalized corruption, absence of long term planning), many examples can be cited where a beautifully designed project in Stockholm or Hamburg would be painfully and frustratingly difficult –or impossible! - to implement in a poor nation, despite adequate funding. Understanding this from the beginning, we incorporated uncertainty and flexibility into the planning of *TepozEco*. By participating with the local government and key organizations beyond the scope of the project, we have built important cooperation bridges that, despite the apparent initial detour of our objectives, have strengthened the *TepozEco* program.

One example of these "cooperation bridges" is the wetland treatment system that is being considered to manage the wastewater from Tepoztlán's downtown tourist. Having invested much time and resources installing a sewage collection pipe for the city center as part of the an urban restoration project organized by *Tepoztlán Valle Sagrado* (TVS), the municipal government was about to invest in a large, expensive, septic tank system to deal with the wastewater once collected. The authorities had no idea of the expected flow, or of any other treatment alternative.

Initially, Sarar-T was hesitant to get involved in the wastewater problem, fearing that this would establish a bad precedent and give the wrong signal to the general population when subsequently attempting to encourage dry systems. Yet the alternative was to risk being marginalized completely from the urban renewal planning process that was already being set in motion. Instead, by organizing several meetings with wastewater experts, including an expert from the Pan-American Health Organization (PAHO/OPS) and the nearby Mexican Institute on Water Technology (IMTA), we were able to convince the authorities to postpone the purchase and helped them investigate other options. As a supportive initiative we carried out a water characterization study to determine flowrate projections and documented advantages and disadvantages of a range of possible wastewater treatment options. From these, both the local government and TVS favored a constructed wetland system designed on ecological engineering principles (Mitsch and Jorgensen, 1989) and its wildlife habitat potential. A public park and environmental education center are part of the integrated/holistic design of the wetland project. By participating as a team, together with the municipal government and TVS, we have had several meetings with the appropriate state and federal institutions that might fund or support the wetland project. In these meetings not only have we been sharing ecosan ideas and promoting the *TepozEco* project, but also developing important bonds with the same people and institutions that can be of great importance for the acceptance and long-term success of ecological sanitation in Mexico.

Moreover, by demonstrating our willingness to listen to the local Government and respond to their priorities, we have succeeded in making them more receptive to our broader concerns for the environmental impact and longer-term sustainability of the proposed systems. Ironically, even the state and federal authorities have insisted that they can only reasonably consider supporting the wastewater treatment plant if it is presented within the context of an integrated water and sanitation program.

Results

Over the past year the RedSeco, with seed funding and technical support from UNDP/BDP/ESDG, has worked closely with the municipal authorities of Tepoztlán to lay the groundwork and determine the feasibility of a comprehensive ecosan urban program. Among the principal accomplishments so far:

1. A number of baseline studies (water supply, wastewater treatment for the town center, comparison of existing sanitation systems) have been completed and pilot demonstration projects initiated –including urine-based organoponic horticulture modules and domestic graywater filters.
2. The multiple and diverse organizations involved, directly or indirectly, in the TepozEco program are creating a web of relations that make this ecosan effort more resilient and promote symbiotic relationships among the collaborators. In addition to providing a more holistic and interdisciplinary perspective on the program, this interacting network of collaborators and stakeholders enrich the learning process; make the project more interesting; and is a major asset for the promising development of the TepozEco agenda.
3. A strong multidisciplinary TepozEco program team; and
4. a cooperation agreement with the Local Government and funding for an initial 1-year research and development phase --to draft a 5-year integrated urban ecological sanitation demonstrate program leading to a functioning ecosan system in the municipality of Tepoztlán.

Program components and objectives

Following are the *TepozEco* "Phase I" (2002) pilot program objectives:

Program component	Objectives
Ecological toilets	To establish and demonstrate that ecological toilets, in different models, are both economically and technically viable, as well as culturally acceptable options for water conservation and environmental protection.
Water supply	To assure that the population and local authorities recognize the real and critical situation of the potable water supply, as well as the importance of designing and applying water conservation and protection measures.
Graywater	To demonstrate the economic, social and environmental viability of reusing graywater, through alternative technologies, to resolve the principle wastewater problems felt by the population.
Composting and organic agriculture	To establish and demonstrate that composting and organic vegetable gardens are a technically viable and culturally acceptable option for organic recycling and utilizing human urine.
Education and environmental training	To widely disseminate the theory and practice of ecological sanitation among families and groups in the municipality of Tepoztlán.
Management, monitoring and evaluation	To assure the effective management of Phase I (2003) of the *TepozEco* Urban Ecosan Program and establish the necessary conditions for a successful transition into Phase II (2004-2007), as well as the ultimate success of the initiative.

An array of activities have been and will be carried out to attempt to accomplish each of these objectives, including: training workshops; public presentations and practical demonstrations; applied research and case studies; family visits and technical support; dissemination of educational material and advertising; public relations and advocacy; and participatory monitoring and evaluation. Each program component presents unique challenges and will require an ongoing iterative process in which we learn from both successes and failures and readjust our strategies as we move forward. However, in all cases, the network of partners and project collaborators will be of paramount importance for establishing and ensuring the continuity of the program.

Implementation strategies and future work

The overall strategy for achieving the program objectives listed in the table above is threefold:

1. Intensive: to concentrate an integrated approach in at least three specific communities. Work has already begun in a peri-urban neighbourhood and an outlying rural town. The third community will be selected following the same criteria:
    - Good level of group organization and committed local leadership
    - Water scarcity or supply problems and/or severe contamination problems
    - Low economic class
    - Easy access and good visibility
    - Existing ecological practices and/or a genuine interest in closing the nutrient cycle
2. Extensive: to involve the entire municipality, targeting motivated individuals/families and organized groups. The TepozEco project has established an office and information center in downtown Tepoztlán. The TepozEco multi-purpose facility will serve as an ecosan demonstration area and training center, as well as a place where people can have access to permanent exhibits, freely distributed information materials (brochures and leaflets), technical support and purchase materials (urine-diversion toilet seats and urinals, water conservation kits, books, manuals, etc.). In addition to learning about different sanitation and water conservation and treatment options, visitors will be referred to model "green houses" and "certified" masons capable of building ecosan systems. Ecological sanitation mini-workshops will be given at least twice a month to explain the philosophy, introduce basic technologies and "recruit" motivated individuals. The strategy will include systematic monitoring and follow up.
3. Downtown: to help the local government develop an integrated water and sanitation plan for the downtown tourist center, which includes the treatment wetland system. In collaboration with TVS and the local government, we aim to develop an adequate and just system of incentives and tariffs for the future wastewater service customers, which would help recover the plant's capital and operational expenses and, at the same time, encourage the installation of eco-toilets (including urine-diversion), graywater filters and other water conservation strategies. By strategically merging the *TepozEco* program with the wetland treatment system, a significant portion of the population will receive adequate sanitation services.

Finally, the TepozEco program will employ a household centered approach; response to local felt needs; and use of participatory methods to develop equitable services and distribution of benefits. Respect for freedom of choice will be assured through access to information and options, incentives to stimulate the use of ecological technologies, and a system of sanctions in cases of noncompliance and negligence.

During the "second phase" (2004-2006) the *TepozEco* program will scale up pilot activities in order to organize and implement an integrated ecosan system involving household ecological sanitation facilities; neighbourhood and municipal collection; secondary processing of household residuals and refuse; and reuse of organic nutrients. It is expected that ecological sanitation will be a central component of municipal plans and services.

The “third phase” (2007+) will concentrate on ongoing monitoring and evaluation; documentation and dissemination of the lessons learned; and training and information exchange to facilitate replication of the approach in other areas of Mexico, Central and South America. It is anticipated that the *RedSeco* would play a major role in designing and coordinating the training and study visit program, initiated during initial phases of the program.

Although the implementation of most of these plans are still ahead, with commitment, effort and professionalism we hope that within a decade Tepoztlán could become a model town in ecological sanitation.

Conclusions

The *TepozEco* program is essentially a challenge in small-town urban planning and development, and as such has been navigating through still uncharted waters. Thanks to the patience and flexibility of the team and the invaluable ongoing support of UNDP/BDP/ESDG, the program has been able to evolve incrementally. Rather than rushing into a hastily cooked project document, the partners have taken the time to test approaches, develop a high level of mutual trust, consensus regarding goals and objectives, and a realistic understanding and acceptance of their mutual strengths and limitations. Although only time will tell whether this process has established the necessary groundwork for a solid and sustainable program, the participants are confident the seeds sown will yield positive results and lessons learned.

We hope that our experience will challenge the audience to question their own planning and funding practices. What are some of the preconditions and strategies required for stimulating holistic and sustainable community based ecosan programs in developing countries? Ironically, as discussed in this paper, the strategy that has been most effective –though frustrating at times- is not to have a fixed plan or strategy, but to adapt or co-evolve with the circumstantial events and opportunities that develop as we work towards achieving our program objectives. Consequently, we recommend this adaptive planning process, along with a strong network of partners, as central project management tools to help promote the long-range success and impact of ecological sanitation programs in Latin America.

Finally, ecological sanitation promotion programs must include not only proper engineering, but also sound psychology, and sensitivity to local priorities and politics.

Ecosan: an unsuccessful sanitation scheme at a rural school: Lessons learned from the project failure

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Session C

Keywords

Ecosan, institutional toilets, pupils, school, teachers, urine diversion

Abstract

Emzamweni High School is a rural educational institution in South Africa that serves a number of low-income communities. Sanitation was a badly neglected aspect, with the facilities consisting of old, unimproved pit latrines, which were in a filthy and unhygienic condition due to a lack of proper care and maintenance. The Municipality decided to construct a new toilet block, using the opportunity to demonstrate ecological sanitation technology. The challenge was to introduce ecosan at an institutional facility, rather than in a home. The concept was therefore thoroughly workshopped with the principal and teachers, who would be ultimately responsible for transferring the required knowledge of operation and maintenance procedures to the pupils, in order to ensure proper use of the toilets. Information booklets and posters were also prepared and given to the school for use as teaching aids. Despite the careful preparation and intensive training, however, the teachers were not committed to ensuring that the pupils used the facilities properly, and the project was therefore a failure. Nevertheless, some valuable lessons were learned for future implementation of urine diversion sanitation projects at South African schools.

Introduction

Emzamweni High School is a rural educational institution situated within the municipal boundary of Msunduzi, in KwaZulu-Natal province, South Africa. It is located in a scenic area and serves a number of low-income communities in the surrounding district. In the majority of schools populated by Blacks, sanitation had been badly neglected by the previous authorities, and while the present government has committed itself to improving school sanitation, it is struggling to catch up with the backlog of inadequate amenities. Emzamweni's "toilets" consisted of dilapidated, smelly and unhygienic ordinary pit latrines, with no handwashing facilities. They were also in a filthy condition, due partly to vandalism, but mostly because of a lack of proper care and maintenance (Figure 1). The latter problem was largely the result of the teachers' poor attitude – they had the use of flushing toilets connected to a septic tank, as well as proper washbasins with running water, and were either completely unaware of the pupils' plight or did not care. The school janitor obviously also avoided cleaning the pupils' toilets, because the floor was never even swept. The result of this neglect was that female pupils did not make use of the facilities, preferring to wait until they returned home, while male pupils simply relieved themselves behind the nearest convenient tree or against the wall. Interestingly, the teachers' toilets were also neither clean nor properly maintained.

Figure 1: The existing school latrines

Although the school property belonged to the provincial education department, the Municipality decided, as a community project, to sponsor the construction of improved sanitation facilities. It was, however, stipulated that the municipality would only sponsor half the actual number of toilets required for all the pupils, and that the school would be expected to raise its own funds to build the remainder. CSIR was requested to assist with the technical and social input, and it was agreed to use the opportunity to demonstrate ecological sanitation technology, which was completely unknown in this area. It was also an interesting challenge to introduce urine diversion at a school, rather than in a home – it is always easier to implement a sanitation project in a domestic situation, because the family owns the toilet and the mother usually assumes control of it, keeps it clean and teaches the children how to use it properly. An institutional toilet is not subject to this personal control, and ownership can thus be a problem. Social aspects therefore took priority during project implementation.

Project implementation

A meeting was arranged between the CSIR project team and the school staff (principal and teachers), where urine diversion technology was explained (Figure 2). The intention was to gain acceptance in principle of the proposed technology before detail project planning commenced. Much interest was shown – and also some scepticism – with many questions being asked concerning the operation and maintenance of the toilets.

The next step was to facilitate a workshop for the teachers (Figure 3). The intention of this workshop was to transfer to them the knowledge required for teaching the pupils how to use and maintain the new toilets. This included discussing the various aspects of sanitation in some detail, starting with basic hygiene awareness and disease transmission routes associated with

Figure 2: Initial meeting with teachers where urine diversion technology was explained

poor sanitary practices. Operation and maintenance of urine diversion toilets, including excreta re-use in agriculture, were then discussed at length, using posters specially prepared for this purpose (Figure 4). There was wide debate on the latter aspect, as re-use of human excreta is a foreign concept in South Africa.

Figure 3: Workshop for teachers

Booklets containing all the information covered in the workshop, as well as copies of the posters, were given to the school for use as teaching aids. It was made clear to the teachers that only they, and nobody else, were in a position to transfer this knowledge to the pupils, and that it would be their responsibility to do so once the new toilets were built. It would also be their responsibility to ensure that the pupils kept the toilets clean and properly maintained. Some maintenance methods were suggested, such as developing a roster for the various classes to

Figure 4: Examples of ecosan posters

be involved in cleaning activities, ensuring proper supervision, limiting use of the facilities to only half the pupils, etc.

Figure 5: Examples of illustrations in teaching aid booklet

The booklets contained a written and pictorial description of urine diversion sanitation, as well as information on basic health and hygiene, water- and excreta-related diseases, operation and maintenance of the toilets, and re-use of urine and dehydrated faeces. Figure 5 shows some of the illustrations contained in the booklets.

Meanwhile, construction of the toilet block had begun. The pupil numbers dictated that, for the first phase construction decided upon, 6 toilet pedestals for girls and 4 for boys were required. The boys would also be supplied with a urinal. The faeces vaults were designed to be easily accessible, while the urinal was flushed by wastewater from the handwashing trough. All urine was collected in a single pipe and led to a storage tank, where it would be available for agricultural use if desired. Figure 6 illustrates these aspects, while Figure 7 shows the relevant design details.

Figure 6: Construction details: left, handwashing trough and part of urinal; right, urine tank; below, nearly completed structure

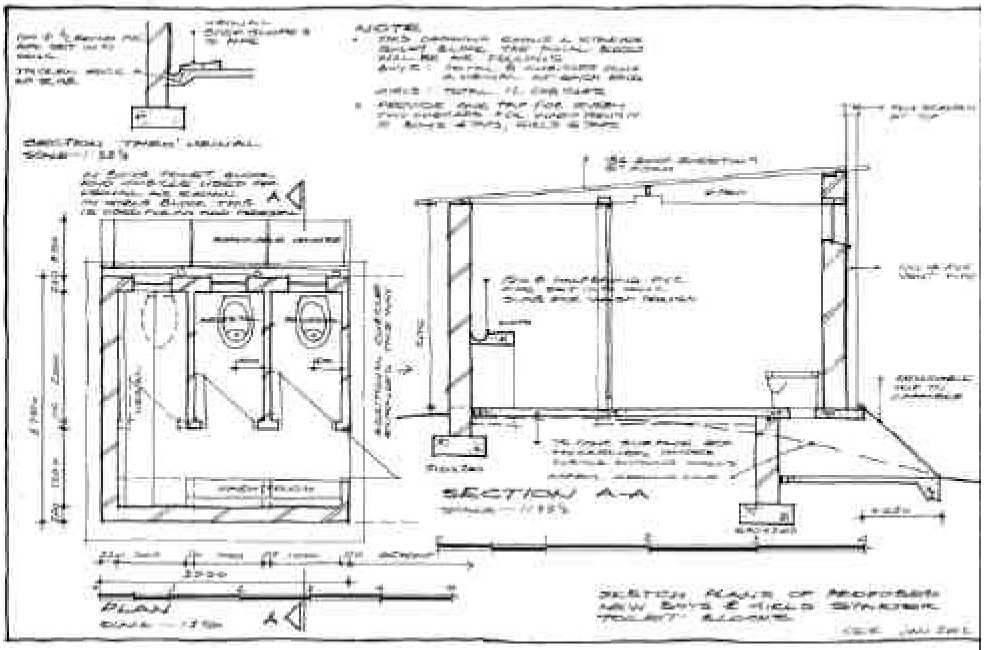

Figure 7: Design details of the toilet block showing vaults.

Results

The toilet block was completed in July 2002. Due to the fact that a few months had elapsed since the teachers' workshop, a refresher session was offered on the important aspects of urine diversion toilets. This took place just before the facility was opened for use. The teachers were reminded that the toilets would not work properly unless they committed themselves to ensuring that the pupils adhered to correct operation and maintenance procedures. This would be especially important at the beginning of each year, when a new crop of pupils would arrive at the school. Posters were put up on the walls inside the toilet block and a large pile of ash, as well as plastic buckets, were provided. The principal appointed one of the male teachers as manager of the toilet block, with the responsibility for ensuring proper operation and maintenance.

An opening ceremony was held and various dignitaries, including the mayor and officials from the education department, attended. There was much pomp, with speeches by the dignitaries and singing by the pupils. The event ended with a ribbon cutting as the new facility was officially opened. Although there appeared to be much enthusiasm about the new facility, the principal, in his speech, made use of the opportunity to lobby for more classrooms and better teaching equipment, and the intended focus on sanitation therefore diminished. It was nevertheless hoped that there would be successful and beneficial use of the toilets, as originally intended. This was not to be, however.

While the teachers made an initial attempt to explain the technology to the pupils, it very soon became obvious that they were not committed to the task. During a visit made a few weeks after the toilets were put into use, it was found that pupils had been defecating in the urine bowls of the pedestals and throwing anal cleansing material into the vault instead of into the plastic containers provided. Some of the urine outlet pipes were blocked as a result of the misuse, and the toilets were malodorous. It was also discovered that the principal was not aware of the problems. On being informed, however, he castigated the toilet manager who subsequently arranged for the facilities to be cleaned up.

A further visit was undertaken approximately seven months later, in February 2003. This occurred about six weeks into the new school year, and was unannounced. A foul odour, similar to that found in the school's old pit latrines, was detected from outside the toilet block already. An inspection revealed that the toilets had again been misused very badly, with nearly all the urine bowls being blocked with faeces and rubbish, the plastic containers intended for used cleaning material filled with urine, the handwashing troughs littered with cigarette butts, and the faeces vaults containing paper and rubbish but very little ash. The facility had also been vandalised, with the educational posters having been torn off the walls and some fittings broken. When the principal was approached concerning the matter, it was again evident that he was not aware of the problems. In fact, his only comment was that there were not enough toilets for the

Figure 8: Some graphic examples of toilet misuse

whole school, that any problems that may have arisen were due to congestion, and that the second phase facility should be built. The teacher who had been appointed manager of the facility also claimed that cleaning had been carried out on a regular basis, but this was obviously not the case. Figure 8 shows some results of the misuse.

Discussion

The project can certainly not claim to have been a success. On the contrary, it was an embarrassing experience for the project team, for whom project failure was an uncommon experience. However, some salutary lessons were learned in the process, and the following conclusions can be drawn regarding the installation of urine diversion toilets as institutional facilities (i.e. as opposed to domestic toilets) in the South African context:

- The teaching profession in South Africa, particularly at poor, under-funded government schools, has been under a great deal of pressure for a number of years to produce good academic results with very limited resources. Issues like sanitation facilities, therefore, while seemingly important for the authorities, are less significant for the teachers. This becomes even more evident when the teachers themselves, while having better facilities than the pupils, do not even look after their own toilets.
- There has generally been much success in the domestic sanitation scene with the implementation of urine diversion toilets, for reasons already mentioned (ownership, etc). It is probably advisable, therefore, to ensure implementation in the school's feeder community before attempting to install these toilets at the school itself. In this way, pupils will be fully conversant with the technology and will understand the operational issues without needing any training by the teachers, who are in any case unwilling to do it.
- Unless the education authorities make it compulsory for the teachers to ensure proper training for the pupils, it is unlikely that they will have any incentive to do so. The education and health departments should enforce proper care and maintenance, to be carried out by the schools themselves, by means of regular visits by inspectors and sanctioning for non-compliance. This could be linked to incentives such as more or better educational aids.
- Both teachers and pupils should have the same type of toilets, so that teachers and pupils can share the same experiences.
- The problem of ownership will always occur when something is given for nothing. Every school, no matter how poor, should contribute **something** towards new sanitation facilities in order to obtain some sort of commitment to proper care.

Longitudinal study of double vault urine diverting toilets and solar toilets in El Salvador*

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Keywords

Composting toilets, ecological sanitation, El Salvador, latrines, solar toilets, hygiene, bacteria, helminths, viruses, protozoa, die-off

Abstract

This one-year study took repeated measures of the physical (moisture content, temperature), chemical (pH) and microbiological (faecal coliforms, *Clostridium perfringens*, coliphage, *Trichuris*, hookworm and *Ascaris*) properties of biosolids from 156 ecosan toilets in El Salvador with different designs, use and maintenance patterns. In double-vault urine diverting toilets, pH and long storage time were the primary factors that contributed to microbial inactivation. In solar toilets (with black metal covers), high peak temperature, pH and storage time were the critical factors affecting microbial inactivation. This study demonstrates that improvements in toilet design (larger, partitioned vaults and good solar exposure), longer storage time and consistent use of high pH additives will result in an endproduct that meets USEPA standards for Class A biosolids that are safe for agricultural use.

Introduction

El Salvador is the most densely populated country in Central America, and ecological sanitation (ecosan) has been promoted by the Ministry of Health, UNICEF and several non-government organizations. Double-vault urine diverting toilets (DVUD) and single-vault solar toilets are intended to store faecal waste under conditions that promote desiccation and inactivation of faecal pathogens. The treated biosolids are then removed and disposed of or may be used for agricultural purposes. We previously reported on a baseline survey of over 400 households with DVUD or solar toilets in six rural and one urban community in El Salvador where we observed a wide range in the physical characteristics and microbial quality of the stored biosolids (Moe et al., 2001). We now report on a longitudinal study of 156 DVUD and solar latrines in seven rural communities in El Salvador from November 2000 to March 2002.

Methods

Field Methods: We conducted a survey of 118 households with DVUD toilets and 38 households with solar toilets in seven rural communities in El Salvador. The toilets had been in operation for an average of 5.4 years, with a range of 1 to 13 years. The head of each

*This paper has been peer reviewed by the symposium scientific committee

household was interviewed in order to collect information on household demographics, water supply and treatment, toilet use and maintenance behaviors and household knowledge and attitudes about the toilets and disease transmission. In addition, we conducted a sanitary inspection of the toilet and recorded information about design and construction, cleanliness, ventilation, and presence of additives. Finally, the vault not currently in use was opened from the top, and biosolids samples were collected from the top, center and bottom of the pile using a core device. Households were asked to keep a written record of the last time they used that side of the toilet in order to determine the age of the biosolids in the vault at the time of sample collection. The color and texture of each sample and the ambient temperature and temperature inside the pile were recorded at the time of sample collection. Peak temperature was the highest recorded temperature inside the pile and was usually recorded during the middle of the day. Each household was visited every 3 months. Physical measurements were taken and biosolids samples were collected at each visit. Ten households were excluded from the final regression analyses because: 1) the toilet was located near a river and the vault was frequently flooded when the river level rose (N=2), or 2) both vaults were used at the same time (N=8).

Laboratory Methods: A series of physical and microbiological measurements were performed on each biosolids sample to assess microbial inactivation under the environmental conditions found in DVUD and solar toilets. Microbial indicators (faecal coliforms, *Clostridium perfringens*, somatic coliphage) were selected as models for the survival of enteric bacterial, protozoal, helminth and viral pathogens. For each toilet, a composite sample was prepared by weight from the samples collected at the top, center and bottom of the pile. The composite sample was suspended in buffer (10% suspension) and then aliquoted for each of the physical and microbiological tests. Sample pH was measured by adding distilled water to the sample until it was possible to take a measurement with a standard pH probe. Moisture content was measured by comparing initial weight of a 10-50 gm sample of the composite sample that was put in oven at 103^{o}C overnight and weighed the following day and weighed again until variation in the dried weight measurements was <4%. Faecal coliforms were analyzed using A1 broth and a multiple tube technique. *C. perfringens* were analyzed using iron milk media and a multiple tube technique. The faecal coliform and *C. perfringens* estimates per gram of sample were calculated using most probable number (mpn) tables. Somatic coliphage were measured as plaque forming units (pfu) on the CN 13 host. The presence of viable *Ascaris, Trichuris* and hookworm ova was assessed by an adaptation of the US EPA "Methods for Detection, Enumeration, and Viability Determination of *Ascaris* Ova in Sludge".

Statistical Analyses: Multivariate analyses were performed with SAS system software (version 8.1, SAS Institute, Inc., Cary, NC) using the REG procedure for regression analyses and the LIFETEST procedure for survival analyses.

Results

The physical parameters for DVUD and solar toilets are compared in table 1. The most notable difference is the shorter average storage time of the biosolids in the solar toilets (26 days vs. 306 days) due to the smaller vault design of the solar toilets. Also, solar toilets were slightly drier and reached higher peak temperatures than DVUD toilets.

Measurements of the temperatures of the biosolids in the vaults indicated that true aerobic composting was not occurring because the temperatures were only slightly higher than ambient temperature rather than the 60^{o}C typical of a large thermophilic composting reaction. We observed a difference in the temperature of biosolids measured in the middle of the day (peak temperature) compared to the temperature measurements made in the morning. This difference was especially notable in the solar toilets where the average peak temperature of the stored biosolids was 7 degrees higher than the average morning temperature of the biosolids.

A wide range of pH conditions was measured in the biosolids – reflecting different household use of lime and ash additives. Soil additives had an average pH of 8.8, ashes were around pH 9.4, and the average pH of lime was 10.5. There was no clear relationship between pH and biosolids storage time (data not shown). Some communities tended to use certain additives more frequently. Reported addition of ash varied by community from 0 to 89% of households, and reported lime use varied by community from 1 to 64% of households.

Moisture content of the biosolids was inversely related to storage time (data not shown). Samples of biosolids that had been stored for more than 12 months had mean moisture content of <34% compared to a mean moisture content of 40% in samples stored less than 6 months.

Parameter	DVUD toilets (N=117) Mean (Min-Max)	Solar toilets (N=38) Mean (Min-Max)
Storage time (days)	306 (80-720)	26 (0-90)
Moisture content (%)	37 (15-96)	31 (3-77)
Temperature (^{o}C)	31 (22-36)	30 (23-37)
Peak temperature (^{o}C)	~1^{o}C higher than ambient temp	37 (30-44)
pH	9.6 (6.2-13.0)	9.9 (7.1-12.9)

Table 1: Comparison of physical characteristics of DVUD and Solar Toilets

In addition to the routine samples collected every 3 months, we also collected biosolids samples immediately before the vault was going to be emptied in order to describe the microbiological safety of the biosolids that would be handled, and either discarded or used for agriculture. Analyses of the microbial quality of these endproduct biosolids samples (table 2) indicated that the solar toilets were less likely to produce USEPA Class A biosolids (<1000 faecal coliforms per gram) compared to the DVUD toilets (55% vs. 81%, respectively). Biosolids from the solar toilets also had higher levels of *C. perfringens* and coliphage. However, no viable *Ascaris* ova were detected in any of the 22 samples analyzed from solar toilets. In contrast, 20 of 49 (41%) of DVUD biosolids had viable *Ascaris* ova.

Microorganism	DVUD toilets (N=117) No. pos samples/Total (%)	Solar toilets (N=38) No. pos samples/Total (%)
Faecal coliforms ≥1000 mpn/gm	21/108 (19)	17/38 (45)
Clostridium perfringens ≥1000 mpn/gm	60/108 (56)	25/38 (66)
Somatic coliphage ≥5 pfu/gm	15/108 (14)	12/38 (32)
Ascaris (≥1 ova/gm) Viable Not viable	 20/49 (41) 33/49 (67)	 0/22 1/22 (5)
Trichuris (≥1 ova/gm) Viable Not viable	 7/49 (14) 32/49 (65)	 1/22 (5) 4/22 (18)
Hookworm (≥1 ova/gm) Viable Not viable	 0/49 0/49	 0/22 2/22 (9)

Table 2: Microbial concentrations in endproduct biosolids from DVUD and solar toilets

Multiple regression models were used to analyze the effects of storage time, moisture content, temperature and pH on microbial indicator concentrations and viable *Ascaris* ova (table 3, 4). In both DVUD and solar toilets, pH was the most important single factor determining the inactivation of the bacterial indicators and coliphage. Desiccation was also a significant factor controlling bacterial and coliphage die-off in the DVUD toilets, but the magnitude of the effect was smaller. For solar toilets, where the peak temperature can reach as high as 44°C, temperature was the strongest predictor of *Ascaris* die-off. In the DVUD toilets, storage time was also important factor affecting viable *Ascaris* ova concentration.

Microorganism	Storage Time[1]	Moisture[2]	Temperature[3]	pH[4]
Faecal coliforms (Log mpn/gm)	-0.03 (p=0.04)	-0.01 (p=0.007)	-0.06 (p=0.10)	-0.43 (p<0.0001)
Clostridium perfringens (Log mpn/gm)	-0.09 (p<0.0001)	-0.05 (p<0.0001)	-0.08 (p=0.07)	-1.05 (p<0.0001)
Somatic coliphage (Log pfu)	-0.05 (p<0.001)	-0.02 (p<0.001)	-0.07 (p=0.023)	-0.20 (p=0.005)
Ascaris (viable ova/gm)	-0.72 (p=0.001)	-1.33 (p=0.57)	-6.95 (p=0.61)	11.61 (p=0.73)

1 Parameter estimate and p-value for effect of one additional month of storage
2 Parameter estimate and p-value for effect of 10% decrease in moisture content
3 Parameter estimate and p-value for effect of 1°C increase in temperature
4 Parameter estimate and p-value for effect of increase by one pH unit

Table 3: Multiple regression analyses of microbial inactivation in 107 DVUD toilets

Microorganism	Storage Time[1]	Moisture[2]	Temperature[3]	pH[4]
Faecal coliforms (Log mpn/gm)	-0.19 (p=0.08)	-0.019 (p=0.11)	-0.12 (p=0.007)	-0.91 (p<0.0001)
Clostridium perfringens (Log mpn/gm)	-0.03 (p=0.72)	-0.03 (p=0.03)	-0.10 (p=0.03)	-1.02 (p<0.0001)
Somatic coliphage (Log pfu)	-0.08 (p=0.33)	-0.02 (p=0.02)	-0.06 (p=0.05)	-0.47 (p<0.0001)
Ascaris[5] (viable ova/gm)	-0.036 (p=0.01)	-2.25 (p=0.10)	-19.80 (p=0.0008)	-1.19 (p=0.95)

1 Parameter estimate and p-value for effect of one additional week of storage
2 Parameter estimate and p-value for effect of 10% decrease in moisture content
3 Parameter estimate and p-value for effect of 1°C increase in temperature
4 Parameter estimate and p-value for effect of increase by one pH unit
5 Ascaris results from both DVUD and solar toilets (N=71) were included in this regression model in order for the model to converge.

Table 4: Multiple regression analyses of microbial inactivation in 38 solar toilets

We used survival analyses techniques to examine the effect of each physical parameter on microbial inactivation over time in both the DVUD and solar toilets. These analyses indicated that the most rapid inactivation of faecal coliforms (figure 1a and 1b), *C. perfringens*, somatic coliphage and *Ascaris* (figure 2a and 2b) occurred when pH was ≥11 and peak temperature was ≥36°C.

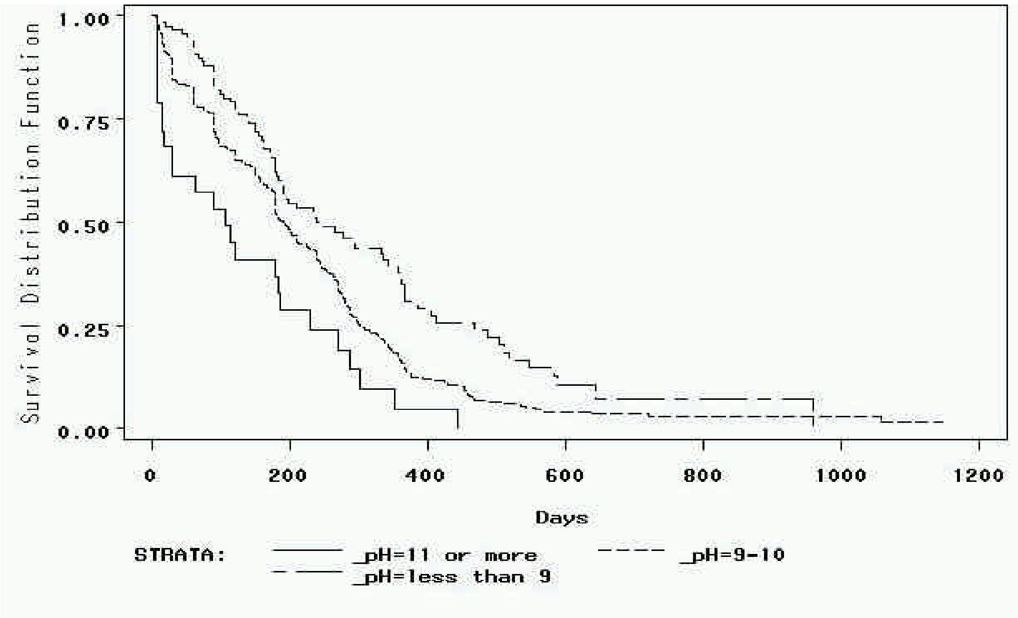

Figure 1a: Effect of pH on faecal coliform inactivation over time

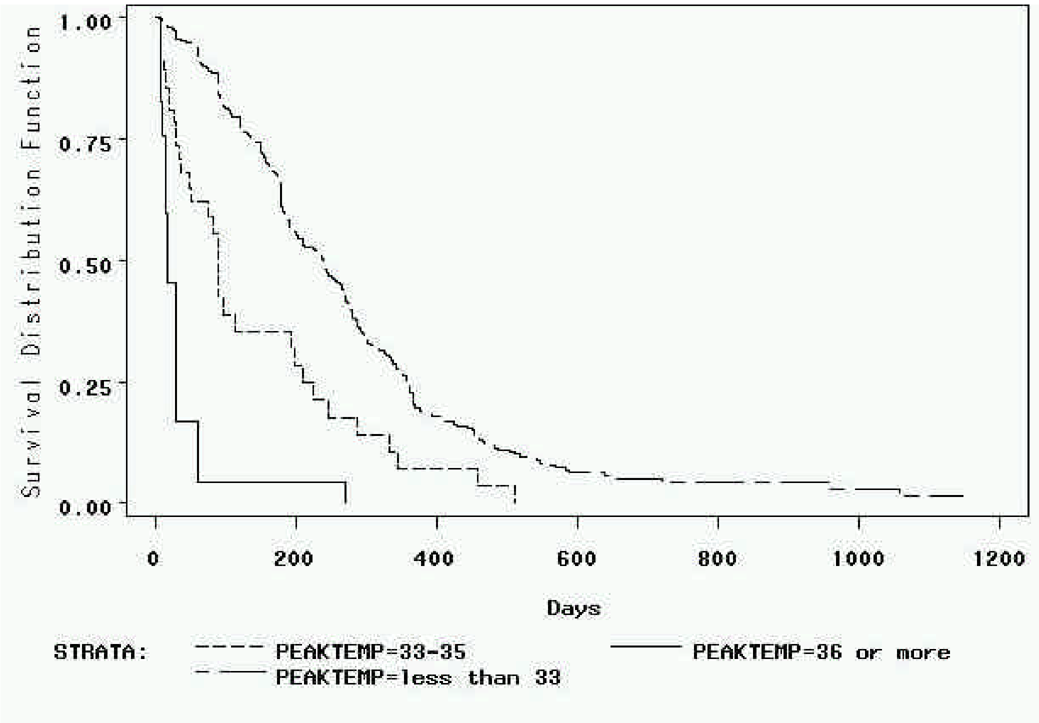

Figure 1b: Effect of peak temperature (degrees Celsius) on faecal coliform inactivation over time

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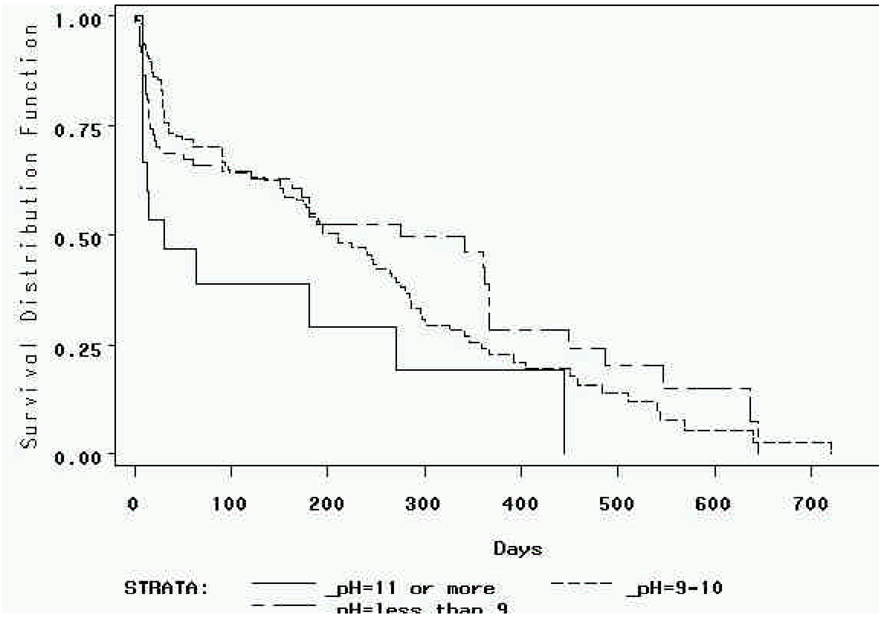

Figure 2a: Effect of pH on *Ascaris* inactivation over time

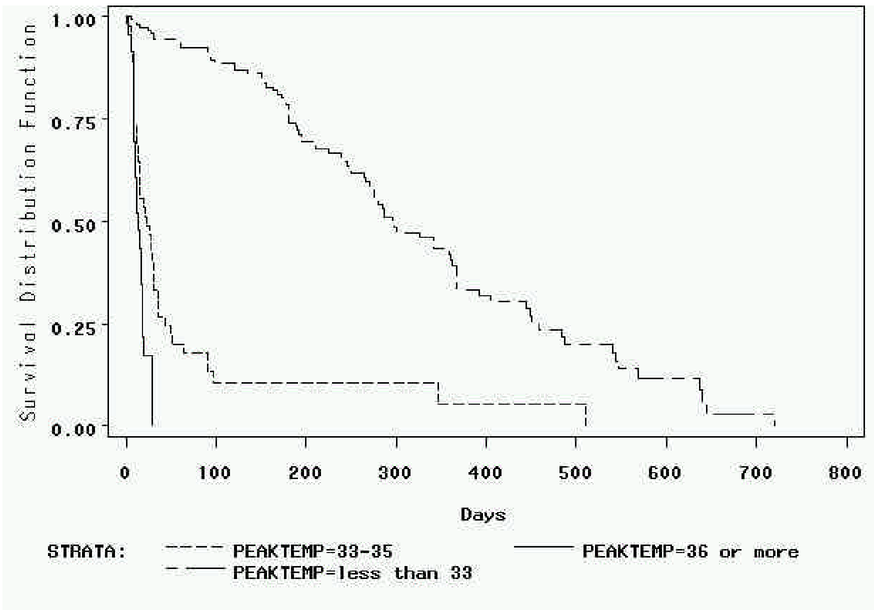

Figure 2b: Effect of peak temperature (degrees Celsius) on *Ascaris* inactivation over time

Discussion

In 1992, the Ministry of Public Health of El Salvador initiated a national program to promote DVUD toilets, and the population was encouraged to use the biosolids as fertilizer for agriculture. Because of concern about the safety of reusing DVUD biosolids, evaluations of the DVUD toilets were conducted in 1994 and 1996 by Creative Associates International (CREA International, 1996). In the second evaluation, 51 samples of DVUD biosolids were examined in the CEMAT laboratory in Guatemala. The laboratory reported concentrations of faecal coliforms in the range of <3 to 460 (MPN/g). Based on the laboratory results, the report concluded that 39.2% of the DVUDs were being used and maintained adequately, 25.5% had some problems indicated by the presence of total and/or faecal coliforms, and 35.3% were in bad condition because of high levels of total and faecal coliforms in the biosolids samples. Paradoxically, in spite of reporting the presence of total and faecal coliforms, none of the samples showed presence of *Ascaris* ova. The results of the CREA study raised questions about the safety of the biosolids from the DVUD toilets as they were being used and maintained in El Salvador. The purpose of our study was to learn more about the factors that determine the die-off of bacterial and viral index organisms and *Ascaris* in biosolids over time by collecting repeated measures from 156 households in El Salvador with DVUD or solar toilets.

The DVUD toilets were generally effective at producing biosolids (81% of endproduct samples) that met the USEPA faecal coliform standard for Class A biosolids (<1000 faecal coliforms/gm) that are considered safe for agricultural use (USEPA, 1994). The long storage time in the DVUD toilets (average = 306 days) may be the primary factor contributing to bacterial inactivation. Only 59% of the DVUD samples met the *Ascaris* standard for Class A biosolids (<1 ova/4 gm). The multiple regression and survival analyses results indicated that the most critical parameter for inactivating the bacterial indicators and coliphage was pH and for *Ascaris* the most critical factors were high temperature and high pH. In the DVUD toilets, we observed a broad range of pH (6.2 – 13.0), but the peak temperature was typically only 1 degree higher than the ambient temperature (average 31^{o}C) and therefore was unlikely to have an effective impact on *Ascaris* inactivation. Carlander and Westrell, in their 7 week study of DVUD in Vietnam (1999), also concluded that high pH (pH>10) was the single most important factor for inactivation of bacteriophage in biosolids and that high pH and temperature were important for rapid inactivation of *Ascaris*. In the 12 DVUD (6 with solar panels) they studied, the biosolids temperature ranged from 28.3 to 40.1^{o}C, pH ranged from 8.1 to 10.9 and % moisture ranged from 21% to 45%. However, Carlander and Westrell reported surprisingly rapid inactivation of *Ascaris suum* ova seeded into the biosolids pile with an 80% reduction in viability compared to the control ova after 2 weeks of storage and 95-100% reduction after 9 weeks.

We detected no viable *Ascaris* in biosolids samples from the solar toilets where the average peak temperature was 37^{o}C and sometimes as high as 44^{o}C. These toilets also had a slightly higher average pH than the DVUD toilets that may have promoted *Ascaris* inactivation. However, the endproduct samples from the solar toilets were more likely to have high concentrations of faecal coliforms, *C. perfringens* and coliphage compared to the DVUD toilets. Only 55% of the samples from the solar toilets met the faecal coliform standard for Class A biosolids. Nonetheless, this is better than the performance of 90 single vault solar composting toilets described by Redlinger et al. (2001) where only 36% of the samples met Class A biosolids standards after 6 months. Shorter storage time (average = 26 days) was a problem with the solar toilets and may explain in part why the bacterial and coliphage levels were high in some samples.

Solar toilet designs have been evolving in El Salvador. Our study examined three different designs in three different communities. The earliest design had a large, single vault, and fresh excreta were mixed with the stored biosolids. Also, the "solar panel" (a metal cover painted black) was often not oriented toward the sun or was in the shadow of trees and bushes. This design did not reach a high peak temperature (mean = 33^{o}C), but this community added a lot of lime to their toilets so the average pH was very high (10.4). In the second solar design, the vault had a partition between fresh and stored biosolids, but the overall vault size was smaller and had to be emptied about every 15 days. The average peak temperature was low (34^{o}C) because many solar panels were not exposed to maximum sunlight, and the average pH was low (8.2) because this community used mainly soil and little ash as additives. The latest solar toilet design had a larger partitioned vault that separated the fresh excreta and allowed longer storage time for the biosolids (average = 31 days). Most of the solar panels in this community had good southern exposure, and this resulted in an average peak temperature of 42^{o}C. This community also added a lot of lime to their toilets and the average pH was 10.3. The biosolids from this latest solar toilet design consistently had lower bacterial and coliphage levels than the other two designs, and 75% of these samples met the faecal coliform standard for Class A biosolids. Redlinger et al. (2001) also emphasized the importance of solar exposure in single vault solar toilets in Mexico. They reported that 95% of biosolids samples that met the Class A biosolids standard were from toilets with good solar exposure.

Conclusion

The longitudinal design of this study allowed us to take repeated measures over one year of the physical, chemical and microbiological properties of biosolids from a large number of ecosan toilets with different designs, use and maintenance patterns. In this humid climate, pH and peak temperature were the most important factors affecting the microbial quality of the biosolids in both DVUD and solar toilets. Additives to raise pH levels in ecosan toilets should be strongly promoted. Our study examined three different solar toilet designs and found that the most recent prototype with good solar exposure, a partitioned vault and longer storage time yielded the best quality biosolids. Improvements in ecosan toilet design and use should provide a safer biosolids product for agricultural use. The risks of applying biosolids to land have been recently reviewed by the National Research Council (NRC, 2003). However, further studies are needed on how to promote more rapid and complete microbial inactivation under conditions that could be achieved and sustained in DVUD and solar toilets in different climates.

Acknowledgement

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Skaneateles lake watershed composting toilet project

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Keywords

Composting toilet, pail service, privy, Skaneateles Lake

Abstract

The City of Syracuse has selected composting toilets to phase out a century-old service of collecting pails of raw sewage from privies (currently referred to a 'pail service'), which it has subsidized for almost a century in the watershed of its primary drinking water supply, Skaneateles Lake. Following a two-year pilot study, it was evident that composting toilets were the only economic and environmentally sound alternative as a replacement to pail service. Surprisingly, many cottage owners were reluctant to abandon this unique service that had been used for generations. Even though cottage owners utilizing pail service were accustomed to offensive odors and unsanitary conditions, their prejudice towards composting toilets was not easily dismissed. To offset these concerns, informational mailings, workshops and site visits were conducted throughout the process to insure a smooth transition. Cottage owners were closely involved with the toilet model selection and placement of the unit, either in the cottage or placed in the existing privy. At the end of 2002, eighty six percent of composting toilet installations had been completed. To date, only one cottage owner has choosen to install a flush toilet serviced by a holding tank.

Introduction

Skaneateles Lake, located in the Finger Lakes region of New York State, serves as the primary drinking water source for the City of Syracuse. It is one of the few remaining unfiltered drinking water supplies left in the United States. The lake and it's watershed are situated within three counties and five townships. Watershed Rules and Regulations adopted by the City have been in effect since 1896 to insure the protection of this unique resource. To address development pressures on the watershed and specifically, the lakefront, a City sponsored pail service was initiated in 1908 to create a uniform and efficient method of sanitary protection (City of Syracuse Department of Water, 1908). Privies were built to specifications issued by the City to facilitate pail removal and replacement. Five-gallon pails were placed under a hinged box seat in the privy and collected by City personnel when full, replacing traditional pit privies (City of Syracuse Department of Water, 1912). All of the common barriers to installing conventional wastewater technologies in 1908 were represented at these sites: poor or shallow soils, steep slopes, extremely small lot sizes, converted boathouses used as residences, and limited access. There were a number of cottages that could be accessed only by boat.

Today the City of Syracuse funds and coordinates numerous water quality protection programs including: the Watershed Protection Program, Skaneateles Lake Watershed Agricultural Program and the Skaneateles Lake Watershed Land Protection Program. These programs utilize sophisticated management tools such as Geographic Information Systems (GIS) and Global Positioning Systems (GPS) in an effort to protect and/or enhance water quality in Skaneateles Lake. One of the primary facets of the Watershed Protection Program is conducting comprehensive inspections of all properties within the watershed. This entails routine inspections of the estimated 2600 residences in the watershed (including approximately 1000 of which are lakefront dwellings), farms and commercial enterprises. Another facet deals with on-site wastewater treatment systems (OWTS). City personnel and the respective County Health Department concurrently review all design proposals and inspect installed systems. In addition, the City has direct oversight of repairs to failing or improperly installed systems. This insures timely abatement of problems and has significantly minimized potential adverse impacts. With the above layers of watershed protection and technology in place, the century old practice of collecting five-gallon pails of raw sewage and transporting them by pick-up truck and boat for disposal is antiquated and inefficient. Along with the obvious environmental benefits, initial estimates project that the purchase of composting toilets will have a return on investment of two years. Cost savings to the City are estimated to be over $70,000 annually.

Pilot project

A pilot project was initiated in the summer of 1998 to determine the feasibility of replacing the remaining 100 pail service locations with composting toilets. Five pail service cottages were selected, representing certain challenges. They included proper sizing of units based on volume of waste produced and installation logistics. Since the inception of pail service, the City has documented the number of buckets collected at individual cottages. Ultimately, decades of usage data provided the necessary baseline for the proper sizing of composting units for the specific site.

Two composting toilets certified by the National Sanitation Foundation (NSF), an independent testing laboratory, were selected for the project. Following installation, users of the composting unit were required to record urine and fecal contributions on a daily user sheet. An optional comment section was also provided to correspond with each event. The user sheets provided valuable information regarding the ability of the toilets to handle peak loading during weekends, holidays, social functions or during extended periods of activity. Additionally, extended periods of inactivity could be identified, further validating the reliability of units throughout a range of conditions.

The City worked closely with the cottage owners and vendors to troubleshoot problems. Issues related to improper installation, offensive odor and excess leachate were all corrected prior to the termination of the pilot project. Participants and City personnel concluded that the composting units were an acceptable and welcome alternative to pail service. The success of the pilot program provided the necessary impetus and justification to create an official pail service replacement program for the remaining sites.

A database was created to collect information on cottage owners, including the composting toilet model selected, installation location, occupancy of residence, unit cost, installation cost, etc. The database also documented correspondence with cottage owners and recorded the progress of each installation. Problems encountered during installation and operation were identified on the individual cottage owner's records. The database has been expanded and utilized during the official replacement program (discussed below).

Transition from pail service to composting toilets

In the summer of 2000 the City's Common Council appropriated the funding to provide Sun-Mar composting toilets as a replacement to pail service. Shortly thereafter, a notice was sent to pail service residents signifying the phasing out of pail service. This letter did not specify a termination date. However, owners were encouraged to start making arrangements for a composting toilet installation or pursue approval of an OWTS. The latter would not be subsidized by the City. An agreement was drafted by the City outlining both the cottage owners' and City's responsibilities. Essentially, the City would purchase a self-contained or central waterless composting toilet and provide a contractor to install the unit. The property owner would be responsible for preparing the area for installation and the future operation and maintenance of the unit. In order to properly operate the unit, the cottage owner would have to place finished compost material in five-gallon pails, which would be provided and collected by City personnel. (Discussed below).

Education and training

Prior to each composting toilet installation, a site visit was conducted to identify present and possible future occupancy of the cottage, assist property owners in selecting the appropriate unit and determine placement of the unit. Since many cottage owners were unfamiliar with composting toilets, the site visits provided an excellent opportunity to address their concerns and provide information regarding the operation and maintenance of the units.

Continuous interaction with cottage owners has been essential to the success of this project. Many cottage owners were apprehensive about abandoning a unique and functional waste disposal method which they had utilized since childhood. Others voiced their concerns regarding potential odors, mechanical failures and operation and maintenance responsibilities. To address residents' concerns, workshops were offered featuring representatives from the composting toilet manufacturer, installation contractors and City of Syracuse representatives. Mailings continue to be distributed frequently. These provide information on composting toilet operation and maintenance protocols such as *Spring Start Up and Fall Shut Down Procedures* and announcements for finished compost collection dates. To ensure that cottage owners would have immediate and convenient access to bulking material, (an essential additive for cottage composters) along with optional products distributed by the manufacturer, local hardware and home and garden stores were set up as dealers to carry the products.

Installations

It was evident from the inception of this project that improper installation or initial start-up of composting units could easily compromise the success of this project. Since the majority of cottages utilizing pail service were clustered on fire lanes or secondary roads located on the South end of the lake, any negative experiences would inevitably be broadcast throughout the pail service community. Cottage owners apprehensive about abandoning pail service would routinely request the names and locations of individuals who recently had toilets installed so they could carefully monitor the project.

Cottage owners had a choice between waterless self-contained toilets or central composting toilet systems. Most cottage owners selected the self-contained Sun-Mar Excel model since it can be installed directly in outhouses or existing cottages with minimum or no alteration to the structure. Because there is no separate toilet, installation time is typically less than four hours. The Centrex 2000 Air Flow (AF) was selected for the central composting toilet system. This unit requires approximately four feet of space directly underneath the toilet stool, limiting toilet locations. However, cottage owners determined to utilize the larger capacity central unit or who wanted a more traditional toilet have worked diligently with contractors and the City to find creative solutions. Although a few of Centrex 2000 AF's have been incorporated in existing cottages, most of the units have required construction of a small enclosure off of the cottage or existing accessory structure.

After several composting toilets were installed an installation checklist was compiled, addressing problems encountered by the contractors. The checklist streamlined the installation process and also ensured uniform installations.

Initially, overflow drains were discharged to five-gallon containers to determine the volume of leachate which could be expected during peak use and to allow for collection of leachate samples for pathogen and nutrient testing. After monitoring 42 installations, overflow leachate was observed in only six containers. To reduce maintenance and monitoring responsibilities of cottage owners and more importantly, provide added insurance in the event of a prolonged power outage or unusually heavy cottage use, evapotranspiration (ET) beds were installed in the summer and fall of 2002 replacing the containers. The bed design and dimensions are based on research conducted by Dr. Alfred Bernhart's publication titled *Evapotranspiration, Nutrient Uptake and Soil Infiltration (Bernhart, 1985)*. Because leachate overflow loading rates ranged from 0 to 5 gallons per week, typical bed sizes were dramatically reduced in comparison to beds incorporating standard household graywater and blackwater design flows. The *required bed surface area* was calculated using *total input per season* (total people-days per season multiplied by total waste input per person per season) and dividing by *net total ET* obtained from a bed over the course of a whole season. A cottage estimated to have total person days per season of 400 would require a 5½ square-foot ET bed.

Beds were excavated to 18 inches and lined with 20 millimeter (mm) plastic. A six-inch base of ¾ inch gravel was placed above a thin layer of sand. A four-inch perforated PVC drain pipe was placed on the stone and backfilled. Ninety-degree elbows were connected to the perforated pipe and extended to the bed surface, thus, stimulating air movement through out the bed. Next, the beds were filled with 12 inches of 1 mm sharp sand with a center crown approximately six inches above the sidewalls. Plant selection was limited to Hostas and daylillies in 2002. Other plant types will be incorporated in 2003.

Results

As of August 2002, 69 composting toilets have been installed at residences on the Skaneateles Lake Watershed. Thirty-seven units have been installed in cottages and 32 units in outhouses. Ninety three percent or 64 installations have been self-contained units. Only five central units have been installed as of December 2002, however, an additional six are scheduled for Spring 2003.

For the most active pail service cottages (>100 5 gallon pails of raw sewage), the transition to composting toilets has resulted in less than 4 buckets of finished compost. In the majority of cottages, compost can accumulate for an entire season and be removed the following spring. In 1998, 3,402 pails or approximately 11,226 gallons of raw sewage were collected on the Skaneateles Lake Watershed. A operation which required two full-time and two seasonal workers, totaling over 2,400 man hours, was devoted to collecting pails of raw sewage. A progressive reduction in pail service cottages through the installation of composting toilets has allowed the City's remaining pail service employee to be gradually incorporated into the watershed inspection team. Person-hours are now more effectively utilized for patrolling the watershed to detect various violations of the Watershed Rules and Regulations.

Finished compost is collected by City personnel on a designated date every spring and fall and transferred to composting bins on City property within the watershed. The finished compost is combined with carbon-based materials such as grass clippings, leaves and hay and allowed to secondary compost. To ensure complete pathogen destruction, the internal temperature of the compost will be monitored in an effort to achieve thermophilic or high temperature conditions in the pile. Alternate compost bins have been constructed allowing the compost to age, undisturbed for a minimum of two years after the pile has been built (Jenkins, 1999).

Finished compost was tested at 10 locations in the Spring of 2002 for fecal coliform, total kjeldkahl nitrogen and total solids. Fecal coliform samples were tested utilizing the membrane filter technique. Results ranged from < 2 coliform forming units/gram (cfu/g) to 540,000cfu/g. However, eight of the samples were under 4,000cfu/g. Total kjeldkahl nitrogen ranged from

4,400 milligrams/kilogram (mg/kg) dry wt. to 30,000mg/kg/dry wt. Total solids varied considerably, ranging from 18 % to 93 %.

Overflow leachate was sampled at eight locations for fecal coliform, biological oxygen demand (BOD) and nitrates. Fecal coliform samples ranged from 330cfu/100ml to 90,000cfu/100ml, providing a much narrower range than the finished compost. BOD samples ranged from 2,460mg/l to 20,250mg/l. Nitrate samples were all under 6.32mg/l. Although overflow leachate would not be introduced into groundwater, since the ET bed bottom and side walls are lined with plastic, samples were taken, since it appears that limited research has been documented on the subject.

Due to the limited samples tested and variability of the results, finished compost will continue to be sampled annually. Secondary compost is scheduled to be tested in Summer 2003. This material will be tested regularly for fecal coliform and nutrient levels.

Most problems encountered during this project were due to errors in installation or poor operation and maintenance of the unit. The most commonly occurring problems and the resultant actions taken are listed in the table below.

Problem	Cause	Solution
Offensive odor indoors	Loose or disconnected vent pipe adjacent to toilet	Reconnect pipes
	Fan not capable of forcing air through vent	Alter air flow in unit, forcing more air up vent, or install high speed fan
Offensive odor outside	Fan not capable of forcing air through vent	Alter air flow in unit, forcing more air up vent, or install high speed fan
	Vent pipe not sufficient height	Raise vent pipe
Excessive liquid accumulation in evaporation tray	Unit not installed level, allowing overflow of leachate	Level unit
	Insufficient bulking material in composting drum	Add appropriate material
Excessive liquid accumulation in composting drum	Inadequate bulking agent utilized	Ensure correct ratio of peat moss and wood shavings
Flies in compost	Compost too dry	Add warm water
Anaerobic conditions observed in composting drum	Compost too wet	Ensure correct ratio of peat moss and wood shavings

Conclusions

The Skaneateles Lake Watershed has proven to be the ultimate test for composting toilets. Challenges have included:

- Overcoming extreme venting conditions: cottages positioned immediately below steep slopes and cliffs; dense shoreline development
- Satisfying the demands of cottages with multiple owners/families: coordinating operation and maintenance responsibilities and managing consistently heavy seasonal use
- Convincing cottage owners to abandoned a free sewage collection system which placed virtually no responsibility on the owner

- Educating cottage owners that composting toilets are an efficient and environmentally sound alternative to pail service

Despite these obstacles, with over 80% of the project completed, it is evident that the cottage owners and the City are benefiting. Cottage owners who have elected to abandon their outhouse now have the luxury of an indoor facility. The offensive odor and unsanitary conditions related to accumulation of raw sewage has been eliminated. For the City's investment, it will be rewarded with the elimination of a costly and antiquated service. From the perspective of watershed management and protection, the potential for spillage of accumulated raw sewage during transportation by boat or pickup truck, or contamination of groundwater through a failure at the holding tank has been removed.

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Experiences in setting up ecosan toilets in shoreline settlements in Uganda

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Session C

Keywords

Ecosan, fisher community, operations and maintenance, sensitisation, sustainability

Abstract

Lake Victoria Environmental Management Project (LVEMP) funded by the World Bank (WB) through the industrial and municipal waste management component (IMWM), implemented by NWSC, Uganda identified the use of Ecological Sanitation (ecosan) as the most appropriate sanitation method in pollution control for high density, low income fisher communities along the northern shoreline of Lake Victoria. In 2000, three pilot ecosan toilets of 4 stances, 1 urinal and 1 shower each were setup in two districts. The type of the ecosan employed was the separate and dehydrate technique where urine was considered for direct use in farming and the dehydrated faecal matter composted and reused. Operation and maintenance (O&M) by the end users proved a nightmare since sustainability, multicultural and religious - conflict of faith - issues were some of the aspects initially not considered. This led to the failure of the system to separate faeces and urine and be able to dehydrate the former. Further sensitisation of the population was repeated and after 3 months the O&M of the system improved. The ecosan technology has picked up in Uganda and it is expected to assist in sanitation and pollution control within the Lake Victoria catchment. In the long-run the health of the population and the environment is expected to improve.

Introduction

Lake Victoria has undergone accelerated degradation in the last 50 or so years (Talling, 1987; Kaufman, 1992). One of the contributing factors is the ever increasing population growth that has led to development of human societies and cities (Bugenyi and Balirwa, 1998). This has led to increased urban and industrial run-off that finds its way through watercourses and wetlands to the lake (LVEMP, 1997-2002; NEMA, 2001). Increased human settlement along the shoreline as well as in the lake islands has substantially contributed to the continuous disposal of untreated human waste into the lake water, resulting in an increased pollution load. This has been further aggravated by the degradation of fringing wetlands (MONR, 1995).

The Lake Victoria Environmental Management Project (LVEMP) set up in 1997 under the three riparian East African governments, has as one of its corporate goals to ensure alleviation of further degradation of the lake in regard to industrial and municipal waste. National Water and Sewerage Corporation (NWSC), the lead agency for the management of industrial and municipal waste, in partnership with Uganda Fisheries and Fish Conservation Association (UFFCA) conducted a lake-wide outreach programme to assess the sanitation conditions of the fishing villages and prepare recommendations for possible assistance in alleviating the identified constraints. The programme covered 11 districts within the Lake Victoria Ugandan catchment (Fig.1).

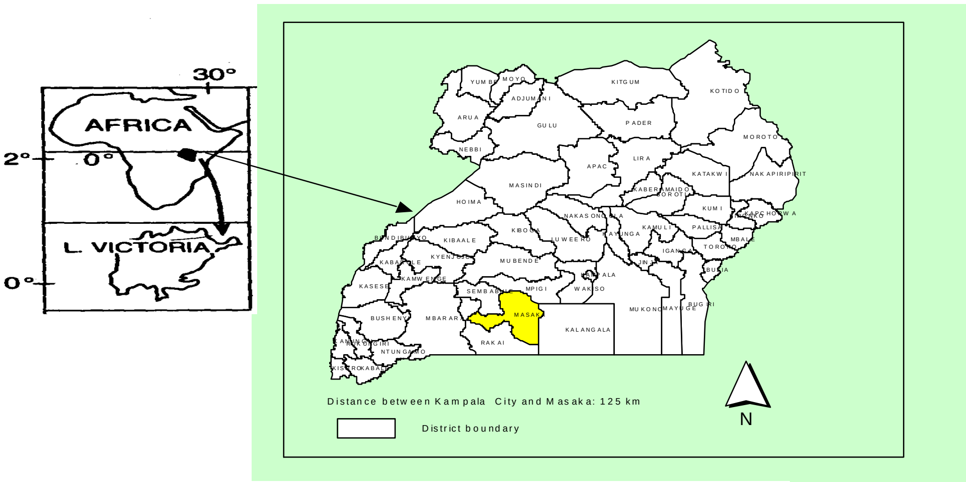

Figure1: Map of Uganda showing the location of the site

Over 124 fishing villages/shore line settlements were visited. It was found that most fishing villages did not have safe drinking water, lacked pit latrines and health facilities (LVEMP, 1997-2002). Poor sanitation ranked as one of the biggest problems with sewerage coverage found to be under 20% (Mott MacDonald, 2001). Though the population appreciated the need for pit latrines, construction costs were very high due to the high water table and sandy soils. A VIP toilet with two stances cost about 4,500 US $. However, better community hygiene and sanitation conditions is of great importance in relation to health and an assurance to good quality fish for human consumption for both local and export markets. However, most fishing villages do not have the necessary facilities to guarantee the health and sanitation conditions for the fisher community. As a result, unorthodox and unhygienic wasy of disposing human waste was a real problem. Defecation into polyethylene bags (*kavera*) and nearby bushes is a common site. ‘Helicopter jets’ / flying toilets have resulted into widespread communicable diseases among the fishing communities in particular the children (The New Vision, 2002).

ecosan toilets are based on dry sanitation which completely sanitizes excreta (urine and faeces) hence decreasing the preverence/transmission of diarrhoeal diseases. The ecosan technology enhances crop production through recycling of nutrients this reduces eutrophication of surface and ground waters (GTZ, 2003). ecosan is based on three main principles;

- **Safe sanitation** i.e. prevents diseases and promotes health by successfully and hygienically removing pathogen risk excreta from the environment
- **Environmentally sound systems** that do not contaminate ground water and,
- It is a **valuable resource** that can be recycled back into the environment.

Dry sanitation is a step towards poverty alleviation and improvement of gender status. The free nutrients from the excreta are of great value to the households in improving crop production. ecosan systems also go a long way in reducing health problems experienced at the shoreline settlements. The dry sanitation approach results in reduced pathogenic microorganisms in faecal matter but it is not safe to handle (Strenström, 2001). The adverse environmental factors in these systems such as pH, temperature, long residence time, reduced moisture and nutrient content provide a conducive environment for the reduction of pathogens (Esrey *et al*., 1998). ecosan toilets can be built in one place and do not have to be closed off (like pit latrines) when full.

Methods

In the initial assessment of the sanitation needs within the Lake Victoria catchment on the Ugandan side, a survey was carried out to assess the sanitation status in 124 shoreline settlements in 11 districts namely Busia, Bugiri, Iganga, Jinja, Mukono, Wakiso, Kampala, Mpigi, Rakai, Kalangala and Masaka (Figure 1). 21 fishing villages were visited where formal and informal interviews were held with the local community. Open-air *baraza's* were also held in 7 villages. In these *baraza's* the community was sensitised on the need for improved sanitation. After group discussions the communities came up with their own proposals on how to best solve the sanitation problems they were facing. In all cases the need for toilets ranked highest.

Figure 2: The old discused VIP toilet (note the rised structure due to ground water table).

In Dimo with a population of over 2500 people, handling 8 tonnes of fish and 120 boats landing daily we could find only 25 pit latrines a ratio of 1 toilet per 100 capita (Mott MacDonald, 2001). In addition, sand soils, sloping terrain and high table made construction of the VIP toilets very costly and with no guarantee for no collapse (Figure 2). The quest to overcome the above constraints and look forward to achieving better and proper sanitation conditions at the fishing village level drove NWSC and its partners to devise strategies to avert the poor sanitation conditions in the fishing villages by the application of Ecological alternatives in sanitation (ecosan). ecosan toilets were found ideal for these two villages for they overcame the problem of high water table and sandy soils. Using funds secured from the World Bank (WB) under LVEMP, 1 block of ecosan toilets were constructed in Musonzi, Kalangala district (one of the islands in Lake Victoria) and 2 blocks in Ddimo fishing village, Masaka district.

In each village, the local authorities provided land on which the toilets were built. Each block of toilets had 4 stances, 1 urinal and 1 shower room. Figure 3 show one of the completed blocks in Ddimo. The cost of construction the two units blocks was US$ 15,000, that is US$ 6 per person in Ddimo. In each village, a micro project committee was set up that comprised of 6 people including a representative of the women. This group then administered the account. A contractor was employed who carried out the design, preparation of bills of quantities (BOQ)

Figure 3: The newly built ecosan toilet for the shoreline fishervillage in Dimo Rakai District, Uganda. In the fore is the urine container.

and supervision of the works. The community contributed 10 % of the total cost. Construction of the toilets took 15 weeks, being slowed down by scarcity of some materials particularly cement availability which had to be got 32 Km away in the case of Ddimo and for Musonzi an island it took 2 hrs on water from the mainland. The toilets were then commissioned within a month of completion. To sustain the system a monthly fee of US$ 0.6 per family or US$ 0.06 per person per use/visit was fixed. Wood ash was to be used every after each defecation; to absorb moisture making it less attractive to flies, and to reduce odour. The use of human waste as a valuable by-product was another positive aspect of this technology that was considered useful to the community.

Results and Discussion

In Ddimo, less than two months after the commissioning of the first block the toilets were in a terrible state. The stench from them was unbearable. This was due to poor understanding of the ecosan technology by the locals, poor participation of the local community in the implementation (i.e. construction was left to the committee alone) resulting in lack of a feel of ownership by the locals, poor operation and maintenance (O&M) practised, affordability of the user (the small fee levied was found to be quite high), lack of on going Technical assistance after the system was handed over and cultural – religious aspects. When the NWSC team visited the site and requested the faeces' closet tank to be opened the flies flocking to the area were unbearable. The locals said the whole place was a mess and unfit for use. They said the ecosan was a failure. On holding discussions with the toilet attendant and the locals it was found that the commissioning had failed due to poor propagation of the technology.

Understanding the ecosan technology

The community took some time to be convinced that the ecosan technology would solve their problems. This was clearly seen during the early stages of construction when the locals raised a number of worries and concerns related to the viability of such a system. Many of them were sceptical, which discouraged the committee. A number of sessions had to be held with the community to convince them that the new technology they were getting would work. The conditions and issues considered for selecting the ecosan were explained to the people and are listed in Table 1 below.

Conditions	ecosan	VIP toilets
Sandy soils	No need to go more than 2 m deep.	At least 6 m depth required.
Unstable soils	Can be built at low cost.	Need to be stabilised at a high cost
High water table	Ingestion of water is controlled	Ingestion of water difficult to control.
Cost	Construction cost lower at US $ 15,000 for 2 blocks (4 stances, 1 shower and one urinal each).	Expensive US $ 18,000 for 2 blocks: 4 stances each due to increased construction costs in such areas.
Use of by products	Dried faeces and urine suitable for agricultural purposes. **	Normally no use.
Maintenance costs	Low	Low (need for a cesspool emptier from time to time).

** *At the time of writing this paper, by-products in both villages had not been utilised.*

Table 1: Conditions and issues considered for selecting ecosan toilets over VIP toilets

Furthermore, the committee overseeing the project took it upon themselves to organise a trip to Kisoro a town on the Uganda-Rwanda border, in the south of the country where such a system had been built. The committee found it prudent to include some of the political leaders of the village in this visit. They hoped that these leaders would be a good mouthpiece.

Community involvement in construction and operation of the system

Initially, the local community participated in identifying their sanitation needs in an open-air *baraza* that was held a year before the construction of the ecosan toilets. Having identified the need to build toilets, the District Fisheries Officer and the local committee chosen, prepared a proposal that was submitted to the LVEMP Micro-projects component for approval. However, during the design preparations, contracting of the contractor and the construction itself the local community played a low-key role. Despite the fact that the local community had to contribute 10 % of the funding (either in materials or funds), the feel of ownership was greatly lacking. One can argue that for better control of the funds a smaller committee was necessary, however, one still sees the lack of adequate involvement of the local community during the construction process. The 10 % would have had more value had the community participated in some of the manual labour on voluntary terms.

Operation and maintenance practice

Maintenance of the facility that included an attendant, buying of toilet paper and soap was not initially considered when setting up the facility. Wrong use of the system i.e. use of water for anal cleansing by one religious faithful led to complete failure of the system. Initially, there was lack of wood ash - a by product of fire wood used for cooking - as the people are poor and generally they are mostly migrant fisher-folks who have no time to prepare food. Hence application of wood ash was hardly done resulting in the stench and flies flocking the place. The

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whole system had to be emptied and restarted. This lead to a cost of up to 100 $ that had to be met from the meagre coffers of the local authorities.

Affordability

Prior to the construction the locals thought that levying a charge on toilet usage would not prove a problem. But since the fisher folk do not have a steady income, this proved a problem. The charges levied on the user were received with mixed feelings, particularly since the community felt that the toilets had been given free! (World Bank funds). The cost of Uganda shillings 100 only (US$ 0.06) per person per visit was considered too high while others thought this was okay for sustainability of the system. Some members suggested that a fee be levied to all income earners on a monthly basis but this was rejected by the majority. The trend of the toilet usage and resulting income generated is shown in Table 2.

#	Visit	Units	Year		
			2000	**2001**	**2002**
1.	Urinal (men)[a]	no./day	0 ± 1	0 ± 1	≥ 3
2.	Toilets – men	no./day	2 ± 1	-	3 ± 1
3.	Toilets – women	no./day	4 ± 3	3 ± 2[b]	≥ 15
4.	Shower	no./day	2 ± 1	-[c]	3 ± 2
5.	Total revenue generated	(US $/day)	0.40 – 1.10[d]	≤ 0.60	≥ 1.10

[a] *Few visits as men do not want to pay.*
[b] *The ecosan failed hence a drop in visits.*
[c] *The operator was not providing water for bathing hence no visits.*
[d] *Collections increase > 1.10 US $ on the day fish trucks collect fish from the fishing village.*

Table 2: Average number of visits and revenue generated per day 2000-2002

Technical assistance

Provision of post construction technical assistance after commissioning the toilets was not taken into consideration during the whole project. It was assumed that once the concept of ecosan toilets was fully grasped, there would be no need for this. Due to the problems raised above and some design errors, it was inevitable that technical assistance from experts be rendered from time to time.

Cultural aspects

Inadequate training initially given to the local community did not consider the issues pertaining to culture, religion and other taboos. It was found that due to some taboo, some members particularly the women in pregnancy do not use toilets, for fear for losing their babies. Negative attitude regarding addition of ash to faeces, moreover by a second party is considered devilish and malicious; as they feared to be bewitched (Okotto-Owour, 2002). Religious beliefs and practices had also brought some problems, e.g. the Moslems practice anal cleansing. Some people did not believe it necessary for children to use toilets. The perception and attitude towards use of urine collected and the dried faeces was very negative; the Ddimo society being faeco-phobic (Drangert, 2001; Okotto-Owour, 2002). The locals did not even want to consider the benefits of such waste particularly for agricultural practices.

Strategies developed

Further open-air meetings (3 in number) were held with a randomly picked audience and teaching and sensitisation sessions held. The community was asked to raise the issues they felt had led to the failure of the system. Emphasis was laid on proper operation and maintenance of the toilets particularly the need to apply wood ash from time to time. The need for improved sanitation, minimal human contact with the dry faecal matter for at least six months was also stressed (Stenström, 2001). Health hazards arising from poor sanitation practices were highlighted. A sub-committee was established that was charged with the responsibility of improving sanitation in the whole village.

Three months later a team from NWSC and UFFCA visited Ddimo and found the toilet working well with no major problems and the second toilet almost complete using their sourced local funds, a sign of acceptance of the technology. A number of clientele visits per day and income generated have also increase, refer to Table 2. A local petrol station has also constructed a two-stance ecosan toilet due to popular demand.

Conclusions

There is ample proof that the concepts of use and re-use do work. Ecological sanitation systems when properly managed do function well. The three main prerequisites for the successful introduction and adoption of ecological sanitation found are:

- Full understanding of the basic principles of operation and maintenance of ecosan toilets by the planners, designers and constructors.
- Local conditions and environment must be taken into consideration.
- End users must be fully involved in implementation and operation of the systems.
- Where there is a will there is a way.

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Results in the use and practise of composting toilets in multi story houses in Bielefeld and Rostock, Germany

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Keywords

Acceptance, composting toilets, improvement, maintenance, peri-urban areas, public use

Abstract

Two projects are reported, using composting toilets as single solution for treating human waste.

An ecological settlement in Bielefeld with 270 inhabitants now, was started in 1994. More than 100 flats up to four stories high and a public Kindergarden were established since then. Problems with building codes and planning details are described as well as the different experiences in maintaining the biological process. The results after 8 years of practise led into different product improvements.

In 1995, an old villa in the middle of the town of Rostock was reconstructed for use as offices, shops and a restaurant, supplied with composting toilets. For five years research was done together with the University of Rostock, proving health aspects in use and experiences in the maintenance of the system. Beside the realization of product improvements, the training of the staff, who are responsible for the function of the system, was determining for a successful process and the high motivation of the project members.

Composting toilets in the ecological settlement Bielefeld-Waldquelle

Pioneer projects in Germany

In Germany composting toilets (Clivus Multrum and similar systems) are offered since 1980 and are mainly installed in family houses. In 1986, the first ecological settlement was established to demonstrate decentralized solutions using composting toilets and constructed wetlands for cleaning greywater (Hamburg-Allermöhe). Others followed in Kiel, Berlin, Bielefeld and Hamburg-Braamfeld, while the ecological settlement in Bielefeld even seems to be the largest one in Europe (70 containers). At the moment there are about 500 composting toilet systems (mainly TerraNova systems) installed.

Concept and realization

In 1988, a group of ecologically interested families and the architectural office Bültmann started planning a peri-urban settlement in Bielefeld-Quelle. Different social groups should participate and additionally the consequent realization of ecological standards be performed. From 1994 until 1999 family houses, multistory houses and a public Kindergarden, planned by different architectural offices, were established, all provided with composting toilets. Greywater should be treated by constructed wetlands, but are not built yet because of the lack of financial means. Greywater is therefore connected to the sewer system up to now. One characteristic of the settlement is the installation of composting toilets for houses up to four stories, which seems to be the first project of this kind in Europe.

The TerraNova composting toilet system

Developed from the Swedish Clivus Multrum system, the TerraNova system is provided with an insulated composting container which is connected to each toilet by a vertical pipe (300 mm diameter). The container is permanently ventilated and connected with an air pipe leading above the roof (150 mm diameter). An electrical and a wind powered fan supply oxygen for the composting process and ensure negative pressure as a seal against smell. Up to four toilets can be installed. They close tightly and are provided with an insert, which can be removed for cleaning. Before starting, a filter bed is installed inside the container, which helps the biological decomposition of organic material within two years, including organic kitchen waste (Lorenz-Ladener, 1992).

Figure 1: Four story building with public Kindergarten

Approval and hygiene

In Germany, all flats and houses have to be provided with water flushed toilets, except in the city of Hamburg. There, toilets without water can be permitted, if hygienic considerations and public interests are not opposed. There is no general approval yet, so single approvals had to be applied for each flat in the settlement of Bielefeld. Special problems had to be solved, concerning the protection against fire and resonance of noise within the four story buildings, but also the ventilation of inside toilet rooms without windows. Further the inhabitants had to sign contracts with each other to ensure their acceptance of using composting toilets.
Beside operating terms, given by us as the producer of the toilet system, the disposal and utilization of the final product (about 40 Litres per person per year) was solved. The inhabitants decide, if they use the compost on their private ground or dispose it on a fixed area within the settlement. Bacterial tests in other settlements showed, that the compost as well as the infiltrated fluid and the exhaust air were free of pathogenic agents. The quality of the final product, however, is much dependent from the function and the maintenance of the system. To be safe as much as possible, the compost should be treated in another extern composting box for one year, before using it as garden soil. In any case, the finished compost should not be given to useful plants, to avoid closing the loop for food. In this case the final product has not to be sterile.

Operation and maintenance

Each owner of a compost toilet system is advised, to take one hour time per month for maintaining the composting system. If there are several flats connected to one container, one of the users has to be responsible for the proper function. For several years, a group of interested and trained inhabitants gives advice to their neighbours. If there is no regular maintenance possible, it can be ordered as a service within the settlement or from the producer.

Monthly maintenance includes levelling and breaking up raw material by means of a special tool and bringing in structural and compensating aids, depending from humidity and biological

Figure 2: TerraNova composting container with improved maintenance area

activity of the process. Part of the work, as personal experiences since 1977 show, can be done by earth worms and other digging compost organisms, provided that conditions are suitable for them (Berger, 1977). This way, expense can be reduced but conditions still have to be controlled regularly. Excess fluid, if not connected to the grey water system, has to be emptied for garden use. The amount is dependent on the number of users, air temperature and biochemical activities in the process.

After two to three years, the wastes are reduced up to 10 % of its original volume and all decomposed material can be removed for the first time. Partly emptying should follow once a year then.

The toilet stool, the seat and the insert are designed in a way that cleaning once a week is sufficient, using little water and soft soap. Fly control is also no problem, as long as the process is kept in a good condition.

Experiences and developments

Composting toilet systems were developed in many ways and for many purposes. All of them need maintenance more or less. Regular maintaining takes time and sometimes muscle power. This way, the amount of effort for maintaining the system is often decisive for the acceptance of the special system by the user.

All inhabitants of the ecological settlement in Bielefeld-Waldquelle were asked about their experiences with the composting toilet system after having used it for several years, initiated by the members of the compost group. Many of the inhabitants complained about the heavy conditions, maintaining and emptying the compost and asked for better design solutions. Some of them wanted automatically operating systems, because they did not want to spent time with toilet maintenance. We worked out a solution, which is more practical and which can be reconstructed in existing containers (Berger, 2001). Also the function of the container and the process itself were improved. We also developed a half automatic system, which is under construction. Our close contact to the user and his demands often gives the impulse for changes and developments, especially in such an intimate area, users do not want to speak about. This way, reservations against composting toilet systems can be reduced and their function be improved.

Composting toilets in the public institution Ökohaus in Rostock

Pioneer projects in Germany

While composting toilets in public areas are one of the main selling fields in countries like USA, Kanada, Australia and South Africa, only about 50 projects are realized in Germany (mountain huts, seminar houses, Kindergardens and public toilets in recreation areas). One of the reasons for this is that building and health codes are more rigid than in private households. The following project is the first one, which is open to everybody in the middle of a town.

Concept and realization

Shortly after the political changes in the GDR, a group of 15 people established an association for supporting ecology, basic democracy and solidarity. They found an old villa, which was reconstructed to establish shops, offices and a restaurant. All building activities had to fulfil ecological standards, so composting toilets became a main project, supported by Deutsche Stiftung Umwelt. From the beginning of the project in 1995, scientific research was started by members of the Ökohaus together with the University of Rostock and the Landeshygieneinstitut was started. Research should find out possibilities for approval, concerning building codes and hygienic aspects (Kacan, 2000).

The TerraNova composting toilet system in combination with the Aquatron separator

All public toilets were realized as dry toilets and connected to four composting containers. The waiters in the restaurant, according to the regulations, had to use a water flushed toilet. The solution was to combine a 4-litre water saving flush toilet together with a separator that separates the flushed water from the excreta, so the solid parts could be led into the composting container. The containers are provided with an overflow connected to the sewer system. There are water flushed urinals in the toilet rooms for men. Each two containers are connected to one exhaust pipe, which is led outside along the side wall above the roof.

Approval and hygiene

A limited approval of 7 years was given by the authorities, depending from further results of the research project. In 2002 finished compost was emptied from all containers for the first time and

bacterial tests were taken. All tests accorded to the hygienic standards so the authorities gave another 15 years approval. The compost material was deposited for further tests outside in separated composting boxes. In this way, comparisons can show after one year, if a second composting has any effect on hygiene and use as a fertilizer for plants. The research also showed that excess fluid and final compost include relatively high contents of salts and nutrients and should be diluted before using them as garden fertilizers (Eckstädt, 1999). Further tests will be made for proving quality for plants in another research project.

Figure 3: Final compost ready for use for garden areas without useful plants

Another part of the research programme was to evaluate possible bacterial effects on the air inside the toilet rooms and out of the exhaust pipes, possible contaminations with pathogens on the toilet seats and the valuation of the hygienic conditions in general. Parallel tests were done in a toilet room of the Landeshygieneinstitut, using water flushed toilets. The results were attested as good enough to continue further approval and some recommendations were given (extract):

The operating staff of a composting toilet system should be trained and be connected to

- consulting partners, in case there are any problems;
- For two years inspections should be under contract;

- A responsible person and his substitute should be named for maintaining and controlling the process (Schöttler, 1999);

Operation and maintenance

According to the recommendations, a training of the staff together with us was carried out, as the former staff had changed. The training was both theoretic and practical. After half a day of basic information about composting, processes and function, the regular maintenance was demonstrated and the final compost was emptied together. Before, the containers were reconstructed for easier handling (see description above). Both actions helped to convince all project members and everybody was astonished about the good smell of the compost.

Figure 4: Toilet stool with black removable insert and sealing

Experiences and development

Users must know, what happens in a toilet without water flushing. When understanding the process, they are open and responsible for using and handling. Therefore, different possibilities of information and training are necessary in theory and practice. Operators and users must see the benefit of being responsible. Of course, the work that has to be done, must be convenient and acceptable. Experiences in this project showed that more simple solutions have to be offered to control and influence the composting process, so maintenance can be reduced on a minimum level. Conditions in the compost must be most favourable, so earthworms are able to overtake a part of the work that has to be done by the operator. They work 24 hours a day, increasing their population. Earth worms are a steady part of the delivery programme of our company since 1985.

Conclusions

Composting is not the only way of treating excreta without water, but it is the only way to transform human waste into earth. Humidity is necessary and therefore the significance of composting toilet systems is more suitable to humid than to dry climates. The described projects give important results for operating and maintaining and what can be improved to make composting toilet systems more acceptable, even for both climates. The separation and collection of urine make drying of faeces possible. Only small changes are necessary, to transform a composting toilet system into a drying toilet system. The problem is, to develop systems on a low cost level with a high standard of hygiene and function.

Therefore, it is necessary to have projects like this in so called developed countries like Germany, because they give orientation and experiences for users, research institutes and authorities for further development, before these solutions are recommended for other countries with less opportunities. Nevertheless, there is still a lot of situations in the developed countries, where hygienic conditions have to be improved or water flushed toilet systems have to be replaced. This gives a chance and a benefit for both.

Figure 5: Successful emptying of final compost after 7 years use, (NNN, 29.04. 2002)

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Bringing ecosan to South Asia

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Keywords

Awareness raising, ecosan, evaporative plant-bed, high ground water, India, participation, peri-urban, Sri Lanka, urban, urine-diversion, women

Abstract

This paper tells how an ecological approach to sanitation in south India arose from a logical analysis of people's needs and the problems of conventional sanitation.

It speaks of the project successes in Urban, Rural and Peri-urban scenarios in south Asia. It records the success of ecosan in waterlogged and water-scarce situations and in the use of urine diverting toilets by people who habitually use water for anal cleansing. The paper also highlights why ecosan is so important for the region's future food, water and soil security. Ecosan brings health not only to people but also to the land and to water. In doing so it not only does what conventional sanitation signally fails to do, it offers an opportunity to improve soil quality and food or biomass production right where it is most needed. That is, within and around the greatest concentrations of population.

Beginnings

The history to our introduction of ecosan to India is that of women fishworkers struggling for what most middleclass people take for granted: a clean, private place to defecate with water to wash with afterwards. Their concerns and efforts and their openness to experimenting with new ideas has opened the way for changes in the lives of many urban and village dwellers, especially in high water table and water scarce areas. Their experience has great relevance throughout south Asia and all places where water is used for anal cleansing after defecation.

It all started back in 1992 when the Mahila Samajam women in Pulluvila decided that the deprivations of open defecation, the most widespread form of sanitation in many coastal communities, were too much to bear. They proposed a community latrine because pit latrines had been a failure in the village and many did not feel they had space or money for a latrine at home After clearly defining responsibilities for cleaning, maintenance and agreeing a user fee to support the operation a facility of ten water closets was constructed with the help of a local ngo, the Programme for Community Organisation (PCO). However the community latrine soon ran into technical difficulties due to the high water table in the area. This was the first I heard of the problem and was asked to help. We solved problems for several years by building a lagooning system for treating the sewage from the latrine and preventing it from entering the ground water. However it focused the attention of the author and community on the problems of sanitation in high water table areas. We learnt by practical experience the difficulty of cleaning water loaded with faeces and urine. Better not put it into water in the first place was the logical (eco-logical as it turned out) solution. It also brought to light the widely held misconceptions in the community about health and hygiene issues.

Keep it simple – no sewage

In a crowded, flat and low-lying coastal area waste-water treatment plants using macrophyte lagooning systems do not lend themselves to simple community management and maintenance. No one wants the responsibility for other people's excreta. Any sewage treatment system would be capital intensive in comparison with local incomes and gravity flow sewers would not be an option requiring the additional costs and complexity of pumped systems. We really needed self contained family toilets as this was the only way responsibility for management would be reasonably assured. These realities thus triggered the search for a suitable on-plot sanitation technology for waterlogged and high water table areas. Septic tanks (whose function, operation and construction are so widely misunderstood), pit latrines and soakaways are all unsuitable in such areas, especially when the ground water is abstracted for drinking, bathing, washing and kitchen use. In spite of this high water table an earlier project in the late 1980s had tried to install water seal pit latrines. The project was a failure since the pits filled up with ground water even as they were being dug. Some of the people at least were able to turn this to their advantage and have used the ring-lined toilet pits as wells ever since!

Knowing we must keep the faeces out of the water table (often virtually at the surface) we developed a urine diverting compost toilet to suit the environmental conditions and sanitary norms in Kerala. The result is a technology which meets the needs of communities living in high water table areas and is suitable for individual households. We diverted urine because it was imperative that there should be no odour from the toilet but that it should also be easy to use. By keeping the urine and washwater (the water used for anal cleansing) out of the faeces it prevented the system becoming anaerobic (and therefore odorous). It also meant that the volume of the toilet chambers remained relatively small and meant there would not be a requirement for additional carbonaceous material (to compensate for the high volume and nitrogen content of urine) . Such volumes of carbonaceous material would not be available to all households so this was an important consideration. This also kept the management of the toilets simple.

Women's participation

At a series of local women's workshops the problems of water and sanitation were discussed and explored. Through this was developed a growing understanding of the factors at play in building a healthy environment for themselves and their children. They are able to make an informed choice about selecting a sanitation technology. They wanted to participate in steps to safeguard their health, save water and protect a resource on which they all depend: the ground water. With this commitment it was a relatively easy next step to explain how the prototype toilet would look and how it would work and how it would have to be used. (Laughter!) There was still more laughter when I gave them a piece of chalk and told them I would go for a short walk whilst they squatted on the classroom floor and drew circles, that would suit them, for separate collection of urine and faeces! However, when I returned they had taken the task very seriously and there were several pairs of chalk circles on the floor and an air of anticipation and enthusiasm. They were clear and united in their selection of the best pair of chalk circles and we duly built to those dimensions.

Confidence building

We completed the first compost toilet in May 1995. It seemed to work well and we built six more and monitored them to see if they would live up to people's expectations. The reader will appreciate that it takes at least a year to get 'compost' and we had no other experience to lean on. (It can be done faster if very carefully managed but for a safe foolproof system it is better to have margins and so we say the ideal is to make toilet such that each chamber takes around 9 months to fill – it is still surprisingly small!) So one could not rush ahead and build more. People had to gain confidence in the idea. We had to be patient and wait for tangible confidence-building results. When we opened the first toilet amidst fearful onlookers everyone was thrilled with the result. No smell, no dragons, no shrieking evil spirits, no shit, just pleasant-smelling forest-like soil! Amazement, and soaring confidence. The women wanted them at home. (See article: Calvert 1997 'Kerala's Compost Toilet' in Waterlines Jan 1997)[10].

Awareness raising

We developed an effective Hygiene Awareness Team (HAT) to unravel and dispel the misunderstandings and confusion in the community that surround sanitation, health, hygiene, water and the environment. This team performed street dramas explaining the many faecal oral routes that result in cholera, typhoid, dysentery, diarrhoea, jaundice, worms etc. They distributed leaflets explaining the compost toilet and important hygiene practices at these performances and then in the subsequent days follow up with numerous house visits in the same area[8,9]. In the house visits they shared feedback on the drama, discuss the practicalities surrounding these issues, cleared doubts and answered questions including those on sanitation choice. We built more toilets because people wanted them.

Women's burdens lightened

At last the women could be free of the stigma of walking publicly to an open defecation site. They could be free of the jibes, taunts and advances of evil men and drunks. Relieved of the burden of that long walk to those stinking faeces-strewn open defecation areas. Of being forced to go to the open defecation areas without carrying water to clean themselves in order to hide the purpose of their journey. (By carrying a pot of water for anal cleansing everyone can see where you are going and will laugh and taunt). Now they were free of many of the constraints on when and what they dared eat or drink in case it should prompt the urge to defecate and thus a daytime trip to the open defecation site amidst public gaze. No longer the discomfort and associated health risks and problems of 'hanging on' long hours to 'go later'. Their daughters could be safe, and the burden of accompanying them in the dark hours was gone at last. Now there was a place to privately and safely manage menstruation and wash and dry menstrual cloths in privacy and dignity.

Since then we have refined the technology and simplified the construction. Now we have 250 family-owned urine-diverting toilets operated by the families for many years. Initially the urine and washwater drained to an *evaporative plant bed* Calvert (1994, 1997)[10,11]. However we soon we saw the benefit of using useful plants, banana, chillies, bitter gourd, flowers, to soak up and use the nutrients and water.

The toilets

These toilets comprise two chambers situated at, rather than below, ground level to prevent flooding in the rainy seasons. Over these chambers the toilet floor slab has holes, conveniently positioned for ease of use, to receive urine, wash water and faeces. The first chamber is used by the family until it is full whereupon use of the second chamber is begun. When eventually the second chamber is full the first is ready for removal of the non-odorous compost. Use of the first chamber then starts again. Between the two chambers is a place for anal cleansing. The washwater and urine can be combined and sent to the evaporative plant bed or a coconut or banana tree, or they may be kept separate.

Many of the toilets are in rough fishing villages where life is hard and little is kept clean or tidy, not houses, surroundings or toilets. But they go on working and the women especially value them for the privacy they convenience they provide. Others are well kept and tidy, some are inside the house. Many are in peri-urban and urban environments. They all solve the problems of sanitation in water-scarce and water logged situations ***and they all point the way forwards for sanitation in south Asia.***

Background

In 1994 we raised the un-addressed problem of sanitation in the high water table coastal areas of Kerala and proposed solutions at a national conference in Trivandrum[11]. In 1996 the early work was recorded in an article[10] in the journal Waterlines published by Intermediate Technology. In July 1998 Uno Winblad came to India at the invitation of the Centre for Science and the Environment to speak at their National Workshop on Health and the Environment in New Delhi. Uno, who inspired and ran the SIDA-funded Sanres programme which initiated ecosan work in Central and South America, China and Vietnam, was to speak on the whether Ecological Sanitation might offer solutions for India's appalling health problems caused by poor sanitation and river pollution. Uno contacted me and asked if the experiment in south India had failed and been forgotten or whether it was still alive. I was able to tell him that we had built many more toilets since then and that they were well accepted by the families that had them. He visited our project just prior to the workshop, was most favourably impressed and asked to include our work, though not part of the Sanres programme, in the book Ecological Sanitation[5]. He encouraged me to contact Anil Agarwal, Director of CSE, to see if I could present a paper at the workshop. Anil agreed wholeheartedly. Thus it was that Uno and I presented a convincing duet, he showing the global perspective on ecosan and I that practical 'ecosan' really could work well and be accepted by users in India[7].

Not alone

Now I discovered there were other people around the world involved in this small but growing field of alternative and ecological sanitation. I learnt that they too had got into this type of work to solve a problem in the places where they lived. A conventional water and sanitation training tends to lead people away from ecosan ideas. Non of the ecosan people seemed to be conventional public health engineers. Perhaps this helped and meant that they looked at the problems un biased by conventional thinking. However I am sure there is much that the conventional engineers can bring to ecosan and ecosan can bring to their work as they explore and take on its many ideals.

Visits to Sweden and America to present the experience of this work soon followed. Then Vietnam to do an appraisal of the Sanres work there[3] and later to China (Nanning Conference Nov 2001) to share the experience of initiating ecosan in India and Sri Lanka[1,4]

Sri Lanka

In January 2000 I visited Sri Lanka with the specific aim of raising interest in ecological sanitation[4]. The reception I got was cautious even a little incredulous, but when I returned there a year later with funds to start a pilot project the National Water Supply and Drainage Board were interested as they had some high water table areas needing a sanitation solution. They agreed to fund the construction costs and ecosan began in Sri Lanka.

Only 20% of the Colombo's steadily increasing population is served by piped sewerage and that is pumped to the sea with little or no treatment. The rest of the city's households depend for the most part on septic tanks. All this is despite the very high water table in many areas of the city. Inundation during rains causes many septic tanks to overflow with the resulting floodwaters being a significant public health risk. Drinking water supplies are under increasing pressure and yet those with domestic piped supplies waste a significant proportion of it for flushing toilets.

The rest of the country depends on septic tanks and water seal pit latrines. However, most of the country is un-served by safe piped water supplies and as many as 60% of the rural wells are suspected to be faecally contaminated. For the water-scarce parts of the country where rain water harvesting off roofs and small catchments is practised or where people carry water from some distance from their dwelling the use of such precious water for flushing toilets is a burdensome waste.

EcoSolutions held the first Ecosan Workshop and Training Course in Sri Lanka and subsequently guided participants from the Water Board, Sevanatha and Sarvodaya in ecosan and ecotoilet construction and monitoring. The Sri Lanka Ecosan Project now has 30 well-established ecosan units being operated and owned by families and more are being built to popular demand.

The units show that ecosan is viable and acceptable in urban and rural situations in Sri Lanka. The Ministry of Health is in approval of a wider demonstration and the NWSDB with support from EcoSolutions plans more extensive use of ecosan under current and future Water and Sanitation projects in the country.

So where are we now?

Now, in 2003, we have urine diverting ecological toilets in many settings in south India and Sri Lanka. We have experimented with reuse of the urine and washwater and in many places these liquids are used for growing healthy stands of bananas, papaya, cassava (manioc), attractive flowers, vegetables and chillies or coconut trees. But, for the most part people like the toilet because it solves a basic need. They need a toilet that works, without smell, is simple and convenient and saves them the burden of carrying water, or protects their water supply. These are the simple facts that make ecosan attractive and appropriate to so many of these users. Most don't have the time to be fascinated about the use of urine as a fertiliser, or the faecal product as a soil improver. They just need a toilet they can use! However, they all understand the importance of correct operations and many of them are now the local experts on this type of toilet. Eventually, when there are large concentrations of these toilets, confidence of the general public in the products will grow such that it becomes interesting and viable for reuse in farming and horticulture and to local service enterprises. The latter or the municipality may also collect community garbage and co-compost the organics with the ecotoilet products and sell it on to farmers.

Many of our toilets are in a peri-urban setting and a good number are in urban settings too. We have toilets that are direct access from the bedroom and bananas flourish on the urine outside the window.

Funding

From the beginning in 1994 through to 2003 the work has been only partially funded with much of it simply being undertaken out of commitment. Sadly the work has never been supported by SIDA Sanres, Ecosanres or GTZ. The work in Sri Lanka in 2001-2 was supported by UNDP.

And where to next?

Bringing Ecosan to S Asia to scale: Ecotowns and Ecovillages

In the village or in the towns and cities ecological sanitation has great benefits to offer. Eco-villages, eco-towns, eco-cities will all encompass the many facets of ecological sanitation.

Ecological sanitation is many things – it is not merely another sanitation technology, not just another type of toilet. It is a new and holistic approach to the concept and management of human excreta. It includes a wide range and scale of technologies and disciplines. The range includes urine diverting non-flush toilets for individual households and high rise flats to materials management systems for solid and liquid ecosan products to urban agro systems and ecological architecture.

Starting the move to scale

The concept of eco towns, cities and villages based on ecosanitation principles was presented to and discussed with over 400 senior government officers across India in September and October 2002 on the author's Ecological Sanitation Awareness Raising tour to 11 Indian cities across 10 states. (The tour, conceived by the author, was co-funded by UNDP and by UNICEF India).

The tour evoked great interest and EcoSolutions and UNICEF will now move ahead with new ecosan demonstrations in India.

In Sri Lanka the government has been impressed by the pilot demonstrations. With the Ministry of Health, Ministry of Housing and the National Water Supply and Drainage Board we are planning a programme to build 6000 ecotoilets. The ngo partners Sevanatha and Sarvodaya are also keen to expand the ecosan activities and we held an ecosan workshop and field visits to initiate awareness in December 2003.

Eco towns cities and villages – don't forget the soil

In ecological cities, towns and villages the intention must be to collect, use and reuse water, garbage and excreta as close to the household and community level as possible. The Bellagio principles of the household centred approach hold true here, (although, in all frankness it must be said many of us working in communities were teaching and practising this long before the Bellagio conference).

In water scarce areas rainwater should be collected at household, community and municipal level. What the household and community cannot catch the municipality aims to collect the runoff. And clearly the precious water collected off the roof would be wasted if it were used to flush the toilet so ecosan toilets become the obvious choice. (Remember flush toilets use almost a third of household water!)

Greywater and storm water can be used in green parks, medians, streets, urban and peri-urban agriculture and horticulture.

Houses, housing clusters and offices and factories have urine tanks and RWH (Rain/Roof Water Harvesting) systems. On-site greywater and urine reuse in 'green' productive areas and rooftops for biomass, leisure, food, fruit fuel etc. Dry toilet products might be reused, further processed or direct on-site too, or sold, collected by ecostation or co-composting centres. There are many scenarios and options.

Existing sewers can still be used for transport of greywater and storm water that is un-utilised on site or escapes the extensive infiltration galleries and perforated paved surfaces that are now provided in our eco towns and cities to minimise runoff. What still runs off into the storm water gullies and old sewers can be used, with suitable quality checks for undesirables, for peri-urban agriculture, be it fruit trees, timber lots, cereal crops, vegetables etc.

Natural and constructed wetlands and lakes can act as treatment systems and reservoirs of this water for use in dry periods.

Ecological toilets will provide good fertiliser for food or non food crops in and around the towns, cities and villages and the humus produced will be used to improve, conserve and rejuvenate soils.

The great value of ecosan in keeping pathogenic used-water-flows out of storm water and grey water flows needs to be stressed.

In south Asia most towns and cities are short of water. Around many of these settlements the hinterland is loosing its soil and what is still left has declining fertility. But S Asia does not have a declining population. Nor does it have a declining appetite. Where is the food going to come from in the future, where is water going to come from? Where is affordable fertiliser going to come from? How long before policy begins to reflect the fact that simply pouring commercial fertiliser on the soil is not going to solve the problem. Rather it is the soil *quality* and not chemical fertiliser *quantity* that is the limiting factor in sustainable food production. Composting to produce good humus, the use of animal manure, green manures and leaf mulches are so important to maintain soil quality. And what does sanitation and sanitation choice have to do with this? Ecosan can make a significant addition to this In fact fertiliser from ecosan, animal and organic manures can produce all the fertiliser a country needs and improve the soil at the same time. Ecosan also collects and uses the valuable nutrients in urine, and for India it could amount to as much as 33 percent of the current fertiliser consumption in the country. (see box: India Fertiliser application) . The benefits don't stop here. Ecosan saves water because the toilets do not need flushing, so that saves on domestic water supplies (or saves precious water harvested off the roof). It saves the costly business of sewerage and treatment. It begins to protect the rivers from massive sewage pollution. It protects ground water in areas of vulnerability unlike conventional pour flush toilets. Improving soils through the use of ecosan products animal and organic manures reduces the water required in agriculture (agriculture is the biggest water consumer) and also the reduces dependency on pesticides resulting in healthier food and water.

In the New Scientist (23 August 1997) the Tata Energy Research Institute described as a 'quiet crisis' soil erosion and depletion now affecting 57% of India's productive land. The report predicted falls in the yields of 11 major food crops in India by as much as 26 per cent. The researchers said the area of critically eroded land had doubled in the past 18 years, partly due to deforestation for fuel or to create new farmlands. Intensive farming was also resulting in rapid depletion of nutrient in Indian soils.

Food security lies in the soil. Management practises which sustain soil health and fertility, the use of natural methods of pest, disease and weed control and low levels of environmental pollution are essential in the long run. They result in greater moisture retention, better pest resistance, reduced use of chemicals and toxins.

Farmers in south Asia have used animal urine and faeces as a fertiliser for generations. They are full of wisdom and experience in the care of the soil. Modern farming is destroying the soil and the wisdom of the farmers. Ecosan forms the natural link back to the soil and should be encouraged alongside organic farming practises. Perhaps the survival of many in south and south-east Asia, where population growth places massive strains on food supply, may hinge on the reuse of our excreta to fertilise and improve the soils that our lives depend upon.

Coral atolls

EcoSolutions is also working with the Laccadive Administration (the Laccadive Islands, a Union Territory of India lie 200km off the SW Coast of India). We have started an ecosan demonstration project in these islands where the precious and fragile freshwater lens and coral reefs are damaged and further threatened by conventional sanitation. Eco toilets will protect and conserve the fresh water lens and also prevent further damage to the coral. Ecosan products will also steadily improve the very poor sandy soils.

Commitment

EcoSolutions has a number of new activities planned across South and S.E. Asia over the next three years 2003 to 2005 including the development of more holistic and comprehensive urban ecosan demonstrations. For sure we plan to continue to bring ecosan to south Asia and to help others do so too. If we are to meet the Millennium Development goals we probably need some 20,000 new toilets a day in India alone.

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Community led sanitation block systems in Kenya

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Session C

Abstract

The Community Led Ablution Blocks System is an ongoing part of a family of interventions within the Nairobi River Basin initiative of United Nations Environmental Programme (UNEP) geared towards working in partnership with community groups, Nairobi City Council and other agencies in design, construction and management of sanitation utility blocks (lavatories, showers and laundry facilities). The project is primarily designed to strengthen community capacities in the design, construction and management of sanitation technologies in order to improve social, economic and environmental health and as a part of the interventions aimed at reversing the acute problems associated with the pollution of the Nairobi River arising grossly from inadequate sanitation facilities.

Upon completion, the project is expected to fulfill the following goals:

- Provision of adequate sanitation facilities and technologies.
- Reduction in pollution of the Nairobi River.
- Provision of sufficient and clean drinking water to the community.
- Equipping the community members with practical management skills through active involvement in management of the project.
- Reduction of prevalence of diseases in the area.
- Improve dignity and the general hygiene of the area.
- Community economic empowerment and improved food security.

The pilot is aimed to influence and guide the ongoing development of infrastructure standard on slum upgrading in Kenya, as well as offer appropriate interventions on sanitation in the sprawling informal settlements within the region.

ITDG-EA case studies - introduction

Fast growth of urbanization in Africa is accompanied by a rapid increase in urban population, currently at a rate of 6.9%. It estimated that world population living in the cities now and by the year 2025 is/will be 50 and 65%, respectively. Urbanization in Sub-Saharan Africa (SSA) reached 36% in the year 2000, and is projected to rise to 50% by the year 2025. The urban sprawls has consequently led to inadequate sanitation facilities and increased accumulation of urban waste resulting from curtailed urban authorities' ability to provide sustainable sanitation and waste collection services; an increasing proportion of low-income urban dwellers characterized by high levels of food insecurity, poverty and unemployment; common occurrence of unabated urban sewage farming, exposing consumers of such produce to poisoning from heavy metals and such other water pollutants. These are issues of great interest and concern to the public, the local authorities and private sector. Consequently, policies are needed (to replace or refine outdated by-laws) that integrate these sectors. They could also facilitate the adoption of emergent technologies, which may be greatly hampered by policy and by-laws governing the urban sanitation and waste management sectors.

The demand for sanitation in urban areas has by far outstripped the ability of local authorities to supply the facilities in a safe, sustainable and acceptable manner (The poor in Nairobi city are estimated to be about 55% of the total population occupying 5% of the residential land). The resultant contamination and environmental degradation adversely affects the health, dignity and quality of life of urban residents. This has led to corresponding increases in development of pay toilets in most of these settlements, without proper drainage and exhaustion mechanism. This has only aided in aggravating the sanitation problems in the slums.

Surveys conducted by ITDG and its partners (2001-02) illustrate the appalling state of sanitation in Nairobi's informal settlements. In areas such as Huruma and Mukuru a conservative estimate of 120 households share one latrine[9]. Toilets are commonly the open pit type, which are often filled up and overflowing during the rainy season. The unavailability of bathrooms also forces the people to bath outside or infrequently (especially among the children) because of the high cost of water supply.

Kibera exhibits many of the conditions that are characteristic of Nairobi's urban poor settlements. Typical of other settlements, Kibera is congested and landlords/structure owners often do not provide ample space for toilets and bathrooms. Although the Nairobi slum improvement project has been facilitating the construction of Ventilated Improved Pit Latrines (VIPs), long-term sustainability remains elusive. This is as a result of two key reasons:

- Whenever the latrines fill up, community members are unable to afford exhaustion services and in instances where they can afford, securing the services from the Nairobi City Council is often difficult.
- Due to limitations of space, it is difficult to construct new facilities in the event that the existing ones are full.

Despite the fact that the Municipal By law 217 requires that one latrine and ablution be provided for each family or group not exceeding 10 persons. Moreover, the pit latrines should be situated a distance away from any habitable rooms i.e. 30 feet. Lack of space coupled by the unwillingness of the slumlords to leave room and provide pit latrines and bathrooms, has resulted in few pit latrines being developed, being located next to habitable rooms (NACHU, 1990). According to the metropolitan household survey, 94% of the population in the informal settlements lack adequate sanitation (Matrix, 1993).

The poor sanitation has been made worse by hawking of pit latrines. As an example, in Lunga Lunga the use of a facility is charged Kshs 3-5 per visit. Lack of showers and bathing facilities is also widespread. A total of 34.7% of the slum dwellers lacked any bathing facilities. In Mukuru 85%, Korogocho 65%, Kawangware 55% and Kibera 54% lacked bathing facilities (Kiamba et al 1992). In response a few people hawk them e.g. to take a bath (bring water and soap) one pays Kshs 2-3, where one is supplied with soap and water they pay Kshs. 4-6. Even for the rental bathrooms the queues are long. Those who cannot afford, bath outside at night (men) that is, where there is space for this. Most women shift things about in the room to bath, which further accelerates the rate of dilapidation of the units (Ngau, 1994). In cases where the pit latrines are also used as bathing facilities, the pits fill up quickly sometimes resulting in the latrine being abandoned.

The existence of few pit latrines coupled with hawking of the few operational ones has resulted in the use of surrounding spaces e.g. in the "**flying toilet**" phenomenon (Gitau, 1996). Where this method is widespread it results in the racking of the conservation fraternity. The human waste that is dealt with through this innovation becomes an immediate pollutant of the river. Moreover, in Soweto, Kayole, Kibarage, Mukuru, Kibera village, Congo, village and Kitui Pumwani those who cannot access reasonable latrines use the **"bucket latrines**" and empty them to the River basin.

The national level of water use, which stands at 647 cubic metres per annum, has compounded the sanitation challenges. This water stress condition has manifested itself through

[9] Community mapping in these areas illustrate that in many of the informal settlements, there are more churches than latrines

unavailability, inadequacy, and unreliability or high cost from vendors. The basic problem relates to the issue of people finding it attractive to provide water but not how to ensure it is got out or removed after usage. This is probably due to no monetary gains for this; it is more costly and technically difficult to get out. A study carried out in 1992 revealed that 74.7% of the people living in Mathare, Kawangware, Soweto, and Kibera, purchase water from the vendors while 20.5% have access to water through communal piping. Due to lack of adequate portable water, diseases have resulted e.g. cholera epidemics, which affected Korogocho in 1997 (Gitau, 1999). Acute water shortages, chocked sewers, housing congestion and torrential rains triggered this. In Mathare almost all residents buy water from the outside taps (Ngau, 1994). A study by Matrix (1993), established that of the Nairobi informal settlement residents, only 11.7% plots were connected to water mains. The majority, 85.6%, obtained water from the kiosks.

Interventions

The project is primarily designed to strengthen community capacities in the design, construction and management of sanitation technologies in order to improve community and environmental health and as a part of the interventions aimed at reversing the acute problems associated with the pollution of the Nairobi River arising grossly from inadequate sanitation facilities.

The construction of the pilot ablution blocks is to be undertaken in phases with phase one having three blocks of sanitation facilities. The proposed sites for the construction of the sanitary facilities, Site A, Site B and Site C, are all sites currently taken up by landlord owned pit latrines and bathrooms which are grossly inadequate and in appalling bad condition.

The projects main aim is to restore urban dignity through providing appropriate community sanitation amenities/ practices to cater for the health and well being of the residents as well as reducing the pollution of the Nairobi River.

Upon completion, the project is expected to fulfill the following goals:

- Provision of adequate sanitation facilities and technologies.
- Reduction in pollution of the Nairobi River.
- Provision of sufficient and clean drinking water to the community.
- Equipping the community members with practical management skills through active involvement in management of the project.
- Reduction of prevalence of diseases in the area.
- Improve dignity and the general hygiene of the area.

Physical aspects of the sites

The community resource persons conducted a comprehensive physical assessment of the proposed sites, with the support of ITDG technical officers and the municipal officers. The physical dimensions were measured and the following physical attributes were noted:

Community design session

A participatory design session brought community representatives, NGOs partners, UNEP representative and the Local Authority officers.

Community design criteria - concepts.

During the session, it was clearly discernible that the community's main areas of concern as regards the move to attaining a cleaner settlement were;

- Upgrading of the sanitary facilities.
- Improving the state of the drainage channels.
- Sufficient and reliable water supply.

Community design criteria-spatial

The community members present at the workshop were given a chance to express their needs, opinions and expectations with regard to the project graphically, and the need for adequate, cleaner toilets and bathrooms, sufficient, clean water supply, demarcation of the spaces in line with gender and age, security of use and the issue of controlled use of the facilities on completion were strongly recommended, Information dissemination was considered key to the satisfaction of their needs and therefore an information office/ centre was one of their most required space provisions, economic empowerment of the community was expressed through income generation proposals such as; water kiosk, shops, the community also expressed the need for an integrated facility to avoid the common notion of 'toilet". A design matrix was therefore developed to determine the priority spatial requirements to be provided for in the design of the ablution blocks.

Community design criteria-technologies

ITDG's strength lies on the appropriate technological interventions on various fields including sanitation. ITDG set to optimize the ecological sanitation, through offering a holistic and integrated view of sanitation, including its relation to human dignity, economic developments, food security, water pollution and environmental improvement.

With the highlighted water scarcity, the community accepted to pilot ecological sanitation as a long-term sustainable approach towards alleviating sanitation problems.

Figure 1: Residents of informal settlements are forced to draw contaminated water from unsafe sources such as this stream.

Figure 2: Independent water vendors have stepped in the fill the gap left by the government water utilities

Conclusion

It is clear that better community sanitation management should be a means to reduce poverty and redignify the community.

The project has and is expected to generate useful lessons for the slum upgrading in the country. The facility has from the initial stage deviated from the 'donor' perception of sanitation (ten door latrine specifications) to an integrated community sanitation center, to optimize the utility value of the space and the waste products. The project will also be a real model to demonstrate sanitation related technologies and of particular concern, the ecological sanitation.

The facility will also demonstrate innovative approaches towards poverty reduction and its interlinkages and relationships – the social, political and economic organizations and institutions that are regarded as important for sanitation development and management. This will finally ensure sustainable development in our cities.

Economical and ecological benefits of decentralised, small-scale human excreta management system in Nepal

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Keywords

Bio-gas technology, human excreta management, economic benefits

Abstract

Decentralised energy and fertiliser substitution, on-site human excreta management and import substitute are the micro and macro-economical as well as ecological benefits of bio-gas technology for human excreta treatment in Nepal. More than 50 percent of communicable diseases in rural Nepal are from polluted drinking water and the main cause of unhygienic water is due to unmanaged human excreta and household waste. On the other side, if waste water and toilet attached bio-gas technology is implemented; rural households can increase the amount of gas needed for a gas lamp for an hour of evening lighting and especially women and children save water fetching time. Government's expenses can be saved if proper economic incentive policy to promote holistic approach of household waste and wastewater combined biogas plants are adopted. Decentralised human excreta and other household waste management with biogas technology has multiple benefits in Nepal.

Introduction

It is now well recognised that human excreta on one hand is a valuable resources of nutrients and energy, on other hand contains pathogens causing diseases (Esrey et al., 1998; Otterpohl, 2001). In Nepal this resources has been either discharged directly into water bodies or stored in a pit. Experience has shown that both practices have caused surface and ground water pollution. Because of the contaminated drinking water outbreaks of diseases like gastro-intestinal, Leptospirosis , cholera, typhoid kill according National Sanitation Policy 2000 report about 28,000 children annually in Nepal. Solution for safe and efficient disposal of human excreta in Nepal is obviously not the conventional centralised sewer system of industrialised countries that needs high investment, maintenance and operational costs. Decentralised and multipurpose bio-gas technology can be appropriate in Nepal for both economic and ecological reasons.

Biogas technology

Bio-gas technology, which was introduced in Nepal in 1950 but has spread rapidly during the last few years, is efficient and provides a cost-effective methods of disposing organic wastes and produces energy and fertiliser (Devkota,1999). In bio-gas reactor toilet wastewater is discharged and treated anaerobically with organic kitchen or garden waste. When anaerobic bacteria degrade organic materials in the absence of oxygen methane and carbon dioxide are produced. The methane can be used as a source of renewable energy and the sludge, which is rich in nutrients and organic matter; and contains low pathogen, can be used after hygienisation in agriculture as a fertiliser.

Calculation of financial benefits from biogas

The benefits from waste water and toilet attached bio-gas are: saving of fuel wood, chemical fertiliser and better sanitation. Saving of 95 kg/year chemical fertiliser due to the installation of a bio-gas plant was found from a study in a mid hill village of Nepal in the year 2000. The local cost of chemical fertiliser per kg was (Nepalese Rupee) NRs. 22. The cost of fuel wood was found NRs. 1.50 per kg, the running cost of bio-gas in the village was NRs. 300 /year. The average cash paid by farmers per plant is NRs 14650 and NRs. 17200 for 6 m^3 and 8 m^3; and total fuel wood saved due to installation of the bio-gas plant is 2128.7 kg and 2530 kg respectively. The average kerosene consumption was found to be 3.2 litre per month per Household and price paid was NRS. 20/liter before biogas installation. Taking interest rate of 16%, 25 years life span and no liquidation the financial calculation are given in table 1.

(1NRS= 80 EUR)	Plant size 6 m^3				Plant size 8 m^3			
	NPV	BCR	IRR	PBP	NPV	BCR	IRR	PBP
Without subsidy	5732	1.22	20%	4.95	6852	1.24	20%	4.87
With subsidy of 10,000	15732	1.95	34%	2.95	16852	1.89	32%	3.08

Table 1: Values of different financial parameters of bio-gas plant in Nepal (NPV: Net Present Value, BCR: Benefit Cost Ratio IRR : Internal Rate of Return PBP:Pay Back Period)

Micro economical benefits

The main cause of unhygienic water and environment is due to unmanaged human excreta and household waste. Household expenses in health care, productive time losses due to illness, social costs of individual's psychological stress and social disharmony due to communicable disease (sometimes epidemic), normally, the hidden micro-economic costs to an individual or a household (HH) in rural Nepal, can be saved if small-scale interventions are made in bio-gas plant with attached toilet and wastewater. A survey carried out by Bio-gas Support Programme (BSP, 1998) showed that about 30% of bio-gas users feel that the cases of intestinal diseases and diarrhoea have been prevented after installation of bio-gas plant. Discharging of other wastewater into the toilet attached bio-gas plant would reduce the drudgery of women and children, an important factor to be considered for the rural women and children in Nepal, for their health, development and empowerment. A 6-m^3 family size bio-gas plant needs about 45 litres of water everyday (BSP, 1998) and water collection - often from a long distance, is the job of women and children in Nepal. From the study it has been found that if waste water is not connected to the biogas plant average of one hour daily work load is added to women and children. Inclusion of waste water can reduce this extra work load. If analyses are done the magnitude of such benefits can easily out-weight the investment needed for the small-scale technological intervention. On the other side, if toilet attached bio-gas technology is implemented (currently 36% bio-gas owner are doing so in Nepal), rural households can increase the amount of gas production-by an hour of evening lighting. From a biogas plant, as per findings from the study, about NRs. 720 has been saved by each HH in a village of mid-hill.

Macro economical benefits

Government's expense for public health mainly for communicable disease caused by unhygienic environment, even though insufficient for rural masses, is significant. Governments regular expenditure in the year 2000 for the health sector was 3.84% and development expenditure was 6.67 percentage of total budget allocated respectively. Only 16% Nepalese are having managed sanitation facility and only 20 percent are having access of health facility (UNDP 2000). There are more than 37% people who can hardly manage one dollar a day. And 42% are under the absolute poverty. On the other hand more than 30 percent of hard currency reserves are drained for fossil fuels and kerosene is the only medium of lighting for more than 80 percent of rural households. Government's expenses can be saved if proper economic incentive policy to promote holistic approach of household waste and wastewater combined with the bio-gas plants are adopted. Additional benefit, obtained from bio-gas sludge, is reduction of usage of commercial fertiliser that is produced with high energy and fossil resources. An economic analysis, even taking financial costs and benefits only, shows that such policy will have high rate of return.

From figure 1 and 2 it can be said that by incorporating rural sanitation concept into the popular bio-gas technology the rural people can get more relief from communicable diseases and its consequences. Inclusion of waste water and toilets in bio-gas digester cost less than NRS. 2500, as already implemented by a UNDP supported programme in few villages of Nepal. Such additional cost will have exponential benefits altogether if we able to monetarize benefits.

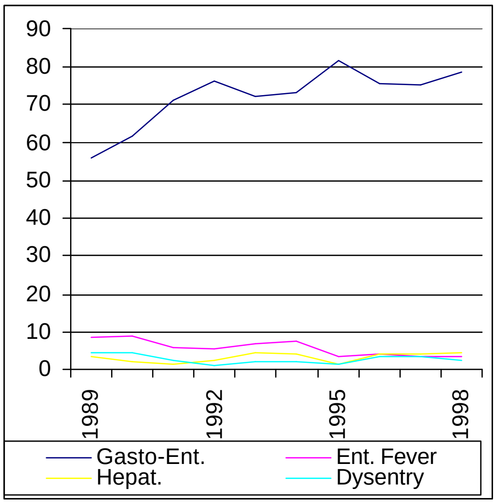

Figure 1: Percentage of water-borne diseases reported to the government hospitals (CBS 2001 data compiled into the graph)

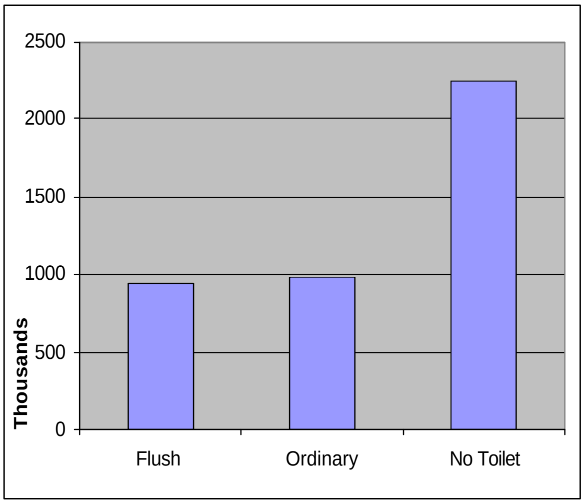

Figure 2: Households and toilets in Nepal (CBS 2002 data compiled into the graph)

Ecological benefits

The most important ecological benefits of human excreta and other household waste management with bio-gas technology are prevention of water pollution and production of energy. The sludge of bio-gas plant is rich in nutrient and organic matter, which can be used in agriculture as fertiliser and soil amendment. Bio-gas energy when used for cooking and lighting

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in household can help to reduce CO2 emission from fossil fuel consumption and rapidly increasing deforestation that causes decreased bio-diversity, soil erosion and desertification and global warming (BSP, 1998). About 90 percent of all wood consumed in Nepal is fuel for 73 percent of rural households and there is already a situation of fuel wood deficit (Bluffstone, 1995, NLSS 1996 Baskota et al 1999). Forest degradation has led to extensive exploitation of a valuable natural resources, flora and fauna and valuable species In Nepal.

Conclusions

In Nepal decentralised human excreta and other household waste management with biogas technology has multiple benefits. This low cost and self-managed system can be built with people's participation for improved sanitation and decentralised energy system. It will help individual at micro level whereas a nation can be better off when calculating macro level ecological and economical benefits.

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Eco-toilet: a sustainable approach of sanitation in the lowland eco region of Nepal

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Session C

Keywords

Ground water contamination, recirculation of nutrients, water borne diseases

Abstract

Terai, the lowland part, shares 23% of the land area but harvests 47% of the country's population. Ground water is the main source of water for drinking and domestic purposes and people use shallow tubewells to pump ground water (GW). Survey reflects that more than 57% of the tubewell water is microbiologically contaminated. The sanitation system is very poor and most of the Terai people use riverbanks for defecation. In the rainy season most part of the Terai gets inundated and pit latrines and soakpits overflow. Waterborne disease claim about 50000 under five child deaths annually. Agricultural productions contribute about 50% of country's GDP. And one estimate indicates that about 1.8 million tons of plant nutrients are removed away from soils of crop harvest and soil erosion of which only 16% are replenished by organic and mineral fertilizer sources. Construction of sewerage system and WWTP is very expensive so Eco-toilet seems to be the cheap and sustainable alternative to conventional system, which prevents GW from contamination and helps to replenish nutrients and organic matters of the soil.

Introduction

Nepal is a mountainous country. It has an area of about 147181 km^2 and a total population of about 23 millions. It mainly consists of three physiographic regions, viz. Mountains, Hills, and Terai (low land). The share of land and population of these regions is presented in table 1

Physiographic Region	Share of				Access of people to physical facilities		Population growth rate (% per annum)
	Land		Population				
	%	Area (10^3 km^2)	%	Millions	Piped water (%)	Sanitation (%)	
Hills	15	22.10	7	1.61	75	15	~0
Mountains	62	91.20	46	10.58	65	45	~2
Terai (low land)	**23**	**33.90**	**47**	**10.81**	**74**	**42**	**>3**
Total	100	147.18	100	23.00	69	43	~2.1

Table 1: Share of land and population by physiographic regions

Water quality in river and lakes near urban areas is deteriorating due to unregulated discharge of domestic and industrial effluent, and the health of the people is compromised by both inadequate wastewater treatment and insufficient supply of potable water.

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Historical background of water and sanitation facilities

Many water supply projects have been completed since the establishment of the Department of Water Supply and Sewerage (DWSS) in 1972. The projections show that about 70% of the people are served by drinking water facilities. But records show that more than 10% projects are not functioning anymore whereas about 50% of the completed projects require major rehabilitation work. Thus the actual population served by water supply facilities comes out to be less than 50%. The drinking water sector was given a top priority only after U N 's declaration of the 80's as the International Water Decade. But the sanitation sector was left unemphasized. Normally public taps of a rural water supply project should fulfill many prerequisites (Table 2).

Households to be served	Max. time to fetch water (to the tap)	Max. distance to the tap		Per capita cost of the project	Remarks
		Horizontal	Vertical		
3-10	≤ 5 minutes	300 m.	100 m.	≤ NRs. 3000.0	US$ 1. = NRs 78.0

Table 2: Criteria for a Community Tap of a rural water supply project

Water born diseases claim about 40,000 under five child deaths (UNICEF 2000) and the country suffers an estimated loss of NRs. 9000 millions each year. The emphasis on sanitation sector has been assigned top priority only after the UNICEF's report indicating high children mortality.

Since then toilet construction is made mandatory to the communities requesting a new water supply project. The toilet construction in the rural areas has been the main sanitation activity since 1992, when ADB funded Second Rural Water Supply and Sanitation Sector Project was launched.

History of use of faeces as fertilizer

Farmers from Bhaktapur (a historical city in the Kathmandu valley) have been using fresh faeces instead of composted faces in vegetable farming since ancient times. The tradition of using fresh faeces still continues but to a reduced scale. Though use of faeces in the field helps to replenish nutrients/organic matters but the health risks associated with handling could claim much more than the increased growth. It seems that the knowledge about nutrient contents of faeces and urine was not known. If it were understood earlier, they would have been using also urine instead of using faeces only.

National Sanitation Policy (NSP)

The National Sanitation Policy (1994) was formulated and brought into action with an aim to increase knowledge and awareness among all level of the community, particularly women and children regarding improved sanitation and bring about attitudinal and behavioural changes for improved sanitation and hygiene practices. Construction and maintenance of wastewater treatment plant (WWTP) and sewerage system is a very costly affair and may cost millions of

Sanitation Activities	Cost sharing (%)		Remarks
	Government	Community	
Construction of Sewerage system	60.0	40.0	People are not willing to share this huge amount of cost but are demanding centrally controlled sewerage system and a WWTP
Construction of WWTP	90.0	10.0	
Construction of Surface drainage	75.0	25.0	
Operation and Maintenance (O & M) costs	-	100.0	

Table 3: Cost sharing mechanism for sanitation systems

Rupees. The NSP expects that levies be charged in such a way that all O&M cost of a sewer system is borne by the community. Table 3 elucidates the Government's policy regarding sanitation systems.

But the question is of sustainability: whether operations and maintenance costs of sanitation systems, to the people of a nation having per capita income of less than US$ 200.0, is affordable or not? Of course not. Therefore there is an urgent need to look for cheap, affordable, Eco friendly and appropriate alternative to conventional sewer/sanitation systems so as to conserve water, environment and to reduce the construction and O&M costs of sewer systems.

National Sanitation Week (NSW)

To publicize the implications of poor sanitary conditions and to motivate people to actively participate in sanitation related activities, Nepal National Sanitation Campaign (NNSC): a five year 2001-2005) campaign has been introduced. Nepal's position in providing water and sanitation facilities compared to global perspective is presented in table 4.

Physical facilities	Global population	Nepal's populatio
People lacking access to safe drinking water	20% (1.2 billion)	32% (7 million)
People lacking access to proper sanitation	40% (2.4 billion)	70% (16 million)
Solid waste not properly managed	50% (3 billion)	90% (21 million)

Table 4: Comparison of physical facilities Nepal's' to Worlds'

It is expected that 80,000 new permanent toilets (service to 480,000 additional populations) will be constructed during NNSC (five years). Share of Terai people to new toilet construction is expected to be 50% and Hills and Mountains share 50%. New and permanent toilet implies flush toilet consuming ample amount of water.

The Terai (lowland) and the water source:

About 90% of the Terai population uses ground water for drinking and other domestic purposes. Estimates show that there are 200,000 tube wells (mostly shallow), which provide drinking water for 10 millions people. The depths of the tubewells mostly vary from 5 to 10 meters, and this depth is liable to be contaminated from the leachings of pit latrines and soak pits (depth ranging from 1.5-3.0 Mt.) and from leaching of contaminants from solid wastes piled up in the street corners.

District	Jhapa (1)	Morang (2)	Sunsari (3)	Saptari (4)	Siraha (5)	Rautahat (6)	Mahottari (7)
Total samples	100	200	200	200	200	200	200
Microbiological +ve	66	126	113	83	121	99	106
% of total	66	63	56.5	41.5	60.5	49.5	53

District	Dang (8)	Banke (9)	Bardia (10)	Kailali (11)	Kapilbastu (12)	Kanchanpur (13)	Total (14)
Total samples	196	200	200	200	200	200	2496
Microbiological +ve	135	44	160	98	115	165	1431
% of total	68.9	**22**	80	49	58	**82.5**	57

Table 5: Scenario of microbiological contamination of water (tubewells) of Terai districts.

The survey conducted by water quality section of DWSS in twenty Terai districts showed that more than 55% of the tubewells have positive results on microbiological contamination but the share of improper sewer system and pit latrines is yet to be ascertained. The results of the survey from thirteen districts are presented on table 5.

Agriculture and Gross Domestic Product (GDP)

Agricultural productions contribute about 50% of country's GDP. It is estimated that Nepal is loosing 240 million tons of top fertile soil annually. Another estimate indicates that about 1.8 million tons of plant nutrients are removed away from soils of crop harvest and soil erosion (Ghimire and Upreti, 1997), of which only 16% are replenished by organic and mineral fertilizer sources. Agricultural productions in mountainous and hilly regions are decreasing by more than 40kg/ha/yr. If this decrease along with population increase (2.1% per annum) continues, the condition of the country after few years can be disastrous necessitating the redirection of nutrients and organic matters to the crop fields that are removed from crop harvests.

Contribution of eco-toilet to national economy

The total agricultural land holdings, average land holding, average fertilizer use and cost required to import the chemical fertilizer is presented in table 6. The trend shows that urea is:

Total agricultural land holdings (ha.)	Average agricultural land holdings (ha.)	Average fertilizer use (NPK) Kg/ha	Total fertilizer use (Mt.)	Urea (46% N) (Mt.)	Fertilizer (N) (Mt.)	Total cost (Cost of urea / mt = NRs.16000) NRs
2598971	0.96	21.2	55098	33060	15210	529 million

Table 6: Fertilizer use trend and cost involved to procure the fertilizer in Nepal

used more than 60% of the total fertilizer use. Phosphates and Potash fertilizers share remaining 40%. The Government is giving subsidies to the farmers of NRs. 3000 per tone of urea and is spending about NRs. 100 millions on subsidies whereas the nutrients that are present in urine and faces are wasted. If the contents of a toilet after proper composting can be directed to the farms millions of rupees that are used to import chemical fertilizer can be saved.

Conclusions / recommendations

At present, the country is not in a position to provide private taps to individual houses in the rural areas (table 2). Since people cannot afford for drinking water almost no one will be ready to share the construction and O&M costs (table 3) of a sewer system. In view of this situation there will be a stalemate situation regarding sanitation systems. It is therefore necessary to think of a cheap and sustainable alternative, which not only manages the sanitation systems but also helps to redirect and replenish the nutrients and organic matters in the field that are taken away as crop harvests. Eco-toilet seems to serve the purpose and is therefore a best alternative. BOD load to the river systems and health risks associated with handling/application are considerably reduced in case of well-composted faeces.

The Terai part of Nepal gets inundated at least once every year in the rainy season (June -Sep). Therefore elevated box (separate boxes for faeces and urine collection) type Urine Diverting (UD) toilets is proposed (figure 1). Ground water, the main source of drinking water in Terai, can be saved from further microbiological contamination. Cost of Eco-toilet (≈ US$ 125) is also comparable to so-called permanent sanitary toilet normally called “pucca” toilet in Indian sub continent. A national level workshop/seminar is suggested to familiarize the advantages of Eco-toilet to political leaders/planners and local representatives.

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Owner-built composting toilets in Lismore, Australia: meeting the needs of users and regulators*

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Session C

Keywords

Moisture content, owner-built composting toilets, odour, regulatory requirements, salmonella, thermotolerant coliforms, ventilation

Abstract

This paper describes a study of 20 owner-built composting toilets, built to three generic designs (the large continuous flow Minimus, the large Farallones Batch and the small Barrel Batch) in the Lismore area in the Australian state of New South Wales. The toilets were assessed for owner satisfaction and for compliance with the national standard for composting toilets. Fifteen of the 20 owners rated their toilet's performance as either "excellent" or "good". The only "poor" rating came from the owner of a Barrel Batch system who had not been adding bulking material. While the three generic toilet designs appear to be basically sound, some toilets required structural adjustment after commissioning. Most problems with toilet management were overcome by minor modifications to management practice on the part of the owner. The study raised a number of questions regarding the standard's requirements for composted end product.

Introduction

The city of Lismore is located in the north east corner of the Australian state of New South Wales, approximately 800 km north of the state capital, Sydney. The area experiences a maritime subtropical climate with mean daily minimum temperature varying from 7°C to 19°C and mean daily maximum temperature from 19°C to 29°C. The Lismore City Council local government area has a population of 43,000, some 32% of whom live in unsewered rural or village situations. These 15,000 people are served by approximately 5,000 on-site domestic wastewater management systems of which roughly 250 (5% of total) include a waterless composting toilet. Some 70% of these composting toilets are not factory-built but are constructed either by the owner, or by a local contractor, usually to one of a number of locally adapted generic designs. The most popular owner-built composting toilet design is the "Minimus", a relatively large (~2,000L) continuous-flow device modelled on the commercially available Clivus Multrum. It is usually built in concrete block (Figure 1). Also popular is the "Farallones Batch" system, a relatively large (~2,000L) two-chamber batch device, also commonly constructed

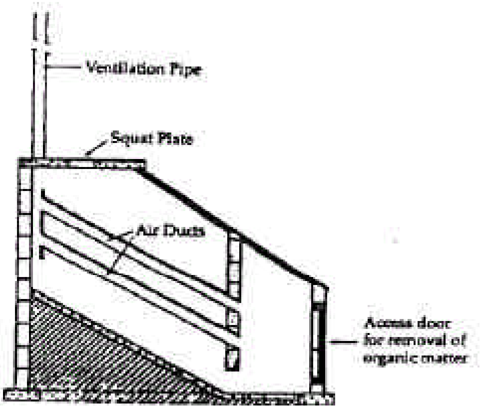

Figure 1: Typical Minimus continuous flow device. Height = 2 m.

[*] This paper has been peer reviewed by the symposium scientific committee

in concrete block (Figure 2). Less popular is the “Barrel Batch” system, a batch device based on relatively small (~200 litre) readily available plastic chambers such as wheelie bins or pickle barrels (Figure 3).

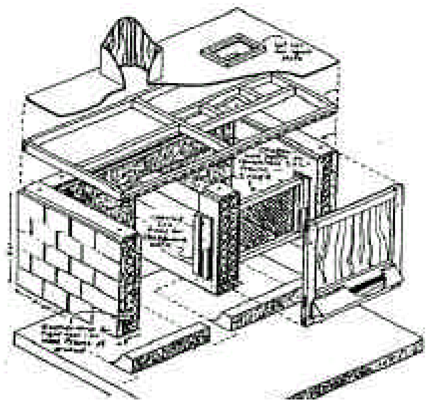

Figure 2: Typical Farallones Batch device - Chamber height ~1m.

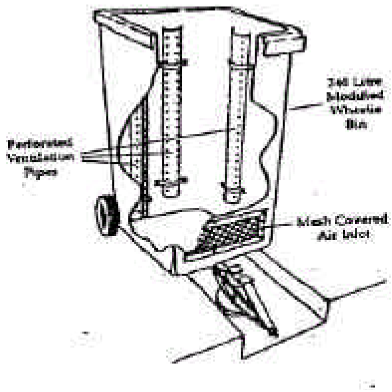

Figure 3: Barrel Batch device–modified 240L wheelie bin

Concerns on the part of local and state government health officials regarding the amenity and safety of owner-built composting toilets were allayed when a study of helminth survival in six composting toilets (four of them owner-built) by Safton (1993) led to the conclusion that “with the possible exception of viruses, the humus end product could be considered pathogen free”. The design, construction and performance of composting toilets in Australia and New Zealand is governed by a standard, AS/NZS 1546.2:2001, which requires that, for each model of toilet, the end product of at least one unit be tested against the criteria set out in Table 1.This process is economically feasible in the case of standard runs of factory-built toilets but becomes unduly expensive in the case of owner-built toilets which, despite the fact that they tend to be based on generic designs, are each unique in some way. For this reason few owner-built composting toilets have been assessed against the criteria set out in the standard.

Characteristic	Performance criterion
Consistency	Sample shall contain no recognisable faecal material
Odour	There shall be no offensive odours from the end product immediately following removal from the chamber
Moisture content at base of pile in removal zone	Not to exceed 75% by weight (all samples)
Pathogen indicators (a) Thermotolerant coliforms (b) Salmonella spp.	 Less than 200 per gram dry weight (all samples) Not detectable (all samples)

Table 1: AS/NZS1546.2:2001. Composted end product requirements (3 x 2 = 6 samples)

The main aim of this study was to assess the performance of 20 owner-built composting toilets and one factory-built toilet from the point of view of (a) owner satisfaction, (b) soundness of design, (c) soundness of construction, (d) level of management and (e) end product compliance with AS/NZS 15476.2:2001. A second aim was to assess the appropriateness of the performance requirements set out in AS/NZS 1546.2:2001.

Methods

A total of 20 owner-built composting toilets (13 Minimus, 5 Farralones Batch and 2 Barrel Batch) and one commercial toilet (Clivus Multrum) were inspected and three samples of finished product taken from each between June and October 2002. The samples were tested for pathogen indicators, consistency, moisture content and other physico-chemical parameters. The owner of each unit was also asked to answer 40 questions relating to issues such as system design, ventilation, odour problems, leachate and greywater management, bulking material, residence time, reason for choosing a composting toilet, performance of the system, visitor response etc, as well as operation and maintenance. An additional three samples of composted end product were taken from five of the Minimuses, two of the Farallones and the Clivus Multrum (the "intensive" group) in order to accord fully with the sampling requirements specified in AS/NZS 1546.2:2001 sampling procedures. The study is reported more comprehensively in Davison and Waker (2003).

Results and discussion

Thirteen of the toilets were less than five years old at the time of the study, six were 5-10 years old and two were greater than 10 years old. Eighteen of the 21 units inspected were passively ventilated. Two of the Minimuses had been retrofitted with wind driven extractor fans. The Clivus Multrum used a mains powered fan as a standard fitting. All but two householders (both owners of passive Minimuses) considered the ventilation of their toilet to be adequate. Apart from the Clivus Multrum all ventilation pipes were < 100 mm diameter. In twelve cases bulking material was added to the heap after every use. Four households practised daily and four practised weekly bulking material addition. The owner of one of the small Barrel Batch units added no bulking material to his toilet with consequent odour problems. Wood shavings and sawdust were used as bulking material in 20 of the households, newspaper in four, grass clippings in three and dry leaves in three. Kitchen scraps were added to the compost heap in twelve of the households. Five of the owners had added worms to their heap, and two were in the habit of adding agricultural lime periodically.

Estimates of the mean residence time of material in the toilets ranged from as much as 34 months for the Minimus design down to 13 and 15 months for the Farallones and Barrel Batch designs respectively. Thirteen of the householders reported that their toilet had at some time produced a "slightly unpleasant" odour. Seven reported either "non-offensive" or no odours. The Barrel Batch unit subject to zero bulking material addition produced an odour classified as "offensive". Of those householders reporting odours, ten undertook no additional remedial management action, four increased the rate of bulking material addition, one improved ventilation of the compost heap, one improved ventilation of the room and one reduced urine input. All 21 householders applied the composted end product to fruit tress or non-edible plants and none applied it to vegetables.

Toilet design	Householder assessment				Most negative visitor response		
	Excellent	Good	Average	Poor	Complete acceptance	Reserved acceptance	Total rejection
Minimus	4	4	5		5	6	2
Farallones	4	1			2	2	1
Barrel Batch		1		1		1	1
C. Multrum	1				1		
Total	9	6	5	1	8	9	4

Table 2: Owner assessment and visitor response to composting toilet vs toilet design

Table 2 summarises the assessment of the toilet owners themselves and the reaction of their visitors to the composting toilet. It can be seen that the only owner who gave a rating of "poor" was the Barrel Batch owner who experienced odour problems as a result of not adding bulking material. Forty percent of toilet owners reported "complete acceptance" of the composting toilet by all visitors. A further 40% reported "reserved acceptance", that is some initial hesitance on the part of some visitors followed by a willingness to participate once the process and requirements had been explained. Only 20% of owners had experienced “total rejection” by one or more visitor.

	Consistency	Odour	Moisture content		Thermotol. Coliforms		Salmonella
			arith. mean % by weight	# samples > 75%	geo. mean cfu/g	# samples > 200	
Minimus #10	OK x 6	OK x 6	**81**	5	28	2	OK x 6
Minimus #11	OK x 6	OK x 6	71	2	54	2	OK x 6
Minimus #12	OK x 6	OK x 6	75	4	41	2	OK x 6
Minimus #15	OK x 6	OK x 6	73	1	**201**	4	OK x 6
Minimus #17	OK x 6	OK x 6	69	3	122	3	OK x 6
Farallones #7	OK x 6	OK x 6	59	1	83	2	OK x 6
Farallones #8	OK x 6	OK x 6	75	4	5	0	OK x 6
C. Multrum #13	OK x 6	OK x 6	**81**	5	**857**	5	OK x 6

Table 3 shows the degree to which the six samples of composted end product from the eight intensive group toilets complied with the performance criteria set out in Table 1. All eight units passed the test for consistency (no recognizable faecal material), odour (no offensive smell) and Salmonella (non detectable) for all six samples. The Salmonella result is probably due to the fact that < 5% of the population carry this pathogen, so the use of this indicator is questioned. None of the units satisfied the moisture content criterion which requires that all six samples contain < 75% moisture by weight. However for all but two of the eight toilets the arithmetic mean of the six moisture content readings was <75%. Only one toilet passed the thermotolerant coliform test by having all six samples < the required 200 cfu/g. Another five toilets had geometric mean coliform readings < 200 cfu/g. It is interesting to note that the composted end product with the highest coliform count and also the equal highest moisture content came from the commercially built Clivus Multrum, the only one of the 21 units surveyed which had been approved under the state guidelines. Questions to the owner of this toilet revealed that the high moisture content was a result of the owner’s weekly practice of hosing off his garden rake into the compost chamber after raking the heap. The high coliform readings were a result of short circuiting of faecal material from the top of the heap to the collection chamber caused by inadequate addition of organic starter material during the startup phase.

Conclusion

Only one of the eight intensive group toilets (Farallones #8) passed the coliform test and none passed the moisture content test. Despite this fifteen of the 20 owner-built composting toilet owners rated their toilet’s performance as either “excellent” or “good”. The only “poor” rating came from the owner of a Barrel Batch system who was not adding bulking material to the heap. While the three generic toilet designs appear to be basically sound, some toilets required structural adjustment after commissioning. Most problems were overcome by minor modifications to management practice on the part of the owner. With regard to the standard: the criteria for odour and consistency appear to be appropriate. The use of Salmonella as a criterion for disinfection is questioned. The criteria for moisture content and thermotolerant coliform levels could also be reviewed and adjusted slightly in light of the study.

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Waste separation and composting at the household level: peri-urban interface, Kumasi, Ghana

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Keywords

Backyard-composting, composting, Ghana, household, peri-urban, waste-separation

Abstract

In the peri-urban areas of Kumasi, Ghana, rapid growth, widespread poverty, inadequate local governance and limited financial resources all contribute to increasing pollution and waste disposal problems. Participatory action research (PAR) was conducted in four selected peri-urban villages (Adagya, Asago, Esereso and Kyerekurom) with the aim of investigating how appropriate strategies and policies can be incorporated into a community-based waste management programme. Results from preliminary and household surveys indicated a high potential for a household waste separation and composting programme. This was reinforced by the communities' willingness to participate and by their eagerness to improve village sanitation while also contributing to their agricultural livelihoods, as the composting and reuse of organic waste is a means of recycling nutrients and restoring soil fertility. Several household-composting strategies were implemented to demonstrate that hygienic composting could be conducted within the community. Methods that were demonstrated and tested included barrel composting, vermicomposting, brick-built compost bins, and a purposely-designed compost tumbler, all of which were implemented using micro-projects and training workshops through community level facilitators. In the context of household waste management strategies, a variety of interventions that meet the low-cost requirements and that are appropriate in the peri-urban areas of Kumasi are feasible.

Introduction

The increasing pollution and waste disposal problems that are to be found in many sub-Saharan African cities have become distinctive features of Kumasi, Ghana, where rapid growth, widespread poverty, inadequate local governance and limited financial resources all contribute to the waste problem. The pollution and waste disposal problem is most acute in peri-urban areas, where waste management services are seldom provided despite rapidly increasing settlement densities. In peri-urban villages where no waste collection services are provided, community members use an allocated site where solid waste is simply dumped and allowed to accumulate, to be burned occasionally. In the past, such dumping posed a low public health and environmental risk because what little waste there was consisted mainly of organic matter, which was either eaten by livestock or decomposed naturally and thus never accumulated to the scales that can be observed today. The increasing population of peri-urban areas has led to higher waste flows, and the rising quantities and proportion of plastics within domestic waste reduces the effectiveness of any natural decomposition. These conditions have resulted in the growth of unsanitary conditions in many peri-urban villages, and with the current in-migration trends that are occurring in peri-urban Kumasi, the situation is likely to deteriorate even further. However, despite these entrenched problems, opportunities for community-based waste management strategies do exist and when implemented appropriately can not only improve environmental sanitation but also enhance local livelihoods.

Research approach

The research project was implemented using a participatory action research (PAR) approach. In essence, PAR is a problem-solving, iterative and systematic approach to research where a range of 'intellectual resources' are drawn upon to find a solution to a problem or to improve current practices (Phillips and Pugh, 1994). The research tools used during the fieldwork – participatory rural appraisal techniques, semi-structured interviews, micro-projects and workshops - were predominantly qualitative methods, and hence bestowed several important advantages which are crucial if a PAR approach is to be successful and truly participatory. These included: flexibility of research design and methods; increased holistic understanding of the issues; more natural settings; and inclusion of local perceptions and viewpoints (Curry, 1996). The first phase consisted of an orientation and familiarisation survey of the four selected peri-urban villages (Adagya, Asago, Esereso and Kyerekurom). This provided an opportunity to make initial contact with the respective village Chiefs (traditional village head), Unit Committee representatives (elected village body), and the community level facilitators (CLFs) (community chosen representatives working on a UK Department for International Development funded livelihoods project), thereby introducing the research project and identifying some of their main issues and concerns. Despite differing social and economic circumstances and geographical locations amongst the four villages, several characteristics proved common in all four sites and were observed during the preliminary surveys: unmanaged open waste dumps; open defecation by children on waste dumps; disposal of chamber pot waste in plastic bags on waste dumps; and indiscriminate dumping of waste on village peripheries.

The second phase consisted of a household survey in which semi-structured interviews were used to collate household, waste, sanitation, health and agricultural details and also to determine micro-project participation willingness in each of the villages (Adagya n=58; Asago n=58; Esereso n=56; and Kyerekurom n=53). Pertinent data from the survey shows the high percentage of households engaged locally ($\geq$4km) in agriculture (88%) and the fact that daily domestic waste consists mainly of food scraps (peels from cassava, yam and coco yam and plantain skins) and wood ash, with only small quantities of sand and plastic bags. Although plastic bags constitute only a small component of daily domestic waste, it is their accumulation over time on the waste dumps which leads to the large unsightly mounds that plague all four villages and many other peri-urban areas of Kumasi. Results from preliminary and household surveys indicated a high potential for a household waste separation and composting programme. This was reinforced by the communities' willingness to participate, and by their eagerness to improve village sanitation while also contributing to their agricultural livelihoods, as the composting and reuse of organic waste is a means of recycling nutrients and restoring soil fertility. Once appropriate interventions were identified, they were implemented using micro-projects and training workshops conducted through the three CLFs of each village. This also contributed to the enhancement of the CLFs' capacity to produce and analyze knowledge (Douglass, 1992). Micro-projects were used to provide simple demonstrations that could be easily replicated, particularly after other community members have observed the direct benefits. However, there may be a prolonged time lag before outputs are available, so the intervention must be well planned and sustainable, with local people actively participating in all stages of the planning and implementation process. By increasing the number and distribution of micro-projects in each village the dissemination capacity is also increased, thereby reaching a wider community audience.

Household composting

In light of the local agricultural activities, the need for soil ameliorates (Nsiah-Gyabaah and Adam, 2001) and the high proportions of organic matter in domestic waste, several household-composting micro-projects were implemented to demonstrate that benefits of hygienic composting methods within the community. When composting domestic waste in densely populated areas, suitable composting containers are required that will keep out mechanical disease vectors, such as flies, mosquitoes, cockroaches and vermin such as rats, which thereby ensures that the composting process remains safe and hygienic. An additional – and immediately observable – benefit from composting organic waste at the household level is the reduction in the number of trips that household members (inevitably children and women) must make to the open refuse dumps, thereby reducing their exposure to potentially hazardous sites. The composting methods that were demonstrated and tested included barrel composting, vermicomposting (use of earth worms), brick-built compost bins, and a purposely-designed compost tumbler. Initially, a total of 10 brick-built compost bins and 5 compost tumblers were distributed at prominent strategic points that were spread throughout each of the four villages.

The brick-built compost bins consist of a double-chamber with a wooden lid. Gaps are provided between the bricks in the bottom course to facilitate airflow, while making holes in the compost pile with a sharp stick provides additional aeration. Each compost bin is sufficient for a household with an extended family. Unlike the brick-built compost bins, the 'Suame compost tumbler' has a smaller capacity and therefore is only suitable for smaller households, as rapidly filling the drum with organic wastes may result in putrefaction. The tumbler is an outcome of collaborative work between the Centre for Developing Areas Research and the Intermediate Technology Transfer Unit, Kumasi, and it is designed to accelerate organic decomposition while ensuring hygienic conditions are maintained; specific design features were included to ensure suitability for tropical conditions and ease of use by children. After construction of a compost bin or allocation of a tumbler, the respective household members received training in waste separation and composting techniques. In addition, information leaflets in both English and the local Twi language were distributed. The leaflets provide clear instructions in composting techniques and include sketches. Training and technical assistance was then provided to a further 6 households which adopted the techniques and supplied their own blocks to construct brick-built compost bins. Likewise training and technical assistance was given to five households in Adagya where a larger brick-built compost bin was constructed for communal use by the 5 participating households. The larger brick-built container consists of three chambers and the blocks on the front of the bins are unmortared to provide easy access when removing the compost. Additional demonstrations included barrel composting in Asago and vermicomposting in Esereso, both of which were constructed using recycled materials found within the respective villages.

Results

Since implementation, regular monitoring of the compost containers has been conducted to evaluate both the performance and appropriateness of the compost containers. In economic terms the most cost-effective have been the containers that were constructed from recycled materials and hence required no financial inputs. These included the barrel composting and vermicompost containers and an unmortared block-built compost bin constructed from recycled blocks. Whereas the average construction cost of each block-built compost bin was approx. EUR 13, the construction cost of each compost tumblers was approx. EUR 58. Despite the compost tumbler being highly effective in decomposing small quantities of organic waste, the construction cost exceeds the purchasing power of many peri-urban farmers and therefore could only be viable if financial assistance was provided. Conversely, the wide availability of building blocks (both modern and traditional sun baked) increase the viability of block-built compost bins, particularly the larger triple chamber container as the cost can be divided by several households. All the containers proved to be effective for decomposing organic waste, particularly when good composting practices were followed, that is where organic materials were shredded and the compost pile frequently aerated. Problems have occurred when containers are filled rapidly and the waste inside compacts and then putrefies. Removing the top layers and increasing aeration of the remaining compost pile has remedied this.

Conclusions

The systematic approach of PAR is highly appropriate in implementing a household waste separation and composting programme. The establishment of micro-projects within a community can be a catalyst for change, particularly when the strategy is affordable, has obvious benefits and contributes directly to the enhancement of local livelihoods. Micro-projects can be used to provide simple demonstration sites that can be easily replicated by other community members, particularly after other village members have observed the direct benefits. However, there may be a prolonged time lag, so the intervention must be well planned and sustainable, with local people actively participating in all stages of the planning and implementation process. Interest in the introduced low-cost technologies has been high within the selected communities and several households have spontaneously adopted the techniques, supplying their own materials to construct compost containers. In the context of household waste management strategies, a variety of interventions that meet the low-cost requirements and that are appropriate in the peri-urban areas of Kumasi are feasible.

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Water development and sanitation improvement activities development

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Abstract

In the history of Uganda the Pastoral Community of the "Bahima" was based on annual migrations that were driven by the seasonal availability of grass and water and the prevalence of cattle diseases. The movement caused a lot of conflict between the Bahima and the neighboring communities, but also among themselves.

This way of life was even made harder by the establishment of Government Ranches in the early 1960s covering 77km, the establishment of the Ankole Ranching Scheme (RS) between 1963 and 1975 covering a total area of 640 km2 gazetting of Lake Mburo National thus squeezing the pastoralists into smaller and smaller areas.

The break-down of law and order in the second half of the 1970s led to the collapse of the ARS and the deterioration of law enforcement regarding the game reserve. As a result pastoralists started re-encroaching on the 2 areas illegally.

As a matter of fact, the traditional owners of the land had become landless squatters.

Following a change of Government in 1986, officials allowed former residents to go back to the gazetted areas, which the pastoralists did in 1987, destroying the headquarters and killing wild life they came across.

Subsequent to these events, the park has since been reduced in size from 650 km2 to 260km2 by a series of degazettments.

The "Integrated Pastoral Development Project (IPDP) Mbarara", aims at enabling 1000 settler families to sustainably satisfy their basis needs from their own resources within 6 years. The Mbarara Local Government (MLG) and the "Gessellschaft for Technische Zusammenarbeit (GTZ)" are in charge of the project implementation from the Uganda and German side respectively.

The ultimate objective for the implementation of an integrated water development programme during the 3 phases of the project, is to have settled communities with sufficient water for both production (livestock) and domestic use; and a sustainable sanitary environment.

This object has been achieved using a gender – sensitive, participatory extension concept.

Community self-help and extension projects can only be successful at target group level, if their activities are closely geared towards the needs as perceived by the target groups. Therefore the first step always has to be an assessment of the target groups needs, before any measures can start.

Both meetings are arranged by a multi-disciplinary group of project officials, representing specialists from communal water and sanitation facilities, women, plant production, forestry, animal husbandry and health.

In about 90% of all cases, water has always emerged on top of their priority needs. Being a nomadic community, development of water activities must include water for livestock and domestic use.

The potential for community based self-help activities such as water development has become a function of social cohension among the families that are living in a particular ranch. As a result over 70% of the settlers have been involved in at least 2 other activities other than cattle rearing. About 50% of the families now have enough food supply from their own gardens and have surplus from which remained in the area and get income from mixed farming which we regard as sufficient by Uganda standards.

All these developments have been sparked off by the 20 valley tanks constructed in the area, with capacities from 6000m3 to 15000m3. on average each of these tanks serve about 20 families and 1000 heads of cattle. Over 200 pit latrines have been constructed.

In this paper, it has been proved that the construction of a drinking water facility, bring security in the form of a regular supply of water and diminished danger of diseases. However, the reduction of risk on the ecological side requires a more complex, or even new form of organisation of water and often new technology.

It is also possible that with availability of a water supply system, what used to be source of conflict (during visitation) can be transformed into a trade link and therefore acting as a starting point in a development agenda.

However, to ensure a lasting water supplying system for the population, it is important that all users develop cultural identification with the water project and one which will enable them to cope with the newly emerging social – cultural risks. This will increase the security for all the water users.

The SUSSAN project: strategies towards sustainable sanitation - presentation of an Austrian applied research project

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Keywords

Decision support, ecological sanitation, sustainability, wastewater disposal

Abstract

This paper presents, on behalf of the project team, the Austrian project SUSSAN. The project aims on the one hand at identifying sustainable strategies for wastewater management, taking into account waste management and the agriculture, and at developing criteria to assess the sustainability of these options. On the other hand, it aims at analysing the possibilities to apply these concepts in existing structures. The existing model communities have been selected in order to represent typical Austrian rural settings, in different provinces. Nevertheless, in the course of the project also a rural city will be analysed. In particular the rural urban interface and its interaction between agricultural and urban areas, is of interest in the context of its wastewater management.

Project context

This paper presents, on behalf of the project team, the Austrian project SUSSAN which started in November 2002 and which will last until beginning of 2005.

In recent years, the sustainability of conventional wastewater management concepts, which usually consist of a collection system and a wastewater treatment plant, has been put in doubt by various experts. For instance, the traditional method of wastewater disposal does not reuse the nutrients (e.g. N and P) which wastewater contains, instead a high energy demand is necessary to eliminate these nutrients from the wastewater, and the invested capital is tied up in infrastructure which is inflexible and expensive. In addition, a large amount of potable water is wasted to flush away the human excreta. However, the traditional system is well suited for centralised systems, and is based on a long experience and thus a fully developed technique.

The reuse of the nutrients is of particular importance considering that, with traditional wastewater disposal concepts, these nutrients are eliminated from the wastewater in the WWTP with substantial energy consumption on the one hand, while, on the other, these nutrients need to be either exploited from limited natural resources (P and K) or converted with considerable energy demand to a form which can be used by plants (N) in order to supply agriculture with artificial fertilizers. In particular bearing in mind the limited P resources, which may be fully exploited within 100-200 years (also other numbers have been mentioned), measures in order to recycle the P in the wastewater are highly required. Since sewage sludge is increasingly not accepted by the public as a fertilizer, other methods are necessary.

Alternatives to the traditional philosophy of wastewater disposal are concepts based on source control and the separation of the wastewater into its constituent parts yellow water (urine), brown water (faeces) and grey water. These concepts have been applied in Europe in several pilot plants in Sweden, and in some pilot plants in Germany and Denmark, in municipal wastewater management. Yellow water is of particular importance as a fertilizer, since it contains the nutrients N, P, K and S in a proportion which is ideal for plants.

However, apart from the aspect of nutrient reuse, other factors, in particular micro-pollutants, acceptance and management of these concepts, have to be taken into account as well. Management encompass the juridical framework, financial aspects, organisation of the operation and the integration of waste-, and urban water management as well as agriculture. This is a challenge for the new concepts since on the one hand, more institutions are concerned, and on the other, the existing structures have been grown in the last 100 years and are therefore adapted to the traditional concepts.

Further, even if the new concepts are more sustainable in selected aspects, a comprehensive assessment of their sustainability compared to conventional systems is up to now and general, difficult. This is in particular caused by a lack of long-time experience and by uncertainties (e.g. micro-pollutants). Currently, there are some projects in Europe which deal with this question, e.g. the Swedish Urban Water Program, the Swiss Novaquatis project, or the German Lambertsmühle project. In a long time horizon the question is being posed if it is more sustainable to keep the existing concepts and improve them, or to change to the new concepts. It is the aim of the project SUSSAN to contribute to answer this question, and in particular to elaborate guidelines how the experts of the authority shall deal with these concepts and how to deal with them in studies of alternatives.

Project objectives

The project aims on the one hand at identifying sustainable strategies for wastewater management, taking into account waste management and the agriculture, and at developing criteria to assess the sustainability of these options. On the other hand, it aims at analysing the possibilities to apply these concepts in existing structures. The existing model communities have been selected in order to represent typical Austrian rural settings, in different provinces. The latter aspect is of particular relevance, since in Austria the provinces are responsible for urban water management, which have their own, different, guidelines.

Therefore, in particular guidelines for how to deal with such concepts during the evaluation process of the authorities and in the course of the analysis of alternative options for wastewater management, will be developed. Further, applied research in the field of decision support and the feasible definition of the term sustainable wastewater management, that the practitioner can deal with, shall be undertaken. The transdisciplinary approach will facilitate that the project results can be applied in practise.

Project content

The project is an applied research project. The interdisciplinary project team consists on the one hand of scientific experts from the fields of urban water and waste management, agriculture, organic farming, energy management, soil science, hygiene, sociology, economy and environmental chemistry. On the other, it consists of experienced engineers, governmental experts, and the inhabitants of 5 selected model communities. This ensures a transdisciplinary approach, which is necessary to facilitate the application of the project results in the political context.

Bearing in mind the poor wastewater management situation in rural areas in Austria, the selected model communities are situated in the rural area, and have no foul sewers yet. In particular in existing settings, the integration of new and innovative wastewater management concepts is a challenging task. Even more conventional options, such as pressure and vacuum drainage, which may be appropriate from a theoretical point of few, are in practice often perceived as problematic, and the devil is usually in the nuts and bolts. Implementing concepts based on a sorting of the wastewater's constituent parts and source control, requires therefore innovative approaches which are adapted to the existing structures. However, such new concepts are of particular relevance in rural areas in Austria which have no foul sewers yet, since new houses are usually being build close to urban areas. Thus, there, a connection to the existing urban sewer system is usually necessary owing to economical pressure. Nevertheless, in the course of the project also a rural city will be analysed. In particular the rural urban interface and its interaction between agricultural and urban areas, is of interest in the context of its wastewater management.

The project features the following tasks:

Pool of options

Several options for a sustainable wastewater disposal have been described and applied in recent years. This WP summarises the technical characteristics of these options and their unit processes. Further, methodologies to improve the conventional wastewater disposal systems will be considered (e.g. adapting existing structures, use of innovative technologies (e.g. eco turbo sewer). This work is based on previous projects, a literature review and own experiences.

Baseline system analyses

A baseline system analysis in the model communities with respect to socio-economic aspects, the agricultural structure and the business administration of selected agricultural companies, as well as the regional energy context and the relevant regional framework for wastewater management will be carried out.

Planning

For selected areas of the model communities new concepts for a comprehensive wastewater management, taking into account the principles of re-use of water and nutrients, will be planned. The emphasis lies on an optimisation of the construction and operation costs of the new systems. Further, possible improvements of the existing systems will be investigated. In particular in existing settings, the integration of new and innovative wastewater management concepts is a challenging task. Even more conventional options, such as pressure and vacuum drainage, which may be appropriate from a theoretical point of few, are in practice often perceived as problematic, and the devil is usually in the nuts and bolts. Implementing concepts based on a sorting of the wastewater's constituent parts and source control, requires therefore innovative approaches which are adapted to the existing structures.

Public participation

In the course of this project the future users shall participate in the planning process.

Evaluation

Selected wastewater management concepts based on urine or black-water separation shall be evaluated.

Economical analyses

Investment and O&M costs for different concepts for wastewater disposal, for several cost scenarios, based on existing examinations, the opinion of the experts and the results of the Austrian project "Benchmarking in municipal wastewater management", will be modelled. In particular the costs are very sensitive to personal preferences. This modelling exercise shall result in a cost estimation which is accepted by both, sceptics and advocates of the new technologies.

Further, cost-benefit considerations, considerations of indicators for the national economy and consideration of the financing, taking into account the existing subsidiation system in Austria, will be carried out. In the context of biogas plants, the regional situation has to be taken into account.

Organisational analyses

From an energetical point of few, small organisational structures may be less effective than big ones. In particular concepts of ecological sanitation are characterised by small structured and decentralised organisational forms, and are thus often considered to be inferior to central organisational systems. This point is therefore crucial for the implementation of such concepts. Different possibilities for the organisation of the operation of these concepts, taking into account the existing local and regional structures, and aiming at increasing the competitiveness of decentralised concepts, will be analysed.

Integrating agriculture and waste management

The integration of urine and composts in the agricultural cycles of the model communities, taking into account the national and provincial frameworks for agriculture, waste management and subsidiation, will be analysed.

Social analyses

The experiences and attitudes of potential users of innovative wastewater management concepts will be examined. It aims firstly at investigating the acceptance (considered as a result of a learning and decision making process) of alternative concepts in the model communities, secondly at the development of planning-relevant user feedback, and thirdly, at the development of a diffusion concept, to support the implementation of such concepts.

Decision support

In the course of the evaluation of a proposed project by the authority, the experts of the authority have an important role. In particular with new options, the experts face a difficult task. On the one hand, such options are not considered to be BAT standard, on the other hand, the advantages of these options may not be relevant in the existing decision making framework.

Based on the project “Deciding and comparing in environmental risk management”, which was co-ordinated by the Institute of Mathematics and Applied Statistics of the University of Natural Resources and Applied Life Sciences, Vienna, it will be examined, on the one hand, how the decision making process of the authority may become more transparent (assessment rules, procedures for decision making), and on the other hand, how the term “sustainable wastewater management” can be defined in a feasible way, in order that the practitioner can deal with it.

Hygiene and Environment

These topics are characterised by several questions which are still not answered sufficiently. Nevertheless, these questions are most important in the context of the political acceptance of the considered concepts. The hygienic constraints and requirements in the context of the Austrian guidelines will be analysed. Further, the available information dealing with micro-pollutants and hormones in the urine and composts will be analysed in the context of the relevant Austrian guidelines and laws.

Decision support system

An expert DSS shall be developed.

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The integrated water management system at the „Kulturfabrik Mittelherwigsdorf"

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Keywords

Waste water recycling, rainwater utilization

Abstract

The investigated water management concept based on the decentral treatment of domestic waste water in a constructed wetland, the re-use of the treated waste water and rainwater utilization. The service water obtained is used in the house for flushing toilets and for irrigating the garden.

These investigations were made to achieve a diploma theses. The aim was to test the applicability of the system with a main focus on the quality of the service water. The work was carried out in two steps: First the temporal development of concentrations of water constituents after starting the water recycling were estimated mathematically. The theoretical simulation was based on hydraulic flows and concentrations of waste and rain water constituents which were measured before starting the operation of the system. The second step of the study focused on the monitoring of the run in period of the system.

Referring to the results obtained from the mathematical simulation and the monitoring period the system is applicable in principle. According to the short time of the investigations no clear statement can be given concerning the long-term behaviour of the system.

In spite of the applicability of the system still some improvements have to be reached: Under present conditions the waste water treatment in the constructed wetland leads to an accumulation of CO_2 above carbon balance and thus to corrosive effects on installations. The organic load of the service water is about four time higher than recommended for domestic service waters.

The water management system

The water management system at the "Kulturfabrik Mittelherwigsdorf" consists of a digester and a constructed wetland for waste water treatment, a system to collect rainwater from the roof of the house, a pond for storing, mixing and polishing of the obtained service water and a secondary pipe system for the recycling of service water into the house. In figure 1 a scheme of the system is shown.

At first raw sewage is pre-treated by filtration. Separated solid matter is collected in a digester. The digester consists of two chambers, alternately delivered with waste water. After this physical pre-treatment the waste water is treated biologically in the constructed wetland.

This wetland consists of two soil filters with vertical flow, overgrown with reed. After passing the reed beds the cleaned waste water is pumped into a storage pond. The rainwater coming from the buildings roof is fed into this pond as well. The service water is pumped from the storage pond to the flushing tanks in the house.

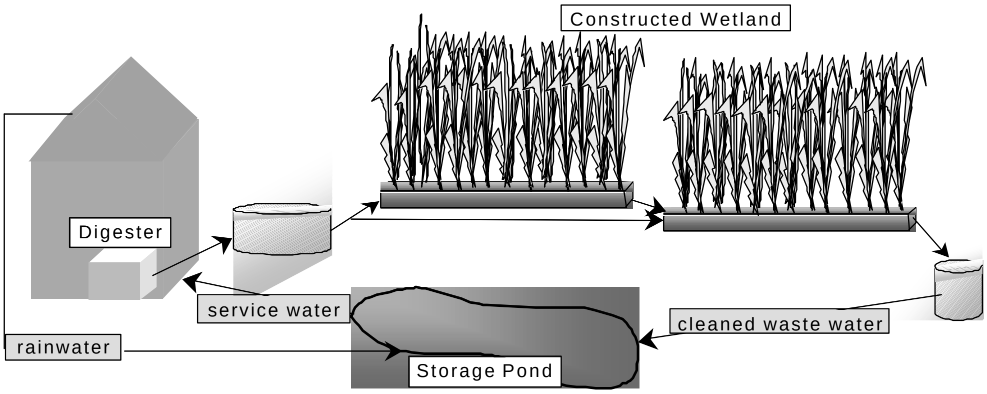


Figure 1: Scheme of the water management system at "Kulturfabrik Mittelherwigsdorf"

Modelling of the temporal development of concentrations of water constituents

In the first step of this investigation the temporal development of concentrations of water constituents in the service water were mathematically simulated. Therefore the data of concentrations and amounts of hydraulic flows were collected and measured before starting the operation of the recycling system. Water samples were taken at three points: at the in- and the outlet of the constructed wetland and at the storage pond. The amounts of the hydraulic flows were estimated from tap water consumption data, statistical elevation of the water consumption in German households (Förstner, 1995) and the long-time meteorological data of this region (Peschke et al., 2001).

For the calculation of the various constituent concentrations, different behaviour of these water constituents in the constructed wetland were presupposed which lead to different calculating methods. Parameters corresponding to the organic load of the treatment plant, i.e. BOD and COD an elimination to the same low level as before the waste water recycling was supposed. This supposition was based on the fact that the constructed wetland was originally designed for 35 persons whereas the influent load corresponds to only 12 persons. For inorganic nutrients and salts no surplus elimination in the reed beds was supposed, as these compounds were eliminated to a limited level even before installation of the water recycling. This supposition resulted in elevated effluent concentrations of inorganic nutrients and salts by the gradual accumulation of these compounds in the system.

As to be seen in fig. 2 the concentration of the organic matter in the service water will not be changed by the water circuit and the linked surplus load of the constructed wetland. The estimated concentration of BOD_5 will be 12 up to 15 mg/l O_2. The estimated concentration of COD will be 16 up to 19 mg/l O_2.

The concentration of nitrate and of phosphate will increase considerable. In figure 2 the graphs of both nitrate and phosphate concentration are showing a plateau after October. By October the constituents concentration will change only by the different input volume of rainwater. The highest plateau concentration of nitrate will be 44 mg/l. The highest concentration of phosphate will be 6,6 mg/l.

Monitoring of the run in period of the circuit

The water management system has been started on May 25th 2002. Water samples were taken weekly at the in- and outlet of the constructed wetland, at the storage pond and at a flushing tank in the house.

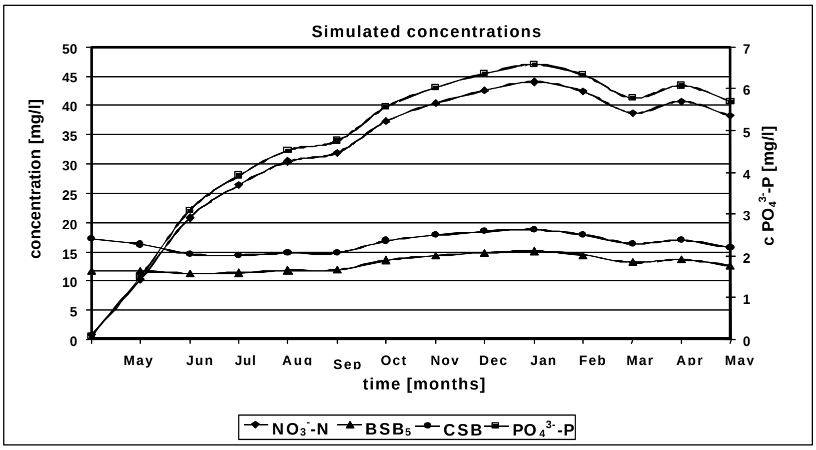


Figure 2: Simulated constituent concentrations in the service water

Measured concentrations of BOD_5, COD, Nitrate and Phosphate

At the run in period of the circuit a BOD_5 concentration between 12 and 25 mg/l O_2 was measured in the service water. The COD concentration was between 18 and 28 mg/l O_2. So the measured concentrations of organic constituents were higher than those calculated.

The measured concentration of nitrate sank from 15,3 mg/l at May 29th down to 1,3 mg/l at June 26th and 4,1 mg/l at July 10th. The measured concentrations were about one magnitude lower than those calculated. The measured concentrations of phosphate were between 1,1 mg/l at May 29th and 0,3 mg/l at July 10th. Again the measured concentrations were lower than those calculated and reached about 1/3 of the calculated ones.

Investigation of the carbonate balance in the service water

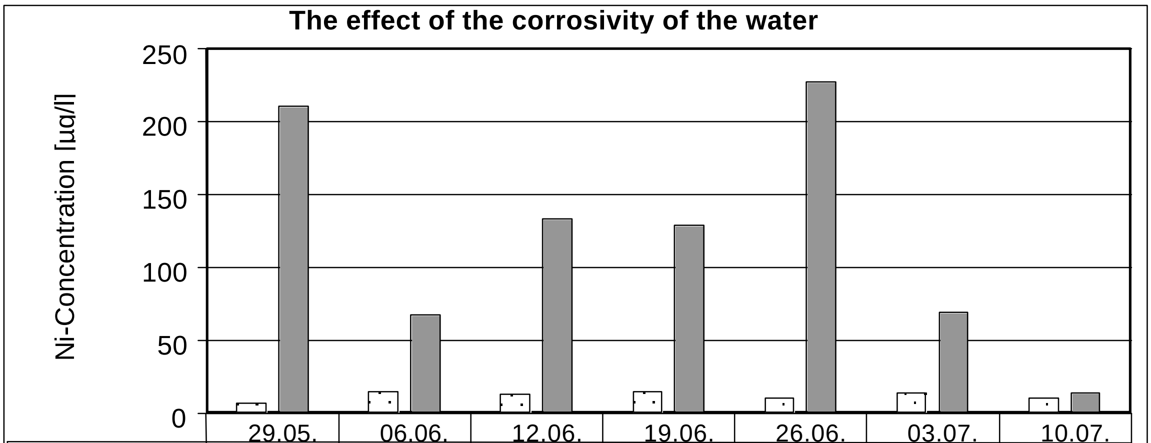
To test the carbonate balance in the service water the acid and alkaline capacity of the service water were determined and the concentration of Ca, Mg and sulphate were measured (DIN 38407-H7; DIN 38404-C10). In order to test an eventual corrosion the concentrations of Cu, Ni, Zn and other heavy metals were analysed as well.

Calculating the carbonate balance resulted in negative saturation index (pH) for every tested sample, thus indicating that the water is aggressive and corrosive (Kölle, 2001).

The data obtained from analysing the concentration of Cu, Ni and Zn confirmed the corrosivity of the service water. Figure 3 shows the mobilisation of this metals on the example of Ni. The increasing of concentration between the pond and the flushing tank was 109,6 µg/l Ni, 51 µg/l Cu and 49,4 µg/l Zn on average.

Discussion and conclusions

The monitoring of the run in period of the system showed differences between the estimated and the measured concentrations for organic load and inorganic nutrients in the service water. The higher concentration of organic compounds, reflected by BOD and COD could be explained by the not finished process of system adaption to the higher load. It can be supposed that calculated concentrations will be reached when adaption is completed. A clear statement concerning storability of the service water is not possible before these conditions are reached. At present the organic load of the service water is about four time higher than recommended for domestic service waters (Sen Bau Wohnen, 1995).



	29.05.	06.06.	12.06.	19.06.	26.06.	03.07.	10.07.
Storage pond	6,3	14,8	12,9	14,8	10,4	14,1	10,4
Flushing tank	210,6	67,7	133,3	128,6	227,3	69,3	14,0

Figure 3: Ni-Concentration in the storage pond and the flushing tank

As biological processes were not regarded in the estimations, the higher elimination rates for inorganic nutrients could be effected by the nutrient intake by plants and microorganisms in the summer months, during which the monitoring was carried out (Wissing and Hofmann, 2002).

A major problem of the system under present conditions is the corrosivity of the service water, which would result in pipe leakage in few months if no countermeasures are taken. An appropriate method would be the dosage of chalk into the service water in order to reach carbon balance.

Running the water management system which is installed since the summer 2002 makes sure that no waste water leaves the area of the "Kulturfabrik". Solid matter collected in the pre-filter is used as humus in the garden after aerobic stabilization. A reduction of drinking water consumption of about 1/3 was achieved by water recycling and rainwater utilization. These effects are reached with few and simple technical equipment and therefore investment and operating costs are low. Furthermore only little maintenance is necessary and no special education is required, i.e. after a short training it can be done by nearly everybody.

Practical experience with the outlined water management system is limited to a six months operating period so far. Referring to the results obtained the water management concept is applicable in principle. In case further investigations will show a long-term stability of the system, it will be useable due to its benefits not only in Germany but especially in developing and fast-developing countries.

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Session D

Hygiene and environmental assessments

Chairpersons

Christine L. Moe (Rollins School of Public Health of Emory University, USA)

Thor-Axel Stenström (Swedish Institute for Infectious Disease Control, Sweden)

Lectures

Risk assessment of local handling of human faeces with focus on pathogens and pharmaceuticals
Karsten Arnbjerg-Nielsen, Linda Hansen, Jesper Kjølholt, Frank Stuer-Lauridsen, Arne Bernt Hasling (COWI, Sweden)*, Thor Axel Stenström, Caroline Schönning, Therese Westrell* (Swedish Institute for Infectious Disease Control, Sweden), *Anders Carlsen, Bent Halling-Sørensen*

Environmental systems analysis of small-scale sanitation solutions*
Hans B. Wittgren, Andreas Baky, Ola Palm (JTI Swedish Institute of Agricultural and Environmental Engineering, Sweden)

Faecal contamination of greywater - assessing the treatment required for a hygienically safe reuse or discharge*
Jakob Ottosson (Swedish Institute for Infectious Disease Control, Sweden)

Problems and potentials for urine separation in a small village with a wastewater treatment plant operated with extended nutrient removal*
Jes la Cour Jansen (Lund Institute of Technology, Sweden)*, Elsebeth Koldby*

Life cycle microbial risk analysis of sustainable sanitation alternatives
Simon Fane (University of Technology Sydney, Australia)

Recommendations for the reuse of urine and faeces in order to minimise the risk for disease transmission*
Caroline Schönning (Swedish Institute for Infectious Disease Control, Sweden)

Microbiological risk assessment of greywater recycling*
Friedrich-Karl Lücke (University of Applied Science Fulda, Germany)

Chances and risks of sustainable sanitation (SuSan) in Europe
Helmut Lehn, Christine Nicklas (Akademie für Technikfolgenabschätzung, Germany)

Oral poster presentations

Survival of faecal indicators and bacterial and parasitic pathogens in source separated human urine
L.T. Jørgensen, I. Tarnow, A. Forslund, A. Dalsgaard (The Royal Veterinary and Agricultural University, Denmark)*, H.L. Enemark*

Fate of estrogens in wastewater treatment systems for decentralised sanitation and re-use concepts*
Titia de Mes, Grietje Zeeman (Wageningen University, Netherlands)

*This paper has been peer reviewed by the symposium scientific committee

Poster presentations

Assessing the risks to groundwater quality from unsanitary well completion and on-site sanitation*
Aidan Cronin, Steve Pedley (Robens Centre for Public and Environmental Health, UK)*, Ned Breslin, Richard Taylor*

Composting of faecal material – a hygienic evaluation
Annika Holmqvist, Jacob Møller, Anders Dalsgaard (University of Denmark, Denmark)

The impact of ecological sanitation on parasitic infections in rural El Salvador
Lana Cohen Corrales, Ricardo Izurieta, Christine L. Moe (Rollins School of Public Health of Emory University, USA)

Reduction of faecal microbiological indicators in different compost toilets
Jacob Møller, A. Forslund, Anders Dalsgaard (University of Denmark, Denmark)

Opportunities for eco-sanitation in East-Europe: a Romanian example
Margriet Samwel (WECF, The Netherlands)

This paper has been peer reviewed by the symposium scientific committee

Risk assessment of local handling of human faeces with focus on pathogens and pharmaceuticals

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Session D

Keywords

Chemical hazard assessment, faeces, microbial risk assessment, micro-pollutants, pharmaceuticals, pathogens

Abstract

Dry urine-diverting toilets may be used in order to collect excreta for utilisation of the nutrients. In this project local reuse of faeces as a fertiliser was evaluated regarding health and environmental effects. Human health aspects were evaluated regarding risk of transmission of infectious diseases and ingestion of pharmaceuticals, heavy metals and dioxins. Results from the microbial risk assessment showed that 12-months storage was not sufficient for inactivation of pathogens to acceptable levels. When working or spending time in the garden the yearly risk of infection by rotavirus and parasites were still $>10^{-4}$ in this scenario, taking incidence in the population into account. To achieve a daily dose (DDD) of a pharmaceutical ingestion of 200 g to 1 kg soil was necessary and for the micro-pollutants the exposure was less than 1/16 of the tolerable daily intake (TDI). Environmental risks were evaluted by calculating the risk quotient (RQ) for the three of the 25 most commonly used pharmaceuticals where predicted no-effect concentrations were available and by comparing the concentration of heavy metals and dioxins to current Danish sludge and soil quality criteria. For Oestradiol and Ibuprofen the RQ was >1, implying a negative effect on the terrestrial environment. The concentration of cadmium and lead in the faeces was equal or slightly higher than the quality criteria.

Environmental systems analysis of small-scale sanitation solutions*

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Session D

Keywords

Small-scale sanitation, systems analysis

Abstract

Environmental systems analysis was used to compare five small-scale sanitation solutions in terms of contribution to eutrophication, cadmium discharge to water, recycling of nitrogen and phosphorus to arable land, flows of cadmium to arable land, and energy turnover. The solutions were also compared qualitatively in terms of transmission of disease, economy and robustness. The analysis used Swedish data, and assumptions were based on Swedish conditions concerning sanitation infrastructure. 'New' solutions, with separate treatment of blackwater (wet composting), urine sorting, or both urine and faeces sorting, performed better in terms of discharge to the environment and recycling of plant nutrients than presently dominating solutions (septic tank alone or combined with sand filter bed). From an economic perspective, the 'new' solutions are probably equal to connection to municipal sewers, but more expensive than presently dominating solutions. The 'new' solutions are also either less energy efficient (wet composting) or less robust (urine sorting with or without faeces sorting), but this is partly due to that they are not yet mature.

Introduction

It has been estimated that small-scale sanitation facilities (serving individual households or groups of households) are responsible for approximately 50 % of the wastewater discharge of phosphorus in Sweden (Swedish EPA, 1993). This may largely be explained by that 50-60 % of the approximately one million small-scale sanitation facilities do not satisfy the demands of the Swedish environmental code. Essentially, the reason is that a septic tank is the only treatment step where there is no connection to municipal sewers. Furthermore, the most common additional treatment steps, infiltration or sand filter beds, are not always working properly. Small-scale sanitation facilities thus need to be upgraded. Under these conditions there is a need for new solutions, and also an opportunity to introduce recycling of nutrients. At present, almost no nutrients are recycled from small-scale sanitation facilities, although they are often situated close to arable land.

In the present study, environmental systems analysis was used to compare five small-scale sanitation solutions in terms of contribution to eutrophication, cadmium discharge to water, recycling of nitrogen and phosphorus to arable land, flows of cadmium to arable land, and energy turnover. The solutions were also compared qualitatively in terms of transmission of disease, economy and robustness.

*This paper has been peer reviewed by the symposium scientific committee

Methods

The following small-scale sanitation solutions were compared:

Mixed wastewater (black- and greywater) treated in septic tank

Mixed wastewater (black- and greywater) treated in septic tank and sand filter bed

Blackwater treated by wet composting and applied on arable land; greywater treated in septic tank and sand filter bed

Urine diverted, stored and applied on arable land; mixed wastewater treated in septic tank and sand filter bed

Urine diverted, stored and applied on arable land; faeces collected 'dry', treated by composting and applied on arable land; greywater treated in septic tank and sand filter bed

The aspects for which the comparisons of different small-scale sanitation solutions were made, were partly selected from an assessment of the relative impact of the waste and wastewater treatment sector in Sweden (Kärrman and Jönsson, 2001). A group of priority aspects, for which waste and wastewater treatment may contribute > 5 % of total human impact, were identified: discharge of nitrogen and phosphorus to receiving waters; discharge of cadmium, lead and mercury to receiving waters; recycling of nitrogen and phosphorus to arable land, and; flows of cadmium, lead, mercury and copper to arable land.

In our study, discharges of nitrogen and phosphorus to receiving waters were included in the environmental impact category 'eutrophication', calculated by weighting different emissions according to Lindfors *et al.* (1995). Furthermore, we focused on only cadmium among the heavy metals, since it is of most concern when organic waste is recycled to arable land.

Although energy use is not of the same relative importance (< 1 %), it was still included since some small-scale sanitation solutions may involve considerable transportation work, as compared to the large-scale solutions which formed the basis for the assessment by Kärrman and Jönsson (2001).

According to Kärrman and Jönsson (2001), also the risk for transmission of disease must be given high priority due to its importance for human health. Finally, we considered it relevant to include the aspects of economy and system robustness in our comparison, and thus ended up with the following nine aspects:

- Eutrophication
- Discharge of cadmium to receiving waters
- Recycling of phosphorus to arable land
- Recycling of nitrogen to arable land
- Flows of cadmium to arable land
- Energy use
- Risk for transmission of disease
- Economy
- Robustness

The six first aspects were evaluated with the systems analysis tool ORWARE (ORganic WAste REsearch model: Dalemo 1999; Kärrman 2000; Eriksson *et al.* 2002). Data compiled within a Swedish review (Palm *et al.*, 2002) were used for updating and completion of the ORWARE data base. The same review was also used for qualitative evaluation of the three last aspects.

The content of phosphorus, nitrogen and cadmium in different fractions of untreated wastewater were assigned values according to Table 1.

Substance / Fraction	Phosphorus g person^{-1} year^{-1}	Nitrogen g person^{-1} year^{-1}	Cadmium g person^{-1} year^{-1}
Urine	365	4015	0.4
Faeces	183	548	3.7
Greywater	182	234	18.0
Total	730	4797	22.1

Table 1: Content of some different substances in wastewater fractions (Balmér *et al.*, 2002).

ORWARE is a computer model that calculates flows of energy and substances, e.g., nutrients and heavy metals. The flows of substances are quantitatively described from collection, via transports, to treatment facilities and further on to arable land, landfill or discharge to water or air. The discharges may be weighted into different environmental impact categories according to the methodology used in life cycle assessment (LCA). In the present study this was done to estimate contributions to eutrophication.

In order to facilitate an overview of the results from systems analysis of the six aspects handled with ORWARE, the different solutions were given marks for each aspect according to the marking scale in Table 2.

Mark / Aspect	- -	-	0	+	+ +
Eutrophication (*kg O_2-equivalents person^{-1} year^{-1}*)	161-200*	121-160	81-120	41-80	0-40
Cadmium to water (*% of wastewater content*)	81-100*	61-80	41-60	21-40	0-20
Phosphorus to arable land (*% of wastewater content*)	0-20	21-40	41-60	61-80	81-100*
Nitrogen to arable land (*% of waste-water content*)	0-20	21-40	41-60	61-80	81-100*
Cadmium to arable land (*mg Cd (kg P)$^{-1}$*)	81-100*	61-80	41-60	21-40	0-20
Energy use (*kWh person^{-1} year^{-1}*)	641-800*	481-640	321-480	161-320	0-160

* Definition of max-values:
Eutrophication: The worst solution (no. 1)
Cadmium to water and nitrogen and phosphorus to arable land: The total content of these substances in untreated wastewater correspond to 100 % (see Table 1).
Cadmium to arable land: The Swedish limit-value for cadmium in commercial fertilizer (100 mg Cd (kg P)$^{-1}$)
Energy use: The worst solution (no. 3 for a transport distance of 50 km).

Table 2: Marking scales for different aspects.

Production and consumption of different energy carriers (electricity, fuel and heat) is calculated separately for each carrier in ORWARE. For simplicity we have summed them up in the aspect 'energy use' (net consumption of energy carriers). However, in the 'Discussion' below we are explicit about which carriers that make a difference between different solutions.

The five studied solutions involved collection and transport of different waste products. Collection of septic tank sludge was part of all five solutions. In solution no. 3 also blackwater was collected, and in solutions no. 4 and 5 urine was collected. It was assumed that the distance between households, on one hand, and a wastewater treatment plant (septic tank sludge), a wet composting plant (blackwater) or storage at a farm (urine), on the other hand, was either 10 or 50 km. Furthermore it was assumed that trucks went empty to and full from households (collection at several households). Other potential transports were seen as either part of those mentioned or very short. It was, for instance, assumed that composting of feces and use of the compost (in no. 5) was done on-site.

Results

The results are summarized in Table 3 and Table 4.

Aspect Small-scale sanitation solution	Eutrophication	Cadmium to water	Phosphorus to arable land	Nitrogen to arable land	Cadmium to arable land *	Energy use
Mixed wastewater (black- and greywater) treated in septic tank	– –	–	– –	– –	(+ +)	+ +
Mixed wastewater (black- and greywater) treated in septic tank and sand filter bed	–	0	– –	– –	(+ +)	+ +
Blackwater treated by wet composting and applied on arable land; greywater treated in septic tank and sand filter bed	+ +	+	+	+ +	+ +	– – – **
Urine diverted, stored and applied on arable land; mixed wastewater treated in septic tank and sand filter bed	+	0	–	+	+ +	+ +
Urine diverted, stored and applied on arable land; feces collected 'dry', treated by composting and applied on arable land; greywater treated in septic tank and sand filter bed	+ +	+	+	+ +	+ +	+ +

* The mark (++) for 'Cadmium to arable land' indicates that no recycling was assumed. The sludge from septic tanks was transported to a wastewater treatment plant, and the sludge resulting from treatment went to a landfill.

** This mark refers to a transport distance of 50 km (instead of 10 km). For the other solutions, increasing the transport distance did not change the mark.

Table 3: Comparison of small-scale sanitation solutions in terms of different environmental aspects (+ + = very good, + = good, 0 = neither good or bad, - = bad, - - = very bad) according to Table 2.

Aspect Small-scale sanitation solution	Transmission of disease	Economy	Robustness
1. Mixed wastewater (black- and greywater) treated in septic tank	Considerable risk with water discharge	Very low costs for investment and operation	Risk for odor with water discharge, otherwise robust
2. Mixed wastewater (black- and greywater) treated in septic tank and sand filter bed	Low risk with proper design and loading, otherwise considerable risk	Lower costs than connection to municipal piping and treatment	Robust, but limited lifetime demands reconstruction
3. Blackwater treated by wet composting and applied on arable land; greywater treated in septic tank and sand filter bed	Low risk	Lower or same costs as connection to municipal piping and treatment	Lack of wide experience concerning both very low-flushing WCs and the wet composting process
4. Urine diverted, stored and applied on arable land; mixed wastewater treated in septic tank and sand filter bed	Low risk with proper storage of urine and proper design and loading of sand filter bed, otherwise considerable risk	Lower or same costs as connection to municipal piping and treatment	Lack of long-term experience. Ambitious short-term evaluations exist as a basis for improvements
5. Urine diverted, stored and applied on arable land; feces collected 'dry', treated by composting and applied on arable land; greywater treated in septic tank and sand filter bed	Low risk with proper storage of urine and proper composting, otherwise considerable risk	Lower or same costs as connection to municipal piping and treatment	Urine: see No. 4 Feces: Risk for odor. Demands knowledge and continuos maintenance

Table 4: Assessment of small-scale sanitation solutions in terms of transmission of disease, economy and robustness.

Discussion

Differences between the solutions in terms of eutrophication (Table 3) primarily reflect how well phosphorus discharge was prevented. For two of the solutions (no. 3 and 5), all phosphorus in urine and feces was recycled to arable land, whereas only the urine fraction was recycled in no. 4. The solution where mixed wastewater was treated in a sand filter bed (no. 2), came close to receiving the mark 0. This means that all the solutions no. 2-4 were considerably better than the septic tank only solution (no. 1) in terms of eutrophication.

The sludge from septic tanks was transported to a wastewater treatment plant, and the sludge resulting from treatment went to a landfill. Leaching from the landfill was not included in the calculations, but if it is assumed that leaching is proportional to the load on the septic tank, leaching would decrease in the order: no. 1 and 2 > no. 4 > no. 3 and 5. However, due to the approaching ban on biodegradable waste going to landfills, and the efforts being made to extract phosphorus from sludge, solutions should probably not be judged on this criterion.

With the four solutions no. 2-5 less than 50 % of the cadmium content in the untreated fractions was discharged to receiving waters. This similarity is due to that a major part originated from the greywater, which was treated in the same way (septic tank + sand filter bed) in all these cases with a septic tank only (no. 1), approximately 75 % of the cadmium was discharged to the recipient.

Recycling of phosphorus and nitrogen was a direct reflection of the diversion efforts, and hence the largest fractions were recycled where both urine and feces were treated for recycling (no. 3 and 5). In no. 4 only urine was recycled. Recycling efficiency was higher for nitrogen than phosphorus for all solutions no. 3-5, due to that urine and feces fractions contain a larger part of the total nitrogen content than of the total phosphorus content (Table 1).

In no. 1 and 2 no recycling took place. It would of course be possible to recycle the treated sludge, but since the acceptance for such recycling is low in Sweden it was not considered an option. A further recycling possibility (primarily for phosphorus) is to design sand filter beds so that the filter material can be exchanged and applied on arable land.

All products intended for recycling to arable land (in no. 3-5) had very low cadmium-to-phosphorus-ratios. Concerning this aspect they were equal to or better than manure and commercial fertilizer used in Sweden, which both have approximately 15 mg Cd (kg P)$^{-1}$. Urine, with only 1 mg Cd (kg P)$^{-1}$, even had a lower cadmium content than commercial fertilizer with 'low Cd-guarantee' (2-5 mg Cd (kg P)$^{-1}$).

Energy use at short transport distances (10 km) was very low for all solutions except no. 3, where the electricity needed for heating and stirring of the wet composting reactor made a big difference. Increasing the transport distance from 10 to 50 km also had a considerable effect (on fuel use) only for no. 3, where much larger volumes were transported than in the other four solutions - despite low-flush vacuum WCs with 0.8 l flush^{-1}.

Energy use can be seen in no. 3 as the cost for achieving a low risk for transmission of disease. For the other systems (except no. 1) the risk is not necessarily higher, but more dependent on operation and maintenance by the users of the small-scale sanitation facility.

Estimates done in Sweden indicate that the solutions with recycling (no. 3-5) are likely to be competitive in economic terms when compared to connection to municipal piping and treatment (Table 4). On the other hand, they are more expensive than presently dominating solutions (no. 1 and 2). A general economic comparison of solutions is, however, difficult to do since local conditions influence costs to a large degree. Costs for connection to the municipal system vary a lot in Sweden, between € 4 500 and 11 000, and the costs for installation of, e.g., urine diversion depends on whether it is done separately or as part of remodeling or a new development.

Session D

Robustness is mainly related to operation and maintenance requirements. The solution with separate handling of both urine and feces (no. 5) clearly demands a knowledgeable and interested user to function properly, particularly since it involves composting. Urine diversion (no. 4 and 5) can not yet be considered a robust system. But it may be reasonable to assume that the experience being gathered will lead to a mature system that is as robust as conventional systems (no. 1 and 2), i.e., that maintenance is required at points in time rather than continuously.

Conclusions

The analysis showed that the different small-scale sanitation solutions differed regarding several of the aspect for which they were compared. The 'new' solutions, with separate handling of blackwater (no. 3), urine sorting (no. 4) or both urine and feces sorting (no. 5), were better in terms of discharge to the environment and recycling of plant nutrients. From an economic perspective, these solutions are probably equal to connection to municipal sewers, but more expensive than presently dominating solutions (no. 1 and 2). The 'new' solutions are also either less energy efficient (no. 3) or less robust (no. 4 and 5), but this is partly due to that they are not yet mature.

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Faecal contamination of greywater - assessing the treatment required for hygienically safe reuse or discharge *

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Keywords

Greywater, microbial risk assessment, pathogens, reuse, treatment

Abstract

The aim of this study was to investigate and evaluate health risks from infectious diseases related to the reuse of source-separated greywater. Prevalence of pathogens in the population and the faecal load based on coprostanol concentrations were used to form the basis of a screening-level quantitative microbial risk assessment (QMRA) that was undertaken for rotavirus, *Salmonella*, *Campylobacter*, *Giardia* and *Cryptosporidium*, looking at the treatment required to be below an acceptable level of risk (10^{-3}) for reuse or discharge of the greywater. The different exposure scenarios simulated – groundwater recharge, direct contact, irrigation and recreational water – showed that a mean reduction of 0.7 – 3.7 log was needed for rotavirus, with the measured level of faecal load in Vibyåsen (Sweden). The other pathogen of concern was *Campylobacter*, where a mean 2.2 log reduction was needed for groundwater recharge. The infectious dose of *Salmonella* is high and the excretion numbers of *Giardia* cysts and *Cryptosporidium* ocysts low, resulting in low or no treatment requirements for these organisms for the investigated exposure scenarios. The use of QMRA can serve as a basis for integration of hygiene issues with other parameters as economy and environment.

Introduction

Greywater constitute the major part of household wastewater. The interest of separation and reuse of greywater, e.g. wastewater from bath/shower, the kitchen and laundry but without input from toilets, has increased due to economical, structural and ecological considerations (Asano & Levine, 1996; Gunther, 2000). Based on repeatedly high counts of faecal indicator bacteria, regulatory agencies prior were enforcing combined treatment, or strict separate treatment of the greywater. The risk of introducing pathogens into greywater are mainly from faecal contaminated laundry, diapers, childcare and showering and will most often be much lower than the indicator bacterial counts signal. The faecal input in greywater measured by the chemical biomarker coprostanol was only 0.04 g person^{-1} day^{-1} in a community north of Stockholm, Sweden (Ottosson & Stenström, 2002). To measure the impact on public health quantitative microbial risk assessment, QMRA, was used. Traditionally in QMRAs the probability of infection is calculated. However, the poor data on greywater treatment efficiency, especially virus reduction, has prompted us to simulate the treatment required to be inside the 10^{-3} risk addressed by (Haas, 1996). This has been done for different exposure scenarios (groundwater recharge, accidental ingestion, irrigation of sports fields and gardens) to reused or discharged greywater for rotavirus, *Campylobacter*, *Salmonella, Giardia* and *Cryptosporidium* under Swedish conditions.

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Methods

Microbial risk assessment

Risk assessment is a tool that has been used to assess chemical risks for some time and it is now becoming more frequent as a tool for measuring microbial health effects on a population. MRAs were first developed for drinking water (Regli et al., 1991) but have lately been applied to other practices such as reuse of human urine (Höglund et al., 2002) and discharge to recreational waters (Ashbolt et al., 1997). At a screening level, MRA is a valuable tool to initially estimate risks even when the set of data is poor, giving the potential to make rational decisions at far less cost than epidemiological studies (Ashbolt, 1999). Whether the risk assessment is of a chemical or microbiological nature, the procedure contains four primary elements: 1) Hazard identification, 2) Exposure assessment, 3) Dose-response assessment and 4) Risk characterisation.

Hazard identification

In the hazard identification step, background information on the pathogens in a specific system is described. It also includes the spectra of human illness and disease associated with the identified microorganisms (Haas et al., 1999). For the greywater system, the hazard emanates from faecal cross-contamination, for example from contaminated laundry and other sources. Opportunistic bacteria known to grow in hot water systems, e.g. *Aeromonas*, *Pseudomonas*, Mycobacteria or *Legionella*, could pose a threat depending on reuse options and technical solutions. There is also a risk of introducing pathogenic bacteria from contaminated food via the kitchen sink. However, this study has focused on the faecal contamination, using epidemiological data to estimate the pathogen load in the greywater (Table 1).

	Rotavirus	*Campylobacter jejuni*	*Salmonella*	*Cryptosporidium parvum*	*Giardia intestinalis*
Incidence of infection [%]	0.95	15.6	9.00	0.31	0.84
Excretion time [days]	(1.0, 0.30)	(1.18, 0.325)		(1.48, 0.173)	
Excretion density [no g^{-1} faeces]	(10,1)	(8, 1)	(8, 1)	(7,1)	(7,1)

Table 1: Data used to calculate pathogen density in greywater. The $\log_{10}$ normal distribution has been applied for the excretion time and excretion density, mean and standard deviation given (Ottosson & Stenström, 2003)

The pathogen density in the untreated greywater was thus:

$$\frac{\text{faecal load [g p}^{-1}\text{d}^{-1}\text{] * excretion density [numbers g faeces}^{-1}\text{] *excretion time [d] *yearly incidence}}{\text{flow [L p}^{-1}\text{ d}^{-1}\text{] * 365 [d]}}$$

with the faecal load, excretion density and excretion time expressed as distributions. The faecal load was 0.04 ± 0.02 g p^{-1} d^{-1} and the flow 64.9 L p^{-1} d^{-1} measured in Vibyåsen, Sollentuna, north of Stockholm (Ottosson & Stenström, 2003).

Exposure assessment

In the exposure assessment step, the size and nature of the population exposed and the routes, concentrations and distribution of the microorganisms are determined. The dose of a pathogen is calculated from the density of the organism in the water times the volume ingested. Densities are preferably based on occurrence data from direct measurements, but most often on index organisms or via indirect estimation (density in untreated greywater – expected reduction). However, the reduction in the treatment is what will be simulated in this study looking at the required treatment to be below an infection level of 10^{-3} for the different exposure scenarios listed in table 2.

Exposure	Environmental barriers	Volume ingested	References
1) Drinking superficial groundwater made from recharged greywater (yearly risk from 365 exposures).	Dilution[a], unsaturated zone[a] and saturated zone[c, d, e]	$e^{(6.87 \pm 0.53)}$ mL day^{-1} [b]	[a](Asano et al., 1992), [b](Roseberry & Burmaster, 1992), [c] (Yates et al., 1985), [d] (Thomas et al., 1999), [e] (Medema et al., 1997)
2) Accidental ingestion to treated greywater (one time exposure)		1 mL exposure^{-1}	
3) Ingestion from a field irrigated with treated greywater (yearly risk from 26 exposures)	Survival on grass[f]	1 mL exposure^{-1}	[f] (Badawy et al., 1990)
4) Ingestion/inhalation of aerosols	Tank[c, d, e]	$e^{(-4.2 \pm 2.2)}$ mL [g, h]	[g] (Dowd et al., 2000), [h] (Kincaid et al., 1996)
5) Swimming in recreational water receiving treated greywater.	Dilution	$e^{(3.9 \pm 0.3)}$ mL	

Table 2: Transmission pathways for exposures to reused or discharged greywater and environmental barriers involved.

For exposure to groundwater (Exposure 1), the height of the unsaturated zone was assumed to be three metres and the retention time in the saturated zone two months, based on the recommendation in the report “Wastewater Infiltration: Conditions, Function, Environmental Consequences” (Naturvårdsverket, 1985). The dilution factor was defined as a triangular distribution with min 1 (no dilution), max 30 and most probable 2 (Asano et al., 1992), i.e. most often half of the water from the tap will be reclaimed greywater. The case is thus for reuse of greywater as superficial groundwater. The water intake was log normally distributed with a medium daily intake of 963 mL p^{-1} d^{-1} (Roseberry & Burmaster, 1992).

If the treated greywater is used for an aesthetic landscaping approach (Exposure 2), there is a risk for accidental contact with the water and the assumed water intake is a conservative 1 mL event^{-1} (Ashbolt, 1999). No dilution of the treated greywater was considered.

Treated greywater can be collected in a tank to be used for irrigation. If the water was used for irrigation of a public sports field (Exposure 3), the irrigation was assumed to take place the day before access and with a negligible holding time in the tank. The water intake was assumed to be a conservative 1 mL 26 times per year based on weekly activities during the summer season in Sweden.

For private use of greywater in the garden (Exposure 4), the greywater was assumed to be applied once a week, thus with an average holding time in the tank of 3.5 days. For this exposure scenario *Legionella* spp. were assessed due to their proven growth possibilities and due to aerosols being their mode of transmission. In a survey on the occurrence in Swedish water systems, *Legionella* was detected in all hot-water tanks without circulation and with a temperature of < 50° C and in 25% of all hot water samples tested in densities of $10^{3 \pm 0.6}$ cfu 100 mL^{-1} (Szewzyk & Stenström, 1993). These figures formed the basis for the background level of *Legionella*, estimating half of the water entering the greywater system to be hot water from showers. The water intake from inhalation of aerosols is time dependent based on average aerosol ingestion (Dowd et al., 2000) and droplet size distribution (Kincaid et al., 1996), giving a log normal distribution (Table 2), furthermore assuming 70% of the inhaled volume to be ingested. Exposure 4 can, with some modifications, be applied to toilet flushing. However, the water intake is smaller since the time a person is exposed to aerosols is shorter when flushing the toilet than when irrigating.

Usually the common practice for exposure to recreational water (exposure 5) is a conservative 100 mL water intake based on 50 mL intake h^{-1}, mean bathing time 2 h d^{-1} (Ashbolt et al., 1997).

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This ingested volume was changed for the present simulation to a time dependent distribution with the mean time of bathing being 1 h (Table 2). The dilution in the receiving water was assumed to be 1,000 times.

Dose – response relation

To establish a relationship between the dose of a microbial agent and the rate of infection in a population, human volunteer studies have been performed. The resulting infected and unaffected individuals were used to create a mathematical relationship between the dose administered and the probability of infection in the exposed population. The current baseline information from such studies has been compiled by (Haas et al., 1999; Teunis et al., 1996). Two main equations have been used to describe the relationship; exponential (1) and Beta-Poisson (2):

When organisms are distributed randomly (Poisson) and the probability of infection for any organism equals r, then:

$$P_{inf} = 1 - e^{-rDose} \qquad (1)$$

When the probability r is not constant, but has a probability distribution in itself (ß-distribution) due to either the nature of the organism or the exposed population, two parameters, a and ß, describe the relation as:

$$P_{inf} \sim 1 - (1 + Dose/\beta)^{-a} \qquad (2)$$

Drinking water is something people do every day. To assess repeated exposures, equation (3) is used so that the risk can be measured on a yearly basis (n = 365).

$$P_{n(inf)} = 1 - (1 - P_{inf})^{n} \qquad (3)$$

The Beta-Poisson model (eq. 2) was used for rotavirus, *Campylobacter* and *Salmonella*. For the other organisms for which QMRAs were performed, the exponential model (eq. 1) was used (Table 3).

Organism	**Model**	**Constants**	**Reference**
Rotavirus	Beta-Poisson	a = 0.253; ß = 0.422	(Teunis et al., 1996)
***Salmonella* (multiple strains, non-typhoid)**	Beta-Poisson	a = 0.3126; ß = 2884	(Haas et al., 1999)
Campylobacter jejuni	Beta-Poisson	a = 0.145; ß = 7.589	(Teunis et al., 1996)
Giardia intestinalis	Exponential	r = 0.0199	(Teunis et al., 1996)
Cryptosporidium parvum	Exponential	r = 0.00405	(Teunis et al., 1996)
***Legionella* spp.**	Exponential	r = 1	(Teunis & Havelaar, 2000)

Table 3: Dose-response models and constants used in the risk calculations

Results and discussion

Risk characterisation

The information from the hazard identification, exposure assessment and dose-response relationship steps is integrated in the risk characterisation in order to estimate the magnitude of the public health problem or in this case the greywater treatment required. Since the information was incomplete and since the densities of pathogens fluctuated, distributions were used instead of point estimates or constant values. The distributions were then sampled in a Monte-Carlo simulation to give the results presented below.

The largest risk emanated from rotavirus in all exposure scenarios simulated (Table 4, figure 1 a-e). All the selected pathogens are common in the population. However, the treatment required for rotavirus was higher, since rotavirus is excreted in high numbers compared to the other pathogens (Table 1). The other pathogen of main concern was *Campylobacter*. *Salmonella* has a high infectious dose (ID_{50} = 23,600 (Haas et al. 1996)). That is why it is a less important organism to these exposures. *Giardia* cysts and *Cryptosporidium* oocysts have low infectious doses but they are not excreted in sufficient amounts to constitute health problems of concern with the low faecal load registered in Vibyåsen (Ottoson & Stenström 2003). The average number of (oo)cysts in untreated greywater was simulated to approximately 0.002 (oo)cysts mL^{-1} compared to 1.7 rotavirus particles mL^{-1} (Table 4). The high infectious dose for *Salmonella* and low excretion numbers of parasitic protozoa are the main reasons for the negative values in Table 4. However, treatment of the greywater is needed to be within the acceptable risk with a 95 % confidence interval for exposure to groundwater for these organisms. The simulated standard deviations (StDs) originate from the distributions used in the Monte Carlo simulation. The StD is higher for exposure to groundwater than the other scenarios, since more environmental barriers are included in that transmission route, giving additional uncertainties to the assessment compared to other exposures. The relatively higher StD compared to the mean from exposure to aerosol is due to the higher uncertainty in the water intake

Pathogen	**Median density in greywater [100 mL^{-1}]**	**Exposures and treatment required [log reduction, mean and StD]**				
		Groundwater[a]	**Accidental ingestion**	**Sports field[b]**	**Aerosol**	**Recreational water**
Rotavirus	180	3.7 ± 2.1	3.0 ± 1.1	3.0 ± 1.1	0.7 ± 1.4	1.7 ± 1.1
Campylobacter	44	2.2 ± 1.7	0.9 ± 1.0	0.9 ± 1.1	- 1.3 ± 1.4	- 0.4 ± 1.1
Salmonella	26	- 0.3 ± 1.7	- 1.6 ± 1.1	- 1.6 ± 1.1	- 3.8 ± 1.4	- 2.9 ± 1.1
Giardia	0.24	- 1.4 ± 2.0	- 1.4 ± 1.1	- 1.4 ± 1.1	- 3.7 ± 1.5	- 2.7 ± 1.1
Cryptosporidium	0.17	- 0.4 ± 2.5	- 2.2 ± 1.0	- 2.2 ± 1.0	- 4.4 ± 1.4	- 3.5 ± 1.1
Legionella	0.31				-1.2 ± 1.8	

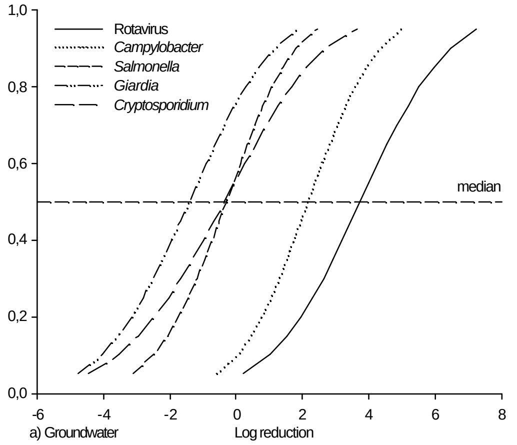
[a] Yearly risk from 365 exposures, [b] Yearly risk from 26 exposures

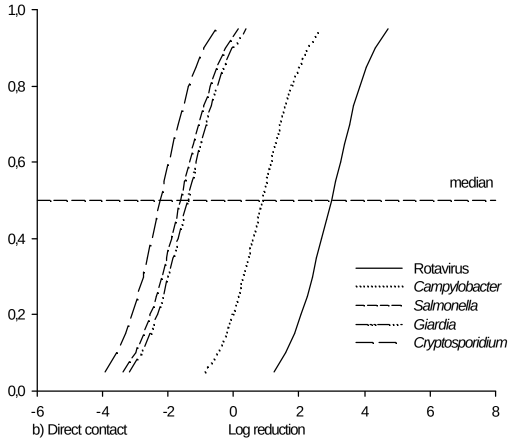
Table 4: Estimated pathogen density and treatment required [log reduction] being below an infection risk of 10^{-3} for different exposure scenarios.

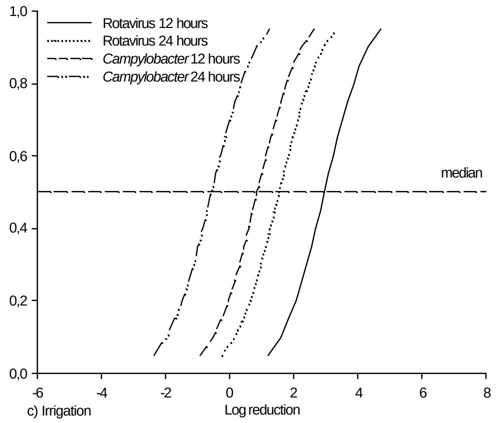
The largest risk for exposure 1, groundwater, emanated from rotavirus and a mean 3.7 log reduction was needed according to the simulation. Rotavirus was used as an index for viruses as a group. The treatment requirement would be about the same for adenovirus and calicivirus, which are also common in the population, excreted in high numbers and have low infectious doses. Slightly less treatment is required for enteroviruses based on excretion numbers (AWWA, 1999). The other pathogen of main concern in this study was *Campylobacter*, for which a 2.2 log reduction was required (Table 4). However, this study simulates a superficial groundwater while the treated greywater at most places is more diluted in an aquifer than was assumed here. However, to be able to release the water untreated into the ground, a 60,000-fold dilution or an extension of the retention time to 190 days is needed to be within the 0.001 risk for rotavirus. The corresponding figures for *Campylobacter* are 1,700 dilution and 170 days retention.

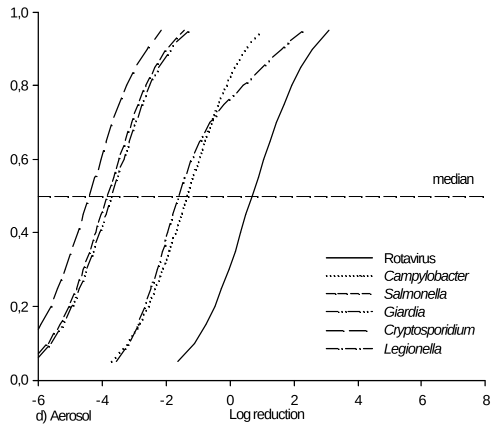
If the treated water is released locally into a pond a mean 3 log reduction is desired for rotavirus and 0.9 for *Campylobacter* (Table 4) to be below a 0.001 risk of infection to a single exposure of 1 mL of treated greywater. A way to minimise risks for direct contact with the treated greywater would be to fence the pond, making it a part of the treatment system. For the other pathogens investigated, the concentration before treatment was low enough not to imply risks over the accepted level.

Irrigation is suggested as a means of reusing greywater (Christova-Boal et al., 1996). This can lead to health risks with contact with the irrigated area or ingestion of irrigated crops, as well as ingestion/inhalation of aerosols during irrigation. To be within a 0.001 yearly risk from 26 repeated exposures to a sports field, a 3 log reduction is desired (Table 4). Drying, UV-light and temperature-mediated inactivation reduced the treatment requirements partly (Badawy et al. 1990). Figure 1c shows the difference in treatment needed for rotavirus and *Campylobacter* with a prolonged retention time between irrigation and access to the field. After a retention time of 37 hours, no reduction of rotavirus was needed according to the simulation, which was based on an assumed decay of 0.11 log h^{-1} (Badawy et al. 1990).









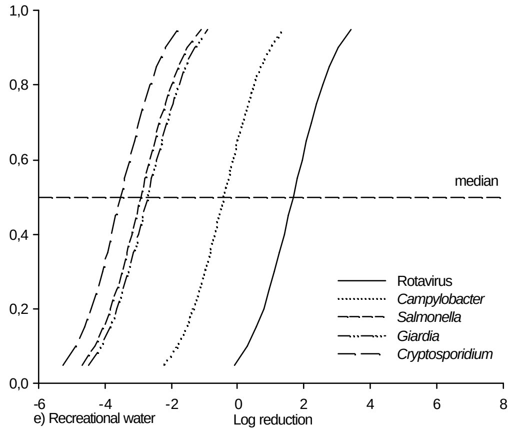


Figure 1 a-e: Greywater treatment needed (5 – 95%) to be within the acceptable risk level for exposure to (a) superficial groundwater, (b) direct contact, (c) sports field (different retention times between irrigation and access), (d) aerosols and (e) recreational water

For exposure to aerosols during irrigation, the treatment requirements for different organisms are presented in Figure 1d. The risk of infection from this exposure is lower due to the lower volume ingested and a mean of 0.7 log reduction of rotavirus is suggested. Besides, the infection status may be known on a household level. For this exposure scenario, *Legionella* spp. were assessed due to their proven growth possibilities and due to aerosols being their mode of transmission. However, the treatment need was lower than for rotavirus, - 1.2 log compared to 0.7 log (Table 4). Depending on the temperature, the presence of other microorganisms, available carbon sources and other factors (Muraca et al., 1988) *Legionella* may grow in the tank, increasing the risk of infection. However, the simulation indicated a low risk and it is probably more likely that an infection would be caught in the shower or from other sources of exposure. Greywater may also be used in combination with rainwater (Albrechtsen, 2001; Dixon et al., 1999). This would dilute the greywater with roof-collected rainwater, which however may be contaminated with pathogens from birds or other animals.The mean treatment required for rotavirus was 1.7 log to be within the risk level of 0.001 with a 1,000-fold dilution in the receiving water of the treated greywater. However, this was based on an acceptable risk of infection of 0.1%. The guidelines for the proposed EU bathing water directive are based on a mean acceptable excess risk of illness due to bathing of 1% (EU, 2002), which is fulfilled with just a 0.6 log reduction of rotavirus. No other agent than viruses would pose any larger threat to public health according to the simulation based on the average values (Table 4). To be inside the acceptable level (95% CI), some treatment of *Campylobacter* is required (Figure 1e). As for direct contact and irrigation, no treatment is required for *Salmonella*, *Giardia* and *Cryptosporidium*.

Conclusions

For the different exposure scenarios simulated, the treatment need for rotavirus was more than 3 log in many cases (Table 4). Kayaalp, (1996) stressed the need for site-specific considerations when planning for infiltration units, which is the traditional method of greywater treatment in Sweden, after pre-treatment in a settling tank. Of great importance is the height of the watertable. The longer the distance organisms have to travel through the unsaturated zone, the better the reduction effect. In “Wastewater Infiltration: Conditions, Function, Environmental Consequences” (Naturvårdsverket, 1985), there are recommendations for the planning of wastewater infiltration units depending on site-specific conditions such as topography, type of soil and height of the watertable. The suggestion is to follow these even though they have been prepared for wastewater, not greywater, infiltration based on the treatment requirements simulated in this study. The simulation also shows that treatment of greywater should be directed primarily at virus reduction.

QMRA as presented here can be used for decisions on treatment as in the example above or to serve as a basis for integration of hygiene issues on a municipal level taking into account other parameters as economy and environment. However, it is important to look at the local conditions and base the QMRA at relevant assumptions and data.

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Problems and potentials for urine separation in a small village with a wastewater treatment plant operated with extended nutrient removal*

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Keywords

Urine separation, pharmaceuticals, extended nutrient removal, modelling

Abstract

Svanholm Community is an ecological village with own wastewater treatment. The residents are working for sustainable production and daily living and are looking for new areas to improve sustainable living. Urine separation has been worked with for fertilisation and for reduced wastewater treatment. Two urine sorting toilets were established in connection with the common dining hall of the community and the urine was used for examination of fertilisation and for examination of potential harmful substances in urine. The urine was a good fertiliser and the content of heavy metals and hazardous organic substances regulated for in Denmark were low. However female hormones and analgesics were found in the urine, whereas none of 16 pharmaceuticals used by the residents could be detected.

A plan for urine separation at all 32 toilets of the community was established and a cost estimate was made. Computer simulation of the wastewater treatment plant with nutrient removal was used to evaluate the impact of urine separation and for estimation of the possible savings in wastewater treatment with urine separation.

The potential savings in operation of the wastewater treatment plant are small and will by far cover the cost for installation of the system. Financial potentials will be substantially higher in new building, where costs of a urine separation system will be lower, and where the significant reduction of contents of nitrogen and phosphorous in sewage enable simpler and cheaper treatment plants.

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Svanholm community

The Svanholm community was established in 1978 and owns an estate that together with a number of neighbouring houses are used for living and production for about 100 residents. The community is one of the greatest producers of ecological vegetables in Denmark and ecological milk is produced from about 100 cows. The community owns a big packing department for ecological fruit and vegetables and a factory for wood boxes focussing on special designed wood containers. Furthermore an ecological catering company and a shop based on ecological products are operated in the community.

The inhabitants have looked for solutions to improve sustainability in production as well as in the daily life since the very beginning. As they share economy as well as daily practise is has been possible to find new solutions towards sustainable livings in several cases.

*This paper has been peer reviewed by the symposium scientific committee

The wastewater treatment system at Svanholm

The community make up a small catchment area with a sewer system based on separate sewers. Storm water is soil infiltrated or diverted into nearby small streams. The treatment plant is a traditional recirculation plant for nitrogen removal with simultaneous precipitation of phosphorous. It was built in 1993 by the residents and it is designed for 110 PE. Effluent requirements correspond to the national Danish standards (for bigger plants) that are Total-N 8 mg/l, Total-P 1.5 mg/l and BOD 15 mg/l. Further the standard for ammonium is 2 mg N/l.

Urine separation at Svanholm

Urine separation has been worked with for several years in order to evaluate fertiliser potentials and risks associated to pharmaceuticals in the urine and to evaluate the potentials of urine separation for improvement of wastewater treatment.

Two different types of urine separating toilets have been established in connection with the common dining hall of the community (see figure 1) where they are used by almost all residents.

Figure 1: Two different urine-separating toilets evaluated at Svanholm Estate

They represent the systems that are available on the market in Denmark at present. The residents of the estate have evaluated the systems and concluded that both types are usable; however improvements are called for, if they are to work optimally. Especially the water consumption seems to be a problem in the system to the left.

Examination of urine

The urine was examined as a fertiliser in a fertiliser experiment with growth of barley and the compliance with the Danish requirements for agricultural use was examined. Further the urine was examined for content of pharmaceuticals, hormones etc. The examinations and results can be found in (Koldby and Jansen, 2001).

Urine was collected in the storage tank connected to two separation toilets. During collection pH and content of nitrogen and phosphorus was followed. After 12 weeks of collection samples for characterisation of the urine as fertiliser and for environmental evaluation and examination of pharmaceuticals etc. were taken. After sampling the urine was used for the fertiliser experiment with growth of barley in parallel with manure.

Urine as a fertiliser

The chemical characterisation of urine is shown in table 1 and the composition is typical for such systems. It is diluted about 10 times compared to pure urine. Several attempts were made to reduce the amount of flush water but especially in the system to the left in figure 1 it was difficult to reduce the water consumption without deteriorate the normal function of the toilet.

Component	Unit	Content
Total-nitrogen	mg/l	2500
Ammonium-N	mg/l	2200
Total-phosphorus	mg/l	170
Potassium	mg/l	1200
Sulphur	mg/l	130
Copper	mg/l	0,30
Manganese	mg/l	0,0052
Magnesium	mg/l	0,82

Table 1: Characterisation of fertilisation components in urine at Svanholm Gods. The growth experiment showed that the urine had the expected fertiliser value.

Content of heavy metals, organic substances and pathogens in urine

The content of heavy metals, organic substances and pathogens included in the Danish regulation for agricultural use of waste such as wastewater sludge and urine is shown in table 2 together with the standard for the individual substance given as content compared to dry matter content and P content (compliance with only one of the limits is needed). The detailed regulation can be found in (Miljøstyrelsen, 2000).

Substance	Content µg/l	Content mg/kg dry matter	Content mg/kg P	Danish Standard mg/kg dry matter	Danish Standard mg/kg/P
Heavy metals					
Cadmium	6.2	1.2	36	0.8	100
Mercury	<0.2	0.04	1	0.8	200
Lead	4	0.8	24	120	10000
Nickel	10	2	59	30	2500
Chromium	1	0.2	6	100	
Zinc	2400	480	14000	4000	
Copper	300	60	1800	1000	
Organics					
LAS	<30	<6		1300	
S PAH	<10	<2		3	
NPE	<15	<3		10	
DEHP	29	5.8		50	
Pathogens					
Salmonella pr 100 ml		n.d.		n. d.	
Faecal Streptococci pr g		<100		<100	

Table 2: Heavy metals, organic substances and pathogens in urine from Svanholm Gods

The urine complies to all requirements with a good margin. Pharmaceuticals and hormones in urine

The examination of pharmaceuticals, hormones etc. in urine was performed based on a detailed

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questionnaire to all residents about their consumption of pharmaceuticals, artificial female hormones, analgesic, vitamins etc. Almost all residents filled out the questionnaire. As the residents share economy all expenses for medicals etc. are paid in common, control of the consumption could be made. The inhabitants used 16 different pharmaceuticals at the time for sampling, further two different analgesics were used and female hormones was expected to be present both as natural hormones and from contraceptive pills. The full list of pharmaceuticals, etc together with the monthly doses are given in table 3.

Pharmaceuticals	**Intake pr month**
Antabuse 400 mg	14 tablets
Bricanyl inhaler	9 doses
Centyl with potassium chlorate	60 tablets
Fevarin	15 tablets
Flixonase spray	60-1500 microgram
Fluanxol	30 tablets.
Insulin - Actrapid	4680 units
Insulin - Insulatard	1860 units
Isoptin 80 mg	30 tablets
Levonorgestrol	1,9 microgram
Rhinocort 100 microgram	45 doses
Spirocort 200 microgram	Inhaled when needed
Teldanex	4 tablets
Tenormin 25 mg	30 tablets
Terbosin inhaler	2 doses
Ventoline spray	0,2 mg
Artificial female hormones	
Ethinylestradiol	1.425 microgram
Analgesics	
Acetylsalicylic acid and Paracetamol	203 tablets

Table 3: Monthly consumption of pharmaceuticals, artificial female hormones and analgesics at Svanholm

Based on the mapping of pharmaceuticals in table 3 the general analytical program for pharmaceuticals was based on the following strategy:

1. The pharmaceutical should be used by at least one inhabitant
2. The pharmaceutical or characteristic residues shall be excreted with urine
3. An analytical procedure to be used in urine shall be found
4. The concentration of the pharmaceutical or a characteristic residue in the collected urine shall have an expected level above the detection limit for the analyses

The first examination looked for female hormones and analgesics since all the other pharmaceuticals could be excluded based on criteria 2-4.

The results are shown in table 4.

The samples were taken with about one month interval during filling of the storage tank. The rather constant content of U-Estronglucoronid suggests that no degradation of the hormones

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takes place in the tank.

	Sample 27/1 µg/l	Sample 22/2 µg/l	Sample 10/3 µg/l
Female hormones			
U-Estronglucoronid	3,6	4,6	4,5
Analgesics			
Paracetamol	Found	Found	Found
Acetylsalicylic acid	Not detected	Not detected	Not detected

Table 4: Results from the first examination of pharmaceuticals etc.

Since all toilet visits at the separating toilets were registered with a user specific number it was next possible to look for pharmaceuticals used by the most frequent toilet users. Based on that four products were pointed out for a more detailed evaluation.

Fluanxol Retard (Flupentixol) "sedative". An analysis was found at one of the hospitals in Greater Copenhagen but analysis in urine showed to be difficult and no results were obtained.

Antabuse: Metabolism is very strong and residues are not expected to be found in urine.

Insulin: Excretion of metabolites is minor, which means that nothing could be expected to be found in urine.

The examination had to conclude that hormones and analgesics can be found in source-separated urine but no other substance from the list could be detected.

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Project for urine separation at Svanholm

Based on the findings above a plan for urine separation in the whole community was established. The plan comprises detailed evaluation of the sewer system and a draft for the costs for the switch over. Further a project for evaluation of the impact on the wastewater treatment plant from storm water, households with and without urines separation and from the industrial production in the community was included. The full examination can be found in (Koldby and Jansen, 2003)

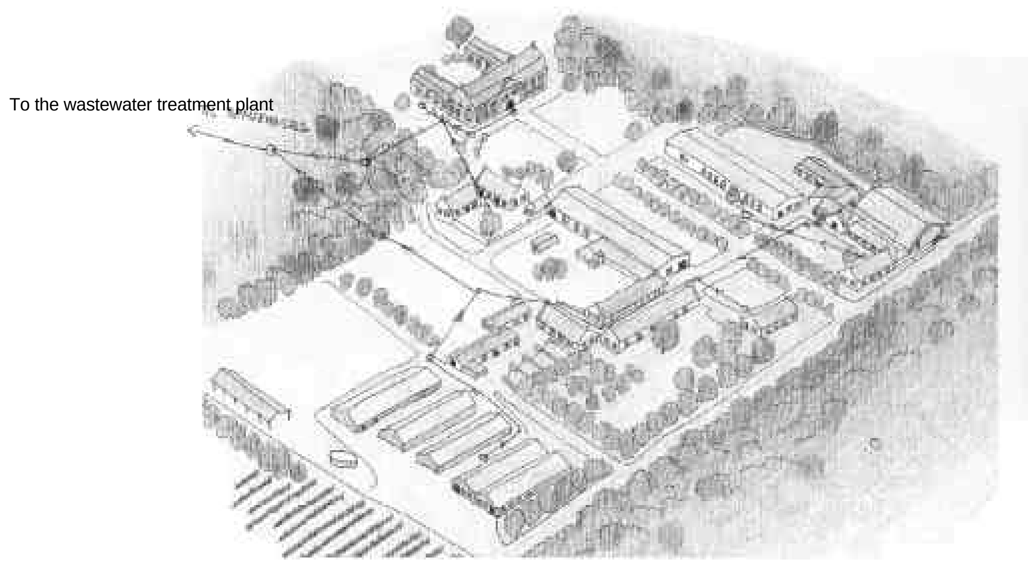

Figure 2: Svanholm Estate and the main sewer system

Change of sewerage system into urine separation

A detailed outline of sewers and toilets in the entire catchment area of the treatment plant has been drawn up. The mapping showed that 32 toilets are located in seven buildings/groups of buildings and that two toilets are located at some distance from the others. Figure 2 shows the community and the main sewer system. In connection with the mapping, continuous water flow measurement was established at the treatment plant. Water flow variations showed that the sewer system generally works as a separate sewer system, with only minor impact from storm water. The draft for complete urine separation in the catchment area shows that a suitable solution would be to divide toilets into four groups with each their collection and storage system based on vacuum toilets, and to establish separate treatment of the two remote toilets, disconnecting them from the sewage system.

Model simulation of impact on wastewater treatment from urine separation

Computer simulations were used to evaluate the impact on the existing wastewater treatment plant operated with extended nitrogen and phosphorus removal. Measurements of flow, load and sludge characteristics were used for calibration of the model and different future scenarios for urine separation were simulated.

An initial load survey of the treatment plant compared with historical load measurements shows that occasionally, the plant received sewage with very high organic matter content. A mapping of enterprises and institutions in the catchment area revealed that the reason might be spillage to the sewer system from the milking area. A minor change of the system ensured that this spillage has been stopped. A subsequent load measurement shows sewage concentrations corresponding to normal domestic wastewater.

Three scenarios have been drawn up for the future load on the plant after establishment of urine separation in the catchment area. The baseline scenario is the present situation without urine separation. Two scenarios describe the option of urine separation in the entire catchment area. If the system works at 100 % efficiency, the load of nitrogen is reduced by 80 % and that of phosphorous by 50 %.7 In a more realistic assessment of the potential for separate collection of urine, a two-thirds reduction of nitrogen and a 40 % reduction of phosphorous are achieved. Water and organic matter contents in urine are very low, and consequently the load of organic matter and the hydraulic load are not changed substantially from the baseline scenario.

Computer simulations of the three scenarios were carried out with the simulation programme EFOR (EFOR, 2001). After calibration of the model corresponding to the present load and present process conditions, the model was used to simulate the impact on the treatment plant from a reduction of the load corresponding to the above scenarios.

In addition to simulation of the immediate impact from the reduced load, the possible savings in electricity and chemicals from optimisation of plant operation under reduced load has been found. Furthermore, calculations have been made elucidating the possibility of achieving sufficient treatment for complying with current discharge requirements by major reductions in plant volumes, since in particular the lower nitrogen load reduces the need for volume for oxidation of nitrogen compounds.

The simulations show that with a 100 % efficient urine separation system the remaining nitrogen is insufficient for keeping the biological processes in the treatment plant. In reality it is not possible to ensure full separation, so problems would hardly arise in practice. However, the calculations show that a balance between nitrogen and organic matter, in wastewater after urine separation is needed.

In a realistic assessment corresponding to a separation of 80 % of the urine, the load on the treatment plant will be reduced substantially, and the treatment for both nitrogen and phosphorous will be improved significantly without alteration of plant operation. Thus, urine separation in the catchment area of a treatment plant, also to a minor extent, can be expected generally to lead to improved treatment.

Reduced ammonium load leads to immediate savings in electricity for oxygenation. The internal recirculation that is part of the denitrification process can be stopped, as only minor nitrate has to be denitrified. Sludge age in the plant can be reduced to a level where no nitrification takes place, further reducing the electricity consumption for oxidation of ammonium. If nitrification is stopped, discharges of Total-N will increase modestly, but larger discharges of ammonium will take place. Neither of the solutions will cause problems in complying with discharge requirements for Total-N for the treatment plant at the community. However, a complete nitrification stop brings ammonium discharges close to plant discharge requirements, so that it is doubtful whether compliance will be achieved in practice.

The capacity of the existing plant will be considerably larger than necessary after urine separation and simulation shows that the volume for denitrification can be omitted and volumes for aeration reduced substantially down to one third of the present volume if loss of nitrification can be accepted.

The modelling demonstrates that urine separation in the catchment area has a potential for significant reduction of chemicals for phosphorus precipitation. The full potential however will first be realised when urine separation takes place in the whole catchment area. Under such conditions the general discharge requirements for nitrogen and phosphorus in Denmark can be met without nitrification in the plant and with a very moderate dosage of chemicals. In that case the activated sludge treatment plant can be replaced by a smaller and less expensive treatment system.

Cost and savings for urine separation

Based on the draft for establishment of urine separation at the community and the computer simulations, cost and savings potential with urine separation can be calculated.

Total costs for establishment of urine separation are estimated to DKK 1.5 million (200.000 Euro). Half covers costs of toilets, collection tanks and other equipment, the remainder being costs for contractors. The latter item in particular is difficult to estimate, as new installations in old buildings can be very difficult and costly.

The potential for savings in the operation at the present plant is limited. It has been estimated that an immediate annual saving in chemicals and electricity of around DKK 5,000 (700 Euro), corresponding to 20 per cent of present operating costs, can be expected. If the plant is operated without nitrification, savings are slightly higher, but plant compliance with discharge requirements becomes less certain.

Upon new construction of a treatment plant it is possible to save considerable plant volumes through urine separation establishment in the catchment area, and it will presumably be possible to ensure very low discharges of both organic matter and nutrients with more simple treatment techniques than used today. Tax reductions relating to discharge of organic matter, nitrogen and phosphorous from the establishment of urine separation will only be limited, and they can hardly be realised in parallel to an optimisation of operating costs.

With the proposed system for urine separation at Svanholm 370 kg of nitrogen and 50 kg of phosphorous will be collected annually. Urine has a good fertilising value; however, it is not believed to have a potential for contributing to the system economy, as there will be costs of transportation and spreading.

Consequently, costs for urine separation at Svanholm will be high and cannot be outweighed by savings in the operation of the present treatment plant and by income from sale of urine.

Financial potentials will be substantially higher in the establishment of such systems in new building projects, where costs of a urine separation system will be lower, and where the significant reduction of contents of nitrogen and phosphorous in sewage can be utilised to build a simpler and cheaper treatment plant.

Conclusions

Source sorted human urine contain pharmaceuticals and hormones from the users of the system, but only hormones and analgesics were found in urine from Svanholm community.

Methods for detection of pharmaceuticals in urine are strongly needed together with risk assessment of utilisation of source-sorted urine in agriculture or locally use.

Systems for source separation of urine can be established with minor problems in a small town but to a high cost compared to the value of the urine and the reduced cost for operation of a wastewater treatment plant with extended nutrient removal.

If efficient urine separation is extended to the full catchment area the plant can comply with Danish requirements to discharge of organic matter, nitrogen and phosphorus without nitrogen removal and the plant can be replaced by a smaller and less expensive treatment system.

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At last but not least we thank the people at Svanholm that have inspired the project and have been excellent collaborators during the whole project. A special thank to Jes Brandt and Frank Knudsen, they have made at lot of the practical work.

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Life cycle microbial risk analysis of sustainable sanitation alternatives

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Keywords

System analysis, hygiene impact, pathogens

Abstract

Moves towards sustainability in urban water and sanitation have seen numerous novel system configurations suggested. More sustainable configurations inevitably involve the reuse of effluents and biosolids. Reuse of such materials carries with it an inherent risk from waterborne pathogens. This paper outlines a methodology, life cycle microbial risk analysis (LCMRA), for assessing the hygiene impact of such novel system configurations.

Like other life cycle system analysis methods, LCMRA compares alternatives on a whole system basis. The methodology is illustrated by comparing alternatives for servicing a new residential development. One alternative would utilize composting toilets with urine and greywater separated a source. In the second, conventional toilets and sewering would be employed. Both alternatives would treat wastewater locally with treated effluent recycled back to households as a non-potable supply. Biosolids and urine would be reused in agriculture. Wastewater and biosolid treatment varies between the alternatives, with each having a comparable life cycle cost.

Modeling showed the infection risk of recycled water from the separating system was between one and three times that of the 'conventional' alternative. The factor being dependent on the assumed likelihood of partial disinfection failure. The model predicts slightly higher pathogen flows to agricultural soils from the 'conventional' alternative.

Introduction

The conventional approach to providing urban water and sanitation is based on 'once through' water usage, large scale common collection of sewage and the disposal of effluents and biosolids after treatment. These systems aim to protect public health by creating a linear flow of potentially infectious material away from populations. For the most part, the conventional approach has been extremely successful in eliminating epidemic waterborne diseases from industrialized societies. However, excessive water use and linear flows of nutrients are problematic in terms of sustainability. Since the early 1990's many and varied approaches to sustainable urban water and sanitation have been proposed. Strategies considered included: the use of sewage effluents for local agriculture, effluent recycling back to households as a secondary supply, greywater separation for reuse by households, urine separation for nutrient capture and reuse, vacuum or dry toilets with reuse in local agriculture. All these strategies involve the reuse of effluents or biosolids, which will be contaminated with human excreta. This has the inherent potential for transmission of waterborne disease.

Over recent years, a number of groups have been working to develop modeling and analysis methods that can be used to identify more sustainable urban water and sanitation system configurations (Speers *et al* ,2000, Urban Water, 2002, Balkema *et al*., 2002). Assessments aim towards being holistic through analysis of 'whole system', 'life cycle' impacts. Analysis and modeling of materials, energy and cost flows have been described. Alternative urban water and sanitation systems have been compared in terms of embodied energy, exergy dispersion (measuring the increase in entropy), nutrient and contaminate flows, and life cycle costs (Hellstrom 1998; Karrmen, 2000, Speers *et al* ,2000). This paper describes and applies the 'life cycle microbial risk' methodology, which takes a 'whole system' and 'life cycle' approach to the modeling of pathogen flows and the analysis of microbial risk or hygiene impact. The development of this method has been described previously in papers by Fane and Ashbolt (2000), Fane *et al.* (2002) and in reports on the MISTRA urban water program (Urban Water, 2002).

Pathogens and sustainable sanitation

Disease-causing waterborne microbial pathogens can be broadly characterised as either enteric virus, parasitic protozoa, enteric bacteria, or helminths. Enteric virus is of concern due to their minute physical size, the potential for infected individuals to excrete extremely high numbers (up to 10^{12} g^{-1} faeces) and the low infective dose required (Rusin *et al*., 2000). Although larger, the ability of parasitic protozoan to persist in harsh environments for extended periods means they must be seriously considered. Enteric bacterial pathogens and helminths become an issue in waste streams, which are poorly treated. Unlike the other pathogen groups some bacterial pathogens may grow in conducive environments within wastewater systems. This potential will compound any risk that results from ineffective treatment. Bacterial pathogens are however more readily assessed through faecal indicators than other groups.

In general, microbial pathogens multiply within infected individuals and with the exception of bacteria such as *Salmonella*, pathogenic microbes found in sewage will have originated from infected persons. Waterborne diseases are characterised by acute gastroenteritis with diarrhea and/or vomiting. These acute symptoms allow the pathogen to be spread from an infected host and become waterborne. The exact symptoms and severity of an intestinal infection vary greatly between pathogens with host factors also important. For many waterborne pathogens, not all infected individuals will show disease symptoms. Asymptomatic 'carriers' can still excrete large numbers of pathogens that will infect others. These carries can be a critical in the spread of intestinal diseases (Rusin *et al*., 2000). Waterborne pathogens are also generally contagious and will pass to varying extents directly from person to person without water as the conduit.

The potential for waters to transmit intestinal disease has traditionally been assessed via enumeration of faecal indicator species such as *E. coli* and faecal streptococci. An assessment being made by comparing measured numbers to guideline levels judged acceptable. After water treatment however indicator numbers are poorly correlated with disease outcomes (Levy *et al.* 1998). For the assessment of effluent quality for reuse this issue is particularly significant. Different microbial groups respond quite differently to various treatment processes. The relationship of indictor to pathogen numbers on which guidelines are based breaks-down with each stage of wastewater treatment. Faecal indicators are then of limited usefulness in assessing the possible hygiene impact from viral and protozoan pathogens in a treated effluent.

To avoid the problems with indicators, some guidelines for effluent reuse have been specified in terms of actual pathogen numbers. Such a guideline causes obvious difficulties in sampling and pathogen recover from large volumes. Applying these guideline is also problematic in small reuse systems where much higher variability in effluent pathogen concentrations over time can be expected (Fane *et al.* 2002).

While problems exist for the use of guidelines in assessing the safe reuse of sewage effluents, the relationship between indicator numbers and pathogen presence is even less certain for wastewater streams for non-conventional configurations. Only limited characterization of streams such as collected urine and household greywater, in terms of microbial pathogens, has occurred to date (Jönsson *et al* 1997; Ottoson and Stenstrom, 2003).

In contrast to the ‘pass-fail’ assessment of water quality guidelines, microbial risk assessment (MRA) involves analysis, which aims to quantify the risk, posed by a given pathogen. Dose response functions are used to estimate the level of risk from a given exposure to pathogens in terms of the probability of an infection occurring (Haas *et al*. 1999). Dose response functions are species-specific and are derived from empirical data that has comes from feeding studies of volunteers. In order to calculate the risk of infection due to a given exposure, both a measured or estimated concentration of pathogens and an estimate of the volume ingested are required. Standard MRA doesn’t then avoid the difficulties of pathogen enumeration faced with guidelines specified in pathogen numbers.

Direct pathogen enumeration in wastewater streams is obviously impossible for system configurations which are still 'on the drawing board'. Even where examples exist, non-sewage streams such as collected urine and household greywater are likely to have only infrequent pathogen present. Also the size of the system can be expected to have a significant impact on the presence of pathogens in wastewater streams. For MRA to be of use in assessing novel sustainable system configurations, a means of estimating pathogen numbers other than by direct enumeration in required. The LCMRA methodology, as described, provides these estimates through modeling the flow of pathogens from infected individuals through system alternatives and into reuse and disposal streams.

Modelling framework

The LCMRA methodology is based on modeling of pathogen flows with analysis of the hygiene impact that could be expected from these flows. Pathogens are sourced in 'waste' steams coming from the community. Pathogens are modeled moving into alternative infrastructure configurations, which include various treatment and disinfection processes. These will processes reduce microbe numbers. Existing dose response functions are used to estimating the hygiene impact of pathogen flows back to the community.

The modeling framework includes three sub-models as shown in Figure 1. The pathogen generation model simulates daily flow of pathogens and wastewater generation by a community. This module provides a common input to the system models being compared. System models represent the microbial removal properties of each alternative infrastructure configuration. Urban water and sanitation systems are modeled as a series of processes termed ‘hygiene modifying units’. Each unit has individual characteristics in relation to pathogen removal by microbial group, partitioning of pathogens and unit reliability. A system model then derives the pathogen concentrations in each of the reuse and disposal streams that leave the system configuration being modelled. A single hygiene impact model calculates infection risks and the comparative impact of the system alternatives.

Assessments are comparative, with system alternatives analyzed in parallel based on common pathogen incidence and exposure assumptions. The rational for comparative assessment is the current weakness of available data on intestinal disease incidence and likelihood of ingestion of recycled waters. The temporal variability expected in parameters governing pathogen flow is accounted for via probability distributions. Monte Carlo simulation is then used to given an output from the models, which accounts for these probability inputs.

Our current understanding of waterborne disease is such that modeling is limited to a number of the better-characterized pathogens. These index organisms have been chosen to represent the microbial groups.

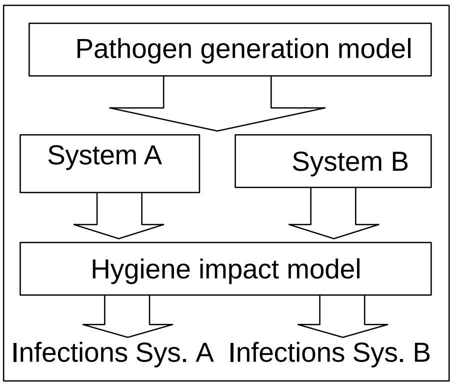

Figure 1: Life cycle microbial risk analysis modelling framework.

Our current understanding of waterborne disease is such that modeling is limited to a number of the better-characterized pathogens. These index organisms have been chosen to represent the microbial groups. The index organisms tend to be the more common and well-understood waterborne pathogen species in that group. Choices are constrained by the availability of a dose response function and data on the disease incidence or pathogens presence in sewage. The index pathogens, which are used in the example below, are *Rotavirus* as an index for enteric virus, *Salmonella* sp. as a representative of bacterial pathogens, and *Giardia lamblia* to index parasitic protozoan. Helminths were judged to be non-significant in an Australian context.

Dose response functions for each index pathogen are embedded within the hygiene impact model. These functions represent the relationship between the number of pathogens consumed and the likelihood of infection. By combining the pathogen concentration outputs from the system models with these dose response functions and assumptions concerning volumes of exposure the hygiene impact model estimates the risks of infection at each exposure point from each index pathogen. The hygiene impact model therefore effectively conducts multiple parallel MRA's. Because the dose response functions are embedded, Monte Carlo simulation allows the distributions of pathogen concentrations in disposal and reuse streams, translated into a distribution of infection probabilities in the hygiene impact model.

The established dose response functions for the index pathogen *Salmonella* sp, *Rotavirus* and *Giardia* are given in equations 1, 2 and 3 respectively (Rose and Gerba, 1991 Haas *et al* 1999; Regli *et al.* 1991). In these functions D is the number of pathogens ingested and P is the probability of infection from that ingestion.

$$P = 1 - \left[1 + \frac{D}{23600}\left(2^{1/0.313} - 1\right)\right] \qquad \text{Equation 1}$$

$$P = 1 - \left[1 + \frac{D}{5.6}\left(2^{1/0.27} - 1\right)\right] \qquad \text{Equation 2}$$

$$P = 1 - e^{-\left(\frac{D}{50.23}\right)} \qquad \text{Equation 3}$$

Number of infection is dependent not just on the pathogen concentrations and dose response but also exposure volume and incidence of exposure. A common low-risk exposure may well be more significant in terms of total number of infections caused than a rare high-risk incident. The hygiene impact model account for this, by estimating the number of infection that might be expected due to the system, as a whole, over an average year. Because there is a lack of definitive data on exposures, common assumptions are made between alternatives and the assessment of systems is comparative.

Example

In this example two alternative systems for a hypothetical greenfield development of 500 houses in Sydney are considered. One alternative (system A) will take an ecological sanitation approach to servicing with urine separating, dry composting toilets. In this system only household greywater will flow to the common sewer. The other system (B) employs conventional flush toilets and a common sewer collecting all wastewaters from households. Both alternatives will treat wastewater locally at a small-scale wastewater treatment plant. In each case effluent is recycled back to households and common areas as a non-potable supply. Wastewater treatment will vary between the two alternatives, with the total life cycle cost of each alternative being comparable. This will mean the extra cost of dry toilets and urine collection in system A is balanced by advanced levels of wastewater treatment in system B. In each system, compost and urine or sludge will be recycled back to agriculture.

All models were developed in MS Excel with Monte Carlo simulation made possible by @RISK V3.5 (Palisade Corp). Monte Carlo simulation involved models being iterated 100 000 time with each iteration representing a separate day.

Pathogen generation model

The pathogen generation model was based on the following assumptions:

- An average occupancy of 2.2 person per dwelling.
- An average greywater generation of 125 liters per person per day and toilet flushing volume in system B of 20 liters per person per day.
- An average faecal generation of 200g per person per day.
- An average faecal contamination of urine of 10mg per person per day.
- An average faecal contamination of greywater of 0.1g per person per day (represented by a log normal distribution with a standard distribution of 2g).
- An average of 50 *Rotaviral* infection per year in the community lasting 2 day with 2E+12 virus shed (represented by a log normal distribution with a standard distribution of 2E+11).
- An average 4E+9 *Giardia* shed by the community per day (represented by a log normal distribution with a standard distribution of 4E+8).
- An average 5E+4 *Salmonella* sp per liter of greywater, sourced in kitchens (represented by a log normal distribution with a standard distribution of 5E+4).

Occupancy and wastewater generation is based on Sydney specific data and end-use modeling of water demand. Contamination assumptions are based Jönsson *et al* (1997) and Ottoson and Stenstrom (2003). Intestinal disease incidence and pathogen shedding assumptions are based on Wheeler *et al* (1999) and Rusin *et al*. (2000).

System models

System A separates urine and faecal solids at source with collection and on-site storage before reuse in agriculture. Household greywaters are collected by a common sewer, primary and secondary treated, disinfected and recycle back to households. Recycled water is used in-house for laundry purposes and out-doors as irrigation water.

System B collects all households wastewaters as sewage. Sewage is primary, and secondary and lime treated, sand filtered, microfiltered and then disinfected. Biosoilds from wastewater

treatment are anaerobically digested and reused in agriculture. Recycled water is used in-house for laundry purposes and toilet flushing and out-doors for irrigation.

It was assumed that both filtration and disinfection processes would suffer partial failures, and these might go unnoticed for short periods. Further it was assumed that these partial failure events resulted in the loss of 1 log of pathogen removal capacity. The model was tested for partial failure rates of 1%, 5% and 10%.

Pathogen removal assumptions for hygiene modifying units, which make up systems A and B, are presented in Table: 1.

Hygiene modifying unit	Virus removal	Bacterial removal	Protozoan removal
Primary and secondary treatment	1.5 log	2 log	2 log
Tertiary (lime) treatment	1log	1log	1log
Sand filtration	1.5 log	2.5 log	2 log
Microfiltration	2 log	3 log	3 log
Disinfection	3 log	3 log	3 log
Anaerobic digestion	1.5 log	3 log	1.5 log
On-farm biosolids storage	2.5 log	2.5 log	1.5 log
On-site biosolids composting	3 log	-	3 log
Urine storage	2 log	-	5 log

Table 1: Removal rates by pathogen groups of system A and B hygiene modifying units.

These pathogen removal assumptions have been based on various sources of data, in particular Long and Ashbolt (1994) and Tussell *et al* (2003).

The hygiene impact model

The hygiene impact model assumed equivalent exposure to 100ml, 10ml, 1ml, 0.1ml, and 0.01ml of recycle effluent in terms of the total volume. No 0.01ml exposures would result from system A as this exposure was considered dependent on flushing toilets with recycle effluent.

Modelling Results

In table 2 the results of the modelling are shown in terms of a comparison between the two system alternatives. For each parameter, the result is shown as the proportion that the system A output was with respect to the system B output.

Parameter	Sys A / Sys B
Average probability of infection with partial failure rate* of 10%	1.0
Average probability of infection with partial failure rate* of 5%	1.7
Average probability of infection with partial failure rate* of 1%	3.1
Total viable pathogens to agricultural soil	0.8

Table 2: Results of comparative whole system assessment of hygiene impact

Table 2 shows that if the reliability of disinfection and filtration processes is high then reuse of effluent from System B could be expected to have a lesser hygiene impact than water reuse in system A.

The results of modeling also showed that risk of waterborne infection from recycled water in either system was due virtually entirely to enteric virus. Of the viable pathogens transported to agricultural soil, both virus and protozoan numbers were significant.

To obtain an estimate of the magnitude of the hygiene impact it can be assumed that an average a person serviced by system A would ingest 0.5ml of recycled effluent per day. At this level of exposure the average number of persons infected per year due to the urban water and sanitation system would be 9 if the partial failure rate were 10% and 1.9 if the partial failure rate were 1%. These numbers can be compared to the 50 *Rotaviral* infections assumed in the pathogen generation model

Discussion

The LCMRA methodology as outlined is based on modelling index pathogen (*Giardia Salmonella* and *Rotavitus*) flows from a community through urban water and sanitation system alternatives, with analysis to estimate the hygiene impact that might be expected from such flows. The modelling framework involves pathogen generation, pathogen flow and hygiene impact submodels. Existing pathogen dose response functions, as used in standard MRA are embedded within the modelling framework. Assessment of hygiene impact is comparative between infrastructure alternatives based on common assumptions concerning exposures. The temporal variability in parameters, which affect pathogen flows, is accounted for using probability distributions. Monte Carlo simulation is used to obtain results. The method allows whole system analysis but will comparative assessment.

In the example of this methodology two 'sustainable' system alternative were compared. The results showed that virus would be the pathogen of greatest concern when reusing treated effluent from either system. Comparing the systems, the results showed that the alternative based on conventional sewering combined with advanced wastewater treatment, system B, had equivalent or lower average hygiene impact than the system based on an ecological sanitation approach, system A, while the 'ecological sanitation' system exported less pathogens to agricultural soil. However though addition of sand filtration or microfiltration to the greywater treatment chain, the hygiene impact of the ecological sanitation configuration, could be easily reduced. System A would then have a significantly lower hygiene impact than system B, however a higher life cycle cost would need to be accepted.

Uncertainties remain in 'whole system' modeling and analysis of the hygiene impact from urban water and sanitation alternatives. These uncertainties include: the prevalence of enteric diseases including the incidence of asymptomatic infections; the characteristics of rarer intestinal infections including dose response relationships and pathogen shedding rates; the susceptibility of unit processing in wastewater treatment to partial failure; and the likely volumes consumed by a population exposed to a secondary source of supply. A further confounding factor not currently included in the model is contagion. This would act as a multiplier for system derived infections The limit to our knowledge about waterborne disease is the reason why the LCMRA methodology is currently based on indicative pathogens only rather than full pathogen loads and why assessments of systems is comparative.

Conclusions

A risk of transmitting waterborne disease will exist for any urban water and sanitation system that recycles household effluents, or collects and reuses human wastes in agriculture. Further, novel system configurations will create new pathways for the possible spread of waterborne diseases. Despite this, there is a need for sustainable systems and these systems inevitably involve some form of reuse. Some level of microbial risk will result, so it is necessary to understand and assess this potential allowing sustainable urban water and sanitation systems to be optimized and the best alternatives selected.

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Recommendations for the reuse of urine and faeces in order to minimise the risk for disease transmission*

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Disease transmission, faeces, guidelines, pathogens, risk, urine

Abstract

It has been stated that excreta, i.e. urine and faeces, need to be considered as resources rather than waste products in order to meet future water and sanitary system demands (WSSCC 2000). These nutrient resources may preferably be recycled in agriculture, leading to the replacement of chemical fertilisers. Of primary importance, however, is that recycled excreta does not add to the disease burden. Faeces may contain a variety of pathogens and should always be considered as a microbiological hazard. Hence faeces need to be treated in order to inactivate any pathogens potentially present, such as by storage, composting to elevate the temperature, addition of ash or other material to raise the pH and incineration where the ash may be used as a fertiliser. Urine-transmitted pathogens are less common but need to be considered for each setting where urine is reused. Faecal contamination of the diverted urine is probably the higher risk and storage before fertilising has been suggested as a safety measure. Treatment methods may also be combined with other barriers such as working the excreta into the ground and choosing appropriate crops.

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Introduction

It has been stated that excreta, i.e. urine and faeces, need to be considered as resources rather than waste products in order to meet future water and sanitary system demands (WSSCC 2000). Today the alternatives to the conventional wastewater system include systems that separate or divert urine and faeces in order to utilise the nutrients more efficiently. In regions without a sewerage network, nutrient utilisation as well as improved sanitation is possible by not mixing the fractions and avoiding flushwater. If the faecal fraction is kept dry there will be less leaching from e.g. pit latrines and the smell will be reduced. Two of the main reasons to separate urine and faeces are thus to recycle the plant nutrients in urine and to obtain a faecal fraction that is more practical and, if treated, safer to handle (Höglund, 2001).

Environmental transmission of urinary excreted pathogens is a concern in tropical climates (discussed below), but generally faecal cross-contamination, that may occur by misplacement of faeces in the urine-diverting toilet (Schönning *et al*., 2002), is regarded as a greater health risk (Höglund *et al*., 2002). The faecal fraction should always be considered a health hazard due to the potential presence of enteric pathogens.

Different factors that will affect the inactivation of pathogens in the environment include temperature, pH, moisture and competition from naturally occurring microorganisms. To obtain a fertiliser product from excreta that is safe to use it is possible to apply treatment methods utilising any of these parameters in combination with time.

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The WHO guidelines (1989) for safe agricultural use of wastewater and excreta (as a mixed fraction) provide limits for pathogens (nematode eggs) and indicators (faecal coliforms). The 1989 guidelines are currently under revision, and the next edition is expected to include guidelines on urine as well (Carr, pers. comm.). The purpose of this paper is to supply background information on the behaviour of pathogens of concern in relation to various options for treatment and to give practical advice on how to minimise the risk for infectious diseases when reusing urine and faeces as fertilisers. It can be seen as a summarised version of a more extensive report that will be published within the Swedish EcoSanRes-programme (www.ecosanres.org), financed by Sida.

Infectious diseases that may be transmitted via urine and faeces

The pathogens traditionally known to be excreted in urine are *Leptospira interrogans*, *Salmonella typhi*, *Salmonella paratyphi* and *Schistosoma haematobium* (Feachem *et al.* 1983). There is a range of other pathogens that have been detected in urine but their presence is not considered significant for the risk of environmental transmission.

Leptospirosis is a bacterial infection causing influenza-like symptoms with 5-10% mortality that is generally transmitted by urine from infected animals (Feachem *et al.* 1983; CDC 2000a). It is considered an occupational hazard e.g. for sewage workers and for farm workers in developing (tropical) countries. Human urine is not considered to be an important route for transmission since the prevalence of the infection is low (Feachem *et al.* 1983; CDC 2000a). Infections by *S. typhi* and *S. paratyphi* only cause excretion in urine during the phase of typhoid and paratyphoid fevers when bacteria are disseminated in the blood (Feachem *et al.* 1983). This condition is rare in developed countries. Even though the infection is endemic in several developing countries with an estimated 16 million cases per year, urine-oral transmission is probably unusual compared to faecal-oral transmission (Feachem *et al.* 1983; CDC 2000b). For diverted urine the risk for transmission of *Salmonella* will be low even with short storage times due to the likely rapid inactivation of faecal bacteria (Höglund, 2001). Schistosomiasis, or bilharziasis, is one of the major human parasitic infections mainly occurring in Africa (Feachem *et al.* 1983). When infected with urinary schistosomiasis caused by *Schistosoma haematobium*, the eggs are excreted in urine, sometimes during the whole life of the host. The eggs hatch in the environment and the larvae infect specific aquatic snail species, living in fresh water. After a series of developmental stages aquatic larvae emerge from the snail, ready to infect humans through penetration of the skin (Feachem *et al.* 1983). As long as the urine is not used close to a fresh water source where the snail is present, it constitutes no additional risk for the transmission of schistosomiasis.

Enteric infections can be transmitted through four groups of pathogens; bacteria, viruses, parasitic protozoa and helminths. From a risk perspective the potential presence of pathogens in faeces should always be considered since there are so many different types of enteric infections and the prevalence is unknown for the majority of them.

Bacteria have generally been considered the leading cause of gastrointestinal illness in surveillance systems, but enteric viruses are now considered to cause the majority of gastrointestinal infections in developed regions (Svensson, 2000). More than 120 different types of viruses may be excreted in faeces, with the most commonly identified including rotavirus, enteric adenoviruses and human caliciviruses (Tauxe and Cohen, 1995). Hepatitis A has also been recognised as a pathogen of concern when applying wastes to land and is considered a risk for water- and foodborne outbreaks especially where the sanitary standards are low. Of the bacteria, at least *Salmonella*, *Campylobacter* and enterohaemorrhagic *E. coli* (EHEC) should be considered when evaluating microbial risks from various fertiliser products including faeces, sewage sludge and animal manure. In areas with insufficient sanitation, cholera may still occur and constitute a risk for contamination of water. Parasitic protozoa such as *Cryptosporidium parvum* and *Giardia* *lamblia/intestinalis* have been studied intensively during the last decade partly due to their environmental resistance. Infectious doses are low and especially *Cryptosporidium* have been the cause of several large waterborne outbreaks. In developing countries helminth infections are of greater concern. The eggs of helminths like *Ascaris* are persistent in the environment, and therefore regarded as an indicator of hygienic quality (WHO, 1989).

Inactivation of pathogens in urine and faeces

The fate of the enteric pathogens entering the urine collection container is of vital importance for the hygiene risks related to the handling and reuse of the urine. To determine the duration and conditions for sufficient storage of the urine mixture before its use as a fertiliser, it is necessary to estimate the survival of various microorganisms in urine as a function of time. Studies have been performed where different microorganisms were added to the urine and their inactivation followed over time (Höglund, 2001). Very limited work has been undertaken on urine treatment other than storage, such as acidification (Hellström *et al.*, 1999), heating and evaporative concentration.

For the urine mainly temperature and the elevated pH (~9) in combination with ammonia has been concluded to affect the inactivation of microorganisms. Bacteria like *Salmonella* (i.e. Gram-negative bacteria) were inactivated rapidly, whereas viruses was hardly reduced at all at low temperatures (4-5°C) (Table 1).

	Gram-negative bacteria	Gram-positive bacteria	*C. parvum*	Rhesus rotavirus	*S. typhimurium* phage 28B
4°C	1	30	29	172[a]	1 466[a]
20°C	1	5	5	35	71

[a] Survival experiments performed at 5°C.

Table 1: Inactivation of microorganisms in urine, given as T_{90}-values (time for 90% reduction) in days (Höglund, 2001)

The inactivation of pathogens in faeces is a more complex issue than in urine, due to varying conditions regarding moisture, other climatic factors as well as a larger influence of the construction of the system, e.g. how well the urine is diverted and whether anal cleansing is practised.

Microorganism	Faeces and sludge[a] 20-30°C	Faeces T_{90}[b] ~20°C	Soil[a] 20-30°C	Soil[c] absolute max[d]/ normal max
Bacteria				1 yrs./2 mon.
Faecal coliforms	<90 normally <50	15-35 (*E. coli*)	<70 normally <20	
Salmonella	<60 normally <30	10-50	<70 normally <20	
Viruses	<100 normally <20	rotavirus: 20-100 hepatitis A: 20-50	<100 normally <20	1 yrs./3 mon.
Protozoa[e] (*Entamoeba*)	<30 normally <15	*Giardia*: 5-50 *Cryptosporidium*: 20-120	<20 normally <10	10/2
Helminths (egg)	several months	50-200 (*Ascaris*)	several months	7 yrs./2 yrs.

[d] Absolute maximum for survival is possible during unusual circumstances such as at constantly low temperature or at well protected conditions.[a]

[e] Data is missing for *Giardia* and *Cryptosporidium*, their cysts and oocysts will probably survive longer than what is here given for protozoa.[a]

Table 2: Estimated survival of pathogens during storage of faeces and in soil, given in days if not stated otherwise (Faechem *et al.*, 1983[a]; Arnbjerg-Nielsen *et al.*, 2003[b];Kowal 1985[c] (in EPA 1999))

Table 2 summarises reported pathogen inactivation in faeces, sludge and soils. During faeces collection, the addition of other material such as ash (lime) also needs to be considered, as it may increase the die-off rate for pathogens. The alkalinity of different types of ashes does however vary, and it may be difficult to predict the final pH and the related pathogen inactivating effect.

Recommendations for the reuse of human urine

As a result of Swedish research into the survival of microorganisms in urine, guidelines based on the parameters urine storage time and temperature have been proposed (Table 3; Jönsson *et al.*, 2000; Höglund, 2001). Guidelines may in this context be seen as recommendations on how to use urine in agriculture in order to minimise the risks for transmission of infectious diseases and as a part of risk management. The guidelines have been endorsed by the Swedish EPA but need to be further approved in order for implementation as national regulations (Swedish EPA, 2002).

The endorsed Swedish guidelines were based on pathogen/indicator inactivation in urine and the results concur with subsequent microbial risk assessment (Höglund *et al.*, 2002). For single households the urine mixture is recommended for all type of crops, provided that the crop is intended for the household's own consumption and that one month passes between fertilising and harvesting, i.e. that a withholding time between last urine application and consumption of the food produce is applied. This approach can probably be used for any smaller system in developing countries, whereas larger (urban) systems may be adapted to the above guidelines (Table 3). Higher ambient temperatures in many developing country settings will however increase inactivation rates and add in safety. One reason for more relaxed guidelines for single households is that person-to-person transmission will exceed the risk from urine related environmental transmission.

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Storage temperature	Storage time	Possible pathogens in the urine mixture	Recommended crops
4°C	≥1 month	viruses, protozoa	food and fodder crops that are to be processed
4°C	≥6 months	viruses	food crops that are to be processed, fodder crops[c]
20°C	≥1 month	viruses	food crops that are to be processed, fodder crops[c]
20°C	≥6 months	probably none	all crops[d]

[a] Gram-positive bacteria and spore-forming bacteria are not included.
[b] A larger system in this case is a system where the urine mixture is used to fertilise crops that will be consumed by individuals other than members of the household from which the urine was collected.
[c] Not grasslands for production of fodder. Use of straw is also discouraged.
[d] For food crops that are consumed raw it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

Table 3: Recommended Swedish guideline storage times for pathogen inactivation based on, pathogen content[a] of the urine mixture and recommended crop for larger systems[b]. It is assumed that the urine mixture has at least pH 8.8 and a nitrogen concentration of at least 1 g/l (from Jönsson *et al.*, 2000 and Höglund, 2001)

Alternatives for treatment of faeces

Storage

Storage of infectious materials will eventually result in the inactivation of pathogens present. The time needed for a certain reduction or elimination is however hard to predict since the conditions may vary significantly. The ambient temperature and moisture as well as the construction of the storage container will affect the inactivation of microorganisms. Naturally occurring microbes will also compete with pathogens and affect their survival.

Faechem *et al.* (1983) presented extensive data on pathogen/indicator survival in different materials including nightsoil and faeces. The data is in the form “less than 20 days” as shown in Table 2, and do not take initial values into consideration, but focuses on total inactivation. From literature studies Arnbjerg-Nielsen *et al.* (2003) estimated the survival times for various pathogens with T_{90}-values given for 20°C in Table 2. The studies of pathogen inactivation in faeces without material added are however few and other materials such as animal manure and sewage sludge were evaluated to estimate inactivation rates. Harsher environmental conditions would be expected in the latter. Nonetheless, based on these T_{90} values full inactivation would be significantly longer than estimated by Faechem *et al*. (1983).

The effect of temperature on the inactivation of pathogens in a diagram giving so-called “safety zones” was first published by Feachem *et al.* (1983). According to WHO (1989), at least one-year storage at ambient temperature is required to achieve the guideline for helminth quality applying this diagram. Strauss and Blumenthal (1990) suggested that one year was sufficient during tropical conditions (28-30°C), whereas at lower temperatures (17-20°C) 18 months would be needed. In a South-African study, *Salmonella* was still found in stored faeces after one year (Austin, 2001). Weekly turnings of the faecal heap rather than having it in a plastic container gave significantly higher reduction of the pathogens as well as faecal indicators. This practise will however expose the person handling the material to unsanitised faeces. Storage is probably most beneficial in dry-warm climates where the low moisture content will result in desiccation of the material and aid in pathogen inactivation. If the faecal material looks dry, and also is dry right through, the risk of viable pathogens being present has decreased significantly. Regrowth of bacterial pathogens may however occur after application of moisture (e.g. by contact with moist soil).

Composting

The relations between time and temperature for various pathogens in the safety zone diagram (Feachem *et al.*, 1983) have been widely accepted even though “new” pathogens have been identified and literature giving other results has been published. In general thermophilic temperatures >55°C are considered necessary to achieve efficient inactivation. WHO recommend thermophilic digestion (50°C for 13 days) or composting in aerated piles during one month reaching 55-60°C (+ 2-4 months for further maturation). Recommendations concerning treatment of e.g. sewage sludge and organic household waste (food waste) also rely on such temperatures (Swedish EPA, 2002; EC, 2000; Danish EPA, 1996). Haug (1993) states that composting at 55-60°C for a day or two should be sufficient to kill essentially all pathogens, whereas the regulations above rely on significantly longer periods, partly because it is common that cold zones are formed within the compost, resulting in locally less inactivation and possibilities for regrowth of pathogenic bacteria.

The moisture content, aeration and the C:N ratio need to be appropriate for a composting process to proceed along with sufficient insulation and/or bulk to allow temperature increases. In the WHO guidelines composting in 10-50 m long piles of approximately 2x2m is described. In order to compost faeces addition of bulk material to allow aeration, such as wood/bark chips is needed. Vinnerås *et al.* (2002) studied small-scale composting of faeces and faeces mixed with urine and/or food waste and concluded that the faeces and food waste mixture (also including straw as an amendment) yielded the most efficient process, i.e. resulted in the highest temperature. In well-insulated compost reactors the temperature reached over 65°C, both in the laboratory scale (1 litre) and pilot scale (90 litre bin), giving high safety margins for most pathogens in comparison with the safety zone diagram of Faechem *et al.* (1983) (Vinnerås *et al.*, 2002).

In many domestic situations, however, composting of faeces from urine-diverting toilets only results in a slight elevation of the temperature, probably due to insufficient insulation and addition of ash in the toilets, resulting in too little available energy (Karlsson and Larsson, 2000; Björklund, 2002). During composting changes in pH and high biological activity will also affect the inactivation of pathogens, probably being more important during mesophilic conditions. In a study by Holmqvist and Stenström (2001) household waste mixed with straw was composted, yielding a temperature of 29-30°C and a pH that ranged from 4.5 to 8.6. During the one-month period the faecal indicators *E. coli* and *Enterococcus faecalis* were reduced rapidly, with a 6 $\log_{10}$ and a 5 $\log_{10}$ reduction during the first 3 days, respectively. A virus model (*S. typhimurium* phage 28B) was reduced 3 $\log_{10}$ whereas the viability of *Ascaris* eggs (ova) only was reduced from 91% to 70% (Holmqvist and Stenström, 2001).

Many toilets are called composting toilets without actually obtaining a well functioning process; it is rather storage and anaerobic putrification that occurs. Unless large and/or well insulated composting units are used which receive faecal and food wastes, it is unlikely that pasteurising temperatures will be reached in domestic-scale "composting" units. Composting is thus a process that requires some skill to run, and it need to be well maintained in order to function. Composting of faecal material at mesophilic and ambient temperatures need to be further evaluated in order to potentially be endorsed as an acceptable treatment method.

Addition of pH-elevating and desiccating material

Most pathogens are favoured by a natural pH. Even though a pH of above 9 is sometimes said to significantly hamper microbial activity a pH of 11-12 is desired in treatment methods where lime is added (e.g. for treatment of sewage sludge) (Boost and Poon, 1998). To add ash (or lime) to excreta is an old tradition in several countries and present recommendations for treating faeces from e.g. the Swedish Institute for Infectious Disease Control (SMI) (not published) is to add ash (or lime) after each defecation. The ash or lime has several benefits; it reduces the smell, covers the material, decreases the moisture content, and aids hygienisation through the elevated pH effect.

Results from a study of urine-diverting latrines in Vietnam indicate that it is possible to within the stored faeces achieve a significant reduction of viable *Ascaris* ova and viruses (*S. typhimurium* phage 28 B) within a six-month period. In these latrines 100-500 ml of ash was added after each visit. The temperature ranged from 31-40°C, the pH in the faecal material was 8.4-10.3 and the moisture content 25-59%. The inactivation could be described by a combination of the factors but only pH for the bacteriophage inactivation was statistically significant (Carlander and Westrell, 1999; Chien *et al.*, 2001).

In a Chinese study by Wang *et al.* (1999) plant ash was mixed with faeces in a ratio of 1:3 yielding a pH of 9-10. A >7 $\log_{10}$ reduction of phages and faecal coliforms, and a 1% survival of *Ascaris* eggs was recorded after three months even though the temperature was low; –10°C to 10°C, resulting in partial freezing of the material. Coal ash was analysed in the same study and had an initial pH of 8 resulting in pH 7 in the mixed material. According to Lan *et al.* (2001) a pH >8 resulted in inactivation of *Ascaris* within 120 days (no detailed information on additives given). In an area in El Salvador a majority of the households added lime or ash (others added saw dust or soil) to the faecal material resulting in a pH of 5.1 to 12.8 (mean 9) (Moe *et al.* 2001). Neither pH, temperature nor moisture could as a single factor be correlated to the concentration of indicator bacteria and bacteriophages that after storage for <1 month to >1 year still was found in the material. The above studies are somewhat contradictory and since other factors affect the result it is not possible to set a lower limit for the pH. The amount of ash added in current systems is uncertain and further studies on appropriate amounts are probably needed but in general terms at least a cup (approx. 200 ml) should be added after each defecation. In China automatic ash dispensers that can be used in a similar way as a water flush have been developed.

The inactivation of microorganisms by addition of 3% urea to faeces, resulting in a pH of ~9.3 that at 20°C corresponded to 8000 mg/l of free ammonia, was evaluated by Vinnerås *et al.* (2002). After five days no *E. coli* or *Salmonella* were detected. Enterococci were reduced 2 $\log_{10}$ and the viability of *Ascaris* eggs was reduced by 10% during the same time. After 50 days only spore-forming clostridia were detected. Since the ammonia will remain in the material if it is properly stored, the risk for regrowth of pathogenic bacteria in the treated matter should be minimised. The urea also adds to the fertiliser value of the faeces.

Incineration

Incineration of the faeces is an option that will eliminate the risk for transmission of disease since all pathogens will be removed. The ash is a potent fertiliser with all phosphorous and potassium retained, whereas nitrogen and organic matter will be lost. Recommendations for how to use it when fertilising to avoid over dosage are however needed.

Discussion

So far, mainly storage at ambient temperature has been considered as a viable treatment option for urine. To further increase the temperature or pH would probably speed up the inactivation of pathogens. The tropical climate in many developing countries will probably result in faster inactivation compared to northern Europe where the above results were obtained. Methods to concentrate the nutrients, e.g. reverse osmosis and utilising zeolites (Jönsson *et al.*, 2000; Lind *et al.*, 2000), have been considered but not particularly for developing countries and they have not been evaluated from a hygienic point of view.

Faeces was identified as the problematic fraction regarding disease transmission at the first International Conference on Ecological Sanitation in China 2001, with some of the studies presented referred to above. Still we have few answers and guidelines for how to treat faeces, and whether they should be reused or disposed need to be further developed. A range of treatment options is available. Incineration is by far the safest method since all pathogens are eliminated. Other methods relying on a raise in pH or temperature or solely on time (ambient conditions) have the potential to reduce pathogens, but further studies to establish appropriate combinations of time, temperature, moisture and/or pH are needed. These processes may also have to be monitored in order to control that the expected limit for each parameter is reached. What options are practical is much dependent on the scale of the system, i.e. whether a household or the municipal level. On the latter scale more options are probably available both due to technical reasons and since, as stated by WHO (1989), implementation of treatment on an individual level may be difficult since it involves changing people's habits and practices that was established a long time ago. Local conditions, such as climate will also effect what recommendations that are suitable.

The focus when handling and reusing fertiliser products of human (or animal) origin should be to minimise the risks for transmission of infectious diseases. Treatment of the excreta is the most important barrier to prevent the spread of pathogens in the environment. There are however other means to limit the exposure to pathogens. For persons handling the excreta personal protection such as wearing gloves is preferred. To use application methods that do not create aerosols (e.g. not sprinkler or during windy periods) decreases the exposure of the farmer and surrounding people. To work the excreta into the ground will minimise exposure to humans and animals, and will also decrease the risk for pathogen run-off to nearby waters. In the WHO guidelines it is stated that excreta having lower microbial quality than required can be utilised if it is placed in trenches and covered by >25 cm of soil. By choosing appropriate crops it is possible to minimise foodborne transmission and it is definitely safer to use excreta on crops that are not intended to be consumed raw. To include a withholding (waiting) period between fertilising and harvest, as suggested for urine above, will allow further reduction of pathogens due to ambient factors such as microbial activity, UV-light and desiccation. If the practical possibility to store urine for sufficient time is limited it is especially important to try to compensate the risk by applying other measures, such as subsurface application and long withholding times. For faeces it is doubtful if other measures than treatment could result in acceptable safety.

A standard measure to control the production of a safe fertiliser product would be the ideal situation, but we are only beginning to get there by storage recommendations for urine. For faeces, the Engelberg guidelines (stated in WHO, 1989) for nematode eggs and faecal coliforms are the focus, even though it is stated that these are not intended as standards for quality surveillance but rather as design goals for treatment systems. Problems with quality control include costs, lack of local laboratory capacity and the lack of routine methods for indicators or specific pathogens that could represent various groups of pathogens. Thermotolerant (faecal) coliforms are still widely used even though it has been questioned how representative they are of the pathogens of concern (parasites and viruses). Detailed recommendations on how to manage a sanitation system including reuse of faeces and urine may therefore be more valuable.

Conclusions

Relying on treatments recommended for excreta is a simpler method to ensure hygienic safety than monitoring by the analysis of microbiological parameters, especially in developing countries. Therefore it has been suggested that urine should be stored (up to six months) before reuse as a fertiliser. The recommended period of storage is dependent on the storage temperature and on what crops that will be fertilised. For faeces different treatment options are possible in order to ensure a hygienically safe fertiliser product. Incineration will render a completely safe fraction and addition of a pH-elevating material may result in sufficient inactivation for the most persistent pathogens (helminth eggs and viruses). These methods may be suitable on a smaller scale whereas other types of chemical treatment and composting seem more suitable for larger systems.

Further research, especially concerning inactivation of microorganisms in faeces during different conditions and risk assessments of sanitary systems, would be valuable in order to further establish guidelines for how to handle and reuse urine and faeces in safe manners. The recommendations need to be adapted to different conditions, e.g. climate. Urine may however in general be considered as a more hygienic fertiliser than faeces and considering its larger content of nutrients it may be recommended for reuse in most settings.

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Microbiological risk assessment of greywater recycling*

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Aeromonas, greywater, microbiology, purification, recycling, risk assessment

Abstract

The effect of biological treatment and subsequent sanitation by ultraviolet (UV) irradiation on the microbiological quality of greywater was studied, and the data were used to assess the risk of the use of this recycled water for toilet flushing. After treatment in a rotary biological contactor, the biological oxygen demand (BOD_5) was below 6 mg/l (arithmetic mean, 1.5 mg/l). The microbiological quality of the processed and disinfected greywater fulfilled the European Union standards for recreational waters. *Aeromonas* was present in the processed water at levels of about 3-12 cells/ml but did not grow in the distribution system. From the analytical results and from data on aerosol formation during toilet flushing, on the virulence of aeromonads and on the epidemiology of *Aeromonas* infections, it was estimated that the health risk from using processed and disinfected greywater for toilet flushing is negligibly small.

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Introduction

Bathing, showering and handwashing turns drinking water into greywater. In typical private European households and hotels, the amount of greywater produced is similar to the amount required for toilet flushing (Scheer and Kimmich, 1999). Hence, use of such water may save considerable amounts of drinking water and has been suggested in particular for dry areas (cf. e.g. Ho *et al.,* 2001). However, unprocessed greywater contains organic matter in form of sweat, skin cells, soaps, detergents, as well as traces of faecal matter (in particular from small children). Accordingly, it has a biological oxygen demand (BOD_5) of 50-150 mg O_2/l (Bullermann *et al.,* 2001) and may contain opportunistic pathogens from the human body. If it is not recycled within a short time and within the household where it is collected, its re-use necessitates a reclamation process involving a biological treatment, in combination with a sanitation step. To assess the microbiological risk of using recycled greywater, we studied the survival of opportunistic pathogens and indicator micro-organisms in a greywater reclamation system in Kassel, Germany.

Description of the greywater reclamation unit, design of the study

Greywater was collected from showers, handwashing basins and bathtubs of 24 households with a total of 65 residents. The average daily load was 2,160 litres (33 l per person). It was processed by biological treatment in a rotary biological contactor carrying about 190 m^2 of active biofilm with a hydraulic residence time of about 23 hours. After passing a sedimentation unit, it was disinfected by a 24W UV lamp (dose $\geq$550 J/m^2 throughout the observation period), and subsequently used as process water for toilet flushing in these households. A scheme of the greywater reclamation system is presented in Figure 1 (from Bullermann *et al.*, 2001). Over a period of 44 months, 577 samples from various sites within the reclamation and redistribution

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system were subjected to microbiological and chemical analysis. For comparison, 44 samples of drinking water and 67 samples of recreational waters were analyzed for *Aeromonas* ssp.

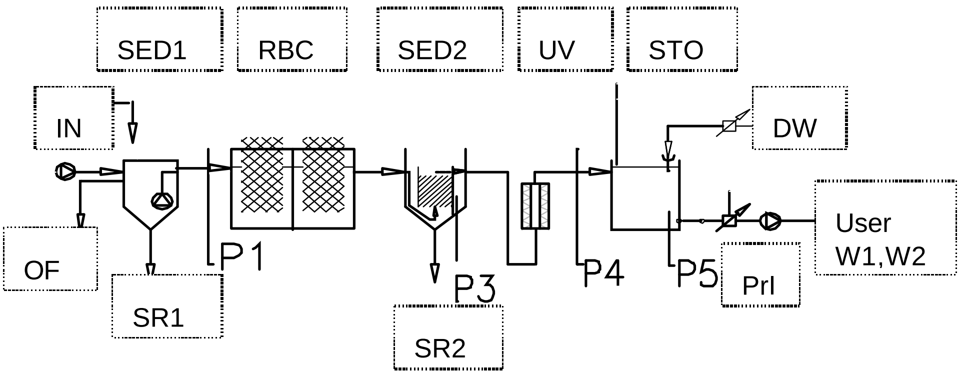

Figure 1: The greywater reclamation system installed in Kassel-Hassenhecke. IN, greywater inlet; SED, sedimentation tanks; RBC, rotary biological contactor, UV, disinfection unit; STO, storage tank; DW, drinking water supply; Prl, pressure increase device; SR, sludge removal; OF, overflow. P1-P5, W1, W2 indicate sampling sites (see text). Modified from Bullermann et al, 2001; © Umweltplanung Schneble

Analytical methods

Water samples were taken and the levels of *Escherichia coli,* coliforms and faecal enterococci, *Pseudomonas aeruginosa* and salmonellae were determined according to official recommendation for the analysis of recreational waters published by the Umweltbundesamt (1995). Briefly, *E. coli* and coliforms were enriched in lauryl sulfate tryptose broth containing methylumbelliferyl-ß-D-glucuronide (Merck no. 12588) at 37°C, and isolates from positive tubes were tested for cytocrom c-oxidase, ß-D-glucuronidase, glucose and lactose fermentation, indole formation and citrate utilization. Enterococci were enriched in azide glucose broth, and isolates from positive tubes were confirmed by colony form on Slanetz-Bartley agar (Merck no. 5262), growth in the presence of 6.5% NaCl, and esculin cleavage. *Ps. aeruginosa* was enriched in malachite green peptone broth (Merck no. 1396) and confirmed according to standard methods (Deutsche Einheitsverfahren, 1982). Tests for *Staphylococcus aureus, Candida albicans,* and *Legionella* sp. were carried out according to standard methods (Burkhardt, 1992). For counting of aeromonads, samples were plated on Ryan agar (Oxoid CM 883). After incubation at 37°C, green, opaque colonies with a black centre were counted. Gram-negative, facultatively anaerobic isolates showing cytochrom c-oxidase activity were designated “mesophilic aeromonads”. In preliminary investigations, the plating media used by Havelaar *et al.* (1990) and Schubert (1987) were used in parallel, and the *Aeromonas* counts obtained were similar. *Aeromonas* strains isolated were further characterized by streaking them on blood agar (Oxoid CM 55 with 5 % defibrinated sheep blood) and on Kligler’s iron agar (Oxoid CM 33). Strains showing haemolysis and forming gas from glucose and hydrogen sulfide from thiosulfate were designated as presumptive *Aeromonas hydrophila.*

A total of 29 *Aeromonas* isolates were tested for the presence of the aerolysin gene, a virulence factor widespread among aeromonads (Granum *et al.,* 1998). For this purpose, the PCR-based method of Ben Kingombe *et al.* (1999) was used with modifications (cf. Bullermann *et al.,* 2001).

Experimental results

The mean initial organic load of the unprocessed greywater was 111 mg BOD_5 (range: 42-350 mg BOD_5/l), 225 mg COD, and 129 mg TOC per litre. The greywater neither contained salmonellae nor legionellae, and opportunistic pathogens from human skin (*Staphylococcus aureus, Candida albicans*) were only present in 42 and 9 % of the samples, respectively (Table 1). However, median levels of coliforms were about 10^5, of *Escherichia coli* about 10^4 and of enterococci about 10^3/ml. These levels are comparable to those reported by Casanova *et al.* (2001) and Ottosson and Stenström (2003). The aerobic treatment of the greywater in a rotary biological contactor reduced these counts by about 2-3 log cycles, and BOD_5 to 1.5 mg/l (arithmetic mean from 152 determinations; a BOD_5 of 6 mg/l was never exceeded; see Table 2), and almost completely eliminated *S. aureus* and *C. albicans*. Subsequent UV treatment reduced microbial counts further: the median levels of coliforms, *E. coli, Pseudomonas aeruginosa* and enterococci were below 1/100 ml. In almost all cases, the microbial levels were below the maximum tolerable levels given in EU Directive 76/160 on the quality of recreational waters (Anonymous, 1976) and below the recommendation for maximum tolerable levels specified by the Senator für Bauen und Wohnen, Berlin (cf. Nolde, 1999) (Tables 3-4). The biological treatment reduced the median levels of aeromonads by two log cycles to about 10^3/ml. At any sampling site between UV treatment and the users, counts were between 3 and 12/ml, and no re-growth of aeromonads or any other microbial group in the water distribution system was observed (Table 5). *Aeromonas* was also detected in 14 of 44 samples of drinking water, and 64 of 67 samples of recreational waters, respectively (100 ml sample volume). The arithmetic means were 0.04 and 39 CFU/ml, respectively, maximum levels were 0.64 and 150 CFU/ml, respectively.

Of the 29 *Aeromonas* strains tested, 25 were found to contain the aerolysin gene, commonly considered as virulence factor.

Microbial group	Sample size (ml)	Numbers of positive samples/total samples at site P1	P3	P4	P5
Salmonella	100	0/49	0/61	Not determined	Not determined
Salmonella	1.000	Not determined	Not determined	0/53	0/60
Candida albicans	0.1	4/48	0/92	0/71	0/77
pathogenic legionellae	0.1	0/33	0/84	Not determined	0/77
pathogenic legionellae	10	Not determined	Not determined	0/66	0/72
Staph. aureus	1	21/50	12/92	2/69	0/76

Table 1: Prevalence of pathogens in the greywater reclamation and distribution system

Parameter	Number of samples	Arithmetic mean	Standard deviation	Maximum
BOD_5 (mg/l)	111	1.5	1.1	6.0
COD (mg/l)	117	15.3	1.1	37.3
TOC (mg/l)	57	10.7	5.4	28.8

Table 2: Organic matter in greywater after biological treatment (sampling site P3)

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	Parameter					
	Escherichia coli			**Coliforms**		
Sampling site	No. of samples	Median	Maximum	No. of samples	Median	Maximum
P3	145	10^3-10^4	≥10^4	146	10^3-10^4	≥10^4
P4	143	<1	10-99	138	<1	≥10^3
P5	151	<1	10-99	145	<1	≥10^3
W1	63	<1	1-9	63	<1	≥10^3
W2	65	<1	1-9	65	<1	10^2-10^3
Official maximum level for recreational waters[1]			2 x 10^3			10^4
Recommended maximum level[2]			10^3			10^4

[1]Anonymous, 1976; [2]Senator für Bauen und Wohnen, Berlin, 1995 (cf. Nolde, 1999)

Table 3: Levels of *Escherichia coli* and coliforms per 100 ml of processed greywater before (sampling site P3) and after UV disinfection, compared to standards

	Parameter					
	Faecal enterococci			***Pseudomonas aeruginosa***		
Sampling site	No. of samples	Median	Maximum	No. of samples	Median	Maximum
P3	138	10^1-10^2	≥10^4	142	<1	10^2-10^3
P4	144	<1	10^3-10^4	93	<1	10^1-10^2
P5	152	<1	10^1-10^2	94	<1	10^1-10^2
W1	63	<1	10^1-10^2	63	<1	10^1-10^2
W2	65	<1	10^1-10^2	65	<1	10^1-10^2
Official maximum level for recreational waters[1]			10^2			Not specified
Recommended maximum level[2]			10^3			10^2

[1]Anonymous, 1976; [2]Senator für Bauen und Wohnen, Berlin, 1995 (cf. Nolde, 1999)

Table 4: Levels of faecal enterococci and *Pseudomonas aeruginosa* per 100 ml of processed greywater before (sampling site P3) and after UV disinfection

Sampling site	No. of samples	Median	Arithmetic mean	Maximum	Geometric mean x_g	S_g*
P3	149	1,000	3.4 x 10^4	1.6 x 10^6	1.6 x 10^3	1.2
P4	145	6	30	1.1 x 10^3	5	1.0
P5	154	12	6.3 x 10^2	8.3 x 10^4	9	1.2
W1	64	3	11	2.4 x 10^2	2	1.0
W2	65	4	11	1.7 x 10^2	2	1.0

*S_g = log (standard deviation of geometric mean)

Table 5: Levels of mesophilic aeromonads (CFU/ml) in processed greywater before (sampling site P3) and after UV disinfection

Risk assessment

To assess the risk due to use of processed greywater, it is necessary to identify the hazards, to assess the exposure of the users to these hazards, to characterize the hazard with respect to dose-response relationship and severity of the disease, and to verify the risk assessment in the light of epidemiological data (Codex Committee on Food Hygiene, 1999).

Hazard identification

The microbiological data indicate that the risk from pathogenic yeasts, legionellae and salmonellae in greywater is very small, even if the users are accidentally exposed to raw, unprocessed greywater. Salmonellae and shigellae have been shown to die off during incubation of inoculated raw greywater (Rose *et al.,* 1991). Likewise, salmonellae died off in raw greywater sediments (Ottosson and Stenström, 2003), and Nolde (1999) reported that salmonellae, *Candida albicans* and legionellae did not persist in greywater. In the present study, these organisms were not detected at all after biological treatment. A few samples of treated greywater still contained *Staphylococcus aureus* in very low numbers but this organism is unable to compete in water and biofilms (Dott and Thofern, 1980). Hence, only pathogenic *Escherichia coli* and *Aeromonas* strains, and enteric viruses are considered further.

Exposure analysis during intended use of reclaimed greywater (for toilet flushing)

The exposure analysis was based on the arithmetic means of the bacterial counts in greywater at the point of use (i.e. treated biologically and by UV). Data like „positive in 10, negative in 1 ml" were entered as 50 cells per 100 ml. The levels of "pathogenic aeromonads" were assumed to be 50% of the total count of mesophilic aeromonads found in this study. This assumption is based on the characteristics of the strains isolated: About 50% of the isolates were tentatively identified as *Aeromonas hydrophila,* and of these, about 90% were found to contain the aerolysin gene. The amount of water per toilet flush was assumed to be 6 litres. According to these assumptions, the average bacterial load in 6 litres of processed greywater was

- 800 cells of coliform bacteria, comprising 80 cells of *E. coli*
- 120 cells of faecal enterococci
- 60 cells of *Ps. aeruginosa*
- 37,000 cells of *Aeromonas* spp. containing genes encoding for aerolysin

From the data of Gerba *et al.* (1975) und Wallis *et al.* (1985), Lücke (1998) calculated a probability of 10^{-7} for a bacterial cell to escape from the toilet bowl. From this assumption, it may be estimated that only in one of 270 flushings, a potential pathogenic *Aeromonas* cell reaches an area where it may contaminate the user. Obviously, the probability that this cell infects the gastrointestinal tract or wounds is much lower. For the other bacterial groups mentioned, exposure is at least two orders of magnitude lower, and since these bacteria are present in faeces anyway, the relative contribution of the flushing water to the total exposure is negligible. Therefore, coliform bacteria, *E. coli*, faecal enterococci and *Ps. aeruginosa* are not considered further in this risk assessment.

From the arithmetic mean of *Aeromonas* counts in drinking water in this and other studies (Gavriel *et al*., 1998; Havelaar *et al*., 1990; Knøchel and Jeppesen, 1990; Mascher *et al*., 1988; Rusin *et al*., 1998), an average daily body exposure to about 1,000 cells of water-borne aeromonads may be estimated. In addition, aeromonads are present in many foods. If one simplistically assumes that the exposure is entirely caused by the ingestion of raw vegetables, the average daily uptake of 50 g of such food containing 10 *Aeromonas* cells per gram (data of Mattick and Donovan, 1998, and Neyts *et al.*, 1998) will add 500 *Aeromonas* cells to the daily exposure. This exposure is not considered as relevant to health (Mattick and Donovan, 1998).

So far, the risk from enteroviruses possibly present in greywater cannot be assessed with certainty. Casanova *et al.* (2001) did not find coliphages in raw greywater while Ottosson and Stenström (2003) found, on average, about 2.000 coliphages per 100 ml of greywater. It is still controversial whether coliphages are a suitable indicator for the presence of enteric viruses (Leclerc *et al.*, 2000).

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Exposure analysis considering risks due to system failures or use of the reclaimed greywater for purposes other than toilet flushing

After a few problems in the set-up phase, the reclamation system studied worked effectively and reliably. Failure of the rotation biological contactor would easily be noticed because of offensive smell. Failure of the UV disinfection unit would raise the load of hygienically relevant bacteria by about 1-2 log cycles. This risk can be easily eliminated if the pump supplying processed greywater to the users is automatically stopped at lamp failure or at UV transmission values below a threshold level. Such a control device is part of the system described.

The system studied is best suited for use in multi-storey residence buildings and hotels, where supervision by the administration of the facilities is available. If water of drinking water standard is available, there is little incentive to manipulate the system in a way leading to contamination of tap water, and it is unlikely that any party deliberately uses greywater for drinking and personal hygiene, i.e. for purposes other than toilet flushing.

Aeromonas infections: Dose-response relationship, severity of the disease, epidemiological data

Pathogenic *Aeromonas* strains have been described as agents of diarrhea and would infections, in particular in risk groups such as small children (von Graevenitz and Altwegg, 1991; Merino *et al.,* 1995). Based on examination of faecal samples from patients with diarrhea, the percentage of cases of diarrhea due to *Aeromonas* was estimated to be 0.6% in The Netherlands (Kuijper and Peeters, 1991), and 0.2% in the United Kingdom (PHLS, 2003). All of 3 well-documented outbreaks of *Aeromonas* gastroenteritis were caused by the ingestion of seafood containing high levels of aeromonads (cf. Palumbo *et al*., 2000). Feuerpfeil and Schulze (1992) reported on an outbreak caused by drinking water gained from a reservoir with algal bloom and a high level of aeromonads, and indicated that oral uptake of 10^2-10^4 *Aeromonas* cells may cause diarrhea in susceptible individuals. On the other hand, von Graevenitz and Altwegg (1991) were unable to elicit diarrhea in volunteers by feeding them much higher numbers of aeromonads. If diarrhea occurrs, it is normally self-limiting and mild. There is no evidence that aerosols containing aeromonads are of public health significance (von Graevenitz and Altwegg, 1991). In summary, *Aeromonas hydrophila* is not a particularly hazardous organism.

A risk assessment of the presence of *Aeromonas* in natural mineral waters was performed by the Scientific Committee on Food (1998) at the European Commission. It was concluded that the risk is negligible and does not justify the introduction of an official limit for the levels of these bacteria.

Conclusions

Greywater that has been subjected to a biological reclamation process in a properly run rotary biological contactor, and to sanitation by UV, can be safely used for toilet flushing because the additional exposure of the users to micro-organisms of hygienic concern (including *Aeromonas hydrophila*) is negligible. However, the occasional survival of enteric viruses in greywater recycling systems cannot yet be ruled out and deserves further study.

In dry areas and/or in developing countries, dry toilets and the use of recycled greywater (bioprocessed to BOD_5 of 5 mg O_2/l or below) for personal hygiene and laundry purposes could be combined. However, the transfer of intestinal or skin pathogens between households via recycled water should be avoided. UV disinfection is efficient but has drawbacks in terms of costs and availability of replacement lamps; in the reclamation system studied, total costs for UV disinfection were about 200 € per year.

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Chances and risks of sustainable sanitation (SuSan) in Europe

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Keywords

Sanitation, source separated treatment, sustainability, hygiene, bathing water, climate change

Session D

Abstract

Infrastructural systems should comply to the ecological and socio-economic requirements of a sustainable development. This is rarely the case for the common water dependent sewerage system in Europe. Sustainable Sanitation Systems (SuSan), a wider concept of Ecological Sanitation including social and economical aspects, not only applies the principle of separate treatment of wastewater streams and thus facilitates an economical use of energy and water, respectively the recycling of important nutrients. It will also - due to a significant reduction in hygienic pollution - make possible high grade uses of rivers and brooks as bathing water in the future.

Introduction

Despite the fact that sewerage infrastructure is as important as traffic or communication infrastructure for the society to function smoothly, there is nearly no public discussion about it. The sewerage systems are hidden in the underground of our cities and towns and new technological developments in sewerage infrastructure – like membrane technology - come to public mind with a considerable delay compared to mobile telephones in communication or fuel cells in traffic.

Water dependent sewerage is not sustainable

The classical sewerage system of central Europe is the answer to problems of the beginning 19th century. In those days the growing and ever more densely populated cities caused a close neighbourhood of wells and latrines. The result of this small "urban water cycle" was the poisoning of drinking water by faecal microbes leading to heavy epidemic diseases like cholera and typhus. At that time the revolutionary flushing of mud and sewage meant an enormous improvement in urban hygiene indeed at the cost of river quality. Until today the system for river pollution protection consists of purification plants to reduce pollutants and nutrients, and rainwater treatment systems to reduce the effects of combined sewage overflows (fig. 1).

Actually membrane filtration systems and nutrient recovery from the sewage sludge are discussed as the next steps of a yet more refined end-of-the-pipe technology. Despite all these progresses the conventional sewerage system can not be regarded as sustainable because of the reasons given in Tab. 1.

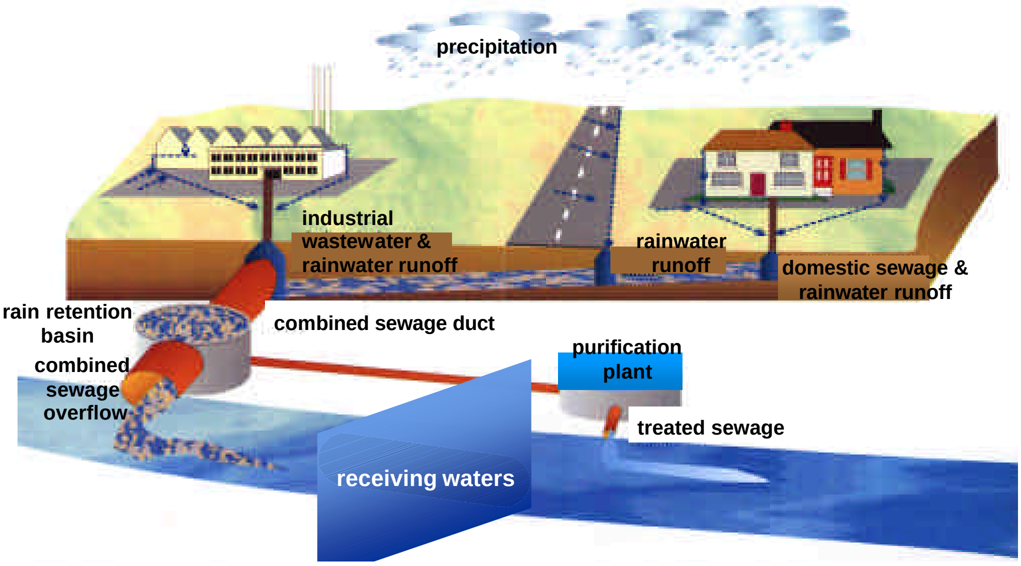

Figure 1: Combined sewerage system during precipitation

1) Ecological reasons: ➢ High demand of fresh water (not sustainable in regions with water scarcity) ➢ Energy demand for construction of sewers and purification plants (concrete production, earth movements) ➢ Energy demand for running the purification plants (pumping, aeration, denitrification, burning of sewage sludge) ➢ Pollution of ground water by defective sewers ➢ Pollution of streams and rivers by incomplete clarification in purification plants ➢ Pollution of streams and rivers by combined sewage overflow (fig. 2) 2) Economic reasons: ➢ High investment and running costs ➢ Disintegrated systems for sewage and solid waste 3) Social reasons: ➢ Unequal distribution of financial burdens regarding countryside and city population ➢ Unequal water treatment requirements for upstream and downstream water users ➢ Hygienic pollution of streams and rivers

Table 1: Reasons for the non-sustainability of the current sanitation system.

With regard to these sustainability deficits, the Deutsche Forschungsgemeinschaft states: There are justified doubts about the resource efficiency and sustainability of today's water management for settled areas. Accordingly, the resource efficiency of existing and alternative systems should be reviewed and improved [Deutsche Forschungsgemeinschaft 2002].

As a consequence of hygienic pollution, swimming is not allowed in nearly all German rivers – some examples: In the state of North-Rhine Westphalia at the moment no watercourse is open as bathing water [Overarth et al. 2001]. The capital of the state of Bavaria, Munich, had to close down river baths in 1998 because of hygienic risks. In the meantime, the strategy is to treat outlets of upstream purification plants by disinfection via UV.

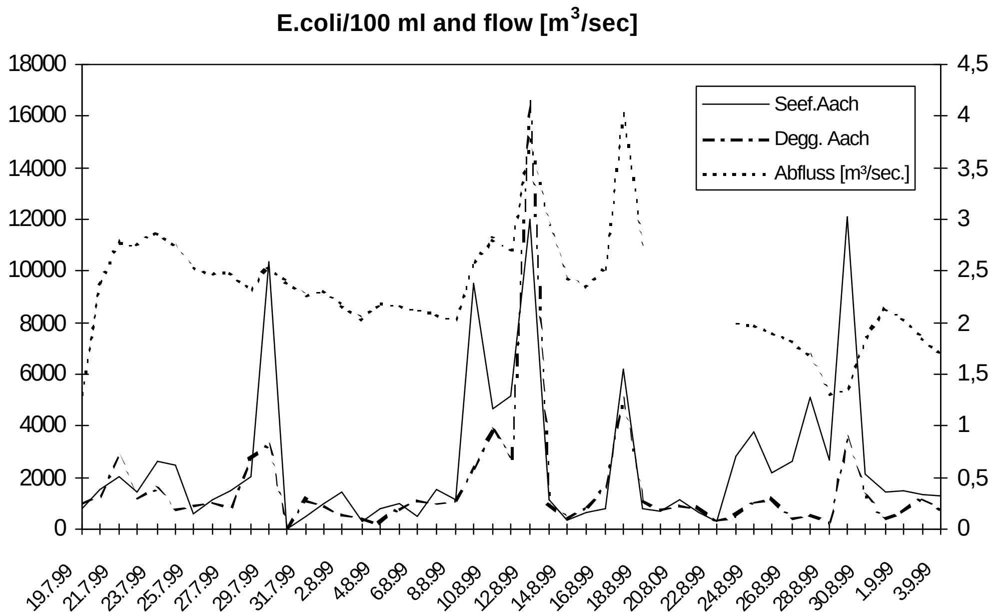

Figure 2: E.coli as a function of overflow – Flow of two brooks (m³/sec) in a 6 week period in summer 1999 and rise of the E.coli concentrations (per 100 ml) as a consequence of combined sewage overflow events caused by rain events. [Güde et al. 2000].

Actual results for the river Neckar in the state of Baden-Württemberg show: On the basis of the European Union guideline on the quality of bath waters and the bath waters regulation of the state of Baden-Württemberg thus none of the examined places from the Schwarzwald-Baar district to the Rhine-Neckar region possesses the demanded bath water quality (fig. 6).

Characteristics of SuSan

SuSan or Sustainable Sanitation has to meet the needs of the present generation without compromising the ability of future generations to meet their own needs [WCED 1987]. This means that SuSan has to fit more requirements than ecological sanitation, because a sustainable development has to combine ecological, social and economic dimensions. Additionally any sustainable development on the regional scale has to take into account not only the needs of future generations (intergenerative aspects) but also the needs of present neighbours (intragenerative aspects). Because of long time spans for their regeneration, groundwater and the oceans reflect the aspect between different generations, streams and rivers the aspect of the same generation (upstream/downstream antagonism) see fig. 3.

The requirements to sustainable sanitation systems are collected in tab. 2.

To meet the mentioned requirements, SuSan-technologies have to pay attention to specific local or regional situations. This means the system will probably differ between rural and urban situations or between water rich regions and regions under water scarcity. They do not automatically lead to decentralised concepts but there are some arguments for a decentralised or semi-centralised design.

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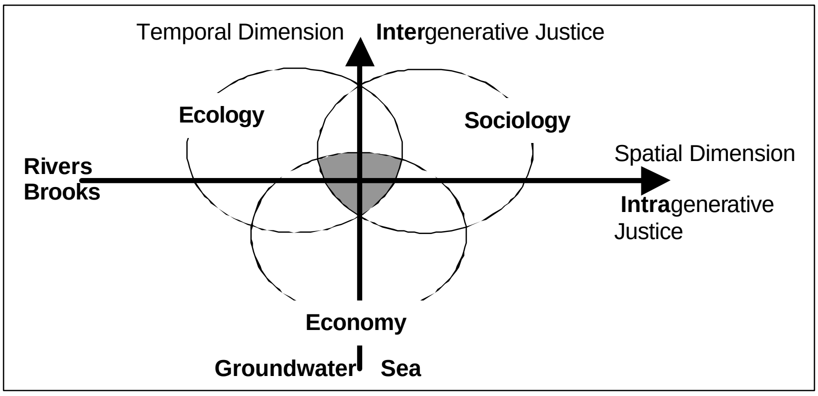

Figure 3: Crosshairs of sustainability.

<u>In ecological respect</u> ➢ Prevention of eutrophication of the sea (e.g. loss of nutrients) ➢ Prevention of high material and energy flows (as long as based on non-renewable resources ➢ Clean waterbodies <u>In socio economic respect</u> ➢ Dry and hygienic settlements ➢ Comfort equally high to current sanitation system ➢ Internalisation of toxic and hygienic risks ➢ Prevention of linear material flows (e.g. loss of nutrients to the sea) ➢ Preferably avoidance of unflexible systems with high capital lockup ➢ Minor vulnerability to possible acts of war/terrorism und natural disasters ➢ Exportability of the technology

Table 2: Requirements to a modern, sustainable sanitation system

SuSan and water saving strategies

In many cases sustainable sanitation technologies and water saving strategies are coupled in mind. As it can be seen in fig. 4, the amount of available water per capita differs widely in the countries of Europe.

Does it make sense to stress drinking water saving options all over Europe? In deed: low consumption conserves heavily extracted water resources. On the other hand it can mean long periods of stagnation in the pipes. In the long run either a new drinking water pipe work with reduced dimensions, or distribution of bottled drinking water could be the consequence. In these cases a new system for water supply for fire fighting has to be found. Because of the fact that 80-90% of costs for the water distribution system are fixed costs, water saving will often lead to higher specific prices per cubic meter. One result could be that the costs for drinking water will not decrease absolutely.

Less consume of water and/or increasing amounts of rainfall due to climate change have lead to rising ground water tables in some regions of Germany. Settlements placed in areas with artificially lowered ground water tables as a result of high extraction rates now are at risk to get damaged by rising ground water as examples in Berlin or the metropolitan area of Frankfurt-Mannheim show. It is therefore obvious that the different natural preconditions in Central, Eastern and Southern Europe advise different solutions regarding water saving.

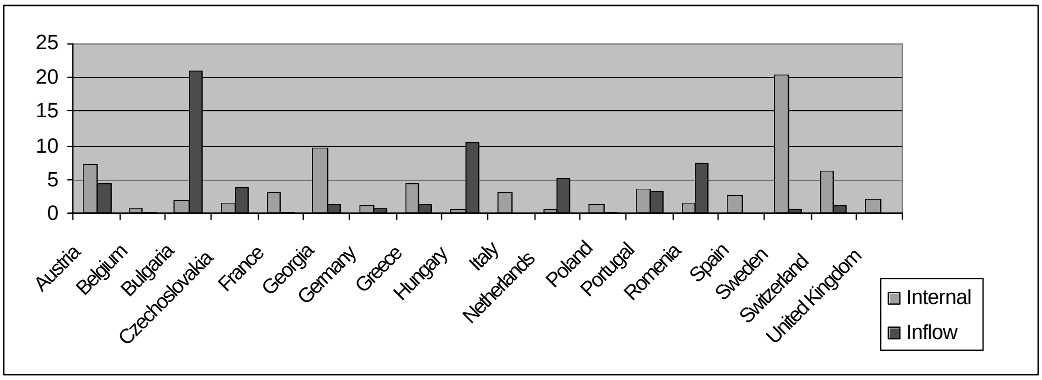

Figure 4: Water availability in Europe (1000 m³/capita*year) [based on WRI 1995

One essential element of sustainable sanitation systems is the separate treatment of different types of wastewater. Usually three steps of separation are discussed:

1. Separation of rainwater (storm water)

For parts of Southern and Eastern Europe the main advantage of keeping storm water from the combined sewage is saving drinking water by use of storm water in households, hotels and industry. Typical uses are: irrigation, washing of clothes and flushing the toilets, washing cars and trucks. In the meanwhile the technology for rainwater use is well developed and designed [fbr 2001].

For most regions of Central Europe the substitution of drinking water by rain water is no urgent topic as far as the point of water resources is concerned (see above topic water saving). The main advantage is to avoid dilution of sewage. If sewage is more concentrated, hydraulic dimensioning of purification plants can be optimised, the sewers can be constructed in smaller dimensions and combined sewage overflow can be reduced or avoided completely. This would be the first step reach a more hygienic situation in streams and rivers. Runoff from agricultural land with animal husbandry should also be taken into account, though. Storm water infiltration can strengthen the problems of rising ground water levels (see above) and bear the risk of ground water pollution due to its often higher concentrations of some heavy metals (tab. 3) stemming from rain water contact with material of roofs or pipes.

Parameter	**Separate sewerage system** Rainwater sewer	**Combined system** Combined sewer
COD [mg/l]	47 – 120	**176 – 720**
NH_4-N [mg/l]	0,1 – 4,0	**0,1 – 17**
PO_4-P [mg/l]	0,3 - 1,7	**3,0 – 4,3**
Settleable Solids [mg/l]	7 – 446	327 – 758
Lead (Pb) [µg/l]	**20 – 422**	12 – 213
Copper (Cu) [µg/l]	**10 – 235**	27 – 136
Cadmium (Cd) [µg/l]	**5 – 16**	0,7 – 4,7
Zinc (Zn) [µg/l]	**610 – 6100**	411 – 1430

Table 3: Range of concentrations of important wastewater carried substances in separation and combined systems [Fuchs 2000]

Seepage of storm water from roofs therefore should be only allowed if there is a control of used materials and/or if a pre-cleaning is guaranteed. Cisterns can be integrated in such a pre-cleaning concept because heavy metals often are bound to suspended matter and thus can be retained in the sludge of the cistern. If the cistern is well dimensioned the retention of storm water in settled areas can be enhanced and minor to middle-size flooding events mitigated.

In consequence separate treatment of rain water in southern Europe is more an instrument to save drinking water. In Central Europe the focus is optimisation of sewage management and reduce pollution of ground and surface water.

2. Separate Treatment of grey water

Grey water from showers, bathtubs, and hand basins or from washing machines and automatic dish-washers is relatively low polluted – compared to sewage from the toilets. In Central Europe a separate treatment in reed bed filters or immersed rotating disc plants often is sufficient for subsequent seepage into the soil or for direct introduction to surface waters.

Similarly to the case of a separate treatment of storm water separate grey water treatment is also a means to reduce hydraulic burden of treatment plants. Yet some questions are not answered completely: For example the rising amount of water soluble paints will lead to an increasing amount of water soluble residues from paint-brushes and other equipment in the grey water after restoration of houses etc. At the moment it is not known whether treatment technologies will be able to destroy or take out all the components of paints and other chemicals which can enter in the grey water.

In parts of Southern and Eastern Europe recycling of grey water can contribute to the saving of drinking water. Typical use of recycled grey water is irrigation and flushing of water closets, but also in washing machines.

3. Treatment of black water

After separating storm and grey water so called black water from WCs is the remaining fraction of a household. Black water contains ~ 97 % of nitrogen, 90 % of phosphorous and 66 % of potassium in the total waste water of a household. This means the overwhelming percentage of the central agricultural nutrients of a household's waste water is concentrated in less than 1 % of the household's waste water volume. Because of the fact that relevant aspects of *closing the nutrient cycle* and agricultural implications are discussed in the contributions to session C and F of this conference, we will not deepen this aspect here. Black water treatment can help to get praiseworthy fertilisers in regions with nutrient scarcity. In regions with abundance of nutrients additional nutrient supply from black water treatment does not seem to face the main ecological problems. In contrary we suppose that in those regions the outlet of new types of fertilisers is very uncertain.

While traditional wastewater treatment plants *consume considerable amounts of energy* (~ 1/5 of municipal energy demand), treatment of separated black water offers the chance to use its energy content by the production of biogas [Nicklas 2002, Nicklas and Lehn 2003]. Biogas can be used for cooking and heating, or co-generation of electricity and heat, and thus reduce dependency on fossil resources like oil. Depending on the local situation (transport distances, water consumption, fertiliser substitution potential etc.), a positive energy balance can be obtained through separate black water treatment.

The third advantage of separate treatment of black water is preserving streams and rivers from contamination by faecal microbes. As shown above *hygienic pollution of surface waters* resulting from urban sewage treatment is the main reason for the low quality of European surface waters for leisure time purposes (swimming, sailing, canoeing, etc.).

Sustainable Sanitation, wellness and sports

In our days sports for the public at large and wellness are seen to be great social values and therefore general conditions for these leisure time purposes play an increasing role in the ranking of regions based on their attractivity. This refers to tourist regions as well as to regions with highly qualified jobs. For long, the quality of water bodies has played a major role for the popularity of regions as the region around Lake Constance in Southern Germany shows – see fig. 5.

Therefore sustainable sanitation could become a central factor within the development towards a higher quality of life. It offers the chance to get economic advantages when regions are competing for residents or tourists.

Figure 5: River baths in Stein am Rhein (Switzerland) [Photography H. LEHN]

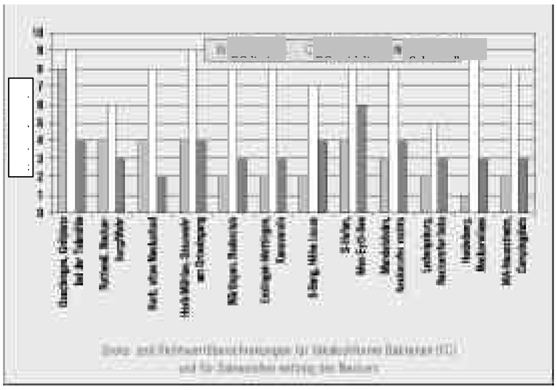

Figure 6: Overstepping of limit and guide-line values for E. coli (EC) and salmonellae along the river Neckar [Landesgesundheits-amt Baden-Württemberg 2002]

In particular for the tourist regions in Southern and Eastern Europe sustainable sanitation could combine the solution of different tasks: it makes a notable contribution to water saving, is the central precondition for hygienic water bodies, is a source of renewable energy independent of weather conditions to cover the base load, yields fertiliser, is less vulnerable to terrorism and natural catastrophes and offers the chance to establish a completely new designed infrastructure for sewage which can be adapted in the future to changing needs.

Sustainable sanitation and the climate change

Climate change is increasingly leading to extreme Situations: On average the summers will be dryer but include partly heavy downpours. Winters will be milder but with increased precipitation, the latter rather in the form of rain than snow. [Rapp and Schönwiese 1996]. One consequence will be that the dryer summers lead to lower water levels of rivers, partly due to decreased or timely more focused summer precipitation, partly due to the shrinking of glaciers. The associated reduced diluting capacity of rivers will pose higher purification requirements for wastewater treatment plants. Heavy showers in summer will on the other hand increase combined sewage overflows and, depending on sewage pipes slopes, will mobilise settled residues from dry weather periods, washing them into rivers. As climate change will probably extend the period in which bathing is possible in Central Europe, it could turn water sports more attractive to the people. Changes in winter will have the overall consequence of more frequent and intense overflow incidents.

Sustainable sanitation can contribute to overcome these challenges posed by climate change: water savings can reduce pressure on already stressed water resources, sewage overflows can be avoided, and biogas production can yield renewable energy to help slow down climate change.

Conclusions

A wide range of ecologic and socio-economic arguments is in favour of the development and testing of new forms of urban water management, with the aim of integrating them in the societies´ infrastructures. The climate induced changes in the European water balance make it seem sensible not to wait any longer. The conclusions of the Johannesburg Conference 2002 show that an improvement of the hygienic situation of water bodies is very urgent worldwide. Sustainable Sanitation techniques in Europe could make a significant contribution to this and also constitute a relevant export factor.

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Survival of faecal indicators and bacterial and parasitic pathogens in source separated human urine

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Keywords

Urine separation systems

Introduction

In urine separation systems, faecal contamination of the urine and hence the presence of faecal pathogens is a likely event. A relatively high pH (9) as well as temperature, dilution and storage time are factors that are considered to affect the concentration and survival of pathogens in a urine solution. Previous investigations concerning the presence and survival of pathogens in source separated human urine have mainly been laboratory studies. The aim of this study was therefore to monitor the occurrence and die-off in human urine of indicator bacteria and bacterial and parasitic pathogens during field conditions and, in addition, to study the die-off of selected bacterial pathogens in laboratory experiments.

Methods

Urine samples were collected from recently sealed collection tanks at four different urine separating sewage systems in Denmark from October 1999 to June 2000. The sites included: two housing areas, Hyldespjaeldet (Hy) and Hjortshoj (Hj), a museum with public separating toilets, Mons Museumsgaard (MM) and Kolonihaveforeningen (Ko), an area with weekend cottages without an existing sewage system, but with small urine collection tanks (approx. 20 L). The parameters analysed in the field survies were total viable counts at 37°C, enterococci, *E. coli*, *Salmonella* and *Campylobacter*.

Urine for survival studies in the laboratory was collected from Hy and stored at 7°C and 20°C during the experiments. The survival of the following bacterial pathogens was studied: *Salmonella typhimurium*, *Salmonella enteritidis*, *Campylobacter jejuni*, *Vibrio cholerae* O1, *Vibrio parahaemolyticus*, *E. coli* O157:H7, *Shigella flexneri* and *Shigella dysenteriae*.

Results

In most collection tanks, total viable counts at 37°C were reduced to below the detection level of 100 cfu/ml after 2-4 months of storage, although a slight increase in counts was detected from April to May 2000 during the final two months of the sampling period at sites MM and Hy. Enterococci were found at an average concentration of 7.4 x 10^4 cfu/ml at the first sampling and were reduced to below the detection level of 10 cfu/100ml in all urine tanks after 2-4 months of storage (Figure 1). One exception was at site Hj, where there was no reduction numbers of enterococci during the sample period. The bacterial pathogens, *Salmonella* og *Campylobacter*, were not detected in any urine samples.

All pathogenic bacteria in the experimental studies were reduced in numbers below the detection level of 10 cfu/ml in less than 20 days. Viable and infective (mouse model) *Cryptosporidium parvum* oocysts were found in low numbers at some of the locations during the study, indicating survival of oocysts even after 6 months of storage. However, the quantification of *C. parvum* oocysts was associated with great uncertainties.

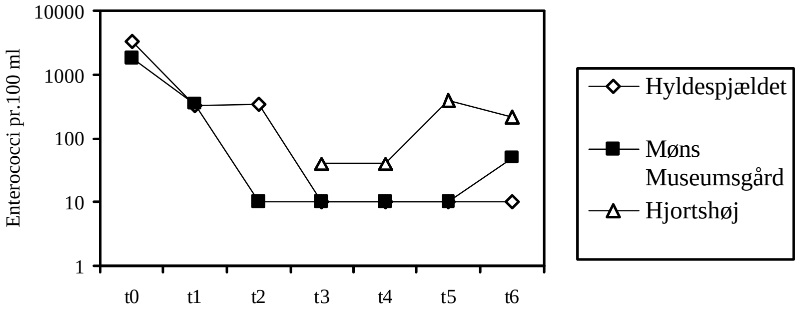

Figure 1: Numbers of enterococcci measured at monthly intervals (t0-t6). The y-axis is logarithmic. Measurements below the detection level of 10 bacteria/100 ml were given the value 10

Conclusions

- The numbers of enterococci were reduced to below the detection limit (< 10 per ml) in the urine tanks after 3 to 4 months storage.
- A small increase in numbers of total viable counts at 37°C and enterococci after 4-5 months storage, suggests bacterial re-growth in the tanks.
- Viable and infective *C. parvum* oocysts appear to survive in urine storage tanks even after prolonged storage.
- In laboratory experimental survival studies, the numbers of all bacterial pathogens tested were reduced to below the detection limits of 10 bacteria per ml within a 20-days period.

Fate of estrogens in wastewater treatement systems for decentralised sanitation and re-use concepts*

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Keywords

Natural and synthetic estrogens, 17α-ethynylestradiol, DeSar-concepts

Session D

Introduction

Currently there is a growing concern about the occurrence and accumulation of pharmaceuticals, estrogens and xeno-estrogens in the environment (Derksen 2001a), (Vethaak et al. 2002). Accumulation can become a problem when waste streams are re-used, for example within Decentralised Sanitation and Re-use (DeSaR) systems.

Due to the large variety of pharmaceuticals and the proven estrogenic effect of treated sewage effluent on fish, 17α-ethynylestradiol (the main estrogenic compound used in oral contraceptives) is selected for research. The estrogenic effect of sewage is shown in Figure 1.

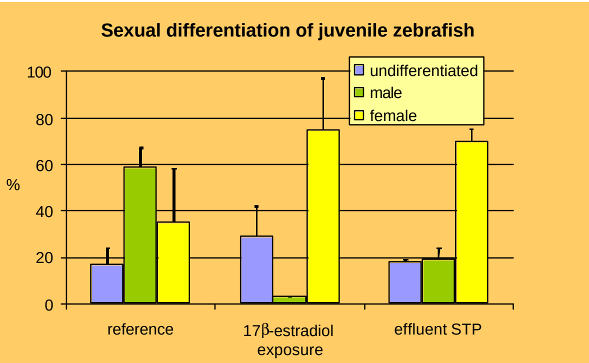

Figure 1: Sexual differentiation of juvenile zebrafish after exposure to a reference (tap-water), 17beestradiol and STP effluent. Adapted from: (Vethaak, Rijs et al. 2002)

In the Netherlands, 46% of the female population aged 16-49 years use oral contraceptives (CBS 2002). The compound is therefore highly prevalent and is expected to accumulate in the food chain. Three sterols were isolated in the effluent of domestic sewage treatment plants (STP) and identified as the prime contributor to the estrogenic character, comprising of the natural hormones 17β-estradiol (E2) and estrone (E1) and the synthetic hormone 17α-ethynylestradiol (EE2) (Desbrow et al. 1998). A direct correlation between the concentration of natural hormones and a yeast bioassay also indicates this (Onda et al. 2002). Although the natural hormone estriol (E3) is 300 times less estrogenic than estradiol, it is not excluded from research at the current stage.

Natural hormones are primarily excreted in urine in a conjugated form, which do not exhibit estrogenic characteristics. Unconjugated hormones do exhibit estrogenic characteristics and are mainly excreted in faeces. Intestinal bacteria, such as Faecal Coliforms, produce enzymes that can hydrolyse conjugates to their original unconjugated forms, which is also likely to happen in STPs. Estrogen conjugates, can be cleaved into 17β–estradiol, as found in batch experiments using activated sludge (Ternes et al. 1999a).

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Of 17α-ethynylestradiol, 35% of the daily dose (0.35 µg/day) is excreted in urine and a relatively large amount of 30% in faeces as a result of oral administration (Reed et al. 1972). The contribution of the total amount of ethynylestradiol to the total amount of estrogens excreted by humans is only about 1%, but this compound is considerably more persistent in STPs compared to natural hormones, as is shown in several studies (Vethaak et al. 2002;Desbrow et al. 1998;Ternes et al. 1999b;Ternes et al. 1999a; Layton et al. 2000). Due to the introduction of the ethynyl-group, the ring becomes extremely stabilised against oxidation.

There is a lack of information on how these compounds are removed in sewage treatment processes. They can be biodegradable and converted biologically, adsorbed to sludge, or inert and pass through a STP. Alternatively adsorption may be necessary to obtain a sufficient retention time needed to degrade the compound. It is expected that concentrations measured in Decentralised Sanitation and Re-use (DeSaR) concepts will be higher, due to a lower dilution rate of the wastewater.

Methods

Firstly, an estimation for the expected concentration of estrogens for different DeSaR scenarios was made based on literature values for the amount of estrogen excretion by humans. The different scenarios comprise of:

- blackwater collection,
- combined system for both blackwater and greywater collection,
- combined system including rainwater catchment,
- separate collection of urine and faeces.

For each scenario, the toilet type and therefore the amount of flushing water is changed. A conventional toilet uses 6-litres of water to flush urine and 9- litres for faeces. The water saving toilet will use 2-litres for urine and 4-litres for faeces. A vacuumtoilet uses around 0.5-litres for both urine and faeces. The calculations are also done for a toilet system with separate urine and faeces collection. A person is assumed to defecate once and urinate five times a day, where the volume of the faeces is 0.25 kg/day and of the urine 1.25 l/day.

The concentration of estrogens is calculated on base of the total excreted amount by the whole population, divided by the amount of wastewater this whole population would produce in the particular scenario. The contribution of different population groups is different as can be seen in figure 2.

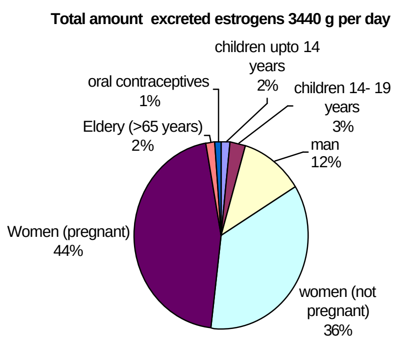

Figure 2: Contribution of different groups to total excreted human estrogens in the Netherlands (figure produced on data of: (Aherne and Briggs 1989), (Okkerman et al. 2001) and (CBS 2002) from: (Blok 2000)).

Results

The main route for excretion is via urine. Therefore highest values are expected in urine, using a separation toilet. Separation toilets are available which do not use any flush water for separate urine collection. The results are summarised in Table 1. Table 2 gives values of measured estrone, 17β estradiol and 17α ethynylestradiol concentrations in STPs influent and effluent.

Total ethynylestradiol and natural hormones (mg/l)	Conventional toilet	Watersaving toilet	Vacuumtoilet	Separation toilet
Blackwater	5.31	13.88	43.03	
Combined system	1.59	1.95	2.15	
Combined system (+ rain)	1.08	1.23	1.31	
Urine (no flush)	-			169.78
Faeces (4 l flush)	-			0.69
Urine (1 l flush)				33.96

Table 1: Estimated total estrogen concentrations for different scenarios.

		estrone (ng/l)		17b estradiol (ng/l)		17a -ethynylestradiol (ng/l)	
Ref.	Location	**E1 influent**	**E1 Effluent**	**E2 influent**	**E2 effluent**	**EE2 influent**	**EE2 effluent**
(Baronti et al. 2000) Italy	Cobis	71(35.48)	9.62 (5.14)	16.1 (7.47)	1.48 (1.02)	3.93(5.14)	0.64(0.31)
	Roma Sud	35.2 (9.63)	30.3(16.26)	8.6 (2.3)	1.89 (0.94)	2.95(2.08)	0.66 (0.37)
(Belfroid et al. 1999) Netherlands	A'dam-Westpoort	140	47	48	12	9.7	7.5
	Eindhoven	42	15	14	1.1	<0.2	<0.2
(Vethaak et al. 2002) Netherlands	Several plants	20-130	<0.4	17-150	<0.8	<0.3-5.9	<0.3-2.6

Table 2: Actual concentrations of estrone, 17β estradiol and 17α ethynylestradiol, measured in some STPs (standard deviation of data set in brackets)

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Discussion

Actual measured estrogen concentrations in STP influents and effluents for different estrogens are difficult to interpret, as there are no standardised methods for determination. In research projects, different equipment is used, with different sensitivity, differing sample sizes and therefore different detection limits. Table 2 also indicates different removal efficiencies for the different estrogens. It is also not clear if the estrogens are biodegraded, adsorbed to sludge or even vaporised. Also the degree of deconjugation at the entrance of STPs has not been quantified.

Separate collection of urine and faeces in DeSaR systems is seen as an advantage, as urine contains most of the nutrients and relatively low pathogens. There are even ideas of bringing urine on the land as fertiliser with only minor treatment. As there is no information on whether these estrogens may accumulate in the foodchain, it is recommended that an investigation be conducted to establish their fate during storage, treatment and on the land. In manure, similar concentrations can be measured for estrogens, higher concentrations have also been measured in the manure of gestating cows, typically between, 22-582 µg estogens/kg (Möstl et al. 1984), (Desaulniers et al. 1989) from: (Blok 2000). Cattle manure contains mainly natural estrogens and no EE2, like humans.

Still, separate collection of faeces and urine might reduce the complexity of the problem, as estrogens are concentrated mainly in urine. Every waste stream should have an appropriate treatment in order to reduce any possible risk.

Although the amount of estrogens produced by humans seems to be very small in comparison with animals, concentrations can be quite high locally, especially in case of separate urine collection. The eventual risk for accumulation and human and animal risks is not researched yet. But it has been done for fish.

For example the no-effect concentration for rainbow trout is 3 ng/l for both natural and synthetic hormones (Denneman et al. 1998). This means that a discharge on surface water should not increase the concentrations to this level.

Conclusions and further research

Further research emphasised on the fate of estrogens, especially the synthetic estrogen 17α-ethynylestradiol in DeSaR systems, is necessary to guarantee safe re-use of treated wastestreams.

There is little information of the fate of estrogens in STPs. So far, most data is collected on activated sludge systems by measuring influents and effluents. There is no information on the removal pathways, and no data is published for anaerobic treatment or sludge treatment. Therefore, during this research, the behaviour of EE2, E2 and E1 will be investigated at various oxygen conditions: Anaerobic-, aerobic-, micro-aerobic- and different physical/chemical treatment. The research includes adsorption experiments on different types of inactivated sludge, vaporisation of the components and the determination of metabolites formed during degradation. Actual concentrations will be measured and their potential impact on the environment ascertained, using a bioassay to identify any estrogenic effect after treatment. There are several potential bioassays available based on built-in genes which respond to estrogenic compounds by producing a protein or enzyme, leading to the production of light which can be measured using a spectrophotometer. The most appropriate method is still to be determined.

It is also of major importance to develop a good and reliable analytical method, which can be used at low concentrations. Regular quality control checks with spiked samples and inter-laboratory testing are seen as necessary measures to be able to draw the correct conclusions at the end of the research.

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Assessing the risks to groundwater quality from unsanitary well completion and on-site sanitation*

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Abstract

Water supply and the provision of sanitation require an integrated approach. Water quality surveillance consisting of water quality monitoring for thermotolerant coliforms (bacterial indicator of sewage contamination) and sanitary risk inspections in two urban areas of sub-Saharan Africa (Lichinga, Mozambique; Kisumu, Kenya) indicates that unsanitary well completion is a greater risk to groundwater quality of shallow wells than the proximity of latrines. Surveillance has highlighted the complex interaction of a variety of factors that affect groundwater quality (such as sanitary completion measures, sanitation, and population density). Use of surveillance tools, as demonstrated in this study, are important to ensure ECOSAN and other sanitation systems are fully meeting their prime objective of improving community health.

Introduction

Improvements in water supply (quantity and quality) and sanitation facilities can reduce the incidence of diarrhoeal disease and lead to both increased rates of child growth and a decline in child mortality rates (e.g., Blum and Feachem, 1983). These improvements, together with the practise of sound domestic hygiene practices (aided by enhancements to the quantity of domestic water supplies) are considered to interrupt the faecal-oral transmission of sewage-derived pathogens. Low-cost improvements in water supply and sanitation in the humid tropics commonly consist of untreated point sources of water (*e.g.,* hand-dug or hand-augered wells) and on-site sanitation (e.g. pit latrines). These rely upon conjunctive use of shallow subsurface both as a source of potable water and a repository of sewage. There is, therefore, concern that faecal-oral pathogen transmission can occur despite these low-cost improvements (Lewis *et al*., 1980) and so the employed form of sanitation is failing to fully meet its prime objective of protecting public health.

Faecal contamination of groundwater-fed water sources occurs directly, as surface sewage (discarded faeces, flooded latrine contents) enters wells via unsanitary (i.e., poorly protected) wellheads, and indirectly as pathogens in sewage deposited in the subsurface are transported by groundwater flow to the pumping well (ARGOSS, 2001). Wellhead protection areas or separation distances between groundwater-fed water sources and sewage facilities are intended to

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minimise the probability of contamination but these remain poorly defined and have not been rigorously imposed. Despite the risk of on-site sanitation to groundwater quality, the absence of improved excreta disposal facilities can often pose a greater risk to human health than indirect contamination of groundwater from sanitation (e.g., Howard *et al.,* in press). Furthermore, the lack of excreta disposal increases the likelihood of direct contamination of groundwater-fed water sources (*e.g.,* Howard *et al.*, in press). Moreover, the issue of sustainability is central to this debate as improved water sources that provide high-quality water but subsequently break down means people will be forced to return to unprotected sources. Water choices need to be based on more than simply water quality.

Hence, it is obvious that the concept of considering both water and sanitation in an integrated fashion is not a simple one. Simple tools are needed to quickly establish the interconnections between the two and such tools need to be feasible, even in the most resource-poor areas. These are needed, furthermore, to ascertain whether advances in sanitation, like ECOSAN, are successful in terms of protecting public health. In this paper, we examine the quality of untreated, water sources supplied by shallow groundwater and assess the risks to groundwater quality from on-site sanitation and poor sanitary well completion in two, urban areas of sub-Saharan Africa.

Methods

Water quality monitoring was conducted using the portable *Delagua* water testing kit (~US$1600). This is a robust, relatively low-cost method of assessing sewage contamination by analysing the concentration of thermotolerant coliform bacteria (TTC), commonly comprising *Escherichia Coli*. in water samples. Sanitary risk inspections are another useful tool and are recommended by the WHO and American Water Works Association. These inspections comprise a systematic logging of observable faults that may lead to the degradation of water quality by sewage (Lloyd and Bartram, 1991). Each fault is considered as one point on the sanitary risk inspection score. Coupling water quality monitoring with sanitary risk inspections is done in order: a) to identify possible causes of sewage contamination; b) to identify potential risks to groundwater quality; and c) to raise awareness among stakeholders as to the impacts of unsanitary conditions or practices on groundwater quality.

Study areas

The first study area is in Lichinga, northern Mozambique (13° 18‘S, 35° 15‘E). The town has a population of ~85,000 people and a small piped water system, though the main water sources consist of (i) sealed wells equipped with an imported handpump, (ii) unprotected *wells* without a concrete plinth and where water is collected by bucket and rope, and (iii) *protected wells* that have a windlass and a concrete plinth with a drainage channel. 59% of households with family wells in their yards had their latrines at what would be considered an unsafe from the water point (Breslin, 2001). Pit latrines are the most common sanitation type though ECOSAN systems have been introduced (Breslin, 2001). Concerns about the impact of sanitation on water quality led to a Water Aid-funded research project (from May 2002 to present) to try to map water quality in the town and understand the sources of contamination.

The second study area is located on the Migosi and Manyatta estates in Kisumu, Kenya (0° 30‘S, 34° 30‘E). Kisumu has a population of 400,000 with over 80% latrine coverage. The infant (under 1 year of age) mortality rate in Kisumu is 120/1000 while the Kenyan national average is 68/1000. Water is supplied via piped sources, street vendors and untreated groundwater. Water shortages are common. Migosi is a middle income area whereas Manyatta is a low-income district of Kisumu. In Migosi, 97% of houses have flush toilets but, due to water shortage and sewerage problems, 70% of the houses with flush toilets use pit latrines. Migosi has 349 pit latrines/km^2, 4 boreholes and 66 wells/km^2. Manyatta has 957 pit latrines /km^2, 321 shallow wells/km^2 and 0 boreholes (Pedley *pers. comm.* 2002). Research was initiated by the USEPA with the Robens Centre following the observation that heavy, seasonal, rains cause sewage to run freely contaminating drinking water wells. At present 60% of wells in Migosi and Manyatta remain unprotected. The data presented here was collected in March 2001. No water monitoring was in place prior to this study.

Results

The outcome of water quality monitoring and sanitary risk inspections from groundwater-fed water sources in Lichinga are presented in Figure 1. Protected wells and sealed wells generally demonstrate both lower TTC counts and sanitary risk scores than unprotected wells. The results from wells that plot outside the diagonal lines (e.g. those with high risk scores but low TTC counts) require further investigation (Lloyd and Bartram, 1991). A broad relationship between sanitary risk scores and concentrations of TTC (log scale) is observable. Reduction in sanitary risks would, therefore, be expected to lead to a decrease in the magnitude of contamination. The relative importance of each risk factor can also be statistically tested (Howard *et al*., in press, ARGOSS, 2001) to identify the main causes of contamination (Figure 2). This approach is also useful to investigate a common presumption that microbiological contamination of groundwater derives from poorly sited or constructed sanitation facilities (Melian *et al.*, 1999). Preliminary data from Lichinga show a strong association between unsanitary wellhead completion measures and the magnitude of sewage contamination (Figure 2). This is consistent with studies in Uganda (Howard *et al*., in press) and Guinea (Gelinas *et al.*, 1996).

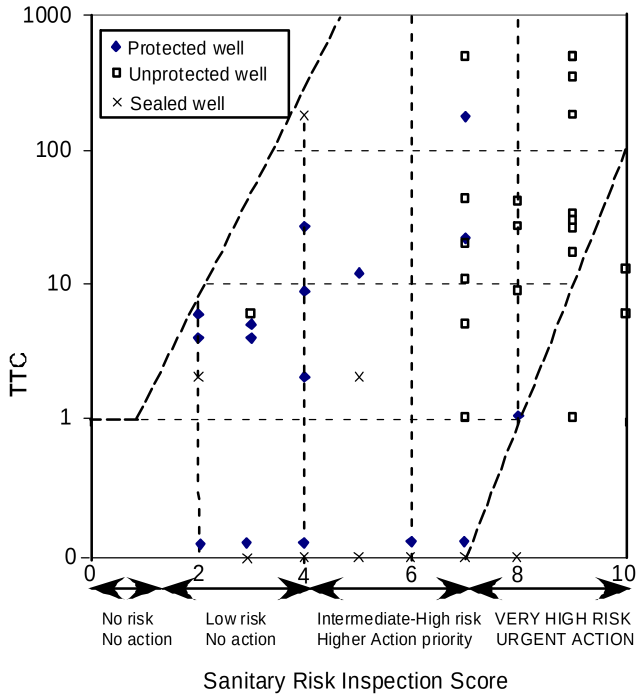

Figure 1: TTC (colony forming units/100ml) vs. sanitary risk score, Lichinga, n=54.

In Kisumu, an approximate trend (R^2 = 0.024) is observable between the magnitude of sewage contamination and sanitary risk (Figure 3). Most sites are, however, characterised by both high TTC concentrations and sanitary risk scores that are influenced by a higher population density than Lichinga though recent rainfall also raised counts. To investigate the influence of particular risk factors on the magnitude of microbiological contamination, the median observed TTC count

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was used to show the frequency with which a risk is associated with TTC counts above and below this value. Risks with the greatest positive % difference from the median TTC will be those that have the greater correlation with the magnitude of contamination. Table 1 shows the interpretation based on existing data and indicates that the greatest hazards relate to wellhead completion and specifically, the lack of adequate plinths and sealing of the upper well walls. The presence or absence of pit latrines within 10m does not seem to affect the magnitude of contamination reflected in TTC concentrations. Low-cost interventions such as digging drainage channels, constructing sloping concrete plinths, installing windlasses and keeping the bucket stored inside the well when not in use should reduce this problems of direct contamination via the wellhead. Lower, more acceptable TTC concentrations (e.g. Feachem, 1980) observed in protected (but unsealed) wells in Lichinga most likely arise from such interventions. It is important to note that the data from both study areas provide useful information on general *regional*

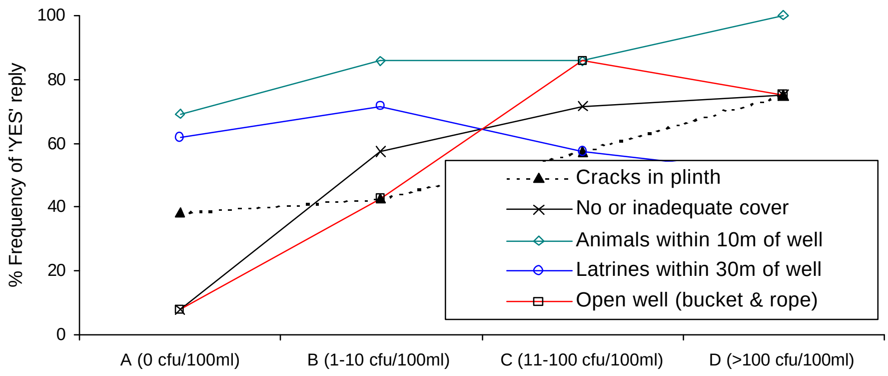

Figure 2: Frequency (%) of the most significant risks vs. TTC counts, Lichinga, (n=32)

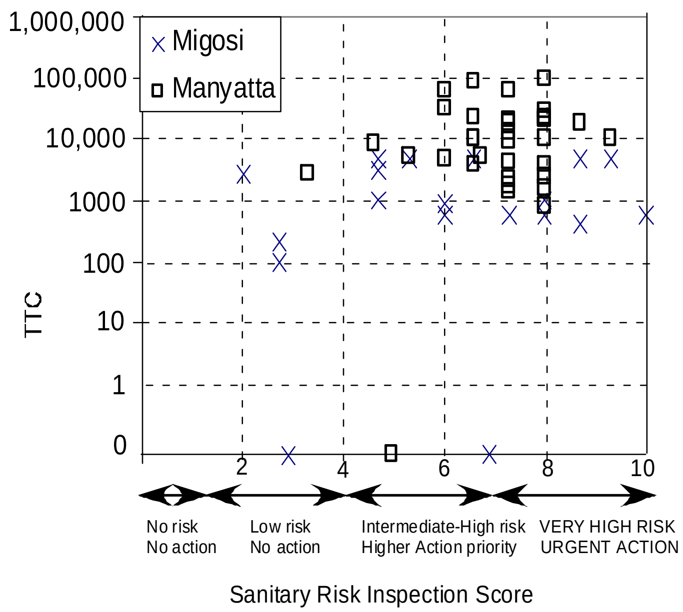

Figure 3: TTC (colony forming units/100ml) vs. sanitary risk score, Kisumu; n= 53.

trends but do not refute the possibility that groundwater quality in some *individual* wells has been affected by on-site sanitation (*e.g.,* pit latrines).

Risk Factor	% Frequency of sampl s < Median TTC/100ml	% Frequency of sampl s > Median TTC/100ml	Differ-ence%
Plinth <1.5m	83	100	+17
Well wall sealed	83	91	+8
Surface waste within 30m	83	91	+8
Ponding on plinth	50	55	+5
Drainage channel inade-quate	100	100	0
Well cover unsanitary	92	91	-1
Latrines within 10m	55	58	-3
Open water within 20m	64	67	-3
Ponding within 3m	92	82	-10

Table 1: Risk factors relating to higher levels of contamination for Kisumu wells.

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Conclusions

Water quality surveillance consisting of water quality monitoring for thermotolerant coliforms (bacterial indicator of sewage contamination) and sanitary risk inspections in two urban areas of sub-Saharan Africa (Lichinga, Mozambique; Kisumu, Kenya) indicates that unsanitary well completion is a greater risk to groundwater quality of shallow wells than the proximity of latrines. In Lichinga, the groundwater quality of protected (but unsealed) wells employing local, low-cost (sustainable) technologies (*e.g.,* windlass, plinth) is generally acceptable and significantly better than that of unprotected wells. This is important as it demonstrates that local, sustainable abstraction technologies can deliver significant improvements in groundwater quality. Surveillance has highlighted the complex interaction of a variety of factors that affect groundwater quality (sanitary completion measures, sanitation, population density). Other key factors such as latrine type, well abstraction, geology, and water table depth were not considered here but are the subject of future work. Further comprehensive analyses are needed to fully understand the impact of sanitation on groundwater quality. This study demonstrates, nonetheless, how surveillance measures can be used to ensure that any advances in sanitation (*e.g.,* ECOSAN) and well construction meet the overall objective of improving community health.

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Composting of faecal material – a hygienic evaluation

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Key words

Latrine composting, temperature, pathogens, Salmonella, enterococci

Abstract

Thermophilic composting of faecal material effectively reduced the numbers of faecal bacterial indicators and pathogens. Pathogens and indicator organisms including a *Salmonella* phage were effectively reduced within a few days of exposure at 50°C. T_{90}-values for *Salmonella senftenberg* 775W were 1.2 hours at 50°C and 0.1 hours at 65°C, respectively. *Enterococcus* spp. or micro-organisms resembling enterococci were continuous isolated as purple colonies on Slanetz and Bartleys agar after prolonged exposure at all temperature levels studied. These findings question the use of enterococci as faecal indicators and test organisms to control the efficiency of composting of human faeces.

Introduction

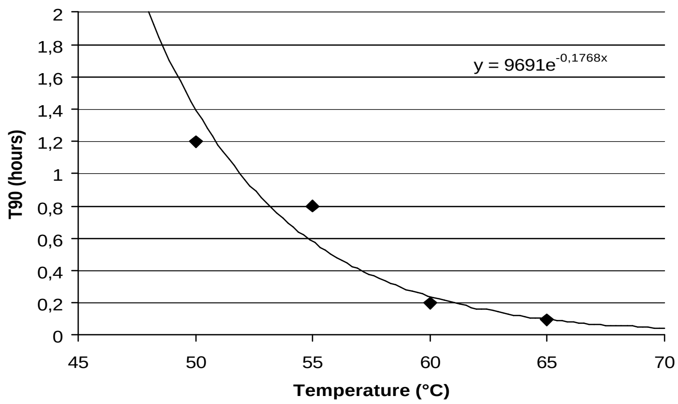
When recycling human latrine, the hygienic and human health aspects need to be taken into consideration. Correct handling and treatment of such waste should result in a hygienic end product that can be used with low risks. But recycling of human latrine may also be associated with the spread of pathogenic micro-organisms into the environment. Separating the nutrient rich toilet waste into two fractions leave a urine fraction relatively free from microbial faecal pathogens, the numbers of which will be reduced during urine storage. In contrast, the faecal matter contains high numbers of naturally occurring enteric bacteria, and occasionally disease-causing pathogens like *Salmonella*, *Campylobacter*, *Shigella*, enteric viruses, and parasites. Thus, the latrine waste must be treated to obtain an end product free or nearly free of pathogens. Correct thermophilic composting of latrine, in particular the generated heat, would be expected to inactivate or kill pathogenic micro-organisms. Our study was initiated to investigate the inactivation of faecal micro-organisms during composting of latrine from urine diverting toilets as a function of temperature and exposure-time. The experiments were conducted using a controlled model compost system.

Methods

During composting at temperatures between 50 and 65°C, the material was analysed regularly at short time intervals for natural occurring indicator organisms (suspected *E. coli* and enterococci), and for the added *Salmonella senftenberg* 775W and the virus indicator *Salmonella typhimurium* phage 28B. Both added micro-organisms have a documented relative high level of heat resistance. The experimental set-up was as follows: Latrine mixed with sawdust was collected from a urine diverting toilet and put into 10-litres composting reactors with controlled aeration and temperature regulation. Small amounts of latrine material were put into semi-permeable chambers (Excelsior Sentinel, Inc., Ny, USA) to which *Salmonella senftenberg* 775W and *Salmonella typhimurium* phage 28B were added. After initiation of the composting process and registration of high microbial activity, the temperature was regulated to 50, 55, 60 and 65 °C in different batch experiments. When the desired temperature was achieved, a number of chambers were added to each reactor. Sampling was done at short time intervals, and two chambers were taken out for analysis from each reactor at each time interval. The material in the chambers was analysed quantitatively for suspected *E. coli*, enterococci and *Salmonella typhimurium* phage 28B, and semi-quantitatively for *Salmonella senftenberg* 775W using accepted standard methods.

Results

Suspected *E. coli* and *Salmonella senftenberg* 775W showed almost identical approx. 1. order die-off rates. It took 6 hours to get a 5-$\log_{10}$ reduction at 50°C, 4 hours at 55°C, 1 hour at 60°C and 30 minutes at 65°C. By combining these data the relationship between die-of rates and composting temperature can be determined. Fig. 1 shows the T_{90}-values, i.e. the time constants for 1-$\log_{10}$ reductions in numbers for suspected E. Coli and *Salmonella*. From this curve the reduction rate at any temperature between 50 and 65°C can be estimated. The enterococci, however, showed a slower die-off rate: It took 3 days to get a 4-$\log_{10}$ reduction at 50°C, 2 days at 55°C, 6 hours at 60°C, and 2 hours at 65°C. It was further seen that after a reduction to a level of about 10^2 cfu/g, growth of enterococci on Slanetz and Bartleys agar medium was detected for approximately two weeks at 50°C. The bacteriophages were found to be more sensitive than enterococci to the lower temperature range, but relatively more resistant at higher temperatures. It took 2 days to get a 4-$\log_{10}$ reduction at 50°C and 13 hours at 60°C.



Conclusions

Thermophilic composting of faecal matter from urine diverting toilets can effectively reduce the numbers of faecal bacterial indicators and pathogen. Already at 50 °C, the numbers of pathogens, including the *Salmonella* phage, and indicator organisms analysed were effectively reduced within a few days of exposure. Although the numbers of enterococci were reduced, they were continuous isolated as purple colonies on Slanetz and Bartleys agar after prolonged exposure at all temperature levels studied. This indicates that certain micro-organisms present in the composted faecal material, *Enterococcus* spp. or micro-organisms resembling enterococci on the agar medium, can survive and multiply even at 60 °C. These findings question the use of enterococci as faecal indicators and test organisms to control the efficiency of composting of human faeces. Further work is in progress to identify the taxonomy of these organisms.

The impact of ecological sanitation on parasitic infections in rural El Salvador*

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Session D

Keywords

El Salvador, helminths, intestinal parasites, LASF, latrines

Abstract

This study was designed to evaluate the impact of latrines on intestinal parasitic infection in rural areas of El Salvador where a variety of latrine designs are used, including double-vaulted, urine-diverting desiccating latrines (LASFs), solar desiccating latrines, pit latrines and no latrines. Demographic, environmental, and behavioral factors surrounding the disposal of human excreta were also examined. The objectives of this study were (1) to provide an estimate of the baseline prevalence of helminth infection in rural areas of El Salvador, (2) to identify the determinants of intestinal parasitic infection in each study region, and (3) to provide recommendations to guide future latrine interventions within the social and environmental context of rural El Salvador. Interviews were conducted with 113 heads of households, and faecal samples from 566 individuals were evaluated for the presence of intestinal parasites. Pathogens identified were: *Ascaris lumbricoides* (8%), *Trichuris trichiura* (20%), hookworm (21%), *Giardia* (12%), and *Entamoeba histolytica* (17%). LASF latrines were found to be significantly associated with an increased prevalence of *Ascaris* and *Trichuris* (OR=16 and 5, respectively). Both LASFs and solar latrines were protective against other pathogens. In this population, biosolids are rarely used as fertilizer, and are usually dispersed in the yard or buried. Increased contact with inadequately treated human excreta during emptying of latrines may explain the increased risk for *Ascaris* infection we observed.

Introduction

The containment of human excreta through the provision of safe sanitation services is one of the most basic and important interventions for preventing the transmission of intestinal parasites and reducing the grave impact that they have on human health. Through various government and NGO-sponsored projects, a variety of latrine models, including LASF and solar desiccating latrines have been installed in rural areas of El Salvador. These are designed to inactivate microbial pathogens while producing a soil conditioner that can be used in agriculture. The theoretical impact of these latrines on health is well accepted, but latrines are often not used in a way that allows for the complete destruction of pathogens in human excreta, and little scientific research has been conducted to evaluate the impact of these interventions on the prevalence of parasitic infection.

In order to maximize the efficacy and safety of latrines and provide the best protection against parasitic infection, public health interventions must consider the biological and environmental

*This paper has been peer reviewed by the symposium scientific committee

contexts, as well as behavioral, demographic and acceptability factors that will determine the most appropriate and effective latrine type for a given area and population.

Methods

Information was gathered through interviews with heads of households from 113 households in 8 communities where one of the four sanitation disposal methods is used. Fresh stool samples were collected from 566 individuals from these households and analyzed for the presence of intestinal parasites. Only persons for whom we had both stool sample results and interview information were in included in the study, resulting in a total of 499 individuals. Thirty-one households used LASF latrines, 22 used solar latrines, 31 used pit latrines and 25 had no latrines. We included 22 households with desiccating latrines that reported use of the excreta in agriculture.

Interviews were conducted with female heads of households at their homes. Names, ages and gender of up to 8 household members were requested. Information was gathered on parental education and literacy, recent antihelminthic treatment, water supply, diarrhea, and the use of natural remedies for the prevention or treatment of parasitic infection. Observations were made of the construction materials of the house, and whether any member exhibited overt signs of malnutrition. Relative socio-economic status (SES) was scored based on house construction and ownership of household appliances. For families with latrines, we asked how latrine contents were used or discarded, how many people used the latrine, whether the users experienced any problems such as flies or bad odor, and about their general level of satisfaction with the latrine. For households that did not have latrines, we gathered information about their defecation practices and preferences. Faecal samples were processed using Evergreen Scientific brand Fecal Parasite Concentrator Kits®, a modification of the Ritchie formalin-ether method that increases the sensitivity of helminth ova detection in stool. Processed samples were checked for the presence of intestinal parasites by light microscopy, and classified as either positive or negative, regardless of load. The field team returned to the study households to provide the results of the laboratory tests and provide medication for persons who tested positive for helminths or protozoa.

Results

Fifty-two percent (258/499) of the population was infected with one or more of the parasitic infections identified. The overall prevalence of *Ascaris* was 8%, *Trichuris* 20%, hookworm 21%, *Giardia* 12%, and *E. histolytica* 17%. Prevalence of infection with helminths and protozoa by latrine type is shown in Figures 1a and 1b, respectively. Table 1 shows the odds ratios for infection by latrine type, controlling for other risk factors (logistic regression analysis).

The study communities differed by several factors that can affect parasitic prevalence, including latrine type, SES, age structure, distribution of antihelminthic medication, literacy, having a dirt floor, and owning pigs. The majority of *Ascaris* (77%) and *Trichuris* (58%) infections were concentrated in one LASF community where 28% and 56% of the population was infected, respectively.

In bivariate analysis, having a dirt floor was associated with a higher prevalence of infection for all parasites, but was significant for *Trichuris* (OR=1.9), hookworm (OR=2.6), and *Giardia* (OR=3.4). Being in the lowest SES group was a risk factor for all pathogens, but significant for *Trichuris* (OR=2.4) and *Giardia* (OR=6.2). Having taken antihelminthic medication in the last 3 months was significantly protective only for hookworm (OR=0.17). Owning pigs was significantly associated with helminth infection (*Ascaris* OR=3.2; *Trichuris* OR=2.8; hookworm OR=2.4). Males had a higher prevalence of *Trichuris* (OR=1.6) and hookworm (OR=2.0) than females. *Ascaris* and *Trichuris* infections were highest among the 6-12 year age group, while hookworm infection peaked in young adults (19-30). Overt signs of malnutrition were observed in association with *Trichuris* and hookworm. Discarding stored latrine contents in fields or around the house protected against pathogens with shorter survival in the environment (hookworm, *Giardia*, and *E. histolytica*), but was associated with an increased prevalence of infection with *Ascaris* and *Trichuris* (Table 2).

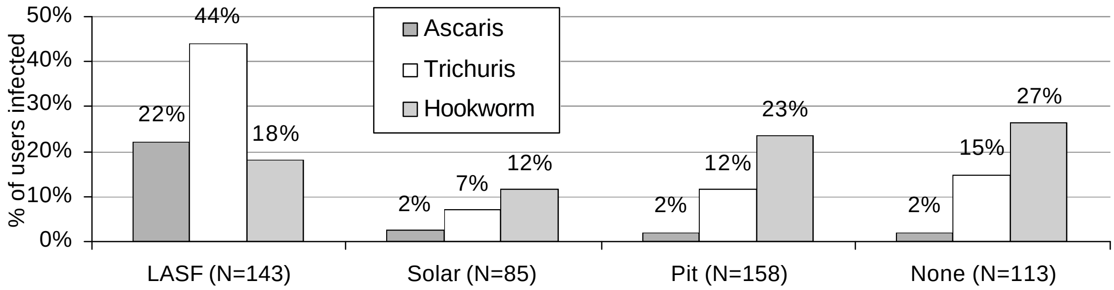

Figure 1 a: Prevalence of helminth infection among users of different latrine types or no latrine

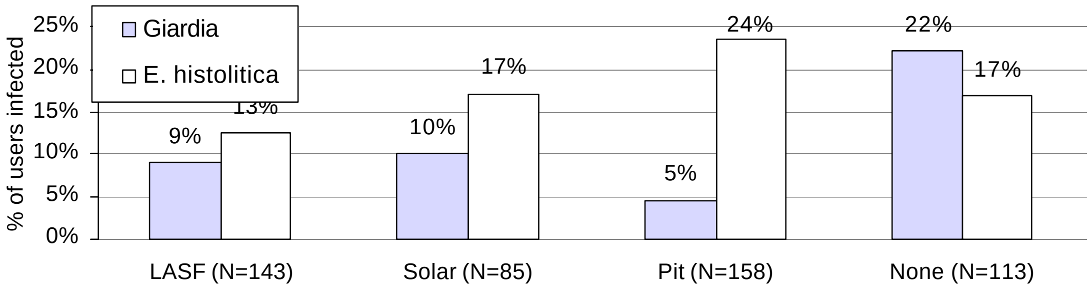

Figure 1 b: Prevalence of protozoa infection among users of different latrine types or no latrine

	Ascaris	*Trichuris*	Hookworm	*Giardia*	*E. histolytica*
LASF	**27.1 (p=0.0002)**	**7.7 (p<0.0001)**	**0.4 (p=0.02)**	0.5 (p=0.12)	0.7 (p=0.53)
Solar latrine	2.5 (p=0.41)	1.7 (p=0.34)	**0.4 (p=0.05)**	**0.3 (p=0.04)**	1.9 (p=0.15)
Pit latrine	1.4 (p=0.75)	0.6 (p=0.39)	1.0 (p=0.93)	**0.2 (p=0.04)**	1.5 (p=0.40)

*ORs for latrine and parasite, controlling for SES, age, gender, maternal literacy, dirt floor, having taken antihelminthic medication, malnutrition, owning pigs, and agriculture. Analyzed using SAS 8.0 (SAS Institute, Inc. Cary, NC). Reference group is having no latrine

Table 1: Odds ratios for latrine type and infection from logistic regression analysis*

How contents are discarded	*Ascaris*	*Trichuris*	Hookworm	Giardia	*E. histolytica*
Fertilize fields	**6.9 (p=0.002)**	**8.3 (p<0.0001)**	1.6 (p=0.16)	1.0 (p=0.97)	1.3 (p=0.53)
Fertilize yard or garden	**11.3 (p<0.0001)**	**9.6 (p<0.0001)**	**0.26 (p=0.005)**	1.0 (p=0.94)	1.1 (p=0.88)
Buried in yard	**9.2 (p<0.0001)**	**3.9 (p=0.0008)**	**0.33 (p=0.01)**	**0.14 (p=0.03)**	**0.31 (p=0.03)**

*Reference group is pit latrine users (latrine contents not discarded)

Table 2: Odds ratios for infection and how latrine contents are discarded (bivariate analysis)*

Discussion

More than half of the population was infected with one or more pathogen, indicating a significant health problem. Differences in prevalence by community were observed, suggesting that community-specific factors affect the prevalence of these pathogens. Communities with no latrines and pit latrines were typically poorer, more remote and less contaminated. One limitation of this study is that, because latrine interventions were carried out as community-wide initiatives, we could not compare households with different latrine types in the same community.

The lower prevalence of hookworm, *Giardia* and *E. histolytica* among users of LASF and solar latrines probably reflects more effective containment and destruction of these less-persistent pathogens as compared to having a pit latrine. In contrast, our previous studies have found that *Ascaris* and *Trichuris* may survive in stored latrine samples for more than 2 years and are highly resistant to destruction by temperature, pH and humidity. We also found that the solar latrines generally achieve higher internal temperatures and lower humidity than LASFs, which should promote more rapid inactivation of helminth ova (Moe CL, R Izurieta, LF Cohen, and SA Esrey. Microbiological studies of ecological sanitation in El Salvador. First International Conference on Ecological Sanitation, November 2001, Nanning, China). It is not clear why the prevalence of *Trichuris* was higher than that of *Ascaris* since they have the same route of transmission and similar survival.

It was striking that the prevalence of *Ascaris* and *Trichuris* infections is higher among LASF latrine users than among users of other latrine types and those with no latrine, suggesting that LASF latrines may pose an increased risk for certain helminth infections. Opportunities for exposure to environmentally persistent pathogens occur during maintenance and emptying of the latrine, or if the biosolids are used as fertilizer in agriculture or dispersed around the home. If contents are buried in the yard, the same risks for contamination exist as for pit latrines, with an additional risk introduced through handling the biosolids when emptying the vault.

When we examined the distribution of enteric infection in the 2 LASF communities, we found that the majority of cases were in 1 community, while the prevalence in the other LASF community was not significantly higher than for other latrine types. Factors other than latrine type may also contribute to the differences observed in prevalence of infection. A higher level of contamination and crowding, and differences in age structure, SES, water source, having a dirt floor, and the distribution of antihelminthic medication impact pathogen transmission independently and are also believed to modify the effectiveness of the latrines. The results of this study must be interpreted with caution because of the relatively small number of study households and possible effects of confounding factors.

Conclusions

- The use of LASF latrines was associated with an increased prevalence of *Ascaris* and *Trichuris*, which survive the conditions achieved by these latrines. Handling of biosolids during maintenance and discarding of latrine contents increases exposure to enteric pathogens, suggesting the need to improve maintenance techniques and/or design to ensure the complete inactivation of biosolids.
- Environmental and demographic factors modify the effectiveness of latrines to control the spread of enteric pathogens and should be considered in latrine interventions.
- LASF and solar latrines were associated with lower prevalence of less persistent pathogens, including hookworm, *Giardia*, and *E. histolytica.*
- Solar latrines appear to be a more effective intervention than LASFs in this environment, and therefore should be promoted in rural areas of El Salvador.

Reduction of faecal microbiological indicators in different compost toilets

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Session D

Keywords

Compost toilets, faeces, entorococci, *Salmonella*, coliforms, helminth eggs

Abstract

Large variations in numbers of faecal indicator organisms in collected humane faeces were found irrespective of the storage time in compost toilets. Little heat was generated from composting processes when bin units were stored. When pathogen indicators were added *Salmonella* died of rapidly, but other faecal bacterial indicators survived in large numbers. We conclude, that the collection and storage of human faeces in the closed plastic bins studied here is associated with only little temperature increase and subsequent reduction in faecal bacterial indicators and pathogens. Thus, the bin units do not seem especially suitable for composting and hygienisation of human faeces.

Introduction

There is much interest in the recycling of organic waste products in Denmark. As a consequence, decentralized sanitary solutions consisting of urine-separating toilets with collection units for faecal material, i.e. compost toilets, are increasingly being build. At present, the Danish legislation does not allow use of material from compost toilets on agricultural lands. However, because of the increased public interest in compost toilets as well as limited knowledge about the efficiency of these types of toilets to reduce pathogens, the Danish Environmental Protection Agency has initiated projects investigating the hygienic and health risks associated with the use of material from compost toilets.

Methods

In experiment 1, survival of normally occurring faecal indicator bacteria and helminth eggs were determined in samples of faecal material from five compost toilets in two Danish eco-villages. The toilets studied consisted of urine-separating toilets with collection of faecal material and other solids in a separate unit, typically a 220 L waste bin. When full, the waste bins were stored for 3 to 8 months. Faecal material was collected from the two villages during the storage period. Samples were also obtained from a more specialized type of collection unit with continuous addition of faeces. In these systems, samples were taken from the oldest faecal material. All samples were analyzed for thermotolerant coliforms, enterococci, *Clostridium perfringens* spores and helminth eggs (*Ascaris* spp. *Trichuris* spp., *Enterobius* spp. and *Taenia* spp.). The temperature in the waste bins was measured at each sampling date. In experiment 2, a waste bin was filled with well-mixed faecal material. Temperature probes were installed in the bin at two different depths and data were logged every half hour. Homogenized faecal material was placed in small (2 cm^3) plastic chambers (Excelsior Sentinel, Inc., Ny, USA) and culture broths containing *Salmonella* senftenberg 775W and the virus indicator *Salmonella* typhimurium phage 28B were added to the chambers. The chambers were then closed with nylon membranes and placed at the same depths as the temperature probes in the waste bin. At regular intervals the chambers were sampled and their content analyzed for total viable counts at 37ºC, thermotolerant coliforms, enterococci, *Salmonella* senftenberg 775W and *Salmonella* typhimurium phage 28B using standard methods.

Results

In experiment 1, temperatures were < 25ºC at any sampling time from April to August 2001 (table 1). Thus, heat-generating composting did not occur during storage of the waste bins. The microbiological analysis showed the presence of *Clostridium perfringens* spores in all samples except one, where as the numbers of thermotolerant coliforms ranged from below the detection limit (<10 cfu/g) to 19,000/g of faecal material. The numbers of enterococci varied a lot and were found in high numbers in one waste bins, but were below the detection limit (<100 cfu/g) in a similar unit. There did not seem to be any clear relationship between the occurrences of the different microorganisms in the collection units and the period of storage. *Taenia* spp. eggs were found in three samples (data not shown).

Type of system	Thermotolerant coliforms (cfu/g)	Enterrococci (cfu/g)	Spores of *Cl. perfringens* (pfu/g)	Temperature in collection unit (ºC)
220 l waste bin no 1	<10	<100	<10	17
220 l waste bin no 2	560	1,500	17,000	5
220 l waste bin no 3	50	710,000	3,000	5
Continuously filled system no 1	19,000	8,000	8,000	13
Continuously filled system no 2	100	1,400	13,000	11

Table 1: Microbiological results from sampling in December 2001 of faecal material from five compost toilets in two Danish eco-villages

Results from the experiments with *Salmonella* senftenberg 775W and *Salmonella* typhimurium phage 28B are shown in fig. 1. The *Salmonella* senftenberg 775W was rapidly inactivated and reduced more than 9-log units following 40 days of inoculation. The numbers of thermotolerant coliforms were reduced 3-log units during the same period. The numbers of *Salmonella* typhimurium phage 28B and total viable counts were only marginally reduced and the numbers of enterococci actually increased indicating occurrence of after-growth. The temperature in this experimental unit did for a short period reach 42.2ºC, but generally the temperature was < 25ºC (data not shown).

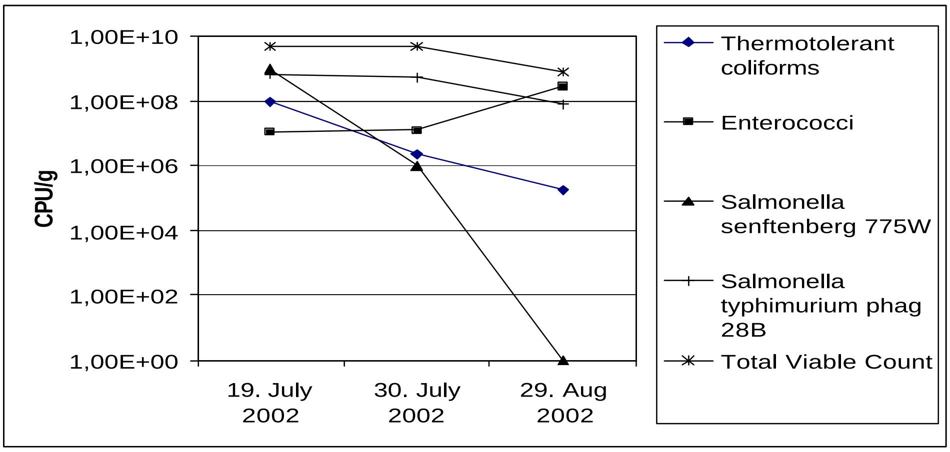

Figure 1: Survival of faecal indicator bacteria and added pathogens in a 220-L waste bin.

Conclusions

Large variations in numbers of faecal indicator bacteria were found irrespective of the storage time of collected human faeces. Little heat seemed generated from composting processes when bin units were stored locally in households. The low reduction in microbiological parameters and very limited temperature increase were generally corroborated by the results obtained in experiment 2 when pathogen indicators were added to thoroughly mixed faecal matter. Even though *Salmonella* died of rapidly the other faecal bacterial indicators survived in large numbers. We conclude, that the collection and storage of human faeces in the closed plastic bins studied here is associated with only little temperature increase and subsequent reduction in faecal bacterial indicators and pathogens. Thus, the bin units do not seem especially suitable for composting and hygienisation of human faeces.

Opportunities for eco-sanitation in East-Europe: a Romanian example

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Session D

Introduction

Women in Europe for a Common Future (WECF) and its Romanian partner Medium & Sanitas (M&S, Bukarest) are implementing a pilot-project "Safe Drinking Water" in the village of Garla Mare (3500 inhabitants) in rural Romania. In planning the project, water tests were carried out of which the results showed very high levels of faecal bacteria in the drinking water, therefore the lack of sanitation was identified as the main source of pollution.

General information about Romania:

- 80% of the rural population (7 million people) rely on untreated water from about 1 million unprotected private and public wells (windlass bucket) for drinking water.
- 3000 cases of Blue Baby Disease (acute infantile methaemoglobinaemie) occurred in the period 1986 – 1996. Blue Baby disease is caused by high levels of nitrates in water used for making baby-milk.
- Microbiological pollution of drinking water causes chronic diarrhoea, disentheria, giardiasis, coli- and salmonella infects.

In most Eastern-European rural areas sewage systems and safe drinking water systems are absent. Ground and surface water protection measures are neglected.

The example of Garla Mare

Garla Mare is a village close to the Danube, an area once well-known for its grain production. The village has no sewage system and no safe drinking water supply.

The inhabitants and their livestock drink untreated water, provided by about 500 private wells (20-28 m depth) and 78 public wells.

About 1200 households have latrines in their gardens. The latrines are a hole in the ground; they are not emptied and they are not sealed.

The economical and environmental situation is bad. The village has no waste management, not for household waste, not for human excrements and not for animal manure. At the same time many farmers do not have money to purchase fertiliser. The nutrient circle is absent. The nutrients go into the groundwater.

Activities of the pilot project

Direct measures taken to decrease the risks caused by the bad water quality:

- Testing of all public wells on nitrates and bacteria and the most used wells also on pesticides
- Sign-posting of wells least suitable for human consumption.

- Information to water consumers how to best use unsafe drinking water, risk reduction.
- Information about the link between polluted water and health for consumers and local authorities.
- Information for consumers and local authorities about reasons for the water pollution, and how to protect drinking water sources.
- Information about alternatives (organic farming) to intensive farming for villagers and local authorities.
- Information about alternatives to pit latrines (ecological sanitation) to the villagers and local authorities.
- Providing safe drinking water for the most vulnerable group by installation of a public water filter in a school.

Water quality of the wells

High nitrate concentrations: 40 - > 500 mg/l .The majority of the wells have nitrate levels between 100 and 250 mg/l

High micro organism contamination with total coli, escherichia coli, fecal streptococci. According to the EU guideline for the quality of bathing water, no well reached the microbiological norms for swimming water.

High pesticide concentrations; weed killer atrazine.

Pesticides exceed the legislation level of drinking water 3 to 5 times, levels of atrazine ng/l 370 and 500 (100) found.

Causes of bad water quality

- Lack of human waste management: unsealed pit-latrines cause leaching of faecals and urine into the groundwater.
- Bad construction and maintenance of wells.
- Use of pesticides (atrazine) and artificial nitrate fertiliser in intensive grain culture.

How to protect groundwater from yet more human pollutants?

A conventional waste water system?

Disadvantages:

- Central water supply and drainage system is needed.
- High investment costs for pipes and treatment.
- High consumption of water for transport of human excrements (flush toilets).
- Pollution of surface and ground water by mostly not sufficient treated waste water.
- Loss of nutrients: nutrient circle is not closed.

Alternatives for Garla Mare: Ecological Sanitation

Drinking water protection by dry diversion toilets

For brown water (faecals): double vault with a storage capacity of half a year.

For yellow water (urine): container buried into soil with a capacity for at least half a year.

For grey water (wash water): decentralized planted soil or sand filters.

After hygienic treatment by storage or composting:

Use of urine as a nutrient in agriculture.

Use of composted faecals as soil improver.

First steps for Ecological Sanitation

Dry diversion toilets: test phase 2003.

- Installation of dry diversion toilets and urinals in yard of the primary school.
- Installation of dry diversion toilet in a private house yard.
- Provide education materials for inhabitants, teachers, children and local authorities about advantages, use and maintenance of dry diversion toilets.
- Identification of person, who is responsible for the school toilets and the treatment of brown and yellow water.
- Identification of possibilities for use of hygienic toilet products (urine as fertilizer, composted faecals as soil improver).

Planted soil or sand filter**:** research phase 2003.

- Feasibility study for the installation of a central cloth-washing building, linked to a planted soil filter.
- Feasibility study for the installation of a bath house, linked to a planted soil filter.

First steps for drinking water supply

Research phase 2002-2003

- Identification of the best water catchment area by a hydrological study and water analyses.
- Identification of water protection area.
- Identification of the best water treatment system.
- Feasibility study for providing safe drinking water to some public water taps under the condition, that the system can be enlarged to house-connections in the future.

Execution end 2003

- Installation of system with 4-6 public water taps for safe drinking water.
- A water protection area is established.

Conclusion: example for Eastern Europe

The Garla Mare pilot-project

- Has shown the causes of water pollution in a rural village.
- Introduces environmentally friendly and economically acceptable solutions to increase the living standards of the village population.

This project has an example function and can be replicated in other rural areas in Eastern Europe and NIS.

The project shows opportunities for ecological sanitation and shows how to avoid environmentally ‘unfriendly’ and expensive “end of pipe” technology as used in Western European countries.

- Project responsible: WECF Women in Europe for a Common Future Email: wecf@wecf.org Website: http://www.wecf.org/
- Supported by: Dutch Ministry of Foreign Affairs MATRA Project "Safe Drinking Water"
- Margriet Samwel * Water and Agriculture Coordinator, WECF
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Session E

New technological developments and experiments

Chairpersons

Peter Wilderer (Technical University Munich, Germany)

Roland Schertenleib (EAWAG/SANDEC, Switzerland)

Lectures

New technological development in ecological sanitation
Ralf Otterpohl (Technical University Hamburg-Harburg, Germany)

Thermodynamics of struvite precipitation in source-separated urine*
Mariska Ronteltap, Martin Biebow, Max Maurer, Willi Gujer (EAWAG, Switzerland)

The functional analysis of compost toilet for remote areas*
Euiso Choi, Junki Choi, J. Ahn, Zuwhan Yun (Korea University, Korea)

Vacuum sewers - an element in ecosan systems
Stefan M. Behnke (Roediger GmbH, Germany)

Dry fermentation biogas technology - a practical approach for closed loop sanitation, waste stabilisation and nutrient recovery
Michael Köttner, Achim Kaiser, Mercy Viviana Avendaño (International Biogas and Bioenergy Center of Competence, Germany)

Solids-liquid separation as the first step and VRM membrane bioreactor as an elementary component of ecosan
Oliver Christ, Hans G. Huber (Hans Huber AG, Germany)

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* *This paper has been peer reviewed by the symposium scientific committee.*

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Closed-loop toilet separation technology, reduces water consumption by 40 to 95% and pollution by 100%
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Phosphorus removal from domestic sewage and possibilities of recovery
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High quality greywater recycling with biological treatment and 2-step membrane filtration
Zifu Li, Holger Gulyas, Joachim Behrendt, Deepak R. Gajurel, Ralf Otterpohl (Technical University of Hamburg-Harburg, Germany)

Temperature effect on aerobic biodegradation of faeces using sawdust as a matrix
Miguel Angel Lopez Zavala, Naoyuki Funamizu, Tetsuo Takakuwa (Hokkaido University, Japan)

Palestinian experience with enhanced pre-treatment of black wastewater from Birzeit University using a UASB septic tank system
Ahmed Al-Juaidy, Ziad Mimi, Rashed Al-Sa'ed (Birzeit University, Palestine)

Specific quantification of pathogenic and indicator organisms in digester samples using quantitative real-time PCR (qPCR)
Michael Lebuhn, Gabriela Garcés, Peter A. Wilderer (Technical University Munich, Germany), *Mathias Effenberger, Andreas Gronauer*

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Source separation of domestic sewage components and integrated management with organic fraction from MSW
Rafaello Cossu, Maria C. Lavagnolo, Mario Gandini, Osamu Hirata (University of Padua, Italy), *Maurizio Borin*

Treatment of phosphorous and bacteria by filter media in on-site wastewater disposal systems
G*unno Renman, Agnieszka Kietlinska (Royal Institute for Technology, Sweden), Victor M. Cucarella Cabañas*

New technological development in ecological sanitation

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Keywords

Ecological sanitation, wastewater reuse, fertiliser reuse

Abstract

The holistic approach of Ecological Sanitation (ecosan) can be realised with a large number of technological options. Many of those have proven to be a viable and advantageous alternative to conventional flush sanitation. Existing infrastructure can be upgraded but implementation in areas where new construction is done is definitely easier. Some new approaches especially for urban and more densely populated urban areas are on the way of development. A low-cost option based on urine diversion and a chute systems for faecal matter without addition of water for flat houses is on the way of development in an EcoSanRes project. In case of successful implementation this can be a breakthrough for many regions. Another challenging system is the blackwater cycle where blackwater or brownwater (with urine diversion) is treated to become toilet fllush-water again. This way high concentrations can be achieved even with higher flush volumes. Implementation of ecosan projects has to follow other procedures than conventional installations. Co-operation with city planners is needed.

Principles and potential of ecological sanitation

Ecological Sanitation is a holistic approach with a set of basic principles and not a specific technology. Almost all known treatment technologies for municipal and industrial wastewater can be included in ecosan systems. The full range from low-tech to high end technologies can be realised. It is very surprising, that the most simple but well designed ecosan systems for rural areas can achieve a performance that can hardly be met by high-end installations. Human excreta mixed into the household wastewater turn the whole flow into a potentially dangerous and hard to treat mixture that is difficult to reuse. No industry with modern wastewater management would mix urine, faeces and the rest of the wastewater (greywater). Figure 1 shows flows and a characterisation of the different flows.

It is very clear, that urine is a good resource for the usage as fertiliser with the disadvantage of the occurrence of micropollutants (pharma-residuals, hormones) and very low heavy metal concentrations. Faecal matter is in contrast rich in humus building organic matter and relatively easy to sanitise when collected without or with little dilution. Greywater can be treated for reuse in a far more cost efficient and psychologically acceptable way when not mixed with human excreta. The basic principles for the design of real ecosan systems are consequences of the above characterisation (partly from [Kyoto 2003]):

- Efficient use of water and prevention of water pollution
- Containment and sanitisation of faecal matter

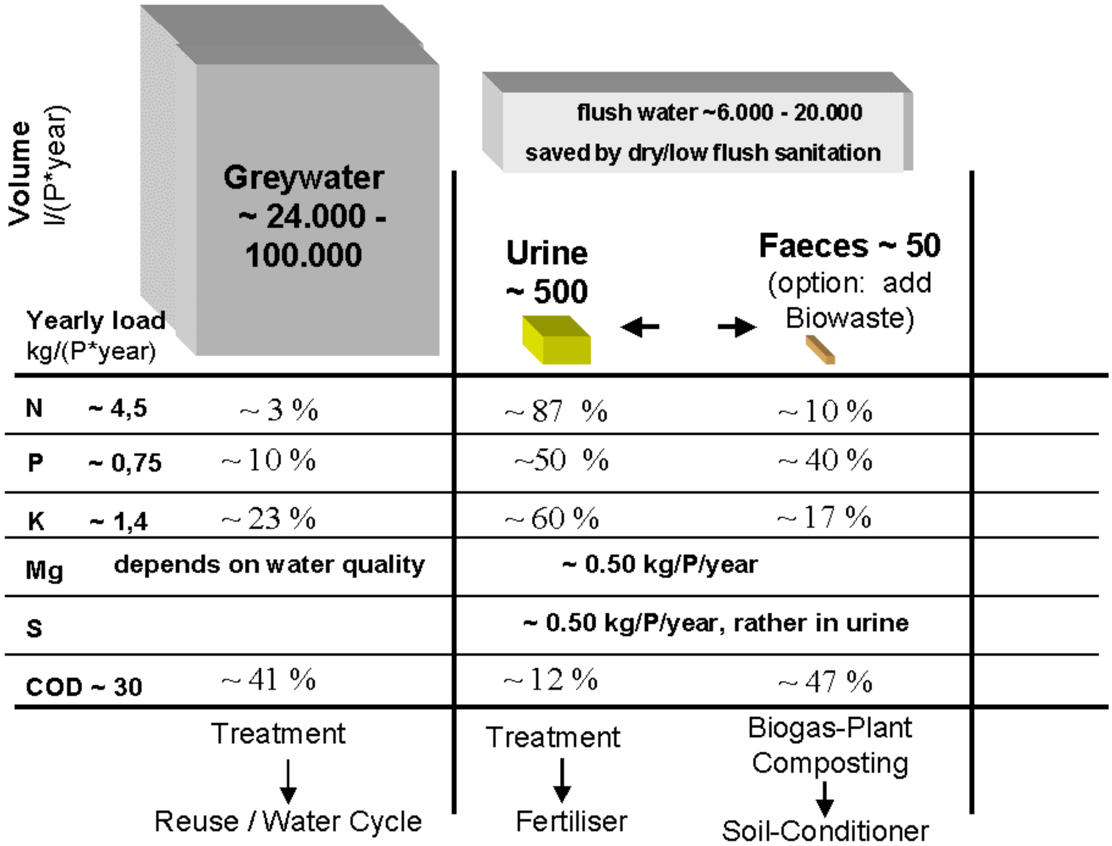

Figure 1: Characteristics of divertable domestic wastewater flows with no dilution for urine and faeces (wet weight) (compiled from: Geigy, Wissenschaftliche Tabellen, Basel 1981, Vol. 1, LARSEN and GUJER 1996, FITSCHEN and HAHN 1998 plus analysis of TUHH)

- Reuse of urine and faecals often with biowaste after appropriate treatment usually on agricultural land to restore soil and its fertility thereby protecting the water bodies
- Reuse of urine on sufficiently large areas of land, from around 50 to 400 m² per person depending on the crops and the number of harvests
- Appropriate treatment of greywater, reuse if needed
- Energy efficiency trough savings in treatment, freshwater transport and in avoidance of industrial fertiliser production, if feasible biogas production

More information on the background can be obtained from ecosanres [www.ecosanres.org]. The possibility for the reuse of greywater is one of the advantages of ecosan systems. Combined with rainwater harvesting treated greywater can add to reliability of local water supply. If geology allows treated greywater can be infiltrated into the ground for further treatment and storage with the same structures as rainwater. Reuse of urine as fertiliser should preferably be done on industrial crops or fodder. If it is needed for vegetables it should be worked into the topsoil before seeding, this way there is a treatment by the abundant soil organisms.

Upgrading of existing infrastructure

Ecosan concepts do include upgrading of existing infrastructure. A large part of the world population uses pit toilets. As a first step they can be improved by making them more shallow, by providing ventilation and by using two shallow pits alternately [Morgan, 2003]. The next step would be to provide urine diversion and to use it on a sufficiently large plot of land.

In the case of conventional waterborne sanitation with an end-of-the-pipe treatment plant the implementation of urine diversion can upgrade towards ecosan. If urine is not mixed into wastewater the remaining flow will not have more nutrients than needed for incorporation [Larsen 200x], adaptation for high amounts of industrial wastewater can be needed. At present Hamburger Stadtentwässerung, the huge wastewater service provider of Hamburg, Germany is calculation scenarios for possibilities of converting the system over some decades (Rakelmann, 2002). In the final phase there would be no more nutrient removal, less emissions from CSOs (combined sewer overflow) and a large flow of raw material for fertiliser production or direct usage.

Conventional sanitation where the effluent is used for irrigation combined with fertilisation can come close to being ecosan. However, if there is no other source of water there will be a strong over-fertilisation. There is a danger from industrial pollution, too. Unfortunately, the typical uncontrolled reuse of wastewater is without any treatment even on vegetables. It is done by a dramatic need for water, upgrading such systems is usually very difficult. TUHH and IWMI (International Water Management Institute, Colombo) have worked on identification of feasible systems in Pakistan in a project funded by BMZ, Germany and had to conclude that most treatment options where too expensive. We did find that aqua-cultures can be a good alternative because of the creation on commodities thereby giving an incentive for operation (TUHH, internal report).

New technical approaches under development

The Vacuum-biogas system, high-tech for urban areas

While there are many viable options for ecosan in rural and less densely populated peri-urban areas, there is still a fairly limited number of concepts available for urban areas. Financial restrictions and the limitations in the capacity to maintain more complex technologies are to be considered for many regions around the world. The key issue is to find toilets that do not dilute too much and still allow transport of faeces or blackwater over distances of some hundreds of meter or some kilometres. An interesting technology is the vacuum toilet combined with a blackwater-vacuum pipe. Such a system is used on a very large number of ships for up to thousands of passengers on ships. It was built for a settlement of up to 400 inhabitants in Lübeck, Germany in combination with a biogas plant (Otterpohl, 2003). Other projects for urban areas are in the planning phase, e.g. in Wageningen, Holland (Mels, 2003). Such systems can be installed even in very densely populated areas in combination e.g. with MBAs (membrane-bioreactors) for greywater treatment. This type of technology is becoming more reliable and economic and does include sanitisation because of the small pore sizes of the membranes. Maintenance is a key issue and the development seems to go to regular replacement of membrane modules and their cleaning in a factory. For greywater treatment with reuse there must be a warning system that gives an automatic alarm to the operators e.g. via phone, cellphone or internet.

Low-tech approaches for urban areas: dramatically needed

Urine, faecal matter or blackwater (toilet wastewater) that is diverted at source by non- or low-diluting toilets can be treated with a wide range of technologies. Due to the very high concentrations and low volumes even specifically relatively expensive technologies can be implemented for affordable prices per capita. However, more simple and cost efficient systems are dramatically needed. Vacuum systems have proven to be feasible where a certain complexity of technology can be handled. Unfortunately there are many regions around the world where this can hardly be done also for financial reasons. In the following there will be a representation of alternatives that may have the potential to be implemented in urban areas at low costs and with maintenance requirements that are feasible even in more difficu lt regions. It is worthwhile to look into history, because in the 19th century conditions where not that different from those in many areas in developing countries today. It can be shown, that the too large amount of flush-water caused the end of agricultural reuse. Two successful systems operated around the end of the 19th century where the early vacuum collection by Liernur in the Netherlands and the 'Heidelberg Barrel System' of the physician Mittermaier in Germany. The barrel system had a chute pipe with siphon and collected blackwater with some flush-water in barrels that where frequently emptied. (Lange and Otterpohl, 2000) Now, more than 100 years later such ideas are coming back and are improved. One example is the dry chute system in combination with urine diversion that is proposed by the EcoSanRes network for installation in China as presented at the 3rd World Water Forum and the Lübeck EcoSan Conference 2003. This idea does have a great potential for urban areas as faecal matter is far easier to handle without water.

The blackwater cycle: good potential for urban areas

Separate collection and treatment of black water and grey water is the foundation of the method “black water cycle process” (see Fig. 3). The idea of appropriate treatment and recla iming the toilet flushing water for toilet usage renders a very high concentration of nutrients during daily operation possible. This can be an important contribution for a new viewpoint in domestic wastewater management. This method is protected by international patents of the inventor [Ulrich Braun, 2001], giving capital investment organisations the opportunity to invest in developing the technology. At the Technical University Hamburg first experiments with promising results have been carried out. Currently, a half-technical sized pilot plant is being installed. Per capita and day only 1 – 2 litre of an ideally clear, odourless and colourless liquid nutrient mineral solution will be produced by this method.

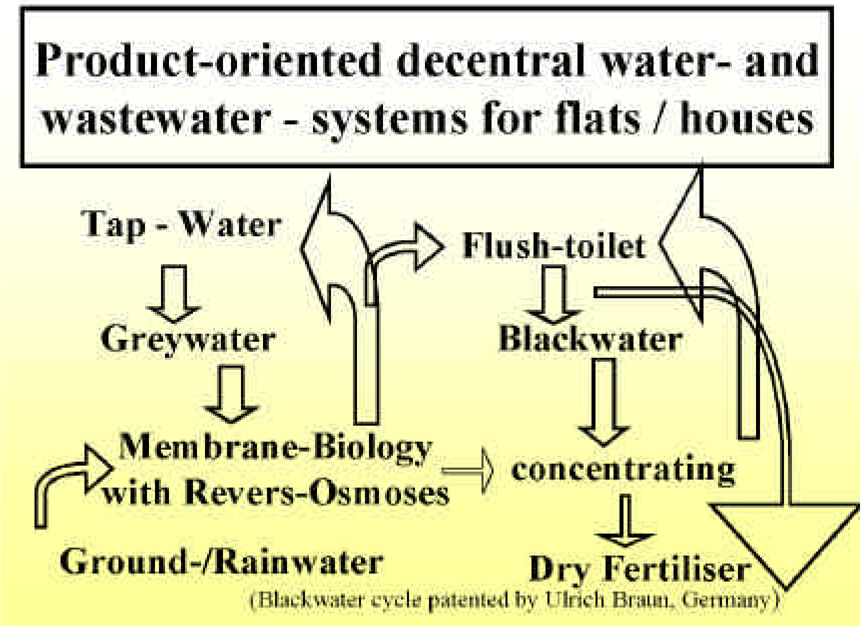

Figure 3: Flow diagram of the black- or brownwater cycle processes

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With this blackwater cycle technology the freshwater consumption of flushing toilets can be reduced down to zero; independent of the water consumption of the specific toilet model by the recirculation after treatment. For countries with limited water resources this can be an interesting and important option. The high concentration of nutrient containing toilet-flushing water opens up completely new treatment options. Due to the very small volumes the usage of sophisticated technologies becomes feasible. The technology of the blackwater cycle became economically feasible with the development of membrane-bioreactors during the last years. The method is also possible with urine separating toilets and re-circulating "brown water cycle processing" modules. Feasible connection-sizes are above about 200 residents. Grey water recycling plants can be realised on an apartment or housing-level. High quality water recycling as tap water is more accepted, if the "own" water is recycled. Fig 3 shows both method options and their embodiment into local water resources.

From a theoretical point of view, no fundamental problems are to be expected by the black or brown water cycle processes. Required is the full oxidation of Ammonia to Nitrate (Nitrification). No hygienic and health risks are expected, because the treated water is treated thoroughly and also only reused for toilet flushing. By utilising the excess-water for direct fertilising, nitrate is not as suitable as ammonia, which is a disadvantage. The de-colouring of the circulating liquid has been an occurring problem due to the concentration of the gallbladder dyes (Urobillin, etc.). That problem has been solved with the research work done at the TUHH. Disinfecting of black or brown water is a minor problem due to the employed membrane bioreactors. It is expected, that even a case of the full automation of these plants, on mid-term a regular maintenance keeps necessary.

In summary, the methods of black and brown water cycle processes are very interesting. They contain a high potential especially in areas of the world, where water, energy, and fertiliser are costly and scarce. This is an approach for gaining a water autonomy in settlements. By production of high numbers of the necessary modules, even in cases of small connection sizes, competitive water prices can be reached.

Implementation of ecological sanitation on a larger scale

Even with reliable and proven systems ecosan requires another approach for implementation. It is necessary to be involved in an early stage of city planning in order to find legal and technological ways of implementation. Help will probably come from the changes in energy supply to more decentral structures where synergies can be found for semi-central installations in urban areas. Figure 2 shows some of the early phases that are to be worked out before the detailed planning can start.

It is very obvious that co-operation with city planners is a key issue. Therefore, besides the urgent need for expanding education of engineers and capacity building in the region city planners must get basic knowledge about alternatives.

Very small peri-urban or urban pilot installations do have the problem, that there is no fertiliser demand yet. For larger scales there is an economic incentive for local operating companies to organise the system and to supply fertilisers for farmers. Transport is to be performed with sometimes tricky logistics, however the amounts of source diverted faeces in dry or low-flush systems are fairly small (see figure 1). The major challenge is the transport of urine, but 1.5 to 3 litres per person and day can be handled in comparison to transports that are done normally. The advantage with urine is the possibility of pipe transport to tanks that are accessible to tankers.

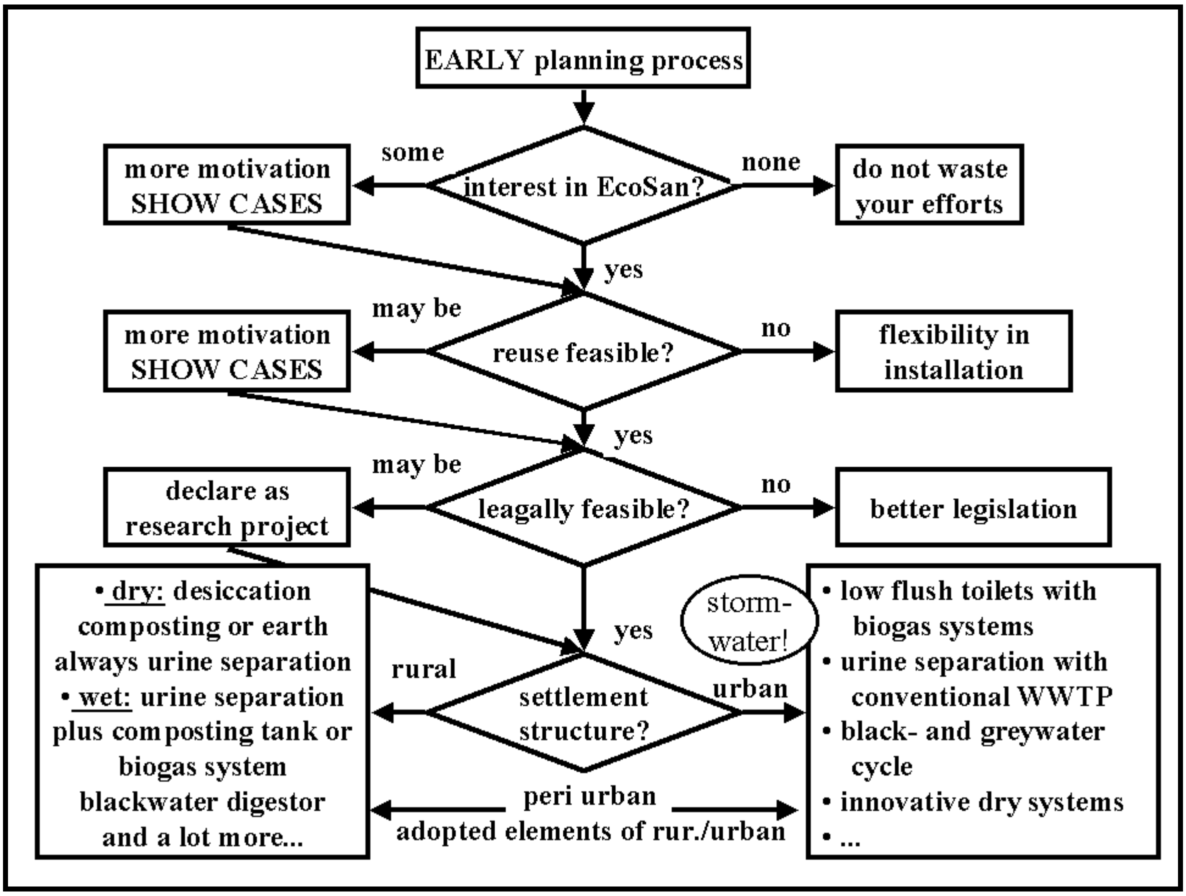

Figure 2: Procedure for the pre-planning process for ecosan projects in new settlements

Economic feasibility does depend on the possibility to get rid of central sewerage. These do cost large amounts of money - instead this investment be used for better technology. It is important that stormwater can be managed without sewers, too. This requires infiltration systems ideally combined with rainwater harvesting structures. The infiltration structures can also be used to infiltrate treated greywater, thereby replenishing local aquifers if appropriate. Otherwise open trenches can be used for rainwater and treated greywater.

Socio-economic consequences and models of operation and impact assessment

Many of these innovative concepts demand only a minor change of the user's behaviour. Another toilet is often the only change. For urine separating toilets and males it has to be considered that they should sit down during urinating. This renders an effective separation of urine and faeces possible. An according demand will generate new and comfortable resolutions very fast. At the moment, the sanitary market is absolutely design-oriented, and poorly innovative technically.

A very important issue is the informing and training of the users to an innovative water technology - or at least about it's basic philosophies. It has been shown that in many cases, after an according explanation, users are very co-operative and interested. In Lübeck, Germany, the residents have been informed about the context between the high concentrations of Phosphorous in the grey water and dishwasher detergents. After that campaign, the residents started an initiative of corporate acquirement of Phosphate-free detergents. Comprehensible courses of action change the behaviour of many human beings.

The 'economy of scale' of central sewage pants is very often pointed out in wastewater management. However, this essentially correct fact cannot be seen isolated. In most urban areas wastewater collection and transport cause 70 to 80% of the total costs. Consequently, savings on the side of the sewage plant have only a small effect in total. Contradicting that, decentralised treatment plants can become very economically priced if they are produced standardised and in high numbers. On the other hand, the much higher operation costs of decentralised plants have to be considered. In summary, investments in decentralised concepts flow into production and maintenance of plants, whereas investments in central concepts flow mainly into large sewerage systems. Thus, decentralised concepts produce more jobs than central. The decentralised concept in Lübeck produced one job for a caretaker including the technical management of energy / water technology with total costs of system plus labour not higher than for conventional wastewater services.

Professional management of operating innovative water systems is of utmost importance. Ideal legal possibilities are local private operating companies or co-operatives. In case of small units, regular maintenance by an external company is suitable as well.

In case of catastrophes like floods and earthquakes, central systems are highly sensitive. Impact assessments are demonstrating that failures of central systems have grave consequences, but are more rare compared to decentralised systems. The risk of many decentralised resp. semi-central plants can be effectively minimised by professional maintenance and modern sensor-based controls with alarm messaging and remote inquiry. The large number of plants can cause more disturbances. But altogether, their impact may be much less than one failure of a central system.

Conclusions

A wide range of ecosan applications has proven the great potential especially in rural and peri-urban areas. The demand is huge as ecosan can address the problems of water scarcity, cheap local fertiliser supply in a better and often also more economic way. For urban areas there is more development needed, but the promising technologies that have been presented do definitely have a great potential to find ways for densely populated areas. Education, logistics and operation are increasingly important when moving to a larger and more urban scale. Larger projects are easier managed in a professional way and do have the potential to trigger utilisation of fertiliser. Fertiliser companies could change from fossil to secondary resources for many of the substances needed on the land. In addition, organic matter can be supplied in order to restore soil fertility.

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Thermodynamics of struvite precipitation in source separated urine*

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Keywords

Struvite, solubility product, precipitation thermodynamics, source separated urine

Abstract

The thermodynamics of struvite ($MgNH_4PO_4$) precipitation in source separated and artificial urine under controlled addition of magnesium chloride ($MgCl_2$), magnesium oxide (MgO) and magnesium hydroxide ($Mg(OH)_2$) were investigated. The solubility product of struvite in source separated and artificial urine was identified by use of experimental results in a precipitation potential model designed for working with urine. A conditional solubility product of $10^{-11.7\pm0.51}$ was determined, which can be used for solutions comparable to source separated urine. With the precipitation model the inorganic complexes $MgPO_4^-$, $MgHPO_4$, $NH_4HPO_4^-$, $NaHPO_4^-$, $MgSO_4$, $MgHCO_3^+$, $MgCO_3$, and $NH_4SO_4^-$ were determined as significant in urine and they exert influence on the solubility of struvite. Ionic strength and formation of dissolved complexes were considered in calculating the average value of the standard solubility product of struvite in urine, which is $10^{-13.41\pm0.31}$. This value is slightly smaller but agrees well with the solubility products reported recently in the literature.

Organic complexing agents do not influence the solubility of struvite.

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Introduction

Forced struvite ($MgNH_4PO_4$) precipitation is known as a possible way to recover phosphate from liquid waste. Several pathways have been described, mostly focusing on the formation of struvite from digester supernatant (Wild *et al.,* 1996; Battistoni *et al.,* 1997; Booker *et al.,* 1999), animal waste slurries (Schuiling and Andrade, 1999; Burns, R. T. *et al.,* 2001) or directly out of wastewater (Durrant *et al.,* 1999; Webb and Ho, 2001). Using struvite precipitation to recover phosphorus from urine has the potential to capture up to 50% of the P-flux in the urban wastewater stream.

Struvite is an orthorhombic crystal consisting of ammonium, magnesium and phosphate in a molar ratio of 1:1:1. Struvite precipitation is controlled by pH, the degree of supersaturation, temperature and the presence of other ions in solution (Doyle and Parsons, 2002). Supersaturation is reached when the activity product (IAP) exceeds the solubility constant (K_s) of a solid:

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Degree of saturation = $\frac{IAP}{K_s}$ (House, 1999)

Fresh urine contains 0.27±0.05 M urea, only little ammonia and its pH is approximately 6.2 (Ciba-Geigy, 1977). Under the influence of bacterial urease, complete hydrolysis of urea takes place, ammonia is formed and the pH increases to above 9 (Udert, 2003a), thereby favouring the chemical properties of source separated urine for the precipitation of phosphorus compounds. The complexity of the solution makes the understanding of the underlying thermodynamics and kinetics difficult.

Many details on the thermodynamics of struvite precipitation in aqueous solutions are known, (Aage *et al.,* 1997; Battistoni *et al,.* 1997; Doyle and Parsons, 2002; Jaffer *et al.,* 2002) but considerably less on the kinetics (Bouropoulos and Koutsoukos, 2000) and precipitation in high strength liquors (Babic-Ivancic *et al.,* 2002). Both parts are important in struvite precipitation research.

This research was conducted to investigate the thermodynamics of struvite precipitation in source separated and artificial urine under controlled addition of magnesium chloride ($MgCl_2$), magnesium oxide (MgO) and magnesium hydroxide ($Mg(OH)_2$).

Background

Solubility product

The solubility product (K_{so}, often expressed as the $pK_{so} = -\log(K_{so})$) is calculated from the total molar activity of the free lattice ions in solution at solid-solute phase equilibrium. In high concentrated solutions such as seawater, apparent or conditional equilibrium constants (K_s or $pK_s = -\log(K_s)$) are frequently used because calculating the ion activity would be too sumptuous or even impossible. The conditional solubility product K_s can only be applied for the kind of solutions they were estimated for and is defined as:

$$K_s = [Mg^{2+}]\cdot[NH_4^+]\cdot[PO_4^{3-}]$$

where $[Mg^{2+}]$ is the measured dissolved concentration of magnesium and $[NH_4^+]$ and $[PO_4^{3-}]$ are derived from the measured concentration of the sum of ammonia and ammonium $[NH_4^+ + NH_3]$ and dissolved phosphate [P], respectively:

$$\left[NH_4^+\right] = \frac{\left[NH_4^+ + NH_3\right]}{\left(1+10^{pH-pK1}\right)} \qquad \left[PO_4^{3-}\right] = \frac{[P]}{\left(1+10^{pK2+pK3-2pH}+10^{pK3-pH}\right)}$$

where pK1 = 9.24, pK2= 7.21 and pK3 = 12.36 according to the equilibrium constants in table 2.

pK_s	Temp. [°C]	Speciation	Ionic Strength	Reference
9.4	nm	no	mention of strong pH effect	(Borgerding, 1972)
12.36	25	yes	0	(Buchanan *et al.,* 1994)
12.6	25	no	negligible	(Bube, 1910)
12.94 12.22	25	yes	0 0.07	(Aage *et al.,* 1997)
13.12 12.97	25 35	yes	nm	(Burns and Finlayson, 1982)
13.15	25	yes	0	(Taylor *et al.*, 1963)
13.26	25	yes	nm	(Ohlinger *et al.*, 1998)
13.36 13.27	25 37	yes	0.5	(Babic-Ivancic *et al.*, 2002)

nm not mentioned

Table 1: Standard solubility product of struvite as reported in literature.

Many researchers report on the value of the solubility product of struvite, with pK_{so} values ranging from 12.22 to 13.36 (tab. 1). A pK_{so} value of 12.6 was first reported by Bube in 1910, which was obtained at 25° C and negligible ionic strength. This value is commonly used in water chemistry texts today (Snoeyink and Jenkins, 1980; Stumm and Morgan, 1996), although no calculation on the speciation was taken into account. In 1963, Taylor et al. reported a value of 13.15, calculated with an ionic strength obtained with the Güntelberg approximation to the Debye-Hückel equation. Burns and Finlayson (1982) obtained a solubility product of 13.12 by using the Davies approximation:

$$-\log f_i = 0.5 z_i^2 \left(\frac{\sqrt{I}}{1+\sqrt{I}} - 0.2I \right)$$ (Stumm and Morgan, 1996)

For solutions of high ionic strength the Davies approximation is used, although it is also limited to an ionic strength of ≤0.5M. Most authors state that the Davies approximation should only be applied for I ≤0.1 M (Pitzer, 1979), but the variance of the equilibrium constants and other data is so high that the error introduced by using the Davies approximation is negligible.

Complexation

The fundamental problem of calculating the ion activity product of struvite is the amount of magnesium, ammonium and phosphate that are effectively available for struvite precipitation; the species can be involved in other complexing equilibria. Also, the speciation of the components is strongly dependent on pH and ionic strength. Ionic strength and complex formation both have an increasing effect on the solubility product. At higher ionic strength the electrostatic interactions of ions are increased, thereby reducing the ion activity and increasing the solubility. In struvite precipitation, complex formation primarily affects the availability of magnesium and phosphate ions.

The need for speciation and complex formation is indicated many times in literature. Although Stumm and Morgan (1996) do not make any calculations on speciation for determining the solubility product of struvite, they do mention that other equilibria beside the solubility equilibrium occur in a solution, and the side reactions increase the solubility. Ohlinger et al. (1998) state that accurate determination of struvite solubility requires consideration of ionic strength effects and inclusion of magnesium and phosphate complexes in the analysis, while both factors increase solubility. In literature, many different complexes involving one or more of the struvite species are mentioned. Ohlinger et al. (1998) take only $MgHPO_4$ into account while other complexes were expected to have little effect on the pK_{so} value in the pH range of 6.3-8.1. Buchanan et al. (1994) include 3 different magnesium ammonium complexes as well as magnesium hydroxide formation. Bouropoulos et al. (2000) also involve magnesium ammonia complexes.

Calculations

Within this work, complexation as well as ionic strength is considered for determination of the solubility product. A selection was made on the complexation reactions within source separated urine. The most dominant species (>3% of the struvite components Mg, PO_4 and NH_4 in equilibrium) were selected using a model for predicting the precipitation potential in urine, developed by Udert (2003b). This model includes many kinetic data on chemical reactions involved in source separated urine. The equilibria constants are taken from literature. (Viellard and Tardy, 1984; Stumm and Morgan, 1996; Martell *et al.,* 1997) When necessary, literature data were adjusted to T=25°C and to the ionic strength with the Van 't Hoff equation and the Davies approximation, respectively (Udert, 2003b). All complexes considered are pH dependent and influence each other; therefore the equilibrium concentrations and ionic strength are determined by iteration.

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Activity factors and ionic strength were determined with the Davies approximation to the Debye-Hückel equation, taking into account all ion species present in source separated urine defined in the model. Ionic strength was calculated with:

$$I = 0.5\sum_i c_i \cdot z_i^{\,2}$$ (Stumm and Morgan, 1996)

Equilibrium							pK_{so}
Mg^{2+}	+	$H_2PO_4^-$	↔	$MgPO_4^-$	+	$2H^+$	12.96
Mg^{2+}	+	$H_2PO_4^-$	↔	$MgHPO_4$	+	H^+	4.3
		$H_2PO_4^-$	↔	HPO_4^{2-}	+	H^+	7.21
		HPO_4^{2-}	↔	PO_4^{3-}	+	H^+	12.36
NH_4^+	+	HPO_4^{2-}	↔	$NH_4HPO_4^-$			-1.3
Na^+	+	$H_2PO_4^-$	↔	$NaHPO_4^-$	+	H^+	6.01
Mg^{2+}	+	SO_4^{2-}	↔	$MgSO_4$			-2.37
Mg^{2+}	+	HCO_3^-	↔	$MgHCO_3^+$			-1.07
Mg^{2+}	+	HCO_3^-	↔	$MgCO_3$	+	H^+	7.35
		HCO_3^-	↔	CO_3^{2-}	+	H^+	10.33
		NH_4^+	↔	NH_3	+	H^+	9.24
NH_4^+	+	SO_4^{2-}	↔	$NH_4SO_4^-$			-1.03

Table 2: Dissolved complexes considered for the determination of the solubility product of struvite in source separated urine. The values for the equilibrium constants are given for 25 °C and an ionic strength of 0. When necessary, literature data taken from Martell *et al.* (1997), Stumm and Morgan (1996) and Viellard and Tardy (1984) were adjusted with the Davis approximation.

Experimental set-up, material and methods

Experiments were conducted to investigate the precipitation thermodynamics of struvite in source separated and artificial urine under controlled addition of 3 magnesium sources. For these experiments, slightly diluted, completely hydrolysed source separated urine was collected from a urine collecting system (consisting of 3 waterless urinals and one NoMix toilet). Artificial urine was prepared according to the recipe of Udert et al (2003c). This preparation does not contain any organic components, so complexation of struvite components with an organic complexing agent is excluded.

Species	g/L	mM	Species	g/L	mM
Na_2SO_4 water free	2.3	16.19	NaCl	3	51.33
KCl	3.4	45.61	NH_4HCO_3	21	265.64
NH_4Cl	3.9	72.91			
NaH_2PO_4	2.0	16.67	NH_4OH	17 ml/L	227.5

Table 4: Composition of artificial urine in deionised water (Udert, 2003c).

Samples were taken from a tap on the bottom of the 0.5 m^3 collection tank (HRT urine >14 weeks), and from an extra tap on the end of the piping system right before the collection tank (HRT urine in the system < 1 week). The composition of the urine used for the experiments are compiled in tab. 4. The source separated urine was slightly diluted because of flushing water from the NoMix toilets. The dilution factor was calculated by comparing the measured total nitrogen to the standard nitrogen concentration of urine (8 gN/L urine, (Ciba-Geigy, 1977)). Batch tests were performed in glass volumetric flasks of 750 ml (real urine experiments) and 500 ml (artificial urine) which were stirred with magnetic stirrers and covered to prevent ammonia volatilisation. Magnesium oxide and magnesium hydroxide were added as a suspension; the water free magnesium precipitants all originated from MERCK (analytical quality). For analysis, 20 ml samples were taken and filtered through a Whatman GF/F filter (0.7µm), acidified with 1.5 ml 2M HCl and stored at 4° C until analysis. Total ammonia, given as the sum of ammonia + ammonium, and phosphate concentration were determined by Flow-Injection-Analyser (FIA, Ismatec AG), magnesium was measured with ICP and ortho-phosphate with IC. COD analyses were done with Dr. Lange LCK 014.

Experiment	Storage time [wks]	[illegible]	[illegible]	[illegible]	[illegible]	$NH_4^+ + NH_3$	Na^+	Cl^-	K^+	$CO_2 + HCO_3^-$	SO_4^{2-}	Mg concentration after addition	
A1	< 4	n.d.	1.77	9.00	8.72	232	80	73	37	176	11	8.45	$MgCl_2$
B1	> 14	6.10	1.77	9.01	5.71	322	68	62	32	91	9	2.96	MgO
B2	< 1	5.42	1.87	9.12	5.13	307	64	59	30	82	9	3.00	
B3	art.	-	1.14	9.17	16.7	501	88	149	40	219	14	2.97	
C1	> 14	5.82	1.93	8.99	4.20	299	62	57	29	77	8	5.98	$Mg(OH)_2$
C2	< 1	6.04	1.86	9.15	3.74	309	65	59	30	83	9	6.02	
C3	art.	-	1.14	9.09	16.7	501	88	149	40	219	14	5.99	

Table 5: Composition of the dissolved components [mM] in urine used for the experiments. Legend: art = artificial urine (recipe see table 3).

Results and discussion

The solubility product of struvite in source separated and artificial urine was identified (tab. 5). All calculations were done in Aquasim (Reichert 1994) with the precipitation potential model (Udert, 2003b).

Experiment	[illegible]	[-]	[-]	[-]	T [° C]	[-]	[mM]	[mM]	mol Mg used … removed	
		12.41	14.11							
A1	< 4	12.41	13.55	0.34	22	9.02	0.50	0.22	0.97	$MgCl_2$
B1	> 14	11.28	13.00	0.40	23	9.03	3.65	0.04	1.00	MgO
B2	< 1	11.68	13.49	0.40	22	9.13	0.97	0.04	1.00	
B3	artificial	11.17	13.31	0.52	22	9.13	9.78	0.02	0.94	
C1	>14	11.89	13.60	0.38	23	9.03	3.13	0.01	1.02	$Mg(OH)_2$
C2	< 1	12.22	13.89	0.39	22	9.16	0.03	0.68	0.97	
C3	artificial	11.18	13.06	0.52	22	9.08	9.17	0.02	1.01	

Table 6: The conditional (pK_s) and standard (pK_{so})solubility product of struvite in urine

The average value of the conditional solubility product for struvite and for slightly diluted urine can be calculated with $10^{-11.7 \pm 0.51}$. This means that compared with the solubility products in tab. 1 struvite is much more soluble in urine than in other solutions. E.g.: Using the solubility constant pK_s of 13.2 and neglecting the ionic strength, the concentrations of dissolved phosphorus and

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magnesium at the end of experiment A1 (tab. 5) would have been 0.28 mM and 0.005 mM, respectively. The real measured concentrations were with 0.5 mM dissolved phosphorus and 0.22 mM for magnesium significantly higher. Fig. 1 shows the correlation between the amount of added magnesium and the fraction of remaining phosphorus for experiment A1. Using an equimolar amount of magnesium chloride leads to a 96% elimination of dissolved phosphorus.

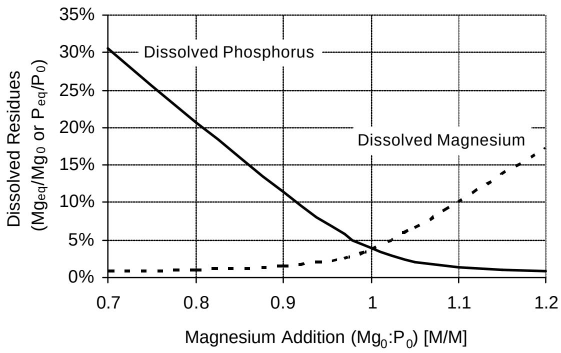

Figure 1: The effect of magnesium addition on the dissolved phosphorus and magnesium concentration at equilibrium. The calculations were done with the urine composition of experiment A1. The initial magnesium is given as molar ratio of the dissolved phosphorus concentration. The residues are given as the percentage of dissolved and therefore not precipitated phosphorus or magnesium.

In order to compare the results from the experiments with the data given in the literature we considered the ionic strength and the formation of dissolved complexes (tab. 2). The average solubility product for struvite is given with $10^{-13.41\pm0.31}$. This value is slightly smaller but agrees well with the solubility products reported recently in the literature. The considered inorganic complexes $MgPO_4^-$, $MgHPO_4$, $NH_4HPO_4^-$, $NaHPO_4^-$, $MgSO_4$, $MgHCO_3^+$, $MgCO_3$, and $NH_4SO_4^-$ play a significant role in urine and influence the solubility of struvite.

The fact that inorganic complexes alone are sufficient to explain the change in struvite solubility indicates that organic complexing agents do not influence the solubility of struvite. This statement is also backed up by the observation that the apparent solubility do not differ significantly between the different types of urine.

Exp.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] [µM]	[illegible] [mM]	[illegible] [mM]	[illegible]	[illegible] [µM]	[illegible]	[illegible] [mM]
A1	91.9	157	0.54	3.15	1.02	0.17	0.10	15.3	2.78	74.8	4.72
B1	3.49	218	4.06	0.81	0.24	1.53	0.66	0.49	1.40	4.00	5.80
B2	15.5	192	1.28	1.16	0.66	0.34	0.17	2.32	5.77	20.8	5.34
B3	7.36	314	12.9	0.66	0.56	5.13	1.28	11.5	1.19	4.25	7.06
C1	4.08	202	3.33	0.79	0.24	1.21	0.57	0.60	1.52	4.26	5.55
C2	22.8	189	0.43	0.56	0.13	0.10	0.053	3.41	8.42	32.5	5.29
C3	3.86	327	10.1	2.00	0.53	4.69	1.35	0.44	2.27	7.23	7.21

Table 7: Calculated concentrations of the species used for the computation of pK_{so} (table 5); activity factors f_1=0.70, f_2=0.24, f_3=0.04 for all experiments.

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Conclusions

In this paper, the thermodynamics of struvite precipitation in source separated and artificial urine have been studied. A conditional solubility product K_s of $10^{-11.7\pm0.51}$ was determined. This value considers the dependency of the solubility on the pH, but neglects the influence of the ionic strength and complexation reaction in the dissolved urine matrix. Due to these effects the solubility of struvite in urine is much higher than under conditions usually applied to determine solubility constants.

In order to compare the obtained conditional solubility product with the K_{so} values from literature we adjusted the measured concentrations to the ionic strength of urine with the Davis approximation and considered the following inorganic complexes: $MgPO_4^-$, $MgHPO_4$, $NH_4HPO_4^-$, $NaHPO_4^-$, $MgSO_4$, $MgHCO_3^+$, $MgCO_3$, and $NH_4SO_4^-$. This approach leads to a standard solubility product K_{so} for struvite of $10^{-13.41\pm0.31}$ as an average for all performed experiments, which does not significantly differ from the solubility products reported in the recent literature (table 1).

The inorganic complexes used for the estimation of the standard solubility product K_{so} were sufficient to explain the measured dissolved concentration of ammonia, magnesium and phosphate. In addition, no difference could be identified between precipitating struvite in source separated urine with organic compounds and inorganic artificial urine. It can therefore be concluded that in our experiments organic complexing agents do not influence the solubility of struvite significantly.

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The functional analysis of compost toilet for remote areas *

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Keywords

Compost toilet (heated and unheated); energy consumption; nightsoil; urine separation

Abstract

A pilot-scale compost toilet for a family of 5 persons and 2 laboratory-scale composting units were operated in this study both at room and elevated temperatures. The sawdust was used as a bulking agent. Elevated temperature operation for pilot-scale reactor could secure pathogen kills and no liquid left except composted material, but the heat loss significantly increased electric consumption. The liquid (urine) evaporation actually required more energy than the potential heat energy to be released during the nightsoil degradation. The energy produced from sawdust was far greater than that of nightsoil, and it was observed the nightsoil addition stimulated the sawdust degradation. A practical modification has been made not only to save energy but also to separate liquid in the compost toilet. The separated liquid could store for agricultural use, or evaporated if needed. The composted material and stored urine could be removed once or twice a year for an unheated operation.

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Introduction

Daily life produces various kinds of wastes such as solid waste and wastewater including faeces and urine. Faeces and urine contribute about 2/3 of the total BOD produced from the daily life. There are 3 options available to treat faeces and urine in Korea depending on localities; traditional toilet with storage tank, flush toilet and compost toilet.

Traditionally, the faeces and urine, or called as 'nightsoil' were stored and used as a fertilizer in oriental countries. However, this practice has been restricted to the limited areas because of sanitation problems and rapid urbanization. Therefore, the stored nightsoil in the traditional toilet had to be collected by truck and treated at municipal nightsoil plants. About 200 nightsoil treatment plants are still in operation in Korea, but this practice has also been replaced by the construction of sewage treatment plants, because people are in favor of using flush toilets for more comfortable life particularly in urban areas. Compost toilet has been developed for an ecological sanitation system without using flush water as well as minimizing odor problem, and aimed for a total recycle of waste material in rural areas.

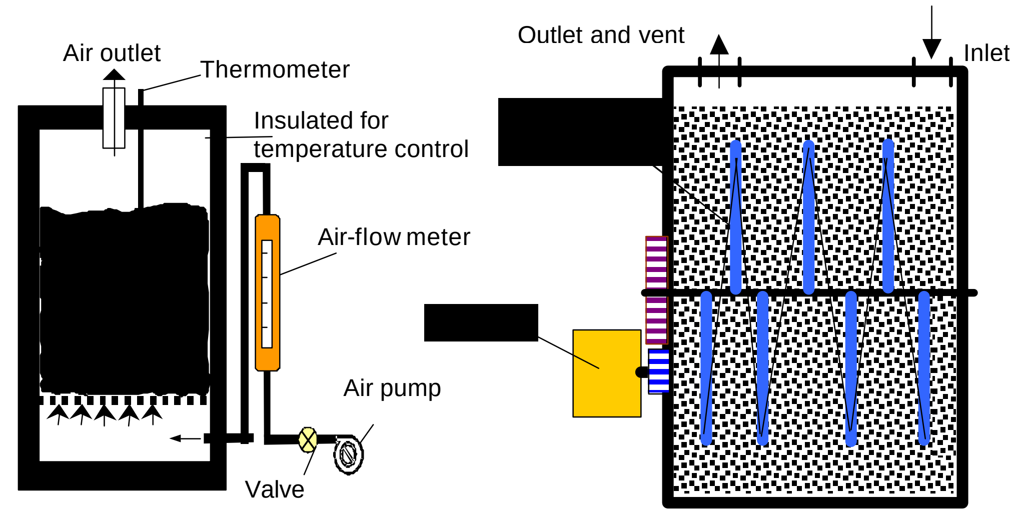
This study was conducted for the functional analysis of a compost toilet developed for remote areas where no sewers are available. This study included the evaluation of overall performances of the compost toilet operated with and without heating operations. Unlike the traditional toilet, no odor problem has been reported in compost toilet. The compost toilet has become a reliable treatment method for feces and urine and used for single dwellings and public places in Korea (Korean NRLSI, 2002). The functional analyses were made with

*This paper has been peer reviewed by the symposium scientific committee

monitoring temperature, oxygen demand, C/N ratios, moisture content, energy consumed for heating and mixing, and others.

Materials and methods

Preliminary laboratory bench scale studies were carried out prior to the operation of pilot-scale unit to determine temperature effects for the active degradation for nightsoil at different temperatures of 35 and 15^{o}C with supplying air underneath the pre-controlled moisture content of 60% with sawdust and nightsoil in the insulated reactors as shown in Figure 1. Table 1 denotes the characteristics of nightsoil and sawdust used in this study. All analyses including total solids (TS), volatile solids (VS) were performed as defined in *Standard Methods* (APHA, 1998).



(a) Lab scale units (b) Pilot unit for a family of 5 persons

Figure 1: General view of compost reactors used for this study

Constituents	Sawdust	Nightsoil*	Urine**	Feces**
pH	5.5	7.0-7.2	9.1-9.2	7.2
Moisture(%)	3.6	96	99+	95
TS (%)	96.4	4.03-4.27	0.8-1.1	4.5-5.4
VS (% TS)	99.4	68.4-70.6	48-49	68-71
TKN (%)	0.12	0.4-0.42	0.55-0.89	0.43-0.5
TOC (%)		3.9-4.5	NA	3.23
C/N ratio	540	9.8-10.7	1-1.4	8.4
COD (g/L)		54-55	7.8-8.5	65-73
BOD (g/L)		18	NA	28-31
Fecal coliform (No/100 mL)		4.6×10^{10}	NA	2.6×10^{10}
Cl^- (g/L)		4.1	7.4-8.8	4.1-5.5
Caloric content*** (Kcal/kg TS)	5,000	5,000	NA	NA

*Measured at a nightsoil plant, **Urine and feces separated from sources,*** Predicted.

Table 1: Characteristics of nightsoil and sawdust used for this study

The pilot unit (compost reactor) had an effective capacity of 228 L with 50 cm width x 115 length x 85 cm depth designed for a family of 5 persons. The reactor was intermittently mixed by 100-

watt (w) motor and heated electrically by heat tapes (160 w capacities) installed at the bottom of the reactor as shown in Figure 1(b). A total amount of 42 kg of sawdust (dry weight: 40.5 kg) as a bulking agent was placed in the reactor at the start, and 5 L of nightsoil was added every day. The reactor temperature, electric consumption, moisture contents, carbon-to-nitrogen (C/N) ratios, oxygen uptake rates and pH were monitored. The pilot unit was installed inside of a room to detect odor easily. The experiment was also extended without an external heating in order to identify possible problem during the operation.

Results

Minimum retention time for nightsoil degradation

It could be said that the nightsoil is relatively easily degradable in comparison to sawdust, which is largely natural cellulosic material. Both batch units operated with 35 and 15°C indicated the temperature increased rapidly within 2 days followed by a slow decrease to about 6 days from the start (Figure 2). The observation suggests that the degradation of easily degradable portion of nightsoil rapidly increased the temperature, and the remaining portions were degraded slowly. The measured maximum oxygen demands were 3.3 $mgO_2/gVS/hr$ with an average of 1.7 $mgO_2/gVS/hr$ at 15°C unit and 5.2 $mgO_2/gVS/hr$ with an average of 2.7 $mgO_2/gVS/hr$ for 35°C. The results also suggest that the higher temperature stimulated the degradation rates and could shorten the time required for composting.

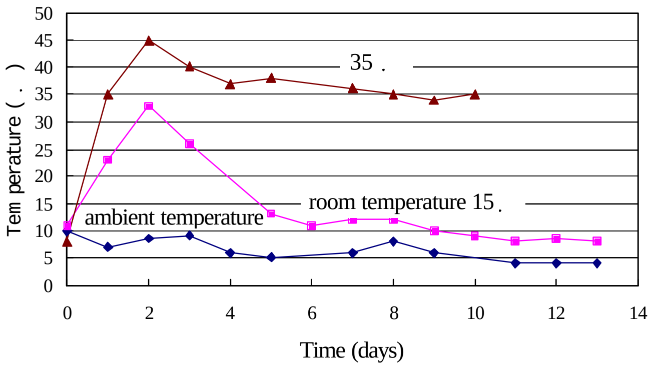


Figure 2: Temperature profile at the batch units

A temperature sensor inside of the reactor controlled the temperature in pilot-scale compost reactor. If the temperature increased excessively, the electrical heater was automatically off, and if the temperature became lower than the preset condition, the electrical heater was automatically on. Therefore, the electric consumption for heating could show how much energy was supplied by electricity as well as how much heat released by the degradation of organic matter applied.

Figure 3 presents energy consumption and the temperature profile in the pilot-scale unit. Some specific features revealed during operating periods of the pilot-scale compost reactor were summarized as follows:

- Idling period with sawdust without feeding: Energy consumption was about 3.07 kwh/d without mixing (data not shown in Figure 3).
- 1 to 20 d period: 5 L/d of nightsoil addition increased energy consumption of 3.8 kwh/d at start, and the consumption increased to about 4.2 kwh/d, to evaporate about 35 L of water during the first 20 days with 29 times of mixing/d. C/N ratios were 341 at 7 d and 43 at 20 d, respectively.

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- 21 to 31 days: Nightsoil and sawdust actively degraded during this period and the energy consumption rate reduced to about 3.2 kwh/d with 9 times of mixing/day. C/N ratio was 36 at 27 d.
- 32 to 40 days: Energy consumption increased to 3.8 kwh/d without feeding of nightsoil with 4 times of mixing/d.
- 63 days: A total amount of 14.4 kg composted material was removed from the reactor and 8 kg of sawdust was refilled. C/N ratio was 20 at 41 d and slowly reduced 15 at 53 d, but increased to 128 with the refilling.

The temperature at 20 cm from the bottom of the reactor was about 30^{o}C, whereas temperature at 10 cm from the top of the sawdust was stabilized at about 60^{o}C, which was high enough to kill pathogens (Lue-Hing *et al*, 1992). The first 20 d of operation represented low temperature because the active degradation of nightsoil seemed not be well developed. The moisture content reached to 60 % at about 20 d from the start. The pH increased to 8.5 and slowly decreased to about 8 at about 60 d. Figure 4 represents variations of pH, moisture contents and C/N ratios along with the operating period. If the desirable C/N ratio of the composted material was around 20 (Diaz *et al*, 1993), the minimum retention time seemed to be about 20 days excluding the start up period. The result was the identical retention time obtained from liquid phase aerobic digestion of nightsoil for 95% BOD removal (Choi *et al,* 1983).

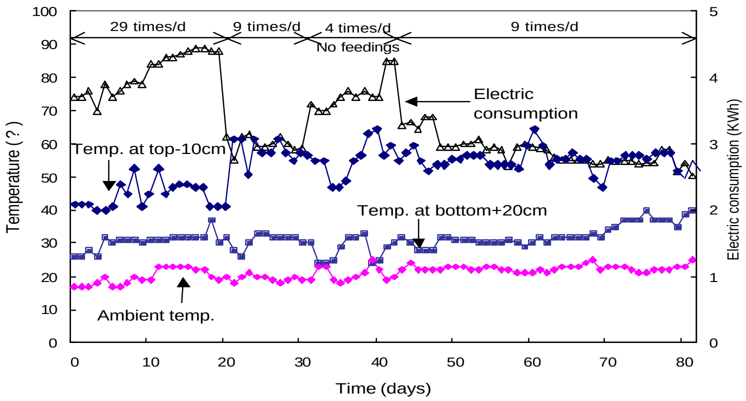

Figure 3: Temperature profile and electric consumption with operating time (pilot unit)

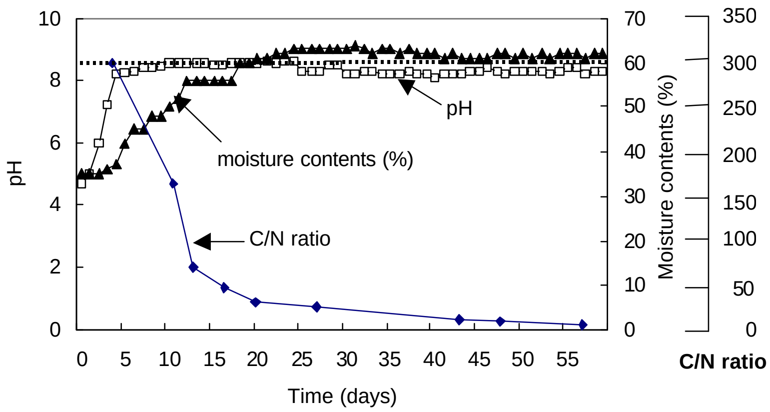

Figure 4: pH, moisture contents and C/N ratios in pilot unit with time

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Energy consumption

Electric consumptions for keeping the temperature of 30°C to 60°C and providing mixing were almost consistent except those periods of start up as well as no feed as shown in Figure 3. The start up period required a higher electric consumption with little energy release from the biological degradation. It is obvious that the frequent mixing provided more aeration resulting an increased cooling of compost, but the energy requirement for mixing itself was very small in comparison to the energy requirement for heating. During the start up period, 3.5 minute of mixing was provided at 29 times per a day, but the mixing frequency reduced to 9 times or 4 times during the later operations. With 9 times of mixing per day, the total average electric consumption was 3.2 kwh/day except the period of 32 to 41 d without feeding which required relatively higher electric consumption of about 3.8 kwh/d. The difference was about 0.6 kwh which is an equivalent to 516 kcal/d. Unit conversions were based on: 1 kwh = 3412 btu = 860 kcal, 1 btu = 0.252 kcal = 1.054 kJ (1 kcal = 4.18 KJ), and btu/lb = 0.252 kcal/0.45 kg = 0.56 kcal/kg. The overall summary of energy balance is shown on Figure 5.

It was assumed about 95% of 5 L nightsoil was evaporated with the electric heat resulting in heat loss of 2,700 kcal/d (3.1 kwh/d) with evaporating energy of 600 kcal/kg water. The biodegradability of nightsoil was assumed to be about 65% and produce 3,600 kcal/kg COD degraded (Lapara and Alleman, 1999) resulting in heat production of 655 kcal/day (0.76 kwh) which is about 1/4 of the energy to be required for evaporation of water from nightsoil. This means nightsoil addition requires 1,970 kcal/d equivalent to about 2.34 kwh/d. The summary of energy consumption is also shown on Table 2.

Since energy consumption was increased from 3.2 kwh/d to 3.8 kwh/d during no feed period of 32 to 40 d, about 2.94 kwh/d (=2.34 + 0.6) of energy was not released. Thus, it could be easily assumed the sawdust was the major source of heat released. Actually, 40.5 kg sawdust could have a total caloric content of 200,000 kcal from Table 1. However, the biological degradation of sawdust seemed to be retarded during unfed period probably due to the deficiency of certain nutrients, which could has been supplied by the nightsoil addition. Nitrogen could be a possible one, since it could vaporize easily at high pH and high temperature. However, it seemed that nitrogen was not limiting during this period showing the lower C/N ratio of about 20 in comparison to the previous periods with higher C/N ratios of 36 to 40 as previously shown on Figures 3 and 4.

The measured oxygen demands of the composted materials from the pilot unit were respectively 2.3 mg/gVS/hr at 20 d, 2.8 mg/gVS/hr at 43 d and 2.2 mg/gVS/hr at 70 to 90 days with an average of 2.4 mg/gVS/hr. Since the composted material consisted of 90% of VS, the total amount of VS in the reactor was assumed to be 36.5 kg VS resulting in oxygen demand of 87.6 gO_2/hr or 2.1 kgO_2/d, which is an equivalent to 7,560 kcal/d (8.79kwh/d). This suggested nightsoil potentially released only about 9% of the total heat released from the compost reactor. The higher oxygen demands at the bench scale units were due to a relatively large amount of nightsoil being added to sawdust to secure the moisture content of 60% from the beginning of operation.

- Measured minimum energy required during idling period: 3.07 kwh/d
- Normal energy consumption: 3.2 kwh with feeding 5 L/d nightsoil excluding 32 to 40d
- Energy consumption without feeding from 32 to 40 d: 3.8 kwh/d
- Energy released from sawdust degradation w/o nightsoil: 2.34 kwh/d
- Energy released from sawdust during normal operation: 5.28 kwh/d
- Potential heat release from sawdust degradation: 8.79 kwh/d (7560 kcal/d)
- Potential heat release from nightsoil: 0.76 kwh/d (655 kcal/d)

Table 2: Summary of energy consumption and potential heat release

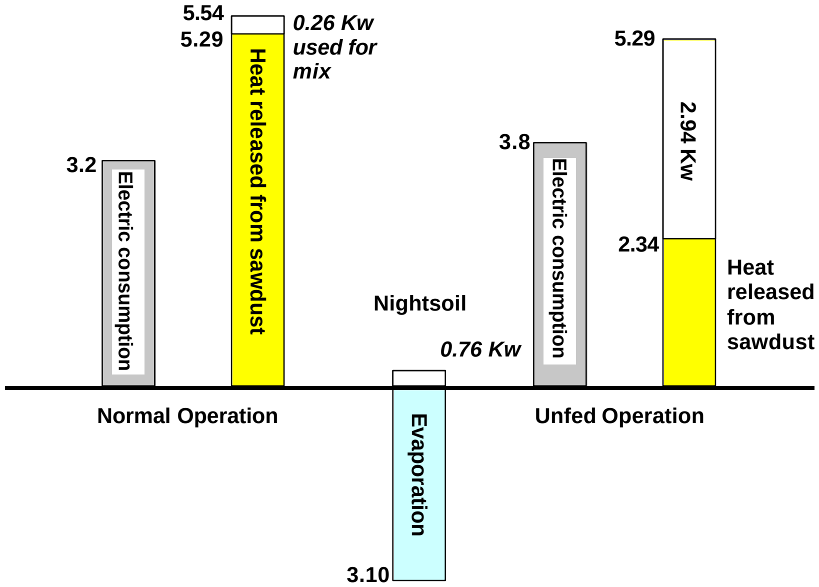

Figure 5: Energy balance during the normal- and unfed-operation

Practical modification

It was understood the energy provided to the compost reactor was mostly lost by heat transferred to outside from the reactor and for the evaporation of excess water from nightsoil. The bench scale and pilot plant studies suggested that lower temperature operation did not cause any significant problem for the degradation of nightsoil, except it would require longer time for composting and unsecured pathogen kills. It was, however, noticed that there were some flying insects, but no odor problem was noticed. The possible reduction of odorous substances in compost toilet compared to traditional toilet was shown on Figure 6. It has been known that sewage sludge and animal waste with a bulking agent could successfully be composted without an external heating, and therefore, a modification was made with separation of urine as shown on Figure 7, which could be done by providing drain holes at the bottom of the composting reactor (Changil Industries, 2002). With a proper amendment in this case rather than applying the bulking agent-only to control the moisture content, the system could easily increase the reactor temperature sufficiently enough to kill the pathogens in feces as well as to shorten the time to be required for composting. In addition, urine separation could reduce the chloride content of composted material accumulated by evaporation. This would be beneficial for agricultural use. Currently, Korean Ministry of Agriculture has selected the compost toilets for improving the quality of life and reducing the environmental problems in rural areas, and provided some subsidy for the construction of this system, which includes compost reactor with mixer and liquid storage (Korean NRLSI, 2002). For those remote areas not served by electricity, only forced ventilations are supplied by solar cells.

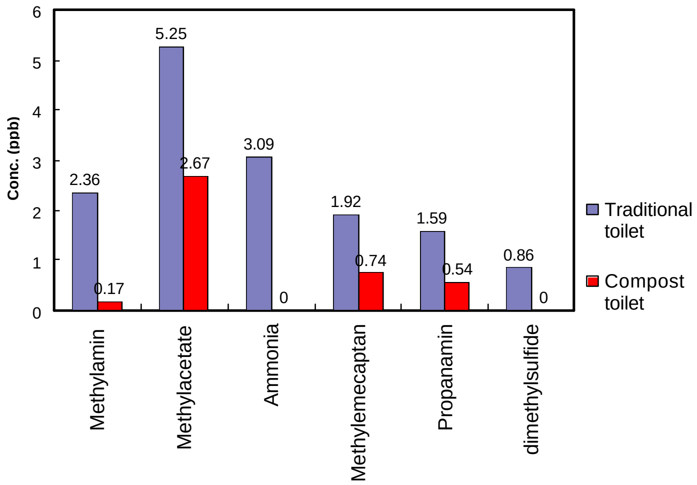

Figure 6: Selected measurement of odorous substances in vent of toilets

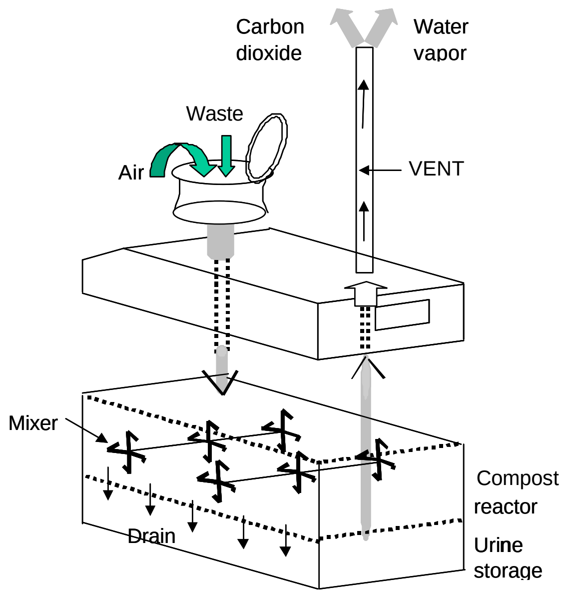

Figure 7: Practically modified compost toilet segments

Separated urine

Table 1 previously presented the characteristics of separated urine from sources. The specific characteristics seemed almost unchanged except COD concentration during the experimental period of 11 months. The first 5 months, however, did show very little change, but the latter 6 months reduced 75 % of COD applied. In addition, NH_4N concentration increased during this period probably due to the increase of ammonification.

The stored urine were removed from compost toilet at about 2 times per a year or evaporated by submerged heaters if required. It was reported that the urine is relatively sterile and can be used without further treatment (Wolgast, 1993). Since the urine in this system was discharged to the top of the compost reactor and collected from the bottom, a special attention has to be paid for possible pathogen contamination from the contact with partially degraded feces.

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Conclusion

Preliminary laboratory bench-scale units and a pilot-scale compost reactor for a family of 5 persons were operated at room (15°C) and elevated temperatures with sawdust for the treatment of feces and urine. Pilot-scale reactor was operated at temperature of 30°C to 60°C with a nightsoil addition of 5 L/d and following conclusions were drawn:

Preliminary studies with laboratory compost units indicated that an elevated temperature (35 °C) stimulated the degradation rates and could shorten the composting time. The minimum retention time for the degradation of feces and urine seemed to be 20 days. The unheated operation of pilot-scale reactor allowed the growth of some flying insects without an odor problem.

The elevated temperature operation for compost reactor could secure pathogen kills and no liquid left except composted material, but a relatively large amount of heat loss increased electric consumption; 3.2 kwh/d for a family of 5 persons or 0.64 kwh/L for the nightsoil treated. The liquid (urine) evaporation actually required more energy than the potential heat energy to be released from the nightsoil addition. The energy produced from sawdust was estimated to be far greater than that of nightsoil itself. It was observed that the nightsoil addition stimulated the degradation of sawdust.

A practical modification to reduce the electric consumption was made with a liquid separation in the compost reactor, and the separated liquid were stored for agricultural use or evaporated if needed. Once or twice a year removal of composted material and separated urine was the common practice with unheated operation.

Acknowledgement

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Vacuum sewers – an element in ecosan systems

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Keywords

Vacuum sewerage system, separation

Conventional sewers

It is a most important aspect of Ecosan Systems to collect different waste streams in a concentrated and not diluted state. Years and decades ago several countries have implemented separate collection systems for solid (household) waste. Different fractions like paper, tins, (coloured) glass, plastics and others are collected separately in different bins, bags, containers and other collectors. The aim is not the collection itself but the subsequent separate treatment of the different fractions. The same should be possible and feasible with different waste water fractions.

The first and most important step is to separate waste waters from households and rain (storm) water. Still today in all countries of the world sewerage systems are installed which do not separate between surface waters and household waters. The consequence is a significant increase of the waste water quantity and a significant dilution of the pollutants. Thus the adjacent STP has to bee designed according to the demands which are higher waste water quantities and lower pollutant concentrations. Otherwise the efficiency of the STP gets higher the more concentrated the waste water flows are.

In addition a constant waste water stream from households without any additional surface waters causes a more substantial and reliable layout of the subsequent STP. Finally the STP may not be charged with overflows caused by heavy rainfall thus implying open bypasses and the transport of untreated waste waters into nature.

Vacuum sewers

The solution are separate sewers for domestic waste waters and for storm waters. And the solution may be even more easy using Vacuum Sewer Systems for the domestic waste water fraction.

Vacuum Sewer Systems have many decisive advantages:

- Closed system – no leakage, no odour
- No ground water pollution – no exfiltratrion
- Only one central vacuum station – no further pumping stations required
- No blockage – no flushing
- Flexible system
- No electrical connection except at the vacuum station
- Small diameter plastic pipes (dn 80 to dn 200); hdpe or pvc
- No clogging due to high velocity in the sewer pipes

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- No flushing tanks required – significant water saving
- No storm water infiltration
- Smaller sewage treatment plant required

It should be mentioned that Vacuum Sewerage Systems (VSS) are not the appropriate solution for every problem. Applications for VSS are such:

- Flat terrain – no natural slope
- Municipalities, residential and commercial areas
- High ground water tables
- Trenching in rocky and sandy environment
- Ecologically sensitive areas – ground water
- Rural and town-near regions
- Where conventional sewage systems become very expensive

Vss are:

- An alternative to gravity sewer
- Ideal for municipal and industrial waste waters
- Less costly than conventional systems (wherever roediger has installed such plants)
- A standardized technology, as per norm en 1091
- Recommended by many authorities and institutions

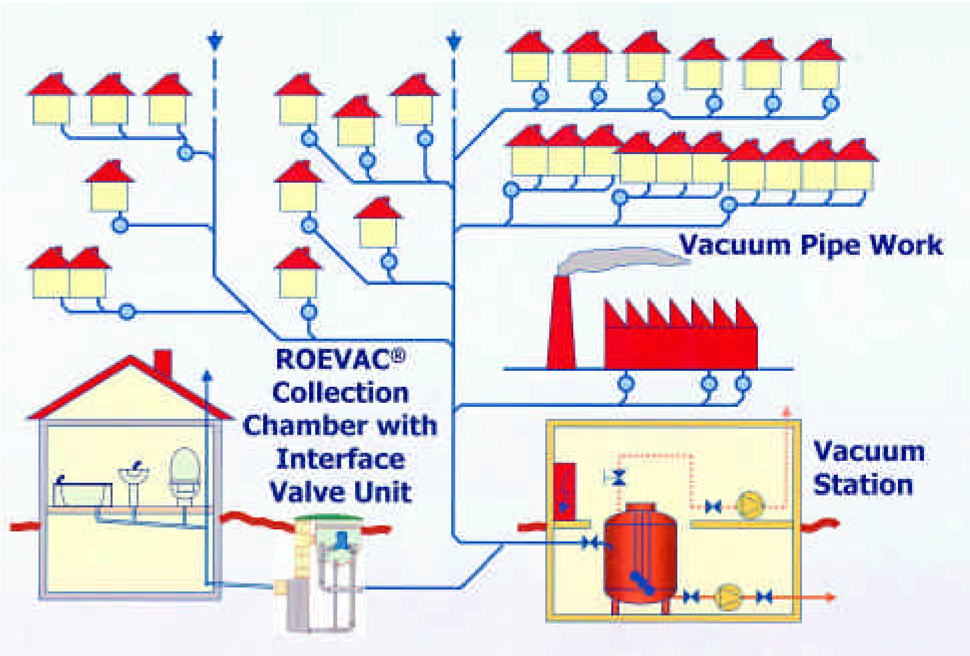

Figure 1: The vacuum system

"Vacuum" is not the correct word, it should be called "Underpressure" Sewerage System as the underpressure in the system is about -0.5 to -0.6 bar to ambient pressure.

The heart of the System is the central Vacuum Station. Two or more Vacuum Pumps will generate the necessary underpressure in the Vacuum Tank as well as the complete Reticulation Network. Air is evacuated from the system by these pumps. This air enters the system via the Collection Chambers which are located nearby the houses in the ground. Waste waters flow via gravity pipe from the houses to the Collection Chamber. They will be collected in the Sump. After a certain quantity of WW is collected (about 30 litres) the blue Interface Valve opens and the WW will be evacuated into the Vacuum Pipe. Together with the quantity of water about 4 times more air will be sucked into the system. This amount of air is needed as transport medium for the water. Thus the transport velocity in the system is about 4 m/s.

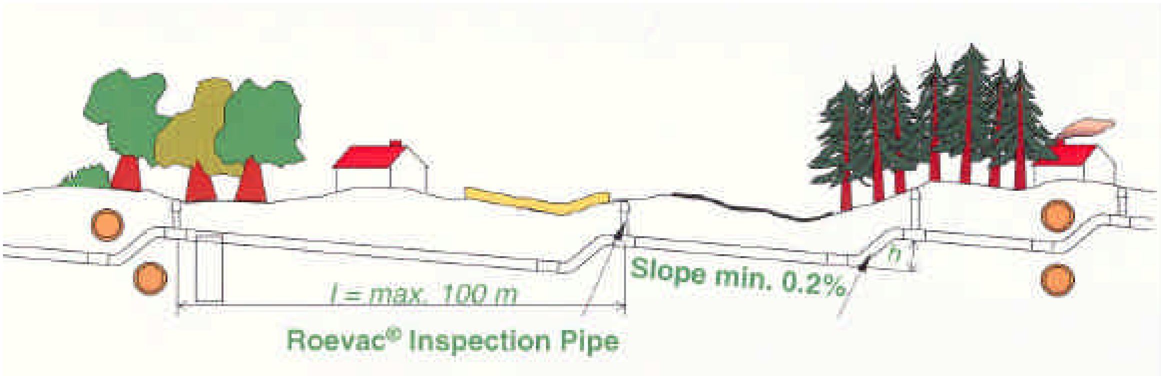

Figure 2: Saw-tooth-profile

	Gravity System	Vacuum System
Pipe Diameters	Large (> 200)	Small (80 – 200)
Pipe Material	PE or stoneware or concrete	PE or PVC
Trenches	Deep (up to 8 m and more) Wide	Shallow (1 – 1.4 m) narrow
Excavation	Complicated and long term	Simple and fast
Machinery required	Heavy machinery	Simple or even no machinery
Lifting Stations	Required as pipe is too low	Not required
Leakage	possible	Impossible
Traffic	High impact on local traffic	Low impact on local traffic
Pipelines for fresh water and waste water in the same trench	Not allowed	Possible and allowed
System	open	Closed
Manholes	required	No manholes, only inspection pipes
Dry Sewers	possible	Not possible
Fouling of waste water	Possible	Not possible
Flushing of pipelines	Sometimes required	Not required

Table 1: Comparison of gravity and vacuum system

The water together with the air are sucked into the Vacuum Tank. The Vacuum Pumps evacuate the air from the Tank through a Biofilter into the atmosphere. Discharge Pumps transport the waste water from the Tank to the next STP or local sewer.

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The pipeline network consists for flexible small diameter Pipes made of PVC or PE. They should be located in small trenches into the frost free zone (about 1.2 m deep). They follow the design of the Saw-Tooth-Profile. Thus even small lifts are possible.

Some more advantages compared to the conventional gravity system are evident which make the system easier, faster to install, cheaper and more flexible:

Ecosan

ECOSAN Projects take advantage of the a.m. criteria. Rain and Storm Water do not have to be treated in a STP. They may ooze away into the ground and fill up the ground water level. Domestic Waste Waters have to be treated in individually designed STPs. Even more steps are possible: the separation between black and grey water. The Lübeck-Flintenbreite Project demonstrated this in a very effective way what OtterWasser and Roediger have installed jointly.

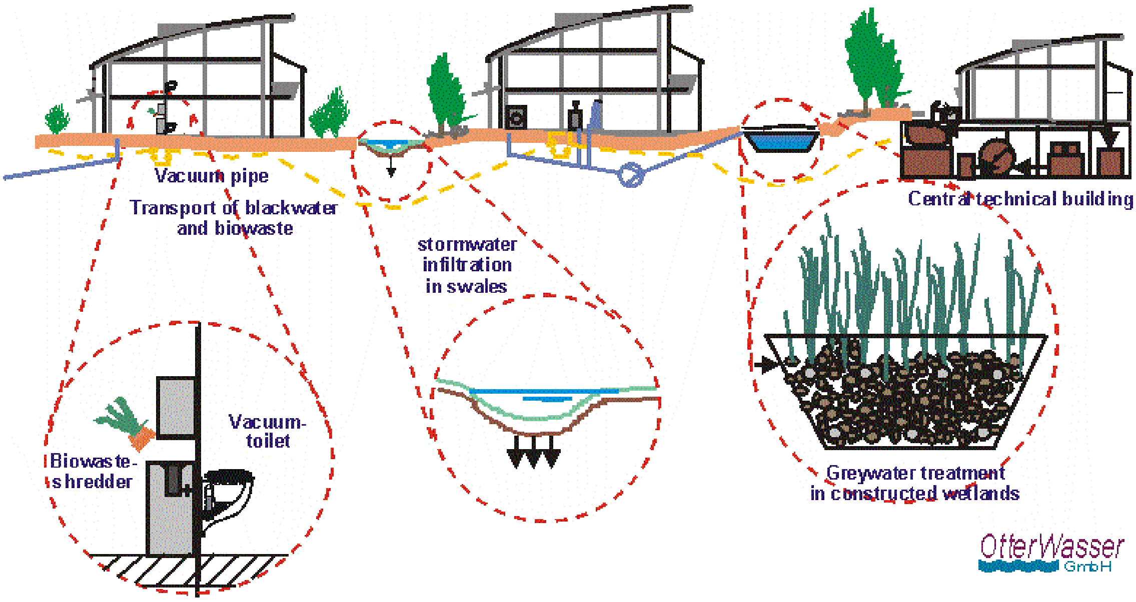

Figure 3: Ecosan project Lübeck Flintenbreite

Storm water shall infiltrate into the ground in swales. Grey water is treated in wetlands/reed bed filters and may be reused for toilet flushing, irrigation or infiltrate into the ground, too. Using a ROEVAC® Vacuum Toilet reduces the water consumption significantly as only 1 litre is used per flush. This avoids any further dilution of the faeces and urine. Black water finally is treated in anaerobic digesters together with kitchen waste and other organic (biologically degradable) wastes. The Black Water fraction is transported to the digesters via a Vacuum Sewer System.

Further Projects in Arab Countries and China follow the same concept of the collection of separated waste fractions. A project in China includes a market place with considerable amounts of bio waste from fruits and vegetables. Other projects prefer reusing significant quantities of pre-treated grey water for irrigation. Vacuum Sewerage is a main component of all these combined systems which makes construction, installation, operation and maintenance more easy.

Dry fermentation biogas technology – a practical approach for closed loop sanitation, waste stabilisation and nutrient recovery

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Keywords

Anaerobic digestion, biogas technology, compost, dry fermentation, ecological sanitation, hygienisation

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Abstract

The technology of „dry fermentation“ can generate energy with communal and agricultural organic waste and biomass. Mixed with substrates from human origin such as yellow water (urine), brown water (faeces, night soil) and to a lesser extent grey water, the aim of a hygienic treatment and additional fertilizer recovery can be realized. Up until now biogas technology mainly concentrated on „wet fermentation“ of agricultural and communal biowaste as well as sewage sludge, the dry fermentation process can produce methane from biomass, which is not liquid, and in a mixture night soil collected from dry toilette systems. The one staged batch process needs no mixing of biomass during fermentation and no adding of water or liquid compounds, as it is necessary in conventional wet fermentation systems. The usual stirring and pumping falls away completely in batch dry fermentation systems. It is especially suited for application in semiarid climates as the water consumption in the process is very low compared to conventional anaerobic digestion systems and can be recovered from the ecological sanitation system.

Introduction

The technology of „dry fermentation“ can generate energy with communal and agricultural organic waste and biomass. Mixed with substrates from human origin such as yellow water (urine), brown water (faeces, night soil) and to a lesser extent grey water, the aim of a hygienic treatment and additional fertilizer recovery can be realized. The dry fermentation process is an anaerobic digestion technology for solid, stackable biomass and organic waste, which cannot be pumped. It is mainly based on a batch wise operation with a high dry matter content ranging from 20 to 50 % at mesophilic temperatures. There are different systems in operation throughout Europe and Africa. Amongst those four systems seem to be the most promising for widespread future application as they are in the starting phase of commercialisation or already in practical use.

Technology description

There are different systems in operation throughout Europe and Africa. Amongst those four systems seem to be the most promising for widespread future application as they are in the starting phase of commercialisation or already in practical use. The four systems can be described as the "garage type" digester with or without percolation, the "bag type" digester in airtight plastic sheeting, the "immersion liquid storage vat" type digester and the "wet – dry combination" digester. The substrates treated in these systems can be solid animal manure with straw, household and communal bio waste, green cuttings and grass from landscape maintenance, energy crops from the field (fresh or ensiled) They are very well suited for application in ecological sanitation systems treating brown water residues (faeces, night soil, residues from compost toilets) in combination with animal waste, biomass or biowastes from households.

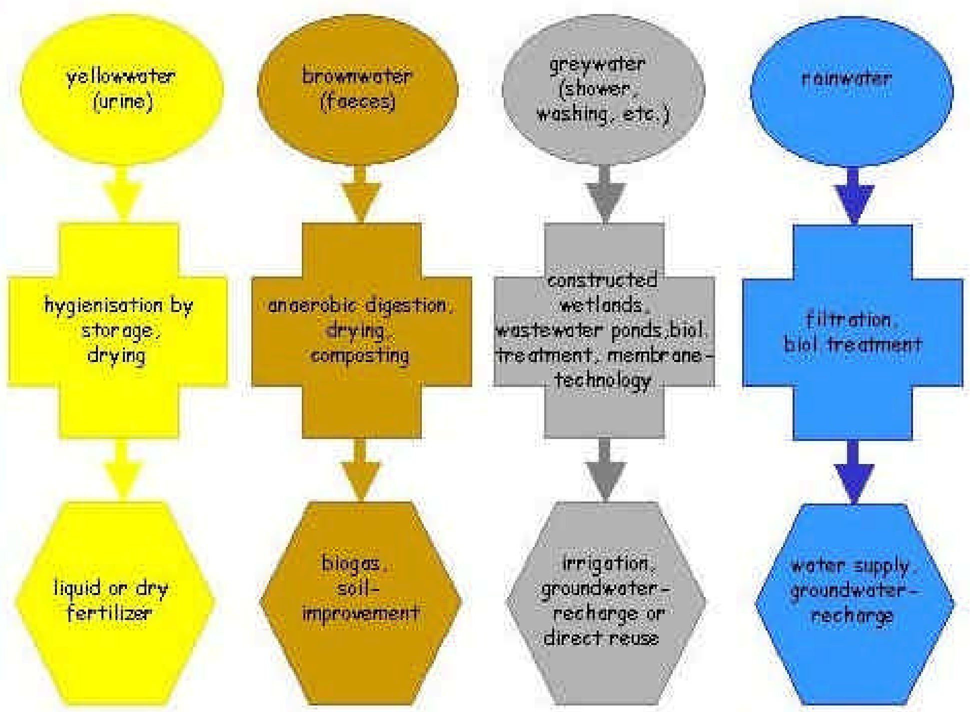

Figure 1: General description of an ecological sanitation system (ecosan, GTZ 2002)

Dry fermentation systems in batch wise operation have been in operation in Algeria, France and Germany since the 1940ies. Especially the French system, which was manually operated with self-heated manure, spread further a field into Algeria. Further tests of the batch wise fermentation of horse manure were undertaken in the former Czechoslovakia and Hungary. Recently further developments took place in Germany, the Netherlands (*BioCel*), Switzerland *(Lully)* and West-Africa (Burkina Faso, Niger and Mali by *GTZ GmbH and by Mali Folkecenter*).

Treatment and collection of the incoming substrates

The substrates are collected from the sources either manually or with special equi pment for manure, bio waste or faces collection or machinery for harvesting energy crops from the field. The substrates are dumped in a special storage section next to the digester and inspected visually. Large contaminants such as wood or non organic of the incoming bio waste from households or landscape maintenance which are a nuisance for the smooth operation of the digester are removed and put aside.

For further pre-treatment the "acidic" and "alkaline" substrates are mixed in equal ratios, e.g. inoculants and fresh material. This is important for digesters, which solely work on the dry

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system with very little or no additional liquid. In these systems, for the optimal performance of the digester, specific bacteria have to be cultured for the substrates and have to be mixed in before hand. The optimal ratio between inoculants and fresh material has to be found and kept up in each batch mixture. In order to keep up a loose consistence in the digestion heap structure material like straw, bark, or wood chips are mixed in.

Biological process management

Through the pre-treatment of mixing and storing of the substrates for one to three days a first aerobic biological conversion in the material is provoked. This is counteracting to an acidification at the beginning of the anaerobic phase. The temperature increase in this aerobic phase is catalysing the start of the anaerobic mesophilic or thermophilic operation. The initial self-heating reduces the heat requirements during the process.The biomass is digested under airtight conditions after inoculation or flooding with digested substrate. The further inoculation with bacterial matter is taking place through recycling of a bacteria rich percolation liquid, which is sprayed over the biomass. When necessary, through a built in floor heating system in the digester and an installed heat exchanger in the tank of the percolation liquid the temperature of the process can be regulated. The different degrading reactions (hydrolysis, acid and methane formation) take place in one digester. After a retention time of around 30 to 40 days biogas production is almost zero and the digesters are unloaded.

In dry–wet fermentation systems the substrates don't need to be mixed or inoculated as the flooding or percolation liquid (yellow water, if this is not separately used, or if it is mixed already with water from wet fermentation; grey water; nightsoil or slurry) takes over the role of the bacterial inoculation and process starting.

Figure 2: Aerial view of a wet-dry combination biogas - plant

Practical operation and energy output

The following figures of biogas yields were obtained partly in pilot plants and are partly taken from wet fermentation as their gas yield are similar to dry fermentation.

	DS (in %)	ODS (% of DS)	C / N ratio	m³ Biogas per kg ODS	Gas yields (rel. to fresh substance and cult area).	
					m³ / t FS	m³ / ha
Bio waste	40 - 75	45 - 70	25 – 80	0,45	120	--
Gras silage	40	83	12 - 27	0,455	220	5720
Poultry manure	50 - 70	60 - 70		0,55 – 0,65	300 - 400	--
Vegetable waste	5 - 20	60 - 90	15	0,45	80	--
Canteen waste	9 - 18	90 - 95	15 -20	0,55 – 0,78	80 - 170	--
Chicken manure	21	75	10	0,5	160	--
Potato waste	20	0,94	25	0,55	120	--
Horse manure	28	75	18 - 25	0,45	82	--
Cattle manure	12 - 25	65 - 85	14 - 25	0,2 – 0,3		

Table 1: Parameters of substrates

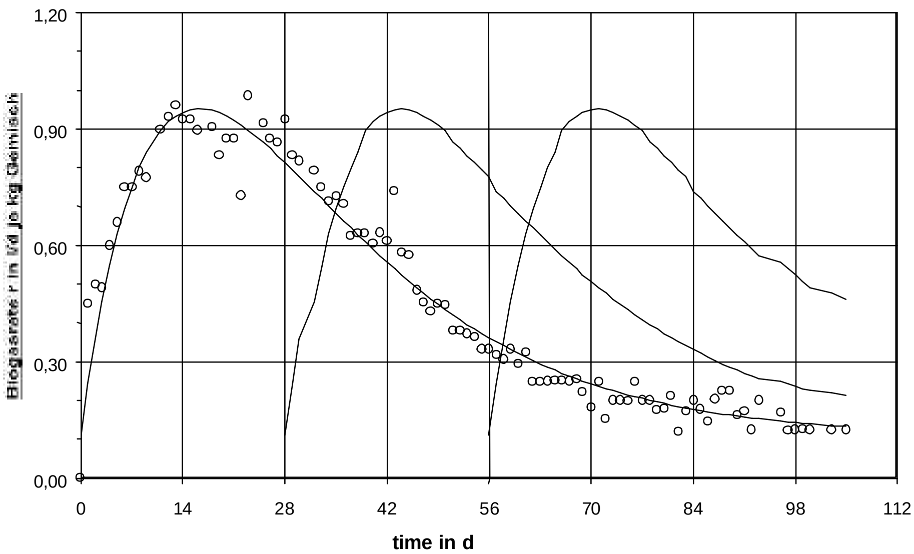
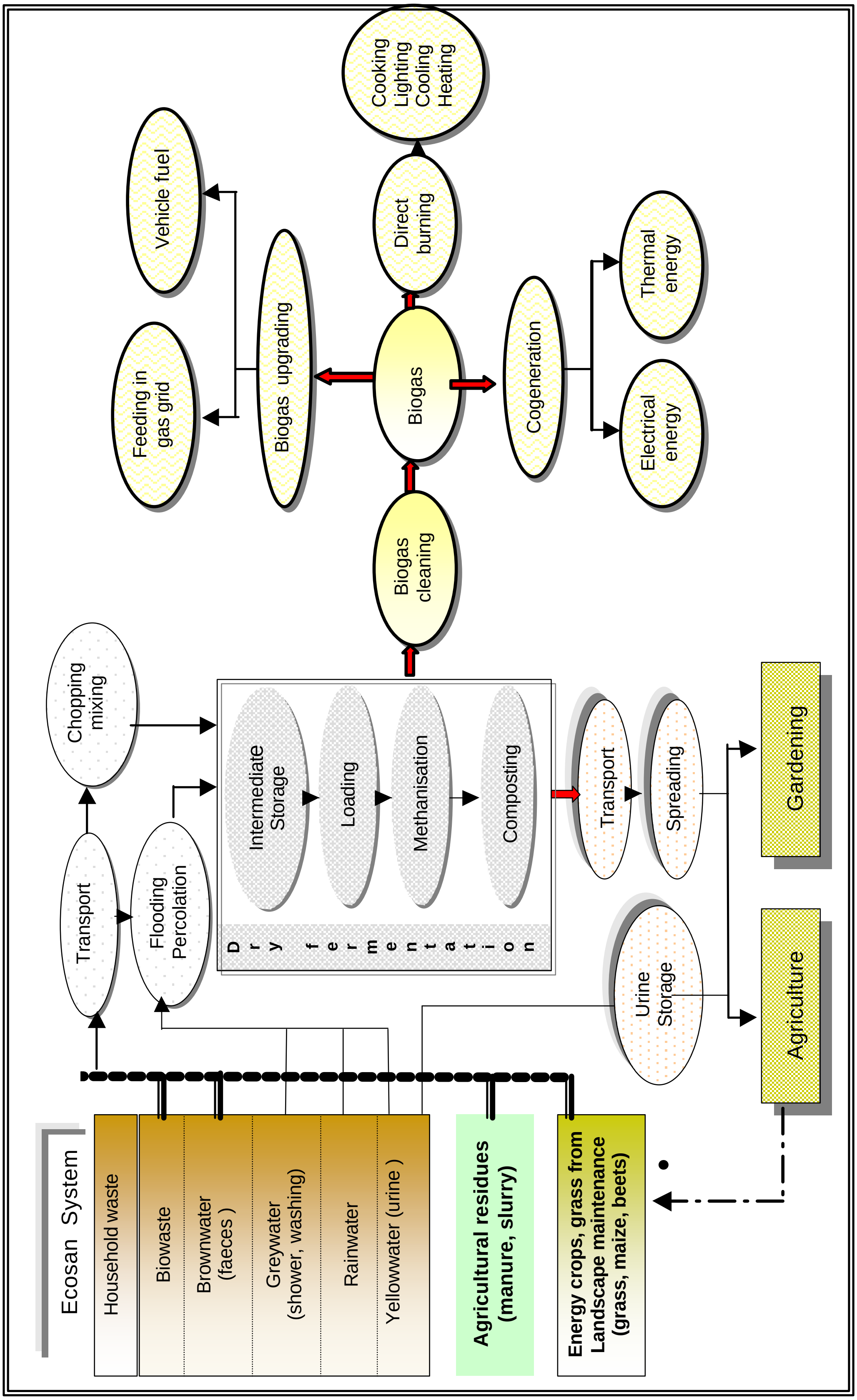


Figure 3: Biogas production in dry fermentation of cattle manure with 50 % inoculate at 35°C, continuous production through delayed operation of two more batches (Linke, 2002)

The biological process is becoming stable after 2 to 5 days after the start of the anaerobic phase and reaches optimal methane concentrations of 60 to 65 %. For the operation of a cogeneration plant for heat and power production an even gas production has to be achieved like in a continuous wet fermentation. In order to secure a continuous gas production in batch dry fermentation systems several digesters have to be run in different time intervals. In an experiment (Linke 2002) with cattle manure, biogas production is at its maximum between day 10 and 28 and is decreasing due to general substrate degassing. The decrease of biogas production can however be compensated, if a new batch is taken into production after 4 weeks.

Figure 4: Biogas technology as an integral part of an ecological sanitation System



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Hygiene and substrate quality

Especially for sanitation purposes the quality of the compost in terms of heavy metals and hygiene has to be taken to closer consideration. One important criterion for the compost quality is the absence of pathogenic micro organisms. It is known that during aerobic composting an inactivation of most animal and plant pathogens is obtained under long period thermophillic conditions (>50°C for several weeks). Also in anaerobic batch reactors Dutch as well as the German studies have proven a complete inactivation of the pathogenic test organisms through the dry fermentation process. A subsequent venting period is designed to condition (reduction of odours and drying) and hygenize the fermentation residues.

Inactivation of pathogenic micro organisms are not only due to the influence of temperature, but especially the occurrence of volatile fatty acids and acetate in the anaerobic process. Also metabolic products of the anaerobic process can be toxic to certain groups of bacteria and fungi. Inactivation rates in batch systems proceed at a higher rate than in continuous systems, as there is no inflow of new material, even volatile fatty acid concentrations are much lower.

Pathogen	Type	Inoculum (cfu / g)	In compost after 21 days (cfu days /g)	% reduction
Enterobacteriaceae	Human and animal pathogenic bacteria (faecal contamination)	1.6 X 10^7	1.2 X 10^3	>99.99
Salmonella typhimurium	Human and animal pathogenic bacterium (intestine infections)	1.4 X 10^7	<3	>99.99
Pseudomonas solanacearum	Plant pathogenic bacterium (potato brown rot)	Infected potatoes tissue (+/- 50 units total)	<1	>99.99
Fusarium oxysporum	Plant pathogenic fungus (root disease)	8.4 X 10^4 biowaste	<1	>99.99

Table 2: Inactivation of several pathogens during anaerobic digestion of biowaste with the Biocel process (ten Brummeler, 2000)

In tests for airborne fungal emissions it was found, that actinomycetes concentration had on average a very low content, which were equivalent to a residential area with no pollution. With normal composting plants more than 200 times higher actinomycetes concentrations are encountered.

Water consumption

During a one and a half year operation of a test dry fermentation facility in Germany (Loock, 1999) the treatment of the substrate as a solid matter proved that the water consumption is comparatively low at around 200 l/t. On the other hand surplus water of up to 200 l/t during the process were recovered, depending on the substrate and its the dry substance content. However a slight overall water consumption of 15 l/t could be observed in the first operating phase of dry fermentation without further dewatering in the test plant.

Practical example of an ecological sanitation system with dry fermentation

Waterless toilets with urine separation are installed in households and for the public. The faeces are preferably powdered with ash after defecation and collected in containers or digestible bags. In an intermediate storage, which is incorporated in the dry fermentation plant, also biowaste, manure and other digestible biomass from the community and agriculture are stored, a preliminary hygienisation through a pH increase and drying takes place. Urine is collected separately in containers and stored. Urban households have very little garden and the need for fertiliser is minimal, therefore it is feasible to incorporate farms, flower producers or urban landscapers for biomass delivery. These enterprises need fertilizer and organic compounds for soil improvement and plant growth.

The collected and partly dried and hygienised faeces are mixed with other organic substrates suitable for dry digestion (grass cuttings, plant waste, manure, straw, bio waste, food waste). The substrates complement each other in their qualities. Through digesting all the substrates together, an optimal fermentation is taking place. Important parameters for dry fermentation are: organic dry substance, pH value, C/N ratio, Redox potential, volatile fatty acids, moisture content, „acidity and alkalinity“, substrate structure. Dry fermentation, as the core part of the system is hygienising, homogenising and producing compost, which is used in the fields, and gardens in a small closed loop for nutrients and organic matter. The biogas can be used directly for burning (cooking, lighting, heating cooling) or in a cogeneration plant for power and heat production.

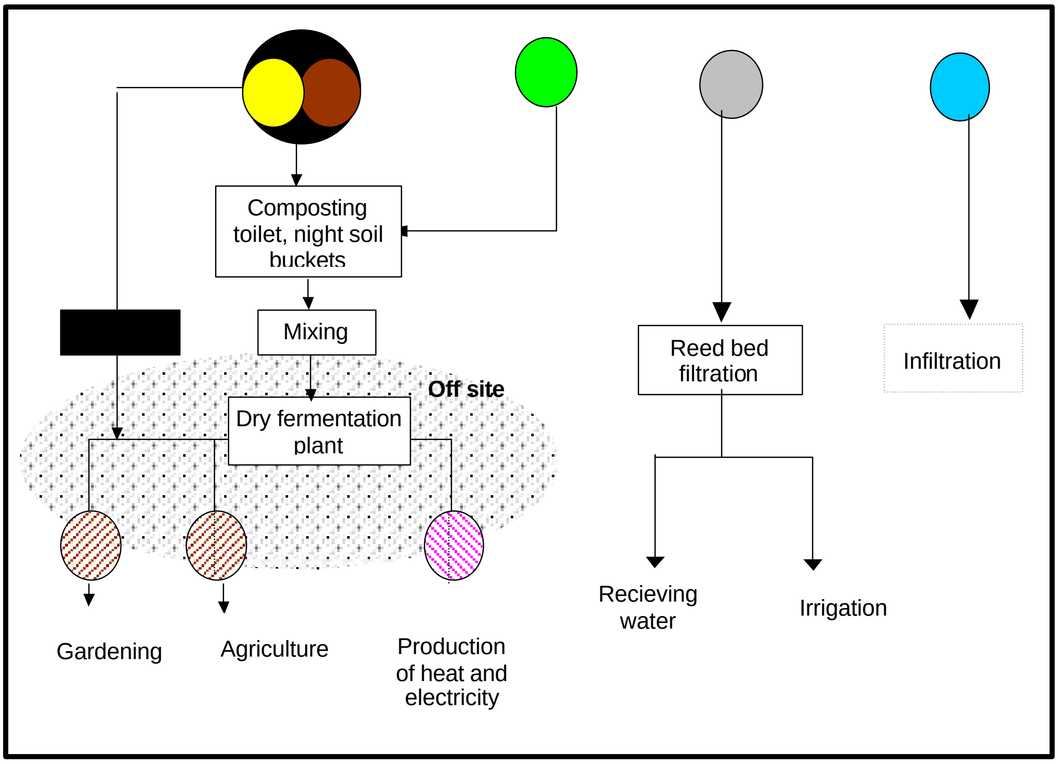

Figure 5: Decentralised off site option, several households: or settlements ~100-500/2000 inhabitants with dry fermentation biogas plant (ecosan, GTZ 2002, altered)

The additional liquid phase of urine is collected and stored for 6 months for sanitation and can be used as additional fertiliser high in nitrogen. If needed, the urine, locally collected grey water and rainwater have to serve as process water for flooding or percolation.

Conclusions

There is a renewed interest in dry fermentation for the digestion of solid wastes and biomass. The digestion of stackable substrates from ecosan systems can be an option for the widespread application in semiarid climates for waste treatment, energy and fertilizer production. Compared to wet fermentation, which has already a widespread application in China, India and Germany dry fermentation is scarcely used so far. Demonstration projects throughout Europe and Africa show similar performance data than conventional wet digestion systems. The difficult handling process of stackable products might have been an obstacle for a wider use in the past.

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Solids-liquid separation as the first step and VRM membrane bioreactor as an elementary component of ecosan

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Keywords

Ecological sanitation, decentralized sanitation and reuse, water- and nutrient recycling, technical solutions, solids-liquid separation, membrane-technology

Abstract

Modern EcoSan concepts require operationally stable and controllable technical processes for treatment and recycling of water and nutrient flows. For evaluation of the acceptance, applicability and benefit of the most promising concepts, an office building for 200 employees will be equipped with a sanitary technology that separates the yellow, brown and grey water flows.

The essential elements of EcoSan concepts are mechanical and biological treatment of the individual flows. Tests were therefore made with a fine-screen for mechanical separation of solid and liquid wastewater phases. A membrane bioreactor was tested for utilisation of the liquid flow.

Although the results showed that the tested elements are well suitable for application in many possible EcoSan concepts, a lot of questions have remained unanswered concerning dimensioning, operation, acceptance and costs of the concepts. But these answers will be found after inhabitation of the office building which is planned for mid 2003.

Introduction

In contrast to conventional wastewater treatment systems, the focus of EcoSan (Ecological Sanitation) or DeSaR (Decentralzided Sanitation and Reuse) systems is the utilization of nutrients contained in wastewater and the intermediate multiple usage of water. The purpose of treatment is no longer elimination of nutrients but concentration and disinfection of wastewater.

Two innovative concepts are especially suitable to concentrate and disinfect wastewater:

- Separation of faeces, urine and grey water directly at source and
- increase of nutrient concentrations in black water by means of toilet flushing water circulation.

Both concepts can furthermore do without water supply conduits through application of a reverse osmosis plant for production of tapwater. The low additional water demand can be covered from other sources like cisterns, surface or ground water.

Figure 1 presents the wastewater separation concept that will initially be implemented in an office building project for 200 employees. Figure 2 shows the principle of black water circulation that will be realized later as an option by combining the brown and yellow water flow.

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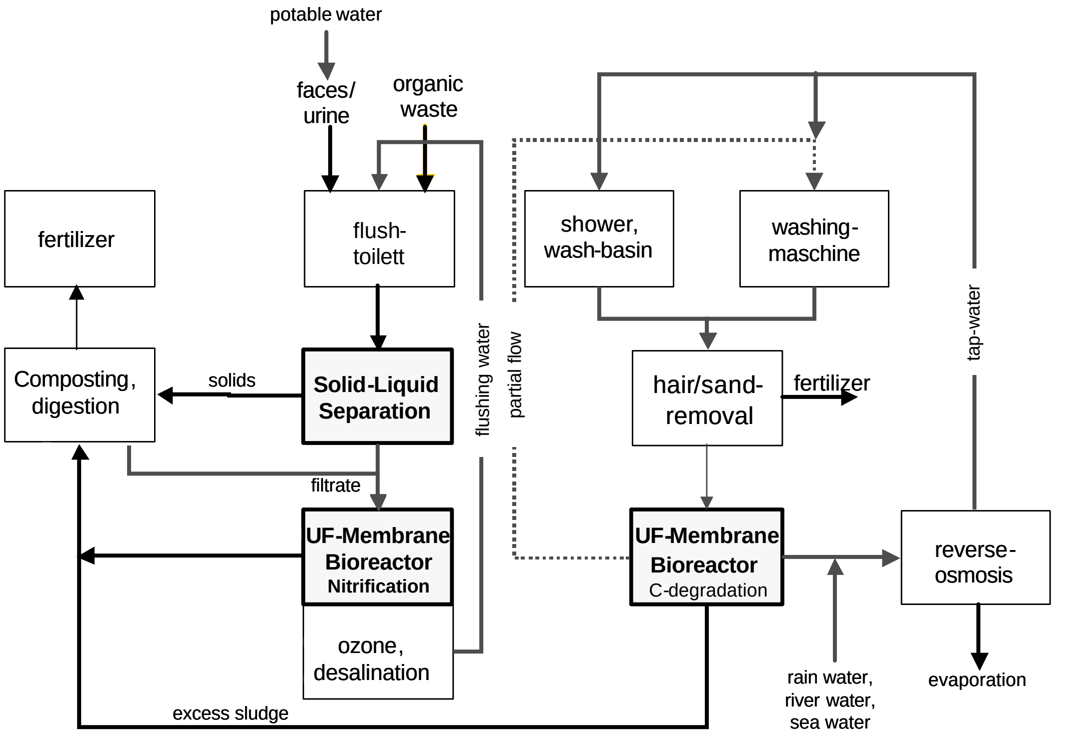

Figure 1: Separation of individual wastewater flows (test objectives in spotted fields)

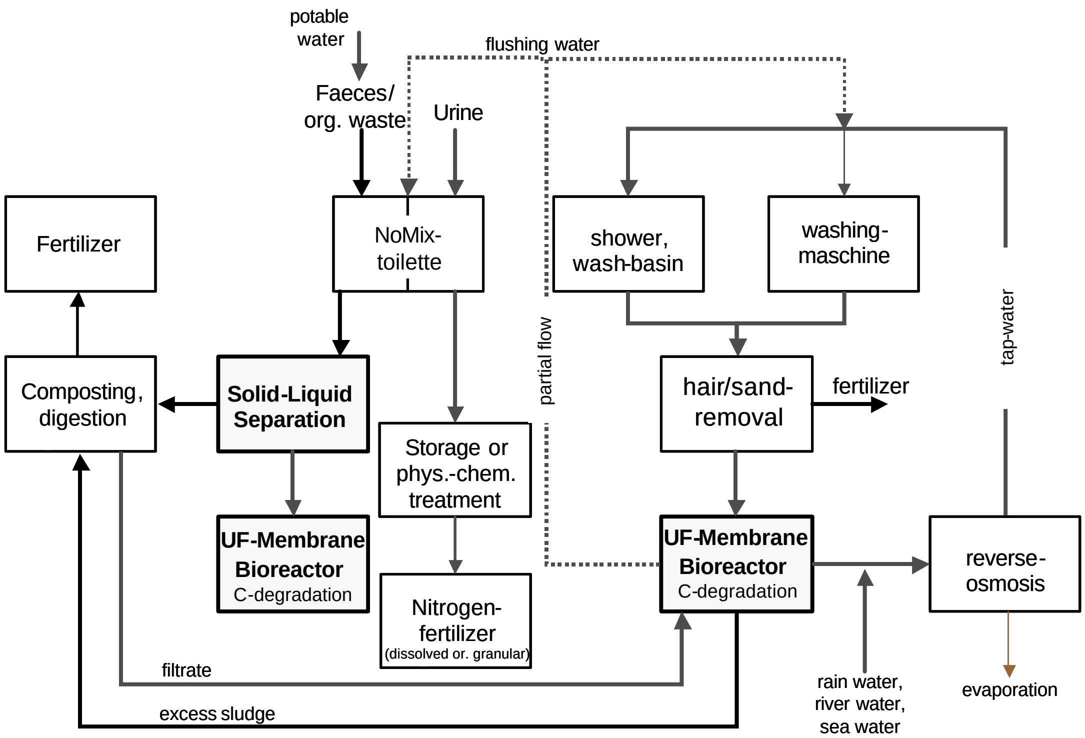

Figure 2: Circulation of black water (test objectives in spotted fields)

Separation of individual wastewater flows

The advantage of yellow water separation as shown in fig. 1 is on the one hand recovery of a highly concentrated N-P-K fertilizer as a great part of these elements is found in urine. On the other hand, the nitrogen content in the remainder of the wastewater flow is significantly reduced. The dimensions of the membrane bioreactors can therefore be by around 50 % smaller as nitrogen elimination facilities are unnecessary.

The carbon compounds and germs contained in grey water are removed in a membrane-activated sludge process and the remainder of the flow used as flushing water for separation toilets. Optional reverse osmosis treatment allows for even more extensive use of the flow as tapwater.

Brown water, consisting of approx. 0.5 l faeces and 10 l flush water per resident, is separated into thickened solids and solids-poor wastewater by means of a fine screen. While the solids are composted or treated in a biogas plant to obtain humus fertilizer, the liquid phase is passed into another membrane bioreactor for biological elimination of carbon compounds. As an alternative, the liquid flow can be treated together with grey water, which however limits its usability to irrigation only, as colouration of the water is inevitable and will lead to non-acceptance as flush water.

Black water circulation

The concept shown in fig. 2 allows for application of conventional flush toilets. Again, the nutrient concentration in the black water is increased through circulation of toilet flush water so that the nutrients can be reused. Nitrogen, however, cannot be used in the form of ammonium, since nitrogen oxidation is necessarily required to obtain a water quality that allows use as flush water. Consequently, this concept produces nitrate fertilizers.

What is still unclear are concentration effects with regard to undesired substances contained in wastewater, such as salts and endocrinic substances or medicine residues. These questions will be investigated within the scope of other current research projects.

Ecosan demo project

To show the feasibility of the presented concepts, but also possible problems and solutions, the new Huber office building in Berching, Germany will be equipped with the following sanitation facilities:

- No-mix toilets with closing valve, separating faeces from flushwater-free yellow water
- Waterless urinals
- Grey water lines

Around 200 employees will produce 200 l yellow water, 1200 l brown water and the same amount of grey water. These flows will be treated with the technology as presented in figure 1 and 2.

Figure 3 shows the building shell of the new Huber office which is anticipated to be ready for occupancy next August and will be equipped with the necessary treatment plants.

Figure 3: Building shell of the new HUBER office which will be equipped with EcoSan/DeSaR technology

Solids-liquid separation and membrane bioreactor are in the foreground as essential elements of EcoSan/DeSaR concepts. Investigations were therefore made to find the individually optimal systems.

Solids-liquid separation

To determine the efficiency of the solids-liquid separation unit, a test screen (fig. 4 and 5) was developed. The screen efficiency was tested with different sieves, such as for example 1 mm wedge wire or 0.75 and 0.2 mm mesh sieve. The tests included fractionation of the inlet and outlet COD into dissolved and solid material. Different coagulants were added to the influent to allow evaluation of the efficiency of COD retention. The tests took place on WWTP Mühlhausen, Bavaria, which is connected to a separated sewerage system with a maximum sewer length of 3 km. The screen drum diameter used was 780 mm, the test flow rate 10 l/s.

The tests (fig. 6 and 7) showed that the solids retention – measured in this case as solid and total COD – can vary greatly dependent on the greatly varying wastewater quality on a municipal sewage treatment plant. Far more constant results are however expected with the application for decentralized concepts. As the produced brown or black water is screened directly at source, possible effects of hydrolysis processes are significantly reduced. To clarify these questions, additional tests are outstanding for investigation of particle size distribution in the wastewater dependent on flow time and method of pre-treatment (pumps, drop structures), although previous tests showed that it is possible to retain a great part of the particular material contained in the wastewater, so that carbon is preserved as humus former. The treatment and energy costs for carbon oxidation of the water phase are reduced significantly.

The solids concentration of the sieve refuse conveyed by a screw lies at around 20 % without an integrated compaction zone, but is technically easy to increase to around 30 % by installation of the compaction zone, so that the material will be well compostable after addition of structural material. Owing to the improved conveyor technique, this type of screening technology allows to thicken even the structureless excess sludge produced in the bio-reactors.

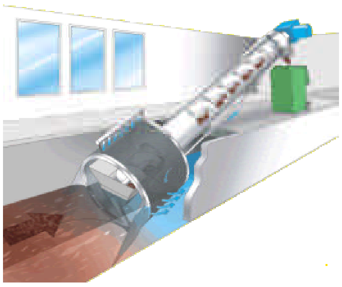

Figure 4: Scheme of the screen

Figure 5: View of the sieve unit

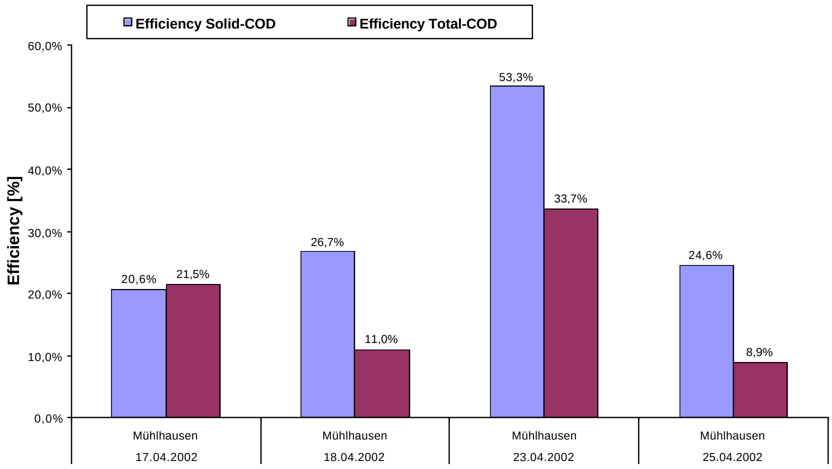

Figure 6: WWTP Mühlhausen (6,200 p.e.), COD reduction without coagulant using a 780 mm dia. screen with 0.2 mm mesh

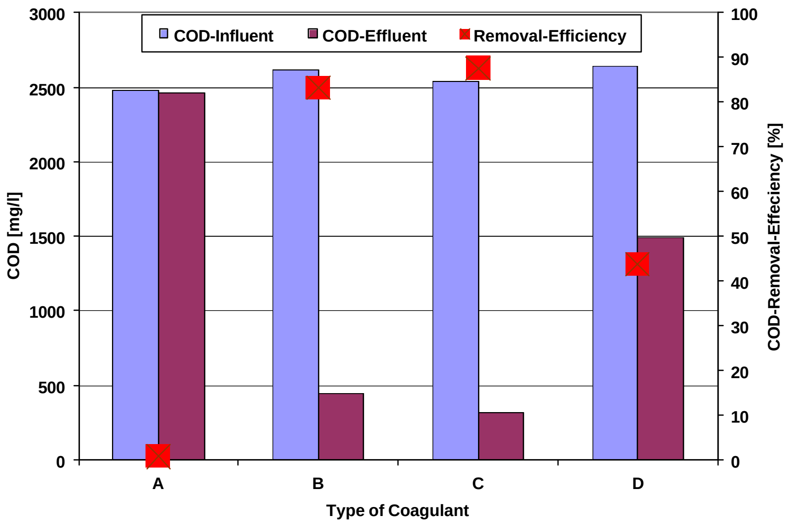

Figure 7: WWTP Mühlhausen (6,200 p.e): initial and final total COD-concentration, and COD reduction achieved with the identical amount but different type of organic coagulant (A, B, C, D) using a 780 mm dia. screen with 0.2 mm mesh

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UF-membrane bioreactor

Since introduction of membrane technology in the field of wastewater treatment it has for the first time become possible to produce hygienic service water at acceptable and reasonable operating costs. The higher costs for the membrane can to a great extent be compensated by the smaller reactor volume, unnecessary secondary clarification and high quality of the clarified water. All these criteria are particularly advantageous for decentralized applications, provided that plant operation is possible with minimized maintenance and energy demand.

These requirements are especially met by the Vacuum Rotation Membrane (VRM) technology (fig. 8). Membrane plates are arranged in a circle around a rotating central pipe, on both sides of which medium bubble air tubes are situated for directed introduction of air into the gaps between the plates to clean the membrane surfaces (fig. 9). Rotation of the plates ensures sequential cleaning of the membrane surface under very intensive aeration.

This type of plate configuration allows to limit the air introduction depth to half the plate height. The air and thus also energy demand is relatively low, lying at around 250 to 350 $l \cdot m^{-2} \cdot h^{-1}$.

An ultrafiltration membrane with 0.038 microns (150 kDa) was selected to ensure that even the smallest of bacteria can be retained. Alternatively applicable micro filtration membranes with between 0.1 and 1.0 microns separation size are unable to achieve this.

Figure 8: Membrane container installation

Figure 9: Container installation of a Vacuum Rotation UF-Membrane unit

To verify the efficiency of VRM systems, intensive and long-term measurements were made on a plant installed in a concrete tank (table 1). This plant clarifies the wastewater of an alpine hotel in Switzerland.

Fig. 10 shows the specific flow through the membrane and respective permeability. Although this decrease initially as expected, it then levels off at constantly around 250 $l \cdot m^{-2} \cdot bar^{-1} \cdot h^{-1}$. This level can at any time be re-established through occasional chemical in-situ purification, as proved by long-term investigations from April 2002 to February 2003. The average results of analysis obtained during the intensive measurement phase are presented in table 2.

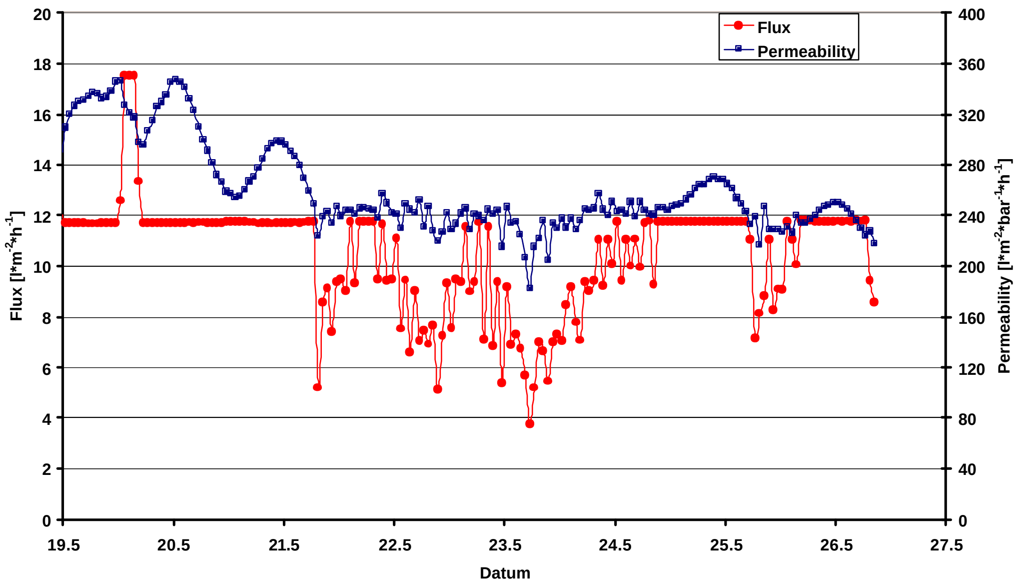

Figure 10: Flux and permeability during the intensive measurement phase

Parameter	Abbrev.	Unit	Maximum
Aeration tank-volume	V_{BB}	m³	160
Membrane area	A_{Mem}	m²	270
Population equivalent	p.e.	-	780
Max. flow rate	Q_{max}	m³/h	6.5
Molecular weight cut off	MWCO	kDa	150
Pressure-height scouring air	h_{sa}	m	1.3 m

Table 1: Data of tested VRM plant designed without N and P elimination

Parameter	Unit	Inlet	Outlet
COD	mg/l	230	8
NH_4-N	mg/l	45	0.01
NO_3-N	mg/l	1.2	29.5
P_{total}	mg/l	18	7.6
E. coli	KBE/100 ml	unknown	0

Table 2: Results of analysis of the VRM system influent and effluent

Conclusions and outlook

The purpose of the described preliminary tests was to select a suitable technology for the treatment plant in the EcoSan/DeSaR office building. It could be proved for the essential treatment steps in EcoSan/DeSaR concepts that the methods applied for solids-liquid separation and biological treatment are suitable to concentrate nutrients and provide for reuse of the treated water.

The fine screen for solids-liquid separation is able to achieve a COD retention of 20 to 30 % for municipal wastewater without (fig. 6) and up to 80 % (fig. 7) with adding coagulants. Since the way of brown water in the office building project is only 50 m from its source to the screen, it is assumed that the results will still improve, so that the recovered sludge will be very rich in carbon and suitable for composting or for anaerobic treatment and use as humus fertilizer.

Compared with simple filter bag or sedimentation systems, the solids residence time in a screen is limited to a few minutes. Any appreciable dislocation of solids into the liquid phase caused by washout or hydrolysis processes is consequently not expected. As a result, the maximum carbon freight is available for reuse.

The carbon and solids-poor filtrate as a product of brown water screening is treated in the VRM system to obtain germ-free irrigation water. Tests related to this aspect could prove that the operation of the membrane system is very stable and therefore suitable for decentralized applications.

In particular the very low membrane separation size contributes to the fact that the recovered service water is absolutely hygienic. Grey water treated in a separate membrane plant can therefore be used also directly in households as wash water, for washing machines or for cleaning purposes.

The new Huber office building is at present the only full-scale project worldwide that will implement the trendsetting and sustainable concept of yellow/brown/black water separation. Such systems have previously been investigated only in a few research and demo projects, which are however unable to give any proof of their feasibility on a full-scale level due to the small connection size and limited circle of users that frequently comprises the participants in the project. After investigation of the efficiency and performance of the essential parts of the system in preliminary tests, the following questions have to be answered now:

- Will such a system be accepted by all users, irrespective of their social, ethnic and religious background?
- What is the quality and amount of the individual wastewater flows?
- Which treatment options are optimal for individual types of wastewater, in particular for yellow water?
- What fertilizing effect can be achieved? Which transport problems may arise?
- How can such systems be supervised and controlled?

It is expected that the experience and results that will be obtained from the demo project, will significantly contribute to a wide acceptance of such concepts. Let us hope that these new findings and insights will finally be realized and implemented on a global scale.

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Anaerobic digestion of physiological waste and kitchen refuse towards resource management in the DESAR concept*

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Keywords

Anaerobic digestion, accumulation system, physiological waste, kitchen refuse, reuse potential

Abstract

Within a long-term Dutch governmental project, a wide array of aspects associated with the applicability of a Decentralised Sanitation and Reuse (DESAR) concept is being studied. Anaerobic digestion of concentrated black water and kitchen refuse is chosen in this concept as the core-technology. An accumulation (AC) digester was selected as a simple reactor to test the feasibility of on-site digestion. Two 1.2 m^3 reactors were operated, AC1 fed with mixture of faeces (F), urine (U) and kitchen residue (K) as produced by one individual and AC2 fed principally with a mixture of F and K in amounts as produced by two individuals. Two research runs were conducted: main of 150 days and verifying for 105 days. The methanisation rates attained for both reactors and in both runs were respectively ca. 30 and 50%. The theoretical biodegradability of the influent mixtures is 81 and 90% respectively. Proper inoculation as well as good buffering capacity ensured stable process. The effluent is rich in nutrients, ammonium of 1300-1700 mgN/L and phosphate of 100 mgP/L, what makes it attractive as a product for reuse in agriculture. Some potential obstacles in the acceptance of the use of treated human manure, like the fate of pathogens and natural and synthetic hormones, are briefly discussed.

Session E

Introduction

An important aspect of ecological sanitation concepts is the separation of wastewater streams based on characteristics, suitable treatment technology and existing potential of resource recovery. A variety of reasons can be listed when attempting to introduce such alternative concepts. Major reason is the prevention of pollution of diluted and avoidance of dilution of concentrated wastewater streams as produced by humans. Moreover simplicity of the system regarding construction and operation and low maintenance and energy use are important criteria for sustainable sanitation. An accumulation digester (AC) has been chosen for the purpose of this study because it fulfils these criteria. An accumulation system can be economically feasible when high concentrated waste has to be digested and long term storage of the digested slurry is needed during the non-growing season, before being used in agriculture. Production of high concentrated waste becomes possible by application of low (or

*This paper has been peer reviewed by the symposium scientific committee

zero) flush toilets (Petersens et al., 2001). Two concentrated streams, mixtures of faeces, urine and kitchen refuse are transported with a relatively small amount of water and subsequently subjected to anaerobic digestion. During a long digestion period, the process performance has been evaluated. In addition the effect of additional storage on stability and pathogen removal was examined. This paper describes results of the first and second feeding period at a process temperature of 20°C and results of preceding studies on wastewater characterisation.

Material and methods

Reactors: Two identical polyethylene (PE) 1.2 m^3 accumulation digesters (AC1 and AC2) were used connected to a vacuum collection-transport system (Figure 1). The vacuum toilets (VT, Roediger, D) use 1 L water per flush. After each flush, wastewater was transported to the equalisation tank (ET) with a working volume of 10L. When the ET is filled up to 10L the sensor gives a signal to start the pump-shredder (WWT) to transport the collected wastewater to the accumulation digester. The vacuum pump (VP) situated on the top of the ET created vacuum in that tank. The head space of the AC reactor was connected to a gas meter (GM) situated on the top of each AC. To monitor the process performance by controlling the quality of the reactor content in time, six taps in line were mounted on the reactor wall in equal distances of 20 cm from each other (tap 1 0.2 m and tap 6 1.2 m above the bottom respectively). Both reactors were placed in a room were the temperature is controlled at 20°C.

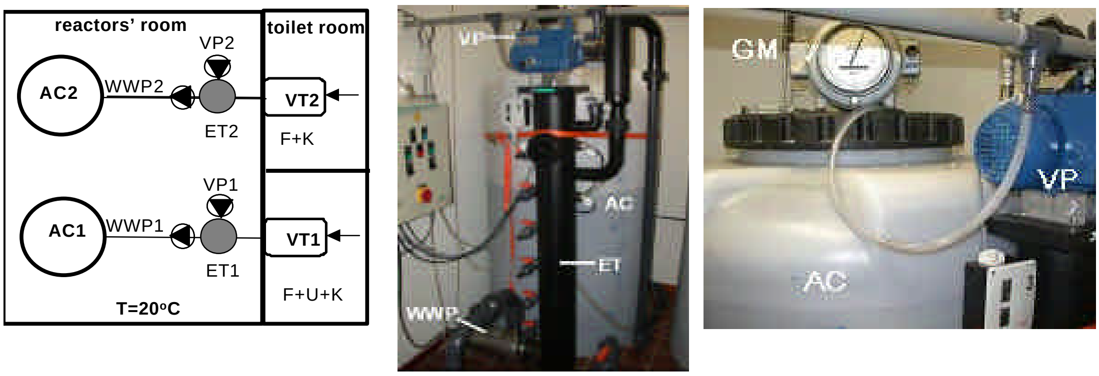

Figure 1: Pilot AC system for digestion of concentrated black water and kitchen refuse and single AC-system; abbreviations: AC – accumulation digester, WWP – wastewater pump, VP – vacuum pump, ET – equalisation tank, VT – vacuum toilet, F - faeces, U – urine, K – kitchen refuse.

Reactor feeding: In attempt to reflect a real situation, a feeding quota was defined for both reactors. The difference between both reactors was the composition of influent, namely the presence or absence of urine. AC1 received a mixture of faeces (F), urine (U) and kitchen refuse (K) as produced normally by one individual (Table 1), while AC2 obtained a mixture of faeces and kitchen refuse in an amount as produced by two individuals. In the latter case no urine was provided separately but only during defecation. The reason for this distinction was to simulate DESAR concept with urine separation, where only faeces and kitchen refuse have to be co-digested. To know the real influent composition and revise the assumed quota, 'providers' filled in on a special form the type of wastewater that was provided (F, U or F+U). A portion of kitchen refuse was added separately, usually in relation to the produced faeces and flushed with water via the vacuum toilet.

Reactor start-up/process conditions: Both reactors were started-up with inoculum sludge to enhance directly anaerobic conversions and to prevent inhibition of the process (mainly volatile fatty acids, VFA). Inoculum sludge was taken from the WWTP Ede from primary sludge digesters (T=30-35 °C). Respectively 10 and 15% of the volume of AC1 and AC2 were filled with inoculum. The digestion temperature in was set at 20°C because of the assumption that such conditions can be relatively easily provided in practice (digester situated in the cellar of a house or in a separated operation building for residential estates). The choice of an accumulation period of 150 days was dictated by a possible reuse option in agriculture in a colder climate (Dutch situation) where soil fertilisation is not possible during winter months (5 months). The second run with accumulation period of 105 days aimed to verify the results and evaluate the effect of adapted inoculum on process efficiency.

Sampling and analysis: Before added to the reactor, the inoculum sludge was analysed on the content of total and volatile solids and its methanogenic activity to calculate the required volume. The influent samples were taken as grab samples from the ET and collected to form a semi-composite sample. Before sample collection, one made sure that influent components were present in more or less appropriate relation to each other. Before reactor start-up, an extended characterisation of separate influent components was performed (Kujawa-Roeleveld et al., 2002). Since a AC-reactor does not produce an effluent, process performance was assessed by taking samples from different reactor heights and mixing them in the same ratio. To judge on process stratification (no mechanical mixing was provided) the profiles were made in certain time intervals. When the accumulation period was terminated part of the reactor content remained in the AC and some additional analysis reflecting the effect of additional storage period on effluent quality were performed. Biogas production was monitored throughout the whole period (including the additional storage period). Gas composition was periodically controlled. All analysis were performed according to Standard Methods. In addition batch tests were performed using the AC-reactor content and influent to assess the biodegradability of the substrate mixture.

Session E

Results and discussion

Composition of raw wastewater streams: Available information on the composition of separated concentrated domestic (waste)water streams is since recently quite extended. Some parameters as obtained within this study are listed in Table 1 and compared with literature ranges.

Parameter	Feaces		Urine		Kitchen residue	
Volume	70-170	**138 g**	1-1.5[1)] L	**1.25 L**	0.2[4)] kg	**0.2 kg**
COD g/p/d (g/kg or L)	46.2[1)]	**78 (567g/kg)**	2-12[2)]	**15.3 (12.8)**	240	**59.0 (294 g/kg)**
N_{KJ} (NH_4-N)	1.4[2)]	**2.5 (0.37)**	7-13[1)](0.75[2)])	**6.4 (0.49)**	0.9	**1.9 (0.09)**
P_{tot} (PO_4-P)	0.69[2)]	**0.95 (0.33)**	1[2)]	**0.4 (0.24)**	0.17	**0.13 (0.05)**
pH		**6.9**	5-7[2)]	**7.08**	4.4[3)]	**4.1**

1) van der Wijst and Groot-Marcus (1998), 2) STOWA (2003), 3) Duynhoven (1994), 4) AAO-IPA (2001)

Table 1: Composition of waste(water), comparison between literature (range) and measured (in bold).

Characteristics of raw influent streams, information on daily production by one individual and known characteristics of the collection (water consumption) system, enabled to predict the characteristics of the total influent stream (Table 2). During reactor performance, the influent was characterised as described before. Any additional flushing (for instance cleaning) was then also taken into account.

Parameter	Predicted*		Measured (1st run)		Measured (2nd run)	
	AC1	AC2	AC1	AC2	AC1	AC2
COD_{total}	14.5	65.3	13.3	66.0	18.6	53.6
$COD_{particulate}$	9.8	47.9	10.3	62.0	15.7	43.4
TKN (NH_4-N)	1.61(0.38)	2.61(0.33)	n.m.(1.3)	n.m.(1.2)	1.3 (0.58)	1.9 (0.78)
TP (PO_4-P)	0.19(0.083)	0.54(0.27)	n.m.(0.08)	n.m.(0.21)	0.11 (0.06)	0.35 (0.31)

* based on subsequent wastewater component as presented in Table 1

Table 2: Characteristics of AC influent – predicted based on results from Table 1 and measured from two research series

Reactor performance

Biogas production: The cumulated biogas production was 2.4 and 9.4 m^3 for AC1 and AC2 respectively for a period of 143 days. The average measured methane fraction was 68 and 66% respectively. Based on biogas production and accumulated COD_{total} loading, the total treatment efficiency in terms of bio-methanisation was attained. A surprisingly low methanisation of 31% was attained for AC1 while AC2 was characterised by a higher value of 51%. These values were confirmed by the second run (28 and 51% respectively).

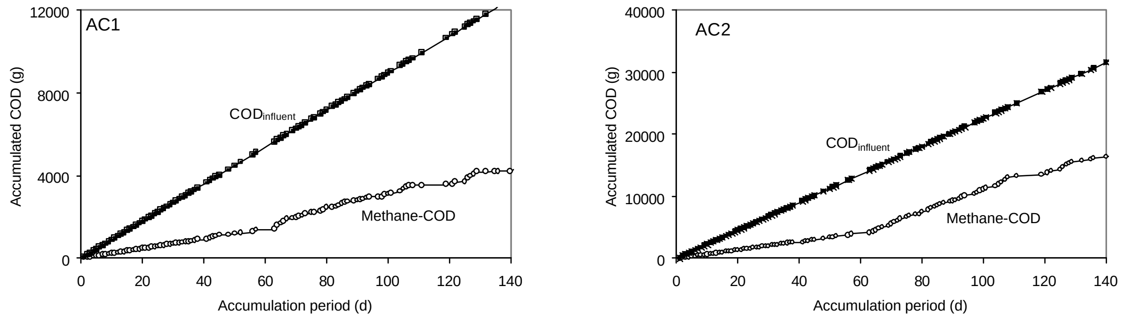

Figure 2: Cumulative biogas production in relation to cumulative influent (total COD) loading

Organics: The VFA-content defines the stability of the process with respect to availability of sufficient methanogenic actitivity. Both reactors were characterised in the beginning of the accumulation period (day 40) by a relatively high VFA-content of 2 and 3 g/L for AC1 and AC2 respectively. After approximately 45 days the VFA concentration started to decline gradually and after approximately 80 days of operation a level of less than 100 mg/L was obtained (40 and 83 mg/L for AC1 and AC2 respectively, Figure 3A) and stayed low throughout the remaining accumulation period. In the second run low VFA content (< 100 mgCOD/L) was measured already from day 40th. The pH in both reactors was similar with an average value of 7.4 during both research periods.

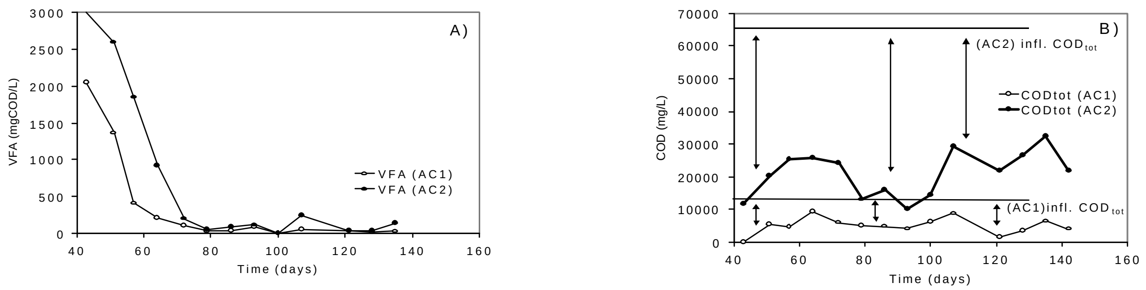

Figure 3: Average concentration of COD (soluble VFA and total) in AC's contents.

Total COD: The COD_{total} content for both reactors is presented in Figure 3B throughout the accumulation period. The average COD_{total} including the sludge layer was 21000 and 5400 mg/L (factor 4) for AC2 than AC1, respectively, while the inf luent strength differed with a factor 5. This suggests a better performance of AC2 than AC1. Assuming that the composite sample represents a well mixed reactor content, the process efficiency in term of total COD removal can be roughly estimated. The reactor efficiency calculated in this way attained 59 and 68 % for AC1 and AC2 respectively. Similar results were obtained in the 2nd run (24000 vs. 4000 mg/L)

Stratification: Periodically, samples were taken from different reactor heights to judge on stratification, mainly related to particulate fractions. The results in Figure 4, clearly show that for

AC1 the most concentrated fraction fills the bottom of the reactor. A high COD_{total} of 16200 mg/L was measured for the first tap, while for the second tap and higher, a relatively low and rather constant COD_{total} , between1370 – 2780 mg/L, was measured (approximately 2000 mg/L in the 2^{nd} run). The settling of sludge on the bottom of the reactor is relevant as it can be retained in the reactor for the following accumulation run. The high concentrated inoculum will provide a faster start up of the second as compared to the first run. The latter is confirmed by the results. The supernatant can be used as a liquid fertiliser.

In the 1^{st} run AC2 was only filled up to the 4^{th} tap instead of the 6^{th} as for AC1. In AC2 a gradual declining COD_{total} was measured starting from 32060 mg/L near the bottom (> 40000 mg/L 2^{nd} run) to 5870 mg/L at the 4^{th} tap. Assuming that 15% of the reactor content remains in the reactor, the COD_{total} content of the decanted volume amounts on an average 17600 mg/L. The remaining concentrated inoculum will also here provide an improved second run. The average soluble COD was in both cases higher for AC2 (1440 mg/L versus 825 mg/L – 1^{st} run; 1200 vs.1600 mg/L 2^{nd} period) than for AC1.

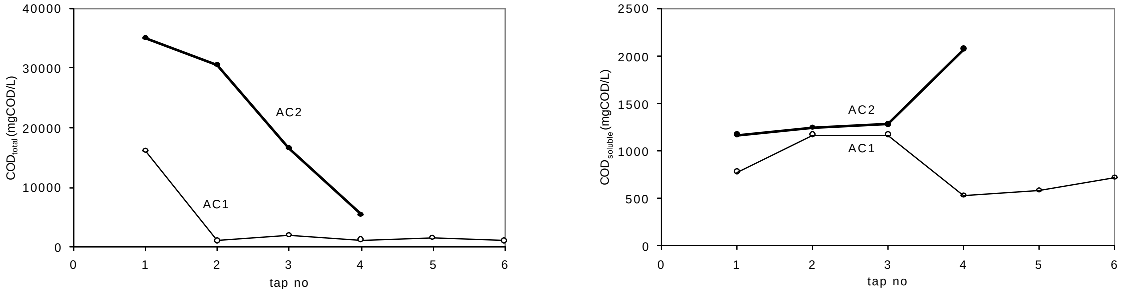

Figure 4: COD (total and soluble COD) profile at the end of the 1^{st} accumulation period (day 121 and 142 for AC1 and AC2 respectively).

Biodegradability: In additional batch tests, a maximum biodegradability was assessed for both influent mixtures. High values of 81 and 90% were determined for influent mixtures of AC1 and AC2 at a temperature of 20^oC. These values were attained after approximately 55 days of digestion in batch tests. Also after termination of the accumulation period in AC1 and AC2, samples were taken at different heights to determine the biodegradability of the reactor mixture. For a batch test with the content of AC1, biogas production stopped after 10 days while for AC2 it took as long as 150 days. The measured gas productions correspond with an additional biodegradation of respectively 5.8 and 8.3%.

Nutrients: The reuse in agriculture is an important objective of digestion of a nutrient rich concentrated mixture. The fate of nitrogen and phosphate was followed in both reactors and measured concentrations were compared with those in the influent. Although for AC2, minimisation or even exclusion of urine was aimed at, this was not completely fulfilled. In most of the cases (75%) there is provision of urine during defecation. The estimated urine contribution in the influent mixture (F+U+K) was finally higher than primarily planned: 0.14 versus 0.10 for AC1 and AC2 respectively (high dilution is AC1 by flush water). The ammonium concentration was however higher in AC2 than in AC1, 1733 ± 142 and 1483 ± 135 mgN/L respectively (in the 2^{nd} run 1650 and 1300 mg/L respectively). This shows that except for decomposition of urea, also a significant fraction of particulate nitrogen from the influent is being hydrolysed and ammonified. The expected ammonium concentration in a pure faeces mixture originating from a urine separation toilet mixed with kitchen waste, would be lower than in case of AC2.

Rather low and comparable ortho-phosphate concentrations were measured in both AC's, viz. 96 and 112 mgP/L, respectively. In the second run the ortho-phosphate concentration in both reactors approximates 80 mgP/L. The measured total phosphate concentrations during the second rum were 550 and 1350 mg P/L in the sludge zone (tap 1 AC1 and AC2 respectively). This value tend further to increase in the continuing currently research in AC2 (already 3rd run). The first measured P_{total} values in sludge layer were approximately 3 g/L. This suggests that except of the fact that a fraction of influent phosphorus is already precipitated (Vinnerås, 2002), the conditions in the reactor itself enhance its further precipitation.

Risks in relation to reuse options and evaluation of agricultural value

E. coli removal (decay): In the second research run, AC1 and AC2 were operated for a period of 150 and 90 days respectively. After filling the AC content remained in the reactor for a period of 120 days, for investigating the pathogen removal during storage. *E. coli* was used as an indicator and analysed through the reactor profile after 84 and 120 days of extra storage. . As shown in Table 34 the residual value of E. coli from tap 1 decreases from 3.6 x 10^5 at a storage period of 84 days to 3.3 x 10^3 /100ml at the longer storage period of 120 days, corresponding to a removal value of 93.8% and 99.999% respectively. Apparently, increasing the storage period leads to a decrease in the E. coli concentration but the remaining residual part of E. coli at a storage period of 120 days is still higher than the standards for unrestricted agricultural reuse (WHO, 1989). The results for AC2 (Table 4) reveal that a significant reduction in E. coli concentration was obtained after a storage period of 120 days. The overall E. coli reduction in the system amounted to approximately 1.8 $\log_{10}$ and 5 $\log_{10}$ at a storage period of 84 and 120 days, respectively. The effluent quality of AC2 after a storage period of 120 days complies for instance with the standards for unrestricted irrigation, where the E. coli concentration amounts to less than 1000 E. coli/100ml (WHO, 1989).

	infl	effluent after storage of 84 days					effluent after storage of 120 days				
tap no		1	2	3	4	5	1	2	3	4	5
E.coli/100 ml	5.8x 10^6	3.6x 10^5	-	0.1x 10^5	-	0.2x 10^4	3.3x 10^3	2.3 x10^3	4.1 x10^3	2.1x 10^3	4.1x 10^3
Reduction % ($\log_{10}$)		93.82 .76		99.82 .76		99.96 3.45	99.94 3.24	99.999 3.39	99.99 92.14	99.999 3.43	99.99 93.14

Table 3: The average E. coli removal (decay) in an AC1 after different storage periods.

sample/parameter	influent	effluent after storage of 84 d		effluent after storage of 120 d	
Tap no.		1	2	1	2
E. coli/100ml	6.8 x 10^7	1.5 x 10^6	7.4 x 10^5	0.4 x 10^3	0.8 x 10^3
% R ($\log_{10}$)		97.8 1.6	98.9 1.93	99.9999 5.2	99.9988 4.9

Table 4: The average E. coli removal (decay) in an AC2 after different storage periods.

Possible consequences due to presence of estrogens: theoretical considerations

Currently there is a growing concern of the prevalence and bioaccumulation of estrogens in the environment. Accumulation can be a problem when waste streams are more concentrated like in the presented concept. Since there is hardly any information on the removal of these compounds in treatment systems, this topic is currently investigated at WUR. Three sterols were isolated in the effluent of domestic sewage treatment plants and identified as the prime contributor to estrogenic character, comprising of the natural hormones 17β-estradiol and estrone and the synthetic hormone 17α-ethynylestradiol (Desbrow et al., 1998, Onda et al., 2002). Natural hormones are primarily excreted in urine, in a conjugated form, which do not exhibit estrogenic characteristics. Unconjugated hormones do exhibit estrogenic characteristics and are mainly excreted in faeces. Intestinal bacteria, such as Faecal Coliforms, produce an

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enzyme that can hydrolyse conjugates to their original unconjugated form, a process that also occurs during wastewater treatment (Ternes et al., 1999, Baronti et al., 2000). Of the synthetic hormone 17α-ethynylestradiol, 35 % of the daily dose is excreted in urine and a relatively large amount of 30% in faeces due to oral administration (Reed et al., 1972). Estimations for the maximum concentration of natural estrogens present in wastewater is about 1 µg/l and for the synthetic 17α-ethynylestradiol about 13.4 ng/l (Blok, 2000), based on a wastewater production of about 200 L per person per day. An estimation was made for different black water collection concepts, using water saving toilets (2 and 4 L flush water for urine and feaces respectively) and vacuum toilets (0.5 and 1 L for urine and faeces respectively). The calculation is done for different collection systems, blackwater collection and separate urine and faeces collection. Estimated concentrations, shown in Figure 6, reveal that in some situations the concentrations are significantly higher than in current centralised situations.

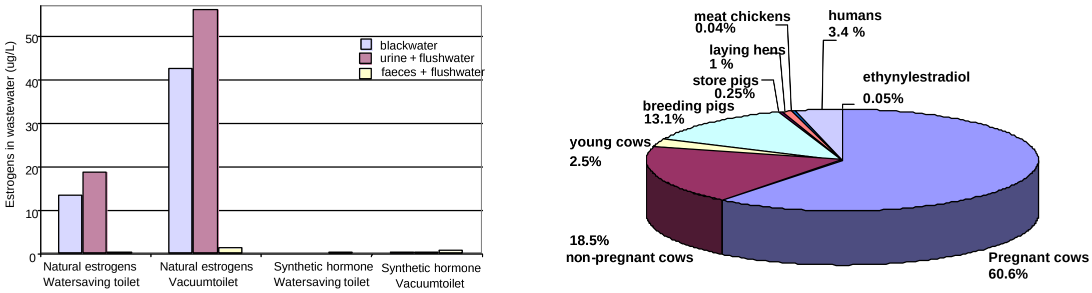

Figure 6: Estimated estrogen concentrations in physiological residues in average produced amounts (Table 1) diluted with flush water for total population of the Netherlands. Total daily-excreted amount of estrogens by humans and cattle in the Netherlands, 81000g (excl. horse, sheep, and goats)(Blok, 2000).

The natural estrogens are mainly present in urine. For synthetic estrogens it is opposite, a significant fraction is found in faeces. Still, the contribution to the total excretion of estrogens by humans is very low, compared with the amount excreted by cattle (Figure 6). The no-effect concentrations for ethynylestradiol for humans is said to be 1/100 below the active dose in the contraceptive pill (0.35 µg/day), which is 350 ng/day. Men produce around 40-130 µg of natural estrogens per day. Looking at the estimated concentration (Figure 6a), the separate collection of urine will result in the highest concentration of estrogens, of around 55 µg/l.

Conclusions/ evaluation

Digestion of physiological waste and kitchen refuse as appropriate technology for a DESAR concept was studied. Two accumulation digesters (AC1 and AC2) were fed with faeces, urine and kitchen refuse in different ratio's and operated for approximately 150 and 105 days at a temperature of 20°C (two runs). AC2 was characterised by a ca. fourfold higher wastewater strength in term of COD_{total}. This wastewater strength for AC2 was attained by a restricted use of the 'associated' vacuum toilet for faeces and kitchen waste. However, it turned out that in 75% of the cases also urine was provided during defecation.

No inhibition of the process was observed, neither by an unbeneficial pH (remained around 7.4), VFA nor ammonia. Based on methane production, a digestion efficiency of ca. 30 and 50% was attained for AC1 and AC2 respectively in both research periods. Batch tests showed that additional storage resulted in an improvement of digestion of 5.8% (in 10 days) and 8.3% (longer period, up to 150 days) for AC1 and AC2 respectively. Roughly estimated total process efficiency (biological and physical processes) for AC1 was 59% and for AC2 this was 68%. On the other hand very high maximum biodegradability was obtained in batch tests at 20 ^{o}C: 81 and above 90% for AC1 and AC2 influent mixtures.

Organic particulate nitrogen is converted to ammonium during long reaction period. The average ammonium concentrations were 1483 (AC1) and 1733 (AC2) mgN/L in the 1st run. Further concentration of ammonium is possible by implementation of 'extremely low flush toilets' (e.g. 0.5 L/faeces; 0.2 L for urine) but then the precaution needs to be taken for process inhibition due to high ammonia concentrations. Soluble ortho-phosphate in both digested mixtures are relatively low (range of 100 mg/L). The total phosphate in the sludge volume, especially for AC2 is consequently increasing (beginning of the 3rd run – 3 g/L) indicating on strong immobilisation mechanisms (phosphate precipitation). (problem further investigated).

It is signalised that additional storage of digested mixture inactivate E.coli in such a rate that it can be accepted by the standards. Research on other indicators continues.

Fundamental research on fate and effect of synthetic hormones during anaerobic digestion of concentrated black water is carried out.

The research focuses now on further intensification of the processes and fate of any health risks on reuse potential. Development of design/optimisation procedure for digestion in accumulation system is undergoing.

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Saving water and recovering nutrients by a closed loop system for toilet flushing – pre tests

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Keywords

Black water, closed loop, decolourisation, flush water, nutrients, reuse

Abstract

The black water cycle (figure 1) is based on the idea to treat the toilet waste water in a way, which renders its reuse as toilet flushing water possible. Additionally the cycle will result in an enrichment of the nutrients. The technique for purification consists of a riddle screen, an activated sludge tank with submerged ultrafiltration membranes and a unit for decolourisation and disinfection. The pre tests have shown, that the main tasks of the development of the black water cycle are solvable.

The semi technical scale black water cycle which at the moment is under construction in the Technical University Hamburg-Harburg (TUHH) will lead to further findings.

Basics of the technical concept

The black water cycle (figure 1) based on the idea to treat toilet waste water in a way, which makes it possible to use it as flush water again. The water demand for flushing toilets is huge. Especially in hotels it is a reasonable part of the total water demand. With the technique of the black water cycle it would be possible to reduce the demand for this use to nearly zero. At the same time nutrients are collected with high concentrations thus allowing their reuse.

The first step of the purification is solid separation by a sieve. In the test plant a riddle screen with a mesh size of 128 µm is in use. After sieving the water flows into a tank. A split flow of this water is mixed with a base. In consequence of the pH adjustment some salts will precipitate. After their settling, these will be removed at the bottom of the tank. Besides of the addition of the base, the second benefit of this tank is a volume regulation. Subsequently, the water is pumped into an activated sludge tank with submerged ultra filtration membranes. This biological treatment is for degradation of organics and conversion of nitrogenous compounds to nitrate. After passing the membranes the water reaches a reactor where it is discoloured and sanitised by ozone or UV-light. Finally the water flows into a storage tank and can be used as flush water again After composting and disinfection the solids separated by the sieve can be sold as soil conditioner or used on site (for example in the garden). If there is enough solid material, the use of a fermenter might be reasonable.

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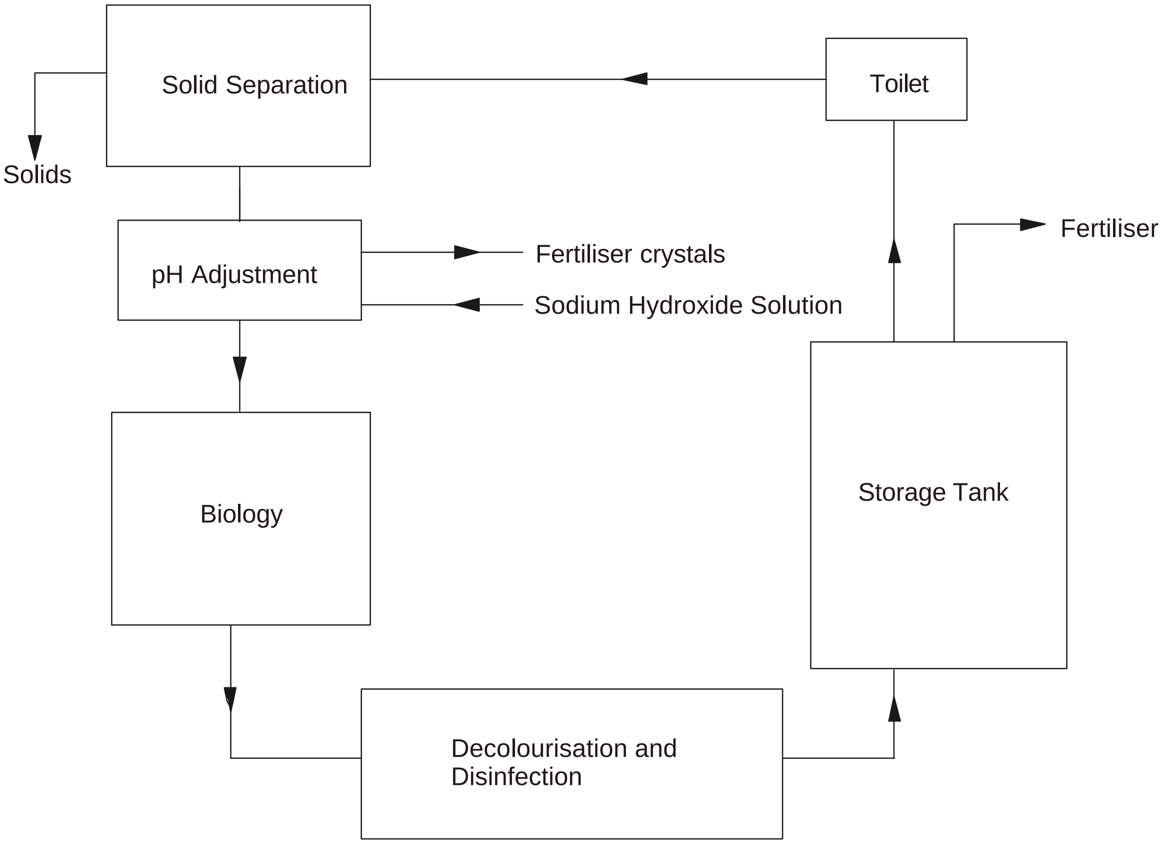

Figure 1: System sketch of the black water cycle

The separated salts can be dried and used as a solid fertiliser. Possible excesses of liquid in the system can directly be used as liquid fertiliser, because concentrations of the nutrients are increasing as consequence of the closed loop system.

Problems solved in pre-tests

A very important point for the purification of black water is the decolourisation. The user will accept the flushing water only, if it is clear and colourless. Experiments with untreated yellow water have shown, that it is possible to reach this goal by using ozone. But these tests also have revealed that recolourisation is possible. By addition of hydrogen peroxide this could be avoided. Other tests have shown that yellow water becomes brown over storage time. Biologically pre-treated yellow water does not react in this way (figure 2). At the moment it is under investigation by some lab tests with UVC-light and ozone, whether the recolourisation also occurs with biologically pre-treated yellow water.

A second important point is the odour. The flush water must be odourless. The main part of the malodorous materials is separated with the solids in the first step of the purification. But since dissolved ammonium is still present in the liquid, odour nuisance can still occur because of outgassing of ammonia. This could be prevented by oxidation of the nitrogenous compounds up to nitrate. In pre-tests (figure 3) yellow water was biologically oxidised. Thereby the product was nearly odourless at the end of the treatment as well as after a longer storage time.

Figure 2: After 8 weeks of storage the biologically pre-treated yellow water is still clear and yellow

For a carrier of such a system it is important that no persistent deposits appear. Especially in hotels it is possible that some of the rooms are not in use over a long period of time. For this reason six tests with fresh and biologically pre-treated yellow water were conducted. In every test yellow water was stored in a simple standard toilet for 8 weeks. At the end of the tests the yellow water was removed and the toilet was gently rinsed by 1.0 litre of water. This was sufficient to remove the main part of the deposits in all cases. The remaining deposits could be eliminated by a wet paper cloth. No toilet brushes or chemical cleaners were necessary. Even after six tests on one toilet no persistent deposits appeared.

The last main issue is the disinfection of the water. It is an extremely important point for the acceptance of the system. But from the technical point of view this problem is already solved by the purification step of decolourisation, since a very high dose of ozone and / or UV-light is necessary for this. So, disinfection of the water is a byproduct of this step. Deeper investigations on this point will follow after the start of the semi-commercial black water cycle.

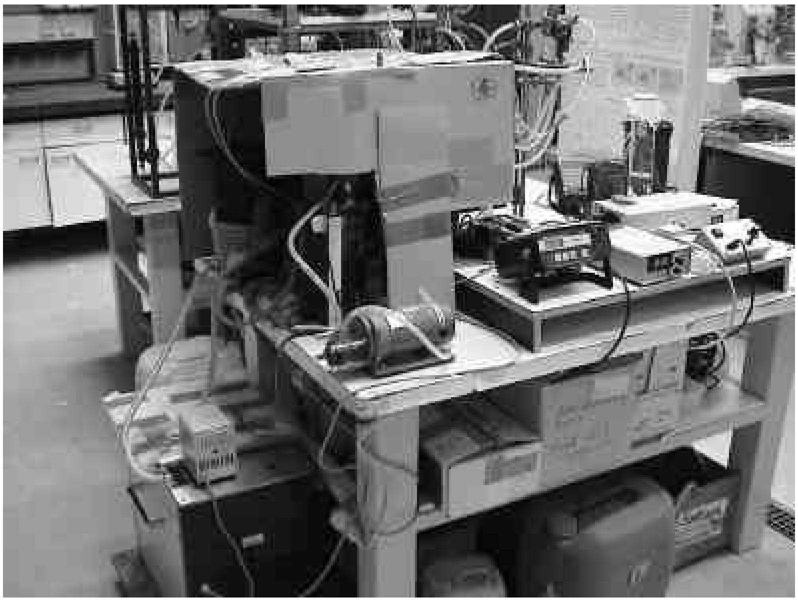

Figure 3: Test unit for biological treatment of yellow water

Further investigations and perspective

At the moment additional sanitary facilities and a semi-commercial treatment plant are constructed at Technical University Hamburg-Harburg. At the end of February the sanitary facilities will be ready for use. The treatment plant will be finished till the end of March. Thereafter a research and development period of approximately one or one and a half years is projected. During this time possible technical problems should be detected and solved. Additionally, knowingly produced failures (power blackout, interfering substances and similar ones) will be simulated. Simultaneous, tests dealing with the fermentation of solids from the test plant and lab tests with addition of other bases will be carried out.

After these works are finished, preparations for an application of this technology will start. A combination of a grey water reuse system and this technique could render it possible to engineer apartment, office or hotel buildings without any connection to a sewer. In this way the water demand could be reduced to an absolute minimum.

Conclusions

In approximately two years for buildings with at least 20 occupants the black water cycle will be a good possibility to reduce the water demand to a minimum. In combination with a grey water reuse system this technique will provide the possibility to build houses without wastewater release and a far-reaching independence from external water resources. As direct result of this the expensive connection to a sewer system will not be necessary anymore.

Especially in arid regions with only little settlement this will be an ecologically and economically important step to the future

Investigation on effectiveness of Rottebehaelter for pre-treatment of brown water in source control sanitation

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Keywords

Brown water, source control sanitation, Rottebehaelter

Abstract

According to their character household wastewater can be divided into three components namely grey, yellow and brown water. The grey water has very low loads of nitrogen and can be treated in different combinations of biological and physical treatment and reused whereas yellow water can be used in agriculture with some crop restrictions as a fertiliser after about 6 months of storage. Brown water can be discharged into Rottebehaelter (an underground pre-composting tank) that retains solid material and drains liquid to a certain extent. Investigation of Rottebehaelter showed that retained faecal material still contained a high percentage of water. However, odour was not noticed in the Rottebehaelter that has been examined. One of the major advantages of this system over other forms of pre-treatment as the septic tanks is that it does not deprive agriculture of the valuable nutrients and soil conditioner from human excreta. It has to be stated that maintenance is a crucial factor. As an intermediate result of the intensive research of Rottebehaelter it seems that these systems are rather a way of solids retaining, de-watering and long-term storage before the contents are further treated.

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Introduction

Household wastewater is generated as a result of household activities. Each activity produces wastewater of different characteristics. Wastewater from washing, cooking, bathing/showering, cleaning dishes, preparation of food- called grey water- contains low nutrients, but has very large volume compared to wastewater from defecation and urination. Wastewater from urination-called yellow water- contains most of nutrients whereas brown water- wastewater from defecation- contains most of the pathogens causing disease as well as nutrients and organic matter (Otterpohl, 2001). Separation of grey, yellow and brown water at source is a primary step for efficient and safe reuse of resources. Comparing to total domestic wastewater grey water reuse has been increasingly practised in many parts of the world because of very low pollution load (Del Porto and Steinfeld, 1999; Li et al., 2001). Treatment of grey water with combination of biological treatment (constructed wetlands or SBR) and membrane technology (Ultra filtration or micro filtration) can produce high quality water.

Since the practising of separated collection of yellow water with using separation toilet, farmers in Sweden have been collecting it in the underground storage tank for applying to their agricultural land (Esrey et al., 1998). Due to pathogen contamination, but in low concentration it is stored at least for 6 months before being used in agriculture (Jönsson et al., 1999; Hellström and Johansson, 1999). Unlike yellow water, brown water contains pathogen in high concentration. Therefore, it must be sanitised prior to its reuse as fertiliser and soil conditioner in garden or agriculture. Pre-composting of brown water in Rottebehaelter and post-composting of it with household organic wastes can produce pathogens free soil conditioner. Rottebehaelter, which consists of an underground concrete tank having two filter bags that are hung side by side and used alternately in an interval of 6-12 months (Figure 1), has been increasingly used in rural areas of Austria, Switzerland and Germany for domestic wastewater treatment. Those which have been investigated have showed its potential for separation and pre-treatment (dewatering to a certain extent) and collection/storage of solid stuff in household wastewater (Gajurel et al. 2001). Combination of source separation concept with Rottebehaelter can be effective to recover nutrients and soil conditioner because most of the soluble nutrients are in urine which is separated at source.

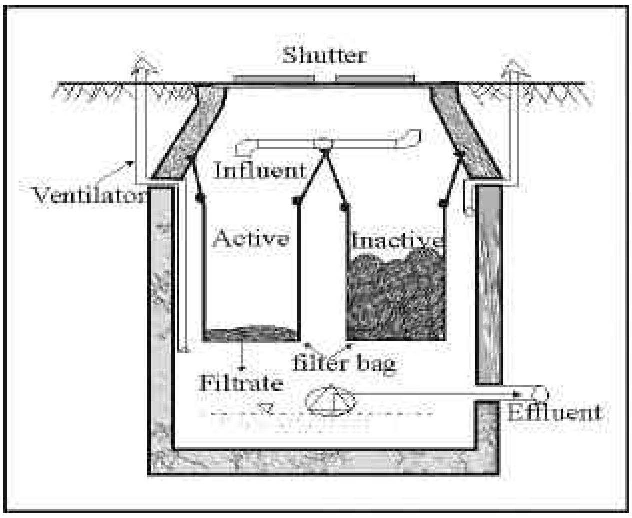

Figure 1: Rottebehaelter

The retained materials that have already been de-watered and pre-composted in the Rottebehaelter for 8-12 months can be further composted with biological kitchen and/or garden waste in a local composter at least for a year and used in agriculture. It avoids expensive tanker-trucks which is extensively used in the conventional sanitation systems to transport sludge. Moreover, comparing to septic tanks methane emission can be very low as outer parts of retained material maintains aerobic condition. However, handling of the bags or the material is not a simple task and should be improved for the future. There are concepts in Austria in areas with strong gradients in the ground where the tanks are accessible with agricultural fork-lifters and can be removed and emptied in a simple way. This paper does show the effectiveness and limitations of Rottebehaelter to recover the particulate fraction of nutrients and soil conditioner from brown water.

Investigation of existing Rottebehaelter in Lambertsmuehle pilot project

Background

The source control sanitation system has been installed in the pilot project in Lambertsmuehle near Cologne city in Germany since the summer of 2000. Detail can be found in Otterpohl et al. 2001a. The yellow water, with the means of separating toilet, is collected separately in an underground tank, where it is kept till it is ready for use in the agriculture. The brown water is discharged into the Rottebehaelter, which is made up of concrete monolithically and constructed underground outside the building (Figure 2). It is covered with a prefabricated concrete slab and provided with ventilation. A shutter of a concrete slab for changing filter bag, inspection and cleaning has been provided on the covering of the Rottebehaelter. Inside the Rottebehaelter, two filter bags are hung side by side in such a way that when one is full, the influent is manually diverted with the help of diversion pipe into the next empty bag. The filtrate, due to urine separation, is nutrient poor, and is mixed with grey water and treated in constructed wetland.

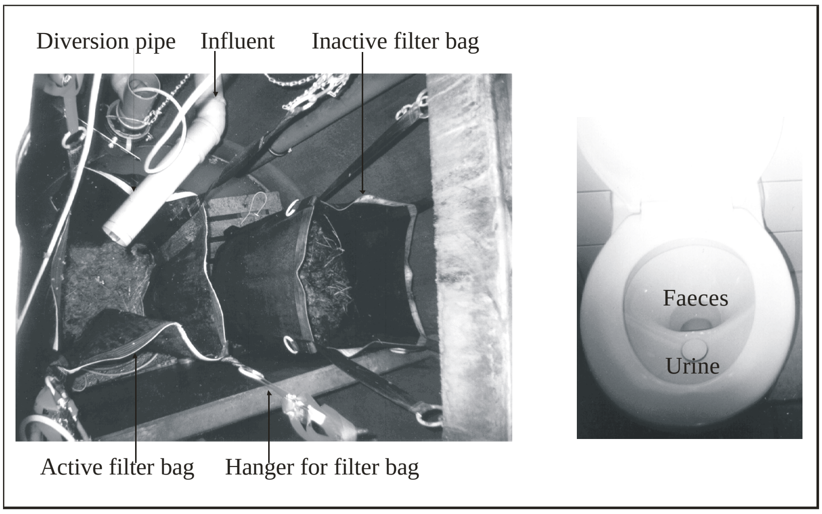

Figure 2: Lambertsmuehle project: Rottebehaelter with filter bag and separation toilet

Performance of the Rottebehaelter

In September 2001 and April 2002, samples from both active and inactive filter bags were analysed. The results are shown in table 2. In both filter bags- active as well as inactive- moisture content was higher than optimal range 40-60% for composting. Moisture content above 70% leads to anaerobic condition (Bidlingmaier, 1983). However, no odour was noticed during the sampling. Also people living in the house have not complained about odour problem so far. Low temperature and low reduction of volatile solids suggest that slow decomposition process took place in both filter bags. It caused slow and low emission of odour, which was not detected with human nose in the open air.

Sample	Water Content % FM	Loss on Ignition % DM	C % DM	N % DM	C:N	P % DM	K % DM	S % DM	pH	Temp °C
Active filter bag										
Sept. 2001	87.72	95.48	46.60	6.74	6.91	0.69	1.07	1.29	7.21	18
April 2002	84.23	92.95	42	2.45	17.14	0.58	0.17	0.20	7.08	n.a.
Inactive filter bag										
Sept. 2001	83.14	93.26	50.30	7.16	7.03	0.61	1.61	1.30	6.30	20
April 2002	82.63	91.41	44	2.96	14.86	0.69	0.17	0.40	6.31	n.a.

Table 1: Characteristics of retained materials (FM: Fresh matter, DM: Dry matter)

Total nitrogen fraction in sample from September was in the same range as in faeces. It showed that structural bulking agent was not added in order to maintain C:N ratio of composting material between 20:1 and 30:1 that is optimal for composting. Later the ration was increased to 17.14 for active filter bag and 14.86 for inactive filter bag by adding carbonaceous structural materials- straw and wood chips, but still not sufficiently added. The structure materials also help to reduce water content and increase air circulation inside the material. pH was in the range of 6.5– 7.5,

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which is favourable for composting. Role of sulphur, Phosphor and Potassium in composting is less known, but they are important nutrients.

Conclusions

One of the major advantages of this system is that it does not deprive agriculture of the valuable nutrients and soil conditioner from human excreta. However, maintenance is a crucial factor. Sufficient amount of carbonaceous structural materials such as straw and wood chips must be added regularly in order to maintain favourable condition for composting. It has also to be stated that reasonably dry product, one that can be easily removed and handle, has not been achieved in Rottebehaelter so far. Therefore, post-composting is necessary before reuse. Compared to septic tanks, there are a couple of advantages that make further development worthwhile.

Research in Australia has shown that vermicomposting is effective methods for the treatment of household organic waste and human excreta . Most of the worm species are able to work when the organic material has moisture content of 70–80%, Temperature below 35 ^{0}C and pH in the range of 6.5 –7.5. Therefore, Rottebehaelter offers favourable condition for worms to thrive and convert organic materials into soil conditioner. Research has been recently started with the worms Eisenia Foetida and Eisenia Andrei at the technical university Hamburg-Harburg.

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Concept for decentralised waste and wastewater treatment

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Keywords

Decentralised concepts, anaerobic treatment, composting, membrane technology, biowaste, blackwater

Abstract

Laboratory experiments for the decentralized waste- and wastewater treatment had been executed and on the base of the results a treatment concept has been developed. As the result of co-treatment of domestic wastewater and separately collected organic kitchen waste (biowaste) the production of biogas can be increased significantly. Additionally the load of the fermentation can be significantly higher due to the concentration of the organic compounds of the wastewater by means of ultrafiltration. The treatment of the grey water can be achieved among others using nanofiltration, treatment in rotating biological disk reactors or constructed wet lands.

Introduction

A concept of a combined treatment of solid and liquid household waste has been developed by the Institute of Waste Management, Technical University of Hamburg-Harburg (TUHH) and is based on extensive investigations and studies.

Concept for decentralised waste and wastewater treatment

Figure 1 shows a concept developed by the authors. In our proposal the grey water is treated by means of membrane filtration (nano-filtration). The concentrate is further treated together with the black water and the kitchen waste in an anaerobic treatment system consisting of a high temperature hydrolysis (hygienization step) and a methanogenic reactor. The residues may be directly applied to land or dewatered where the water phase is treated by means of ultra-filtration. The solid phase can either be post-composted and reused on land or pellitized and stored for future land application or incineration.

The biowaste (kitchen waste) has to be shredded before it is applied to the hydrolysis reactor. Hygienization of the black water and the biowaste should be achieved separately when no high temperature hydrolysis steps is introduced.

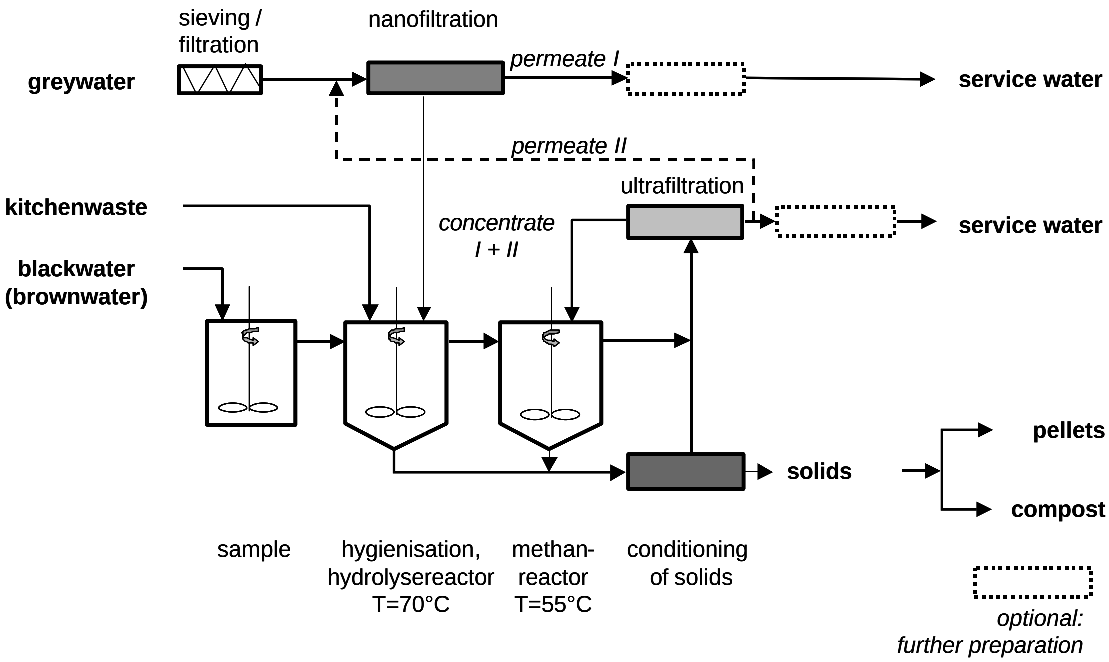

Figure 1: Integrated concept for common decentralized wastewater- and waste treatment with widely utilization of recycling material

Results of investigations

In order to investigate treatment options for the different substrates, facilities for the separate collection of black, brown and yellow water have been installed at the Institute of Waste Management (TUHH). Two separation toilets for yellow and brown water (Fa. Roediger Vakuum und Haustechnik GmbH, Germany) as well as a garbage grinder for kitchen waste are available. The yellow respectively brown water is transported by means of separate pipes into collection vessels that are placed in a refrigerator.

Treatment of grey- and black water by means of membrane technology

For the determination of the grey water quality and for the assessment of the purification capacity in applying the membrane technology, investigations were carried out with separately collected grey water (Hesemann et al, 1999). The chemical analysis of the investigated substrates shows that the grey water had a BOD-concentration similar to sewage with lower contents of nutrients and salt and a slightly alkaline pH value. After the separation of solid substances by means of a screen, the grey water was applied to nano-filtration via a storage tank and the concentrate was led back to the storage tank where it was upgraded. The use of a nano filtration membrane results in a high retention of organic molecules and colloids. In addition bacteria and viruses are retained by the membrane to a high degree. It could be shown that, in general, the feed stream can be divided into approx. 1% concentrate and approx. 99% permeate. For the TOC, the chemical analysis of the concentrate showed retention values of 45-87%, where the TOC of the permeate showed relatively constant values around 60 mg/l. The COD concentrations varied between 700 mg/l and 1150 mg/l in the concentrate and150 mg/l and 350 mg/l in the permeate. The obtained concentrate may be fed directly into the hydrolysis reactor for further anaerobic treatment, while the permeate can be used directly or with further treatment for watering the garden, flushing the toilets, cleaning etc.

Unlike the filtration of grey water, the membrane filtration of black water primarily serves to concentrate the dissolved (organic) components for further treatme nt. Using an ultra- filtration membrane a significant increase of the COD, TOC and BOD_5 concentrations can be achieved when the process stability is sufficient. This concentration step may be necessary when a flushing toilet system is used in order to supply the anaerobic reactor with a higher concentrated substrate.

The possibilities of ultra-filtration for the concentration of black water from households were investigated by the Institute of Apparatus Construction of the TU Hamburg-Harburg. Two different membranes of 5 and 30 kDa were used and in both cases a concentration of. approx. 3:1 for TOC could be achieved. For a further reduction of the dissolved organic compounds the permeate flow may be further treated by means of nano-filtration. Table 1 shows as results the quality of the concentrate and of the permeate after the ultra filtration of black water.

Parameter		Concent ate	Permeate
pH	[-]	8,66	8,80
LF (χ)	[mS/cm]	12,42	11,22
DOC	[mg/l]	7594	1799
TN	[mg/l]	3040	1780
P_{ges}	[mg/l]	365	83,4

Table 1: Composition of the concentrate and permeate after a multistage ultra-filtration (membrane 5kDA) of black water (see table 1)

Investigations of the co-fermentation of black water and biowaste

The investigations for the determination of the biogas potential of different substrates were performed in anaerobic test systems (V=500ml, Heerenklage et al, 2001). The to be investigated substrate were inoculated and incubated over a period of 21 days. The gas production was measured manually every working day. For analysing the gas quality samples were taken by a syringe and injected into a gas chromatograph.

As an example the substrates black water and a mixture of black water and biowaste have been investigated in order to determine gas production rates with time. As biowaste a model waste has been used as to allow for high reproducibility. The composition of the model bio-waste consisted of equal amounts (based on wet weight) of potatoes, white cabbage, apples, wheat grain and dried pees. The black water used was produced by a flushing volume of 2l water per toilet utilization. As an inoculum anaerobic treated waste water from the waste water treatment plant Köhlbrandhöft in Hamburg, Germany, was used. The black water - biowaste mixture was produced by the addition of 40g of biowaste (wet weight) into 1l of black water. This accounts by using vacuum toilets for a realistic relation of 0.025 (black water to biowaste).

If only black water is anaerobically fermented over a period of 21 days a total gas production of 510 Nml (5. l gas/ l black water) was measured. The biowaste/black water mixture (100ml of blackwater + 4 g of biowaste (wet weight)) produced due to a higher organic total solids content ($oDM_{mixture}$ =1,88g compared to $oDM_{black\ water}$ =0.75g) 1050 Nml of biogas. The specific gas production rates based on the organic solid content are comparable for the two substrates (596 l/kg oDM black water and 525 l/kg oDM mixture).

In order to obtain process related prarameters investigations were performed by means of up to 6 reactors with a volume of 6l each. The temperature in the reactor was controlled by operating the reactor in a water bath (35°C, resp. 55°C). The substrate in the test reactor can be homogenized by using a small pump. The pH-value was monitored online. The gas production was continuously measured and recorded using a gas meter. The gas quality was determined by taking samples from the gas bags which were analysed in a gas chromatograph.

For the optimisation of the adaptation phase of the anaerobic reactor where biowaste and black water were co-fermented, four reactors were operated over a period of 23 days. The single reactors were discontinuously fed with varying amounts of substrates as black water and biowaste. As a basis for the operation an amount of black water of 8 l per inhabitant/day and 0.17 kg DM of biowaste per inhabitant/day were chosen. During these investigations the acceptable loading rate for the anaerobic reactor could be determined and optimised. A stable anaerobic fermentation process could be achieved f.e. by the addition of the equivalent of 80 kg (wet weight) of biowaste to 1m³ of black water where the total amount of biowaste was added in two equal parts per week. After the adaptation phase the addition of biowaste could be increased to three times per week (total amount is equivalent to 120 kg of biowaste per week (wet weight). A daily dosage of the equivalent of 120 kg (wet weight) of biowaste to 1m³ of black water resulted in an unstable process. The operational parameters were determined and characterized in order to achieve a stable operation resp. indicate the beginning of acidification. At a concentration of volatile fatty acids (VFA) of 600-1400 mg/l a stable fermentation process could be achieved where the pH-value should not decrease below pH=6.7. If the VFA concentrations increase above 2500 mg/l the chance of an irreversible acidification occurs.

Conclusion

Concepts for the combined decentralized waste- and waste water treatment will become more and more relevant in the future. In order to be able to do more investigations in the future, the Institute of Waste Management (TUHH) develops together with the “Environmental Technology Centre of TUHH (*etc*) a new mobile decentralized waste- and waste water treatment plant based on the concept described in this paper. The plant will be built to be used in a flexible way. The different components will be placed in two containers, so that it is possible to go to the waste and waste water producers, in order to make investigations that allow an optimum design for the full scale plant. In addition since this is a new concept research activities will be performed using different treatment systems and using different substrates.

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Evaluation of techniques for concentrating nutrients in human urine collected in ecological sanitation systems

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Keywords

Urine, nutrient recovery, evaporation

Abstract

This work deals with evaporation as one possible process to concentrate urine and recover the contained nutrients. Under certain conditions, losses of ammonia are very low, thus evaporation seems to be an appropriate technique. More technical investigations are required to get further reliable results.

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Introduction

Domestic wastewater consists of three fluxes of totally different quality. With respect to nutrients, urine (yellow water) is the most important one: About 87 % of nitrogen and still even 50 % of phosphorus and potassium in domestic wastewater originate from that source. As urine separating wastewater systems are available the application of such systems could be a strategy to achieve a high degree of nutrient recycling from human waste to agriculture.

The required removal of nutrients – which is regulated by law - causes high technical efforts in conventional wastewater treatment plants and moreover N, P and K are important fertilising substances, which are essential in agriculture. Thus the separation of yellow water is an important tool of integrated sanitation systems. Since the development of No-Mix-Toilets, the separate collection of urine is no longer a technical problem, but techniques for processing the collected urine will have to be developed. One important aspect is to increase the concentration of yellow water: On the one hand the decrease of volume is of interest in congested areas to save storage capacity, on the other hand a higher urea concentration is advantageous for definite utilisation of yellow water such as using urea from yellow water as a replacement for industrial produced urea (Haber-Bosch-Process). There are a couple of possible techniques, both low tech and high tech options, to be considered. In this work evaporation as one possible technique of enriching urine is investigated. Investigations on applications of membranes for concentrating urine are in progress.

Evaporation

In preliminary studies urine, stored under different conditions and stabilised in different ways, was evaporated by using a rotary evaporator. Distillate and concentrate were monitored on different parameters such as N, P, K and TOC. For the comparison of volume reduction and effective concentration of substances, Theoretical Concentration Factors (TCF = ratio of initial volume to final volume) were calculated.

$TCF_t = V_0 / V_{conc\,(t)}$; $DCF_t = C_{conc\,(t)} / C_0$;
Where, V_0 is the initial volume
$V_{conc\,(n)}$ is the volume of the concentrate at time t
C_0 is the concentration of the first sample
$C_{conc\,(n)}$ is the concentration of the sample at time t

In the evaporator in laboratory scale TCF between 8 and 14 were achieved.

Determined Concentration Factors (DCF = ratio of final concentration to initial co ncentration) of different parameters were marginally lower, e.g. the DCF of ammonia concentration achieved about 90 % of the TCF, thus indicating that the losses by stripping ammonia are in an acceptable range (fig. 2).

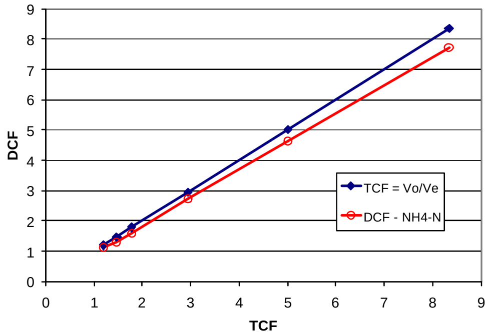

Figure 1: The determined concentration of NH_4-N in the concentrated urine, depending on the increasing TCF

Figure 2: Residuals of urine after evaporation

The highly concentrated residuals (fig. 2) were of viscous consistency and can be described as a "pasty" mass.

Based on these investigations an evaporation unit of larger scale was built to figure out whether the crystallisation by evaporating urine is possible in larger scale. A cycle system with heat exchanger, evaporator tube pump and crystal deduction unit was installed. The he at exchanger heats up the substrate to 90°C. The required heat is provided in the form of steam by a steam producer. Between the heat exchanger and the evaporator, there is a manual valve which controls the pressure inside the evaporator

Figure 3: Self-built-evaporator

In the crystal deduction part, the velocity of the gaseous flux is decreased by the enlargement of the cross section and heavier solids (bigger crystals) can drop down. At the lower end of the crystal deduction unit a very short tube piece is connected with a single solenoid valve which opens in an adjustable interval and discharges a part of the existing material (crystals and concentrate) in the test-tubes of a tray collector.

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Once a sample is filled into a tube, the rotator turns so that the next sample will enter the next tube.

In the test tubes of the tray collector, collected material can be separated into the crystal phase and the liquid phase. In the evaporator, steam is produced and it is drawn off from the lid of the reactor and is conveyed to a condenser. The obtained distillate is collected in a reservoir which is set behind the heat exchanger. The experimental work was done under "low-tech-conditions" with a self-built-evaporator, to figure out whether evaporation is an appropriate technique or not. The main question was to find out if it is possible to evaporate urine without losing high amounts of ammonia.

Results and discussion

Each experiment was done for a duration of 24 hours. Due to problems with the set-up the maximum concentration was not reached.

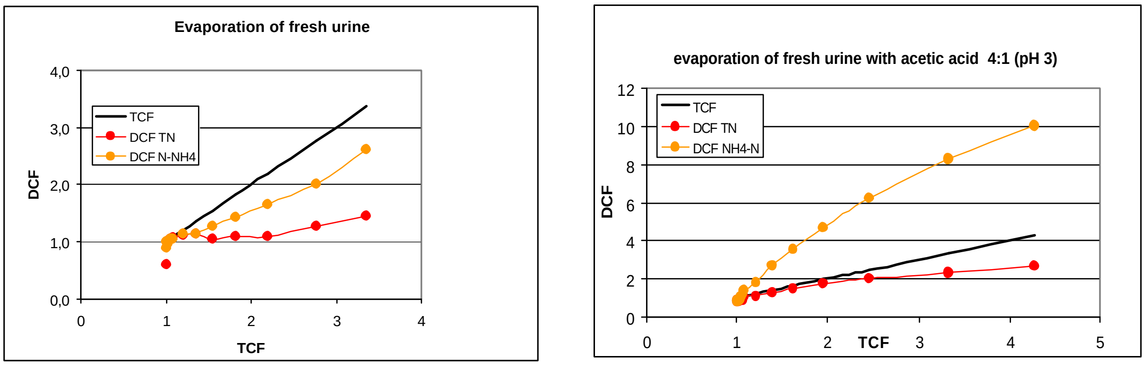

Figure 4: Comparison of TCF and DCF of urine with and without acetic acid.

Observing the graphs obtained from processing acidified urine, a trend for N-NH_4 can be noticed: Measured values are higher than the values of the ideal separation (equal to TCF) so that the recovery is higher than 100%. This unique trend could be explained by the decomposition of urea existing in the substrate.

Possible explanations for the losses (measured as balance losses of TP, TN and TOC) could be due to two reasons:

- Aerosol droplets containing these components carried to the distillate by the action of the vacuum.
- Losses due to scales, which was observed on the walls of the plant and residues in the concentrate test tubes.

As for the experiments performed with non-acidified urine this unique trend of N-NH_4 was not observed in any of the graphs which support the assumption that this was due to dissociation of the urea into ammonium by the action of the acid. The losses of N-NH_4 in these experiments could be attributed to the hydrolysis of urea, which causes a simultaneous increase in pH and ammonia concentration as described in the following reactions

$$CO(NH_2)_2 + 3H_2O \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^- + OH^-$$
$$NH_4^+ + OH^- \longleftrightarrow NH_3\,(aq) + H_2O$$
$$NH_3\,(aq) \longleftrightarrow NH_3\,(g)$$

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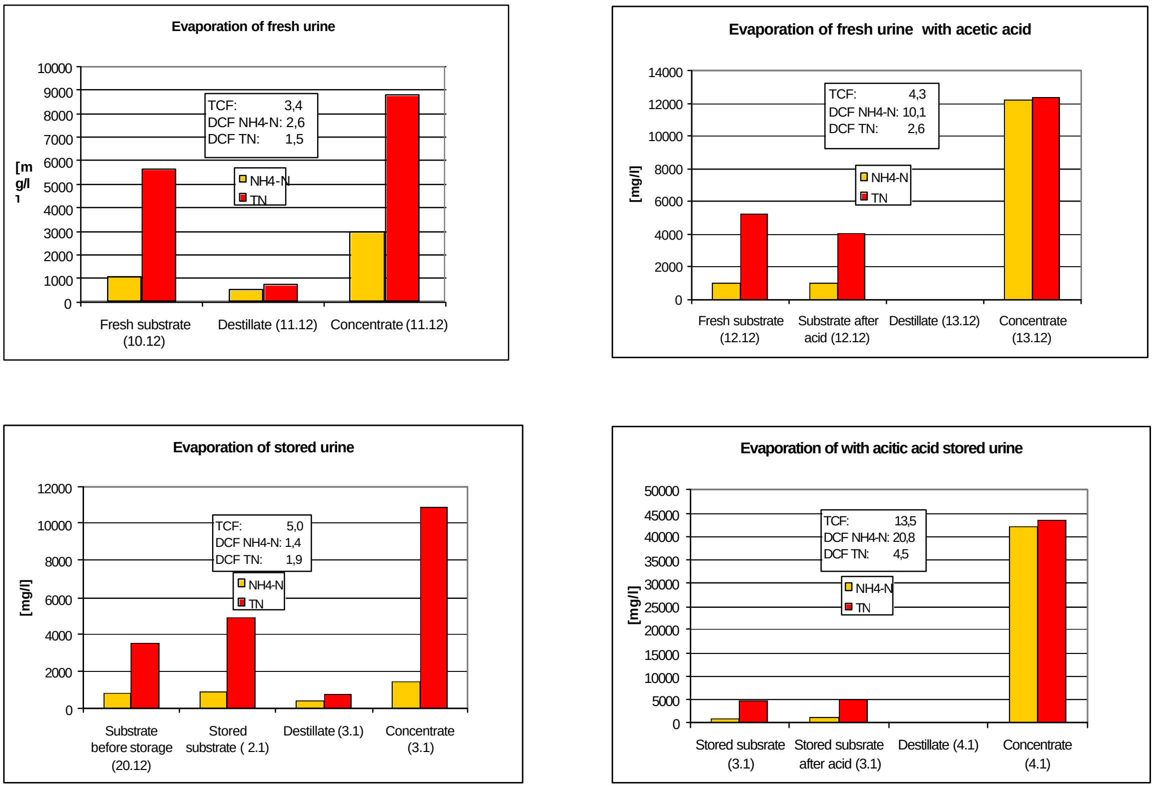

Figure 5: Comparison of evaporation of different urine samples, fresh and stored urine, at each case acidified and non-acidified

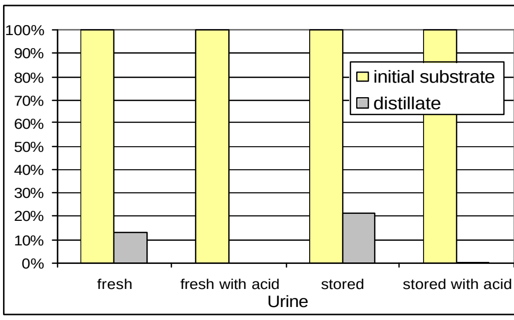

Figure 6: Ratio of lost ammonia depending on storage conditions

Figure 5 shows the differences in evaporation of fresh and stored urine, both acidified and non-acidified. The distillate in case of acidified urine is more or less free of nitrogen. Moreover the concentration efficiency is far higher in the acidified samples. The losses of ammonia can be minimised. It is obvious that the ammonium in urine is stabilised by acidification, ammoniac stripping does not occur so easily. Ammonia losses into distillate are shown in figure 6.

Conclusion

Evaporation of yellow water is an appropriate technique to concentrate urine. Ammonia losses can be minimised by stabilisation e.g. with acid. Further investigations are needed to find out about the effect of parameters such as temperature and pr essure conditions; these parameters could not be varied in the here used set-up. To get reliable results a technical plant should be used for the next steps of investigating urine evaporation. Moreover a theoretical energy-balance of different techniques like freezing, membranes and evaporation is in progress.

Pilot plant study: design, operation and maintenance optimisation of sustainable urban stormwater ponds

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Keywords

Design optimisation, dry pond, roof water run-off, stormwater management, water quality, wet pond

Abstract

The aim of this study was to optimise design and operation guidelines, and to assess the water treatment potential of stormwater pond systems. Performance data (15 months) for a stormwater pond pilot plant were collected. The system is based on a combined sedimentation tank, attenuation wetland and dry pond construction applied for drainage of roof water run-off from a single domestic property. British Building Research Establishment (BRE) and Construction Industry Research and Information Association (CIRIA), and German Association for Water, Wastewater and Waste (ATV-DVWK) design guidelines were tested. These design guidelines failed because they do not consider local hydrological and soil conditions. The infiltration function for the dry pond is logarithmic and depends on the season. Furthermore, water treatment of rainwater run-off was found to be unnecessary. However, seasonal variations of biochemical oxygen demand, dissolved oxygen and pH were recorded.

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Introduction

A domestic property in Sandy Lane (Bradford, West Yorkshire, England, United Kingdom) was selected for this pilot plant case study The surface water (subject to disposal) came from the house roofs and the roof of a tandem (double) garage. In April 2001, the original layout was changed in order to feed a semi-natural attenuation wetland structure with rainwater. The storage water was predominantly used for watering garden plants in summer. If the attenuation wetland structure overflows, the water is transferred to a dry pond structure designed to hold up to approximately 1.9 m^3 water. The purpose of this study is

- to identify technical constraints associated with the design and operation,
- to suggest design calculation alterations and
- to assess the water treatment potential of stormwater ponds for roof run-off water.

Materials and methods

The pilot plant was designed considering Building Research Establishment (BRE, 1991), Construction Industry Research and Information Association (CIRIA, 1996) and German Association for Water, Wastewater and Waste (ATV-DVWK, 2002) sustainable urban drainage system guidelines.

The surface areas of both house roofs are 29 m^2 each. The angle between each roof and the ceiling of the house is 23°. The total theoretical horizontal area of the house roofs is 53 m^2. The roof area of the tandem garage is 33 m^2. It follows that the total horizontal area to be drained is 86 m^2.

The total length of the plastic pipework (mean angle of 2°) is 19.6 m. The maximum horizontal average dimensions (length × width) of the sedimentation tank, attenuation wetland and dry pond are 0.7 × 0.4, 3.2 × 1.7 and 3.7 × 2.5 m, respectively. The maximum depths of the attenuation wetland (or wet pond) and the infiltration pond (or dry pond) are 39.5 and 40.0 cm, respectively.

The semi-natural pond structure consists of three water bodies with a total effective volume of approximately 1.7 m^3 during dry and 1.9 m^3 during storm events. The rainwater drains in the sedimentation tank with a maximum capacity of 0.1 m^3. Suspended solids (e.g., weathered building materials, decayed leaves, bird droppings and particles from atmospheric pollution) from the roofs settle down in this part of the structure that acts as a silt trap. Water from the sedimentation tank overflows into the bottom pond (mean volume of approximately 1.7 m^3), which is designed as both an attenuation wetland and storage pond. The dry pond will take a maximum of approximately 1.8 m^3 during very heavy storm events before it overflows.

All analytical procedures to determine water quality were performed according to the American standard methods (Clesceri *et al.*, 1989) that outline also the corresponding water quality criteria. Water samples were tested for temperature (air and water), five-day biochemical oxygen demand (BOD), suspended solids (SS), total solids (TS), conductivity, turbidity, dissolved oxygen (DO) and pH. Considering Hanna instrumentation, HI 9033 conductivity, C 102 turbidity, HI 9142 DO and HI 8519N pH meters were used throughout the study.

Results and discussion

The critical storm durations for the BRE, CIRIA and ATV-DVWK design calculations were 1.0, 0.5 and 1.0 hour, respectively. The associated maximum dry pond height (and storage volume) requirements were 28 (1.41), 21 (1.04) and 26 (1.27) cm (m^3), respectively.

Water level fluctuations within the attenuation wetland and dry pond are indicated in Fig. 1. Maximum dry pond height requirements calculated according to BRE (1991), CIRIA (1996) and ATV-DVWK (2002) guidelines were not sufficient for the period of the experiment. Figure 1 indicates when the system would have failed if the recommended design depths for the dry pond would have been applied.

Equation (1) indicates the mathematical relationship between the dry pond design depth (D) in mm and the infiltration time (T) in hours. The corresponding mean product moment correlation coefficient (R) the function is 0.92.

$$D = -a + \ln(T) + b \qquad (1)$$

$a = 2.54 \times b^{0.51}$, R = 0.58 (in general)

$a = 0.59 \times b^{0.83}$, R = 0.89 (for $b < 190$ mm)

$a = 0.015 \times b^{1.51}$, R = 0.77 (for $b \geq 190$ mm during spring, summer and autumn)

$a = 0.001 \times b^{1.94}$, R = 0.75 (for $b \geq 190$ mm during winter)

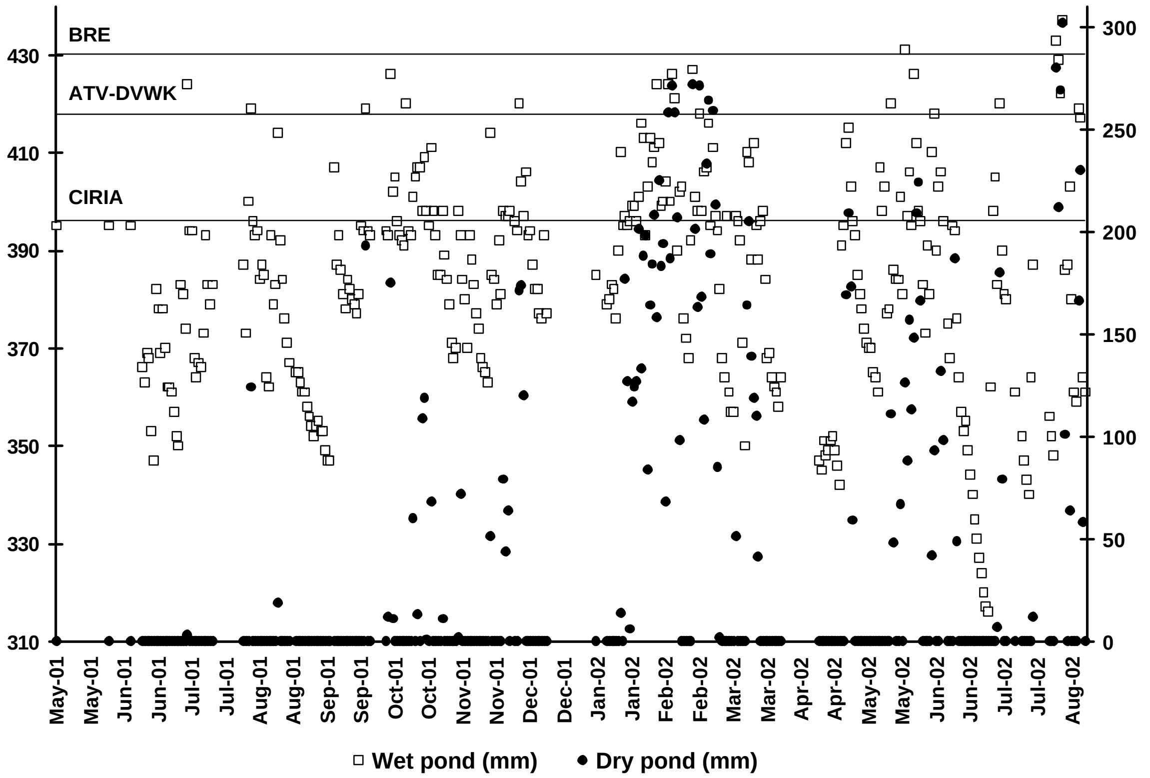

Figure 1: Maximum daily water level fluctuations within the attenuation wetland (left vertical axis) and dry pond (right vertical axis) between 13 May 2001 and 12 August 2002. Maximum dry pond height requirements calculated according to Building Research Establishment (BRE, 1991), Construction Industry Research and Information Association (CIRIA, 1996) and German Association for Water, Wastewater and Waste (ATV-DVWK, 2002) guidelines are indicated by horizontal lines.

The actual design for the dry pond (40 cm depth and 1.7 m^3 volume) was acceptable when compared to BRE (1991), CIRIA (1996) and ATV-DVWK (2002) guidelines. Any signs of system failure (e.g., flooding of the nearby lawn and structural damage) have not yet been observed. However, strict application of all tested guidelines (without adding a higher safety factor than recommended) would have lead to system failures during the first year of operation.

The period of study can be described as a particularly "wet time" (2,160 mm precipitation between summer 2001 and spring 2002). Moreover, the study site is located on a hill (approximately 240 m above sea level) and semi-exposed.

The water quality of the attenuation wetland (Table 1) was acceptable for disposal (e.g., sustainable drainage) and recycling (e.g., irrigation, toilet flushing and washing cars).

Conclusions

1. The successful operation of a stormwater pond system (first 15 months) has been studied.
2. International design guidelines are only acceptable if local environmental conditions (precipitation and infiltration patterns) are fully considered or very high safety factors are applied.
3. Infiltration through the dry pond base is low and should be ignored during the design.

4. The infiltration function for the dry pond is logarithmic.
5. The water quality of the attenuation wetland was acceptable according to standard practice for water disposal and recycling.
6. Rainwater does not require treatment in terms of its soluble content.
7. Seasonal variations in water quality were apparent.

Variable	Unit	Count	Mean	1st SR[2] mean	AM[3] Mean	WR[4] Mean	SG[5]	2nd SR[6]
Air temperature[8]	°C	345	12.2	16.9	8.9	6.5	13.2	17.1
Water temperature[8]	°C	325	11.1	15.4	8.6	9.1	11.9	15.3
BOD[1,9]	mg/l	57	4.3	4.2	3.1	5.6	6.7	2.5
Suspended solids[9]	mg/l	40	46.8	132.5	51.3	3.8	54.8	3.4
Total solids[9]	mg/l	40	193	239	294	105	152	92
Conductivity[8]	µS	281	39.8	75.1	37.5	33.0	37.7	34.2
Turbidity[9]	NTU[7]	39	2.8	4.3	2.7	2.2	2.0	1.5
Dissolved oxygen[8]	mg/l	319	9.3	11.5	4.8	10.1	12.4	7.3
pH[8]	-	263	7.77	8.36	7.27	7.86	8.69	6.84
Algal cover[8]	%	306	44	61	50	36	39	38

[1]BOD = five-day biochemical oxygen demand; [2]SR = summer: 21/06-21/09/01; [3]AM = autumn: 22/09-20/12/01; [4]WR = winter: 21/12/01-19/03/02; [5]SG = spring: 20/03-20/06/02; [6]SR = summer: 21/06-12/08/02; [7]NTU = nephelometric turbidity unit [8]PM = afternoon measurement; [9]AM = morning measurement.

Table 1: Summary statistics: Water quality of the attenuation wetland (26 April 2001 to 12 August 2002)

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Epuvalisation: a developing technique. Experiences, results in different countries

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Keywords

Epuvalisation, Mediterranean countries, plants, tertiary treatment, wastewater

Abstract

Nowadays, the problems related to Water and, in particular the wastewater, are becoming more and more important. Northern countries are facing some serious problems with the water streams pollution and water table contamination with nitrates and phosphates. Southern countries which are suffering from lack of water supply during at least one part of the year, as it is the case for the Mediterranean countries, have constantly increasing need of freshwater for human purpose (drinking water) and for their agriculture (irrigation). The Faculté Universitaire des Sciences Agronomiques of Gembloux (Belgium) have looked into this problem and has developed a simple and low cost technique named Epuvalisation (*épuration* (purification) and *valorisation* (valorisation)) which have shown a really good efficiency in wastewater treatment by using plants. This technique, used as a tertiary treatment, has the particularity to remove the nitrates and phosphates from the wastewater and reduce the indicators of faecal contamination such as faecal and total coliforms and faecal streptococci. The treated wastewater can then be used for irrigation without the risks of water table contamination or sanitary problem and can also be rejected in water streams without the risks of eutrophication.

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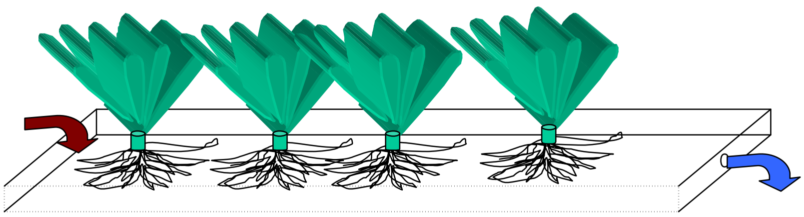
Principle of the purification technique

Epuvalisation is a biological wastewater treatment technique based on the principle of hydroponic cultures. The wastewater flows thru channels in which the plants have been placed with bare roots. The system can be used as an opened (only 1 passage) or closed circuit (recirculation). The channels are 50 cm wide and their length is settled depending on the wastewater quality. Nitrates and phosphates are taken up by the plants for their growing process and the roots are acting as physical filter for the suspended matter and as a support for an abundant bacterial flora. Therefore, the system is also acting as a constantly growing trickling filter.



This technique is used for the physico-chemical and microbiological purification of water polluted by organic matter of fecal origin (tertiary treatment of water treatment plants, small communities). It can also be applied to the treatment of urban wastewater, various agricultural wastewaters (pig slurry whether fermented in digesters or not) or industrial wastewaters (removal by filtration, decantation and concentration of heavy metals). The characteristic of the technique is to considerably aerate the liquid. The liquid to be treated is used as exclusive nutritional source. A channel can be made up of NFT (Nutrient Film Technique) or PNF (Permanent Nutrient Flow) elements operating either in open or closed circuit. One can say that plants, devoid of any substrate, act via their roots, in three ways:

- as a bacteria support in very aerated medium
- as a natural filter retaining suspended matters
- as an absorbent of fertilizing matters : especially nitrates and phosphates

This purification technique differs completely from stabilisation ponds in 3 vital characteristics (Henrard, 1994).

- a very short retention time of the liquid in the channels, which does not in general exceed 1 to 2 hours
- economic in space, making it feasible to set up the system under a greenhouse, kept above freezing by slight heating. The technique could therefore be used year round in temperate or cold climates
- root growth and accumulation of suspended matter around roots leads to the silting up of channels and overflowing. Plants must therefore be replaced after 3 to 4 months of growth.

Species are chosen according to various specific criteria : their adaptation to hydroponic growth ; rooting must be composed of fine rootlets with no tap root ; their ready multiplication by sowing, propagation by cuttings, ratooning, in-vitro, ... in order to ensure plant replacement. The technique is used for the removal of nitrogen and phosphorus compounds and the reduction of pathogen bacteria and heavy metals. A standard channel (length:12 m (cl.circuit) to 50 m (opened circuit)) can treat, on average, 500 litres/hour of liquid which amounts to 12 m^3 /day or 70 to 80 equivalents-inhabitant using tertiary treatment of domestic effluents. The equipment used consists of easily transportable channel elements, which are light-weight and of convenient width for the operator's arm. The most common types are made of metal sheets coated with a layer of epoxy which is particularly resistant to aggressive agents, shaped, 50 cm wide and 9 cm deep, with corrugated reinforcements along the lengths. The standard length of each element is 5 meters. Placed end to end, the channels of the desired length can be obtained. The liquid to be treated flows by gravity along the channels containing the plants. As a rule, the highest purification capacity occurs in the first 20 meters of the channel. Increasing the length to around 50 meters further reduces pollution. However, a greater length poses problems not only for the layout of the land which must necessarily be sloping to avoid raising the elements too high ; but also due to excessive evapotranspiration which can prevent a sufficient quantity of the liquid from reaching the end of the channel.

Growth performances of species used

The most efficient species are celery, cyperus, water cress and iris. These four species give excellent results but their capacity for retaining sludge varies : the iris readily accepts having its roots covered in sludge whereas water cress has a far better vegetation when the liquid does not contain excessive quantities of sludge.
It could be useful, given these varied vegetation characteristics, to use sequences of different species to enhance global efficiency. One can therefore either use one single species or a sequence of species.
It was dear from a species by species analysis that cyperus and celery clearly stood out on account of their better growth performances and higher purifying capacity.

Performances of the purification treatment system

In general, the reductions obtained in closed circuit are better than those obtained in open circuit. The retention time of the liquid in the channels being longer in closed circuits, the longer contact time of the effluent with the plant roots enables the bacteria to carry out a more thorough nitrification and a resulting greater reduction in COD (Xanthoulis, 1997).

Reduction of physico-chemical pollution

In opened circuit

Those results have been achieved with effluents coming from classical purification plants (tertiary treatment - Belgium and Senegal) and with effluents coming from an anaerobic lagoon (secondary treatment - Morocco).

Parameters	Belgium*		Senegal	Morocco *
	in %	g/m.d **	in %	in %
SM				> 60 %
COD	48,2	10,31	20 - 60 %	> 40 %
BOD_5	55,0		30 - 63 %	> 40 %
NH_4	36,6	1,27	25 - 40 %	> 60 %
NO_3	45,3	11,55	25 - 40 %	> 60 %
PO_4	30,9	1,71	50 - 85 %	

* mean
** results in g. removed per channel meter and per day

Those trials have also shown that the major part of the purification was achieved in the 20 to 30 first meters of the channels. For example, these are the results achieved by the 20 first meters of a 40 meters long channel, in percentage of the global purification efficiency (after 40m).

	NEP Channel	NFT Channel
COD	**89**%	**83**%
NH_4	**79**%	**76**%
NO_3	**82**%	**78**%
PO_4	**72**%	**69**%

In closed circuit

The next results have been achieved with the "epuvalisation" of bovine slurry (Belgium) and porcine slurry (Portugal). The retention times have varied (along with the different trials which have been made) between 1 and 7 days.

Parameters	Belgium (in %) *	Portugal (in %)
DCO	64,8	from 35,9 to 95,3
NH_4	78,3	from 33,7 to 98,7
NO_3	88,7	
N total		from 33,9 to 92,1
PO_4	66,2	

* mean

Other applications

This technique has also been tested on municipal landfill leachates, on Olive Oil Mill's Wastewater, and enables the partial removal of heavy metals and the reduction in microbiological and helminth pollutions.

Valorization ways for the plants

As its name says it, this technique is not only a good way to purify wastewater but can also produce interesting and valuable plants. Among the valorization ways we have : pellets production for animal feeding, seed production, biomass production and production of ornamental plants which have real economical potential. Those plants can also be composted or used to produce worm compost which has an high economical and agricultural value.

Conclusion

The purification technique has been refined over a number of years through numerous experiments both in closed and opened circuits, and has resulted in the selection of the best species for ensuring highest treatment rates. The results achieved during the trials clearly indicate the efficiency of the system which, applied as a tertiary treatment of wastewater, leads to substantial physico-chemical and microbiological reductions. With this technique, the treated effluents meet the standards set for discharging wastewater into surface waters and the quality standards for irrigation waters.

The purification technique and the size of the system must however be adapted to the quality of the effluent and the space available. Indeed, trials conducted in open circuit have enabled the characterization of the purification in terms of reduction per meter of channel and per day, and in closed circuit trials, in terms of the required retention time of the liquid in the channels to achieve given reductions. These results can serve as a basis for reflection prior to setting up a purification system. The choice of this technique in opened or closed circuits depends of course on the space available, but also on the quality of the effluent to be treated. Although the use of a closed circuit constitutes a valid alternative when available space is fairly limited, it requires a technically heavier and more complex installation. Furthermore, this type of operation seems to be better suited to the treatment of smaller quantities of effluent presenting a higher load of polluting elements. In the current context of search for an improvement of the environment associated with the problems of the wastewater treatment costs and the availability of water in most of the Mediterranean countries, Epuvalisation can be considered as a good alternative for the small communities. Indeed, this technique is easy to use, low cost, flexible and have shown high efficiency in the purification process.

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Decentralised wastewater treatment – new concepts and technologies for Vietnamese conditions

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Keywords

Anaerobic digestion, anaerobic filter, baffled septic tank, decentralized system, suspended solids, wastewater treatment

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Abstract

The decentralized approach is a new means of addressing wastewater management needs of sewered and unsewered areas in a comprehensive fashion. The basic idea of that is to treat the wastewater (possibly together with refuses) on-site by means of low-cost treatment systems, and make direct use the treatment products (water, compost and biogas). This alternative can meet a sustainable wastewater management requirement and has a promising future, especially for developing country of Vietnam, where the water and sanitation issues are becoming a more and more important issue and are under new period of infrastructure development. Further, the authors describe results from experiment on treatment of real domestic wastewater by baffled septic tank with anaerobic filter that could be a feasible option for on-site wastewater treatment in residential areas of Vietnam. The data show that baffled septic tank with anaerobic filter could effectively treat black wastewater from toilet in Vietnamese conditions, with removal efficiency by COD from 43.24 ~ 94.92 % (average 73.62%), by BOD_5 from 45.3 ~ 90.87 % (average 71.08%), by SS from 47.62 ~ 97.18 % (average 75.44%). Characteristics of influent wastewater, BASTAF performance, relationships between removal efficiency and organic loads, up-flow velocity, hydraulic retention time, ambient temperature, presence of anaerobic filter and number of baffled chambers were discussed. After that, the decentralized schemes of wastewater management are also proposed for medium and small cities of Vietnam.

Introduction

As a part of the Swiss Government funded project of Capacity building in environmental science and technology at Centre for Environmental Engineering of Towns and Industrial Areas (CEETIA), Hanoi University of Civil Engineering, in co-operation with Swiss Federal Institute for Environmental Science and Technology (EAWAG), the decentralization concepts and technologies in wastewater management are being systematically investigated, with focus on its development and practical implementation in Vietnam.

Looking for appropriate technical solutions for improvement of septic tank performance in urban areas in Vietnam is one from major interests of CEETIA-EAWAG research team. Once the issue of simple and effective wastewater treatment facility could be solved at household or group of household level, then the decentralized sewerage system could be released significantly from suspended solids and organic loads as well as it could be operated at more stabilized flow conditions.

Experiment on treatment of real domestic (black) wastewater by baffled septic tank with anaerobic filter (BASTAF) at CEETIA

Material and methods

CEETIA has installed two models of baffled septic tank, small and big, made from Plexiglas. The scheme of arrangement of models is shown in Figure 1. Operation of those two septic tank models started since July 2001. Peristalic pumps were used to feed the reactors with a real wastewater from toilets in building of classes at the University's campus near Laboratory.

Period, days of operation	Flow, l/h	Up-flow velocity v, m/h	HRT, h	Influent SS, mg/l	Influent COD, mg/l	OLR gCOD/ d
Stage 1. 2 models working in parallel, continued feeding, 339 days						
Stage 2. 2 models working in parallel, discontinued feeding, 54 days						
Stage 3. 2 models working in line, continued feeding, 167 days						
Small BASTAF	2.34 ~ 4.74	0.06 ~ 0.3	7.8 ~ 471.8	9 ~ 1065	79 ~ 971	0.006 ~ 3.04
Big BASTAF	6 ~ 20	0.15 ~ 0.15	10.8 ~ 95.6	63 ~ 1065	121 ~ 1031	0.04 ~ 3.04

Table 1: Operational conditions of BASTAF models

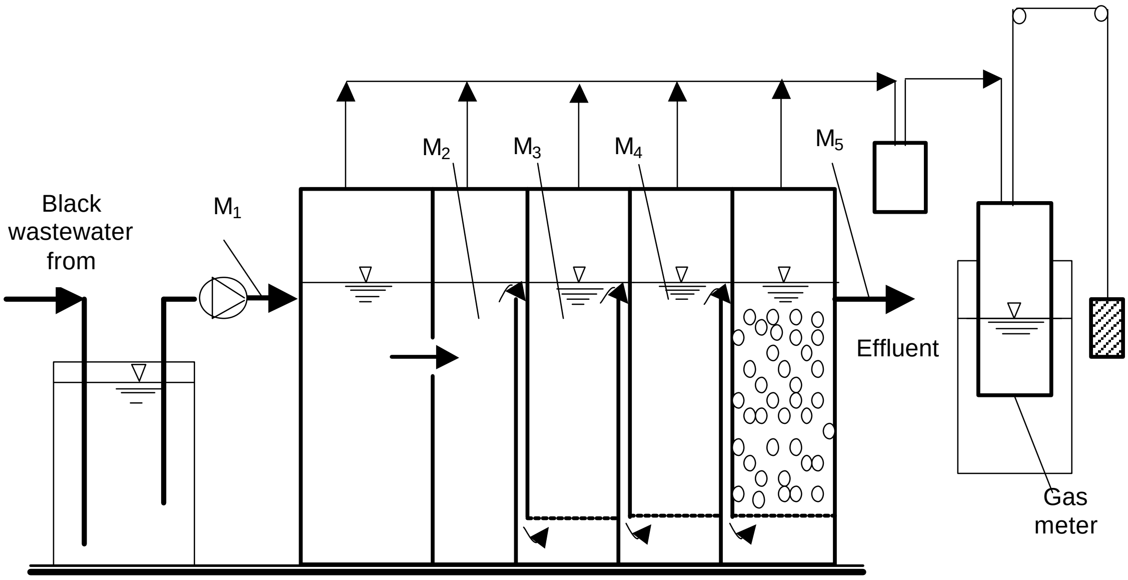


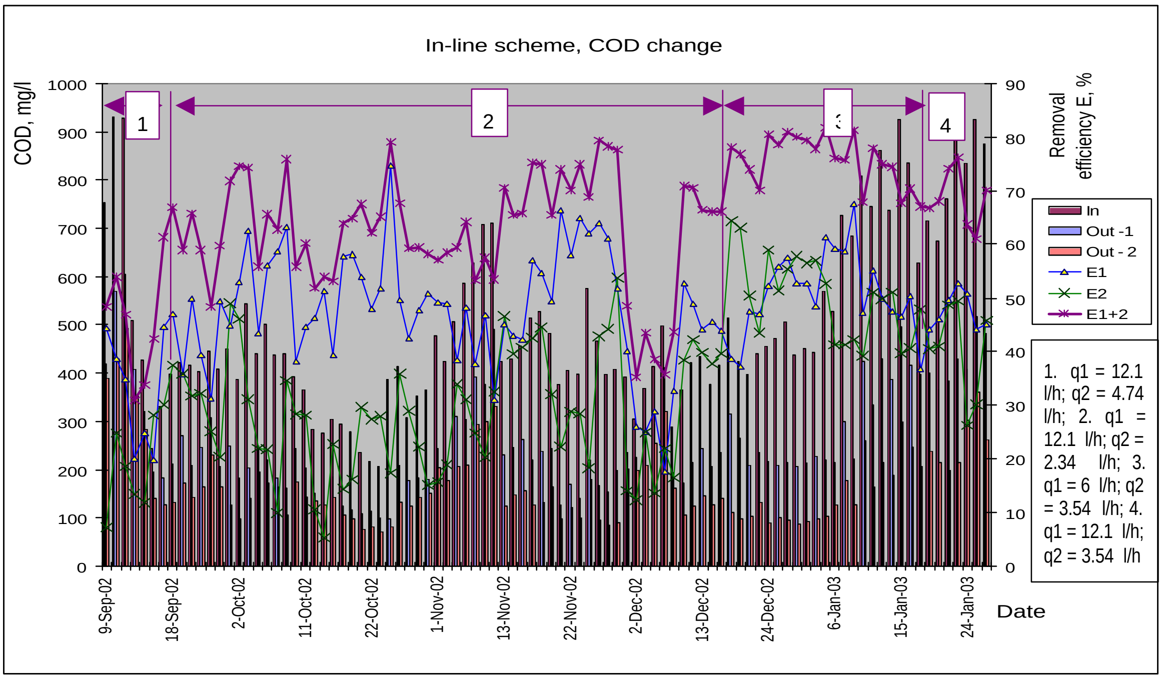
Figure 1: Baffled septic tank with anaerobic filter (BASTAF) M1, M2, M3, M4, M5: Sampling points

Results and discussion

Stages	Small model			Big model		
	SS	COD	BOD_5	SS	COD	BOD_5
1	16.67 ~ 87.50 **(59.12)**	28.33 ~ 90.17 **(50.11)**	23.45 ~ 73.55 **(46.0)**	12.83 ~ 83.29 **(50.99)**	2.04 ~ 61.92 **(30.55)**	19.22 ~ 61.54 **(37.61)**
2	47.62 ~ 97.18 **(75.44)**	43.24 ~ 94.92 **(73.62)**	45.3 ~ 90.87 **(71.08)**	35.86 ~ 91.30 **(68.69)**	28.38 ~ 83.83 **(59.85)**	36.36 ~ 91.23 **(60.70)**
3	50.74 ~ 94.87 **(78.84)**	30.84 ~ 81.75 **(64.71)**	24.52 ~ 81.58 **(64.39)**	(2 models in series)		

(Note: figures given in table: minimum ~ maximum (**average value**)).

Table 2: SS, COD, BOD_5 removal efficiencies, %



In:	Influent COD;	E1:	COD removal efficiency from first BASTAF, %;
Out-1:	COD in effluent from first BASTAF;	E2:	COD removal efficiency from second BASTAF, %;
Out-2:	COD in effluent from second (following) BASTAF;	E1+2:	Total removal efficiency of a system, %.
q1:	Wastewater flow to first BASTAF, l/h	q2:	Wastewater flow to second BASTAF, l/h

Figure 2: COD removal efficiency (stage 3, two BASTAFs in series, Sep. 2002 - Jan. 2003).

Conclusions

- Baffled septic tank with or without up-flow anaerobic filter has shown positive results for real domestic (black) wastewater treatment in Vietnamese condition. It could be developed

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further for practical implementation. Results from this study could be adapted for revision of existing septic tank design standards in the country.

- A combination of settling chamber with HRT 12 h, 4 up-flow baffled chambers with HRT 48 h, anaerobic filter with HRT 24 h, in series, could provide the effluent from black wastewater treatment, with average inflow chaacteristics: SS 350 mg/l; COD 500 mg/l; BOD_5 300 mg/l, at a range of SS 87.5 mg/l (75% removed), COD 180 mg/l (64% removed), and BOD_5 110 mg/l (64% removed) after three months of operation, in the climate similar to Hanoi conditions. System of a settling chamber, 3 ~ 4 baffled chambers followed by 2 ~ 3 filter chambers are suggested for on-site and/or decentralized wastewater treatment schemes for agourp of houses where effluent from BASTAF goes to the stabilization ponds or infiltration facilities such as soak-away chamber, infiltration field, etc., after that the effluent could meet the requirement for secondary treatment before it is infiltrated into the soil or discharged to receiving water bodies. This effluent also can be reused in irrigation.

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Ion exchange with Clinoptilolite. A potential alternative for ammonia recovery from domestic wastewater

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Keywords

Ammonia removal and recovery, clinoptilolite, domestic wastewater, ion exchange

Abstract

Removal of ammonia through ion exchange with clinoptilolite had been demonstrated to be an effective alternative in terms of domestic wastewater treatment. Effective desorption of ammonia from the surface of clinoptilolite had also been shown to be possible. As such, removal of ammonia from wastewater, and possibly from human urine, followed by its elution from the ion exchanger in a sequential process of ion exchange and desorption, seems to be a potential method of recovery of ammonia, and alternatively nitrogen, from liquid wastes originating from domestic use.

Introduction

Depending upon its strength, conventional domestic wastewater contains 20 - 85 mg/l of total nitrogen, the majority of which comes from ammonia. Ammonia content of different strengths of domestic wastewater is given in the range of 12 - 50 mg NH_4/l, and the balance of the total nitrogen is typically attributed to organic nitrogen which is a potential source of ammonia itself. Over 80 % of nitrogen originating from domestic use is attributed to urine (Otterpohl, 2000). Human urine on the other hand, typically has about 600 mg/l of ammonia nitrogen in it. Additionally, it contains typically 10 g/l of urea which in turn is converted into ammonia.

Ion exchange with clinoptilolite has been demonstrated to be an effective method of removal of ammonia from domestic wastewater. Not only can ion exchange with clinoptilolite remove ammonia at its original concentrations in the wastewater but also it can be used as a polishing step after the nitrogen removal unit to maintain the targeted removal level especially during peak and variable loads of ammonia.

Previous work has indicated that except being very effective in terms of removing ammonia from domestic wastewater, effective desorption of the surface ammonium ions is also possible even if only water that is free of ammonia is used in the desoption process. Another effective way of removing the ammonia from the surface is the familiar method of regeneration with a sodium containing regenerant, preferably at high pH's.

An analysis of the previous investigations suggests that ion exchange with clinoptilolite followed by desorption may be a good alternative for the removal, recovery and reuse of ammonia not only for conventional domestic wastewater but also from separately collected, segregated domestic effluent like in the case of yellow water, where ammonia levels are substantially higher than the conventional domestic wastewater. Although it constitutes a minor portion of domestic wastewater, most of the nutrients therein are attributed to human urine and about 80 % of the total nitrogen in domestic wastewater is estimated to come from urine. Typical values of total nitrogen and ammonia nitrogen in urine are given as 12 and 0.6 g N/l, respectively. Typical concentration of urea in urine, which is a potential source of ammonia, is given as 10 g N/l.

This paper aims to present a brief overview of ammonia removal from domestic wastewater through ion exchange with clinoptilolite and a discussion of the potential of ammonia recovery from domestic wastewater, or alternatively human urine, using this method in combination with desorption.

Ammonia removal through ion exchange with clinoptilolite

Ion exchange with clinoptilolite has been demonstrated to be an effective method of removal of ammonia from domestic wastewater. Clinoptilolite is a natural zeolite which is highly selective for ammonia. References regarding this subject matter is abundant, and a recent review is published by Hedstrom (2001).

Various researchers have published isotherm work pointing at the capacity of clinoptilolite to remove ammonia from a variety of different feed streams including pure aqueous solutions of ammonia, synthetic feed solutions, domestic wastewater etc. (Beler Baykal, 1998, Nguyen, & Tanner, 1998, Gisvold et. al, 2000a) mostly in the range of 0-50 mg/l of ammonia concentration in solution. An example to those, produced by Beler Baykal et. al (1996a), is given in Figure 1, where isotherms for a Bulgarian clinoptilolite, Beli Plast, and a Turkish clinoptilolite, Bigadic, in contact with domestic wastewater are presented, with Fruendlich isotherm equations for that range given in the same work as

$q_e = 1.08\ c^{0.664}$ for Beli Plast, and

$q_e = 1.28\ c^{0.594}$ for Bigadic

Work concerning higher concentrations of ammonia are rather limited. Nevertheless, the isotherm by Zwerger et. al (2000) shows that a surface capacity of about 18 mg/g is attained for 700 mg/l of ammonia in solution at equilibrium. Recent on going isotherm work undertaken even at higher concentrations ran with the Bigadic clinoptilolite, has revealed that the capacity may go as high as about 30 mg NH_4/g clinoptilolite at an equilibrium solution concentration of 800 mg NH_4/l (Beler Baykal et. al., 2003).

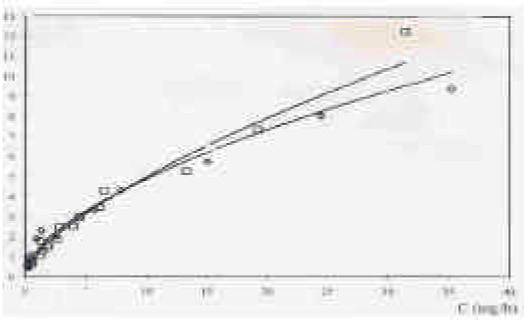

Figure 1: Isotherms for two different clinoptilolite samples at a particle size of 1-2 mm in the range of 0-35 mg/l of ammonia at 20 C (Beler Baykal et. al,1996a)

Moreover, not only can ion exchange with clinoptilolite remove ammonia at its original concentrations in the wastewater but also it can be used as a polishing step after some nitrogen removal unit. Furthermore, the system may be used for upgrading effluent quality from nitrification especially during peak and variable ammonia concentrations, as a result of which effluent peaks may also occur, to maintain a stable effluent quality (Beler Baykal et. al, 1996b, Beler Baykal & Akca Guven, 1997, Beler Baykal 1998, Gisvold et. al, 2000a, 2000b). Examples of a breakthrough analysis and dampening of peak ammonia concentrations with the Bigadic clinoptilolite are presented in Figure 2 (Beler Baykal & Akca Guven, 1997, Beler Baykal 1998).

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Potential as a nitrogen recovery alternative

It is clear from the previous discussion that removal of ammonia from conventional domestic wastewater through ion exchange with clinoptilolite is a successful method. It has been further demonstrated by Beler Baykal et. al. (2003) that at elevated equilibrium concentrations of 800 mg NH_4/l in solution, the capacity of clinoptilolite may go up as high as 30 mg NH_4/g clinoptilolite. This is a good indicator that for segregated collection of urine (Otterpohl, 2000), the system may also be a good alternative for the removal of ammonia from yellow water both as original ammonia and for ammonia generated in time due to the conversion of urea.

Previous work had also indicated that except being very effective in terms of removing ammonia from domestic wastewater, effective desorption of the surface ammonium ions are also possible even if only water that is free of ammonia is used in the desoption process. Figure 3 shows desorption of ammonia from exhausted Beli Plast clinoptilolite using tap water only, indicating that desorption is fast in the first 30 minutes. Another effective way of removing the ammonia from the surface is the familiar method of regeneration at high pH's with a sodium containing regenerant and efficiencies of up to about 100% had been reported (Hedstrom, 2001). Other previous work from literature has also shown that recovery of ammonia from exhausted clinoptilolite is possible and clinoptilolite exhausted with ammonia may also be used as a slow release fertilizer (Liberti, 1979, 1981).

Conclusions

Removal of ammonia from conventional domestic wastewater can be achieved successfully through ion exchange with clinoptilolite within an ammonia concentration of up to about 50 mg/l. It had also been demonstrated that ammonia removed may be recovered through desorption and/or regeneration. As such, a sequential process of ion exchange followed by desorption emerges a potential method of ammonia recovery from domestic wastewater.

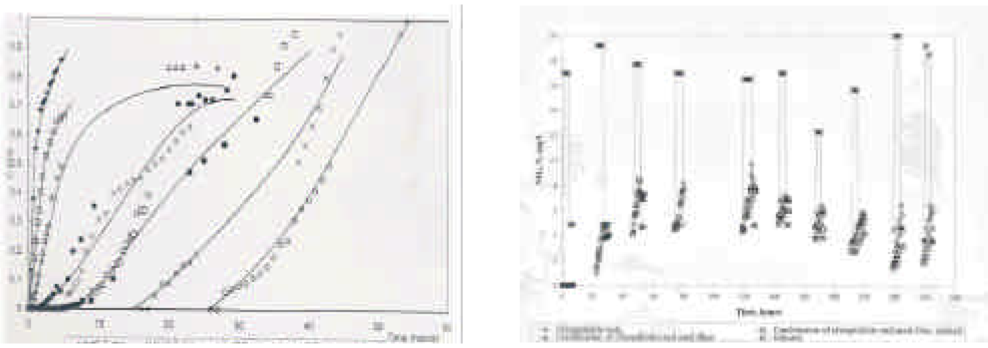

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Figure 2: Behavior of clinoptilolite-ammonia ion exchange systems,

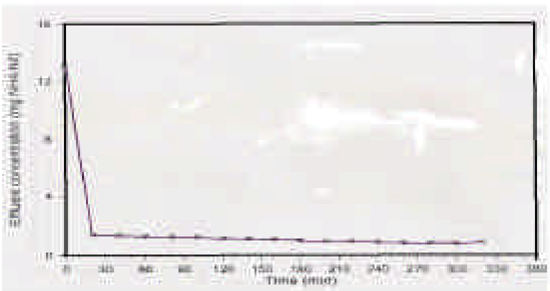

Figure 3: Desorption of ammonia from exhausted clinoptilolite with tap water (Beler Baykal, et. al., 1996b)

Recent work under progress has also given indications that even higher capacities may be attained at elevated ammonia concentrations reaching 800 mg/l, meaning the method may also be a possible alternative for removal and recovery of ammonia from urine, which actually introduces about 80% of the nitrogen in domestic wastewater, if urine is separated from the main wastewater line.

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Characteristics of grey water: Polderdrift, the Netherlands

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Keywords

Aerobic, anaerobic, biodegradability, characteristics, grey water, treatment

Session E

Abstract

The characteristics and biodegradability of grey water of 'Polderdrift' community were determined in this paper. The results showed that the settled grey-water is a low strength wastewater (total COD = 322 mg/l) with low concentration of nutrients (average concentration of Kj-N and total PO_4-P were 19.6 and 3.3 mg/l, respectively). Contrary to sewage, most of the nutrients in the settled grey-water were in particulate form. Particulate N and P represented 81 and 79% of, respectively, Kj-N and total P. Moreover, the results indicated that the settled grey-water had high aerobic and anaerobic biodegradability (88 and 86%, respectively). Accordingly, the treatment of grey water for the removal of COD and nutrients can be carried out in high-rate anaerobic systems, like upflow anaerobic sludge blanket (UASB) or anaerobic filter (AF).

Introduction

Grey water, which represents the major part of domestic sewage (60-75%), can be defined as a wastewater generated in the household, excluding toilet wastes, and includes wastewater from bathroom sinks, baths, showers, laundry facilities, dishwashers and kitchen sinks (Jefferson *et al*., 1999; Diaper *et al*., 2001; Eriksson *et al*., 2002). The characteristics of grey water depend firstly on the quality of the water supply, secondly on the type of distribution net for both drinking water and the grey water and thirdly from the activities in the household (Jeffrey and Jefferson, 2001; Eriksson *et al*., 2002). Grey water reuse on-site and off-site is more feasible as compared to domestic sewage. Jeffrey and Jefferson (2001) carried out a survey in UK and they found that 89% of the public would accept grey water recycling. From a survey of 400 residents of Amsterdam, 97% can accept water recycling for toilet flushing (van der Hoek *et al*, 1999). The reuse of grey water not only represents a sustainable solution, but also reduces the water bill with a reduction of water consumption by 30-35% (Diaper *et al*., 2001).

Grey water is produced over short periods. This generally results in a deficit in water during the afternoon and the late evening (Jeferson *et al*., 1999). Imura *et al*. (1995) found that the peak coefficient for grey water reached up to 6.2, which can lead to a decline in treatment performance during the peak flow hours. Therefore, presence of a storage tank prior to the treatment system of grey water is needed (Jeferson *et al*., 1999). Most researches in the treatment of grey water were sand filtration, natural, aerobic and membrane filtration systems (Jefferson *et al*., 1999). Although high-rate anaerobic system have both physical and biological removal, there is no research carried out on the anaerobic treatment of grey water.

In The Netherlands, there are limited on-site treatment plants for grey water. These existing treatment plants are locally installed and mainly natural systems. In order to make a recommendation on the potential of the treatment and re-use of Dutch grey water, a thorough knowledge of the characteristics of grey water found in the Netherlands is necessary. Therefore, the aim of this paper is to characterise the grey water of Polderdrift community and to determine its anaerobic and aerobic biodegradability.

Materials and methods

In Arnhem, The Netherlands, grey water of about 40 houses (Polderdrift community) is treated using a wetland and reused for toilet flushing, and rainwater is used for washing machines. The main aspect of this system is decentralised treatment of grey water, reduction of net water use by reusing treated grey water for toilets flushing and rainwater for the washing machines and diminishing the amount of domestic sewage, which has to be transported to and treated in centralised wastewater treatment plant. Grey water is transported to a storage tank and then flows to a wetland, which is a subsurface-flow constructed wetland planted with reed. The produced grey water contains all grey-water sources in the households, and it is representative of communal grey water in The Netherlands.

For charactisation of the grey water of Poldrecht community, five grey-water samples were taken after the storage tank (HRT = 1.2 day) in a period of three months. COD was measured using the micro-method described by Jirka and Carter (1975). Raw samples were used for total COD, 4.4 μm folded paper-filtered samples for COD_f and 0.45 μm membrane-filtered samples for dissolved COD. The suspended and colloidal COD were calculated by the differences between total COD and COD_f, COD_f and dissolved COD, respectively. Volatile fatty acids (VFA) were measured from membrane-filtered samples with a gas chromatograph. The Kjeldahl nitrogen (Kj-N) and *E-coli* were measured according to the *Dutch Standard Normalized Methods, DSNM,* (1969). Total PO_4–P was measured with an auto analyser (Skalar) after treatment according to *DSNM* (1969), while NH^+_4-N and dissolved PO_4^{3-}-P were directly measured with the same auto analyser. Proteins and carbohydrates were analysed as described by Elmitwalli *et al.* (2002). The anaerobic and aerobic biodegradability of the grey water were determined using WTW OxiTop. The anaerobic and aerobic biodegradability were calculated based on, respectively, increase and decrease of the gas pressure in the head space of the Oxitop bottles due to, respectively, methane production and oxygen consumption.

Results and discussion

Table 1 presents the characteristics of the grey water of the ‘Polderdrift’ community. The results showed that the grey water was a low strength wastewater, as the average concentration of the total COD was 322 mg/l. The characterised grey water can be considered as a settled grey water, as the measured characteristics were determined based on samples taken after the storage tank with a HRT of 1.2 days. Table 2 presents a comparison between black water and grey water, based on the characteristics of black water mentioned by Kujawa-Roeleveld (2002) and van der Hoek *et al*. (1999) and the measured characteristics of the settled grey water in this study. The major part of the COD and nutrients (N and P) in domestic sewage are mainly originated from the black water (Table 2). As the dissolved COD and ortho-P of the settled grey water is almost similar to that of raw grey-water, based on the data in Table 2, only 34 and 14% of, respectively, dissolved COD and ortho-P in the domestic sewage of the ‘Polderdrift’ community are originated from grey water.

Parameter	Unit	Concentration				Dutch Domestic
		Average	Max.	Min.	St. dev.*	Wastewater**
PH	-	7.12	7.5	6.8	0.27	-
Total COD	mg/l	322	342	296	24	425 (143)
Suspended COD	mg/l	54	75	33	21	201 (118)
Colloidal COD	mg/l	109	137	82	27	99 (9)
Dissolved COD	mg/l	159	185	139	23	125 (30)
VFA	mg/l	40	54	27.7	12.7	38 (25)
Kj-N	mg/l	19.6	28.3	11.1	7.7	62 (13)
NH_4-N	mg/l	3.7	5.9	1.4	2	52 (18)
Particulate-N	mg/l	15.9	26.8	9.5	7.6	10
Total-P	mg/l	3.3	5.6	2.5	1.3	8.6 (2.5)
Ortho-P	mg/l	0.6	1.9	0.2	0.8	5.4 (1)
Particulate-P	mg/l	2.6	3.7	2.3	0.6	3.2 (1.6)
TSS	mg/l	75.8	155	34	42.6	-
VSS	mg/l	53.3	125	16	37.9	-
Protein	mg/l	38.8	47	35	5.1	125 (31)
Polysaccharides	mg/l	11.6	14.9	6.9	2	69 (38)
Monosaccharides	mg/l	8.1	15.6	4.9	3.3	19 (3)
E-Coli	/100ml	$7.7x10^5$	$2.2x10^6$	$1x10^5$	$5.9x10^5$	$5.6x10^6$ ($1.5x10^6$)
Anaerobic biodegradability#	mg/l	276	296	255	29	-
Aerobic biodegradability##	mg/l	283	-	-	-	-

Table 1: Characteristics of the grey water of Poldrecht community. *: standard deviation. **: from Elmitwalli *et al*. (2002). #: after 15 days with inoculum at 30°C. ##: after 20 days at 30°C.

Parameter	Faeces#	Urine#	Black water#	Settled grey water##
	gr/(person*day)	Gr/(person*day)	gr/(person*day)	gr/(person*day)
Total COD	78.3	15.3	93.7	27.3
Dissolved COD	12.3	13.6	25.9	13.6
Particulate COD	62.8	1.8	64.5	13.9
Kj-N	2.5	6.3	8.8	1.7
Ortho-P	0.3	0.2	0.6	0.1
Total-P	1.0	0.4	1.4	0.3
Particulate-P	0.6	0.2	0.8	0.2
Protein	6.0	0.3	6.3	3.3
Polysaccharides	6.1	0.8	6.9	1.0
Monosaccharides	1.6	0.1	1.7	0.7

Table 2: Characteristics of faeces, urine, black water and settled grey water. #: Derived from Kujawa-Roeleveld (2002) and van der Hoek *et al.* (1999), ##: Derived from Table 1 assuming the volume of grey water is 86 litres/person/day, van der Hoek *et al.* (1999)

Contrary to the Dutch domestic-wastewater (Table 1), most of the nutrients (N and P) in the settled grey water were in particulate form. Particulate N and P represented 81 and 79% of, respectively, Kj-N and total P. Therefore, applying an efficient system for the removal of particulate matter (like a physical-chemical treatment, UASB, AF system) will likely result in a high removal of nutrients. However, biological treatment is needed for the removal of the dissolved COD, as the average concentration of the dissolved COD was 159 mg/l. The results of anaerobic and aerobic biodegradability showed the potential of applying both systems for the treatment of grey water. Therefore, in applying anaerobic systems, like UASB and AF reactor, for the treatment of grey water, both COD and nutrients can be efficiently removed. As the grey water has a higher temperature as compared to sewage (Eriksson *et al*., 2002), high-rate anaerobic treatment of grey water can have a high potential, even at a moderate climate. However, the removal of pathogens (which has a slightly lower concentration in grey water than domestic wastewater) in the anaerobic treatment of grey water will be limited, as found by Elmitwalli *et al.* (2002) in the anaerobic treatment of domestic wastewater. Therefore, disinfection of treated grey-water is needed, like the treated domestic-wastewater in high-rate biological systems. Finally, one of the main benefits of grey water separation from sewage can be considered that the treatment of grey water for the removal of COD and nutrients (P and N) can be carried out easily by a low-cost technology in high-rate anaerobic systems.

Conclusions

- The settled grey-water of Poldrecht community is a low strength wastewater (total COD = 322 mg/l) with low concentration of nutrients (average concentration of Kj-N and total PO_4-P were 19.6 and 3.3 mg/l, respectively). Contrary to sewage, most of the nutrients (N and P) in settled grey-water was in particulate form. Particulate N and P represented 81 and 79% of, respectively, Kj-N and total P.
- The settled grey-water had high aerobic and anaerobic biodegradability (88 and 86%, respectively). Accordingly, the treatment of grey water for removal of COD and nutrients can be carried out by a low-cost technology in high-rate anaerobic systems, like UASB or AF.

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Closed-loop toilet separation technology, reduces water consumption by 40 to 95% and pollution by 100%

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Introduction

Nationally and internationally, pressure is increasing to introduce nutrient reducing, water conserving and recycling measures for sustainable residential and small community water/wastewater treatment systems. Newspaper, magazine and television reports of inadequate water quality and quantity are being reported daily. Since 9/11 community water supplies and reserves have become potential targets for bio-terrorism. Systems utilizing rainwater catchment, cisterns for storage, blackwater separation, greywater treatment, filtration and disinfection technologies for partial or total reuse represent a logical and economical option for reducing and eliminating these pressures.

Session E

Methods

One-pint-of-water-per-flush gravity or vacuum porcelain toilet fixtures are plumbed to the Bio-Matter Resequencing Converter (BMRC). The toilets utilize a hand or foot pedal operating flushing mechanism that rotates a ball/trap device, which also controls and adjusts the water level in the toilet bowl to prevent staining or streaking.

Utilizing the vacuum flushing toilet model allows flexibility in locating the BMRC instead of having to design the house or facility around the system. For existing homes that do not have basements or for homeowners who do not want or do not have a location where an above ground building can be located, an underground concrete vault is recommended. The structure can be insulated and heated for cold climate installations and maintenance personnel can easily service the Systems without having to enter the home.

Utilizing Mother Nature's principles of aerobic decomposition (composting), the automated BMRC biologically converts 90 to 95 percent of all toilet and kitchen garbage disposal organic wastes into odorless carbon dioxide and water vapor. The BMRC can handle up to 12 adults full-time and can accommodate larger numbers for brief periods of time.

Greywater is plumbed to a series of separate polyethylene settling and treatment tanks. This System consists of a Surge Tank for flow control, an Aeration Tank to produce aerobic conditions and a Clarification Tank to return the settled solids back to the Surge Tank. An extremely energy-efficient (67 watt) air compressor provides an abundant amount of air to continuously provide oxygen and circulate the greywater. By separating the toilet flow from the greywater, the estimate for water consumption and greywater treatment is reduced from 75 gals of co-mingled wastewater to 40 gals of “Seperated“ greywater per person per day. The estimated treatment capacity of each greywater treatment system is 400 gals per day. Additional systems can be installed in parallel for greater flows. The Greywater Treatment System (GTS) process aerates and biologically treats the organics in the greywater. The Filtration and Disinfection System (FDS) mechanically treats and produces an effluent that can be safely discharged to reduced in size subsurface absorption beds or it can be reused for landscaping or irrigation purposes.

If the greywater is to be totally recycled, it flows into a storage tank that is aerated with ozone to kill bacteria. High and low level float switches control the operation of the Household Water Filtration and Recycling System (HFRS) to make potable water utilizing a high-pressure pump, which directs the ozonated water through filters, ultraviolet light, ultra and carbon filtration, another ultraviolet light and reverse osmosis. The processed water is then stored in the potable water storage tank, which supplies water to the entire household utlizing another pump, ultraviolet light and a .2 micron filter. Because water used for toilet flushing is evaporated in the BMRC and not connected in any way to the greywater treatment system, makeup water is re-supplied from a rainwater cistern, well or city water supply. An installed monitoring/control panel is programmed to activate pumps and valves for maintenance. The panel reports to the central monitoring facility if any alarms are activated or any of the components are in need of service or replacement.

Treated greywater effluent and HFRS results

Testing by Olmsted County, Rochester MN of the treated greywater effluent documented that separation and greywater treatment reduced water consumption by 40%, achieved greater than a 94% reduction for TSS and BOD5, greater than 83% reduction in total organics, over 90% reduction of total-N and a 1000 fold reduction in Faecal Coliform. (grams/capita/day)

Parameter	Olmsted County Effluent	Typical Raw Greywater	Typical Raw Blackwater	Typical Raw Combined	Calculated Reduction
TSS	3.3	17.2	53.5	70.7	95 %
TKN	1.0	1.9	9.3	11.2	91 %
BOD5	3.7	28.5	34.7	63.2	94 %
COD	18.9			120	84 %
TOC	4.7			28	83 %
	Olmsted County Effluent		Septic Tank Effluent		Reduction
Fecal Coliform	1,893		10 (3) – 10 (6)		0 – 1000 fold

Further testing by Olmsted County of the HFRS finished water averages from September 2001 to June 2002 documented consistent safe "Bottled" drinking water qualities.

Coliform Bacteria	E.Col Bacteria	Nitrate - Nitrogen	Nitrite - Nitrogen	Chloride	Sulfate	Fluoride
Health Impacts Can Occur At These Levels						
Present	Present	10 mg/l	1.0 mg/l	250 mg/l	250 mg/l	4.0 mg/l
HFRS Averages						
None Present	None Present	2.9 mg/l	<0.3 mg/l	24.9 mg/l	13.9 mg/l	0.2 mg/l

Conclusions

Psychologically, people may not think that they would like to reuse their own greywater for bathing and especially for drinking. Considering that all water has been wastewater at some point in time, Separation Technology combined with the described tested water treatment technologies provides for the total treatment of the greywater and produces safe water quality for recycle in landscaping/irrigation or "Bottled" water quality for total household reuse. Pricing ranges from $8,000 to separate the toilet wastes and reduce water consumption by 40% to $25,000 for the complete technology, which will treat, filter, disinfect the greywater and reduce water consumption by 60 to 95%. Considering the complete technology eliminates the need to drill an expensive well, which may have no or low flow or bad water quality, design and construct large soil treatment areas for septic systems or expensive collection, distribution and treatment facilities for piped water and sewer systems, this technology is less expensive, safer and healthier for the homeowner and the environment.

Characteristics of organic matter in higher-load grey wate

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Keywords

Bio-degradability, characterization of organic matter, grey water

Abstract

In the onsite differentiable wastewater treatment system, higher-loaded grey water should be treated biologically and then discharged to the soil system. In designing the grey water treatment system, the information regarding the bio-degradability of the constituents and their reaction rate is essential. In this paper, results from characterization of organic matter in grey wastewater are presented. We adopted the procedure proposed in the Activated Sludge Model No.2 and classified organic matter into six categories, that is, fermentation products; readily biodegradable organic material; slowly biodegradable; inert soluble; inert particulate organic materials; and heterotrophic biomass. Characterization results showed that about 40% of organic materials in grey water were inert, slowly biodegradable part occupied 30-40%, and readily biodegradable organic matter was 20 – 40 %. These characterization results coupled with the Activated Sludge Model were used for the simulation of membrane bio-reactor system for treating higher-loaded grey water, and it was calculated that the required detention time of the membrane bio-reactor was about 5 hours.

Session E

Introduction

The wastewater from a household or group of houses is made up of contributions from various appliances, such as toilet, kitchen sink, wash basin, bath, shower, and washing machine. We have proposed the Onsite Wastewater Differentiable Treatment System (OWDTS) (Lopez, *et al.* 2002) based on the concept of a differentiable management and treatment of household wastewater effluents. Figure 1 shows a hypothetical model for onsite wastewater differentiable treatment system. In this system, the separation of household wastewater into three types is essential. Elimination of toilet waste (black-water) from the residential wastewater stream by using bio-toilet system will reduce the mass of organic matters; pathogenic micro-organisms; nitrogen and phosphorous in the remaining waste stream (grey water). Lower-load grey-water could be treated by utilizing the natural capacity of soil microorganisms; and higher-load grey water needs any conventional treatment process for reaching acceptable quality.

Eriksson *et al.* (2002) reviewed literatures on constituents of grey water from view point of the grey wastewater reuse, and they made the tables for describing the characteristics of grey water from bathroom, laundries, kitchen sinks, and mixed sources. These tables list physical and chemical parameters including heavy metals and xenobiotic organice compunds. They also reported traditional wastewater parameters such as BOD and COD, but the information regarding the biological reaction rate of organic matter is not enough.

In designing the higher-load grey water treatment system, simulation of the performance based on the mathematical model is required. Determining composition of influent is a fundamental step for mathematical simulation. The objectives of this paper are 1) reporting the data on organic fractions in higher-load grey water and 2) estimating effluent quality of higher load treatment system by mathematical simulation.

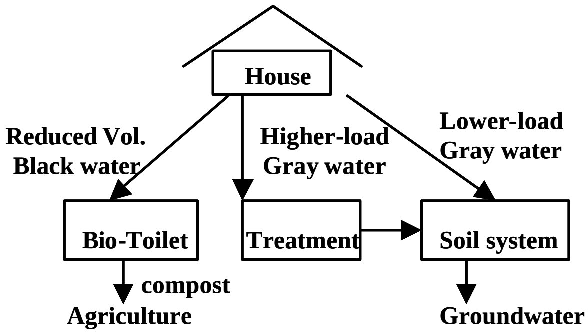

Figure 1: Hypothetical model for onsite wastewater differentiable treatment system.

Methods

Characterization of organic matter in Higher-load grey water. We chose the wastewater from kitchen sink (KS) and washing machine (WM) as a higer-load grey water based on data of the strengh of wastewater from various appliances (Funamizu *et.al.* 2001). The respiration test (Gujer and Kappeler, 1992), effluent COD analysis as well as total COD and volatile acids measurement were employed to classify organic matters into readily biodegradable substrate S_F, volatile acid S_A, slowly biodegradable substrate X_S, inert soluble matter S_I, and heterotrophic bacteria X_H in the samples. The activated sludge for the respiration test was prepared by one month operation of a fill and draw system in order to obtain the sludge acclimatized by KS and WM wastewater.

Simulation We developed a mathematical model for simulating performance of higher-load grey water treatment system. The system considered here is a membrane bioreactor with a flow equalization tank. The Activated Sludge Model No.2 (Henze *et.al.* 1995) was used to express the biological reactions in the reactor. We set the model variation pattern of flow from each appliance with reference to several reported data (Funamizu *et.al.* 2001). We calculated the fate of organic matter in the flow equalization tank first, and then this results were used for input data for simulation of the membrane bio-reactor. In the simulation of membrane bio-reactor, we changed reaction time, membrane performance and sludge withdrawal rate, and compared the effluent quality.

Results and discussion

Organic fractions in higher-load grey water

Total COD values of the wastewater from washing machine (WM) and kitchen sink (KS) are about 950mg/L and 1,300mg/L, respectively. Figure 2 gives the results of characterization of organic matter in WM and KS, showing that 1) the main part of organic matter in WM is slowly biodegradable organic matter, XS, 2) only 60% of the organic matter in WM and KS is bio-degradable (SA+SF+XS), 3) the wastewater from KS contains more readily bio-degradable organic matter than WM. Since inert soluble organic matter, S_I, in the wastewater will not change in biological treatment process, it is easy to understand that about 20% of organic matter in wastewater from WM remains in the effluent. Table 1 is showing the typical range of organic fractions of municipal wastewater after primary settling reported by Henze *et al.* (1995).

Comparison data in Fig.2 and Table 1 shows that grey water from WM and KS contain more inert organic matter than primary effluent of a municipal wastewater treatment plant.

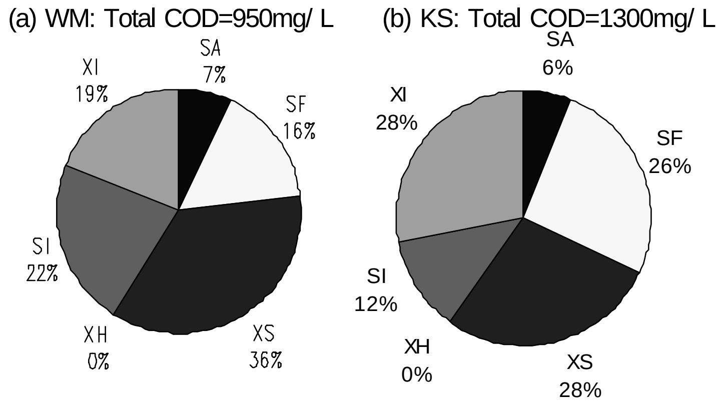

Figure 2: Organic fractions in the wastewater from washing machine (WM) and kitchen sink (KS)

S_F	S_A	S_I	X_I	X_S	X_H
10 - 20	2 -10	5 – 10	10 - 15	30 – 60	5 – 15

Table 1: Typical range for the organic fractions of municipal waswater, primary effluent (Henze et al. 1995)

<u>Simulation of the higer-load grey water treatment system</u>

Figure 3 is a model variation pattern of flow rate used in the simulation. Figure 4 shows estimated results of the effluent from the flow equalization tank. The minimum concentration appears early in the morning, but during 8am to 22pm, the variation of inert and dissolved COD, S_I, concentration is not significant.

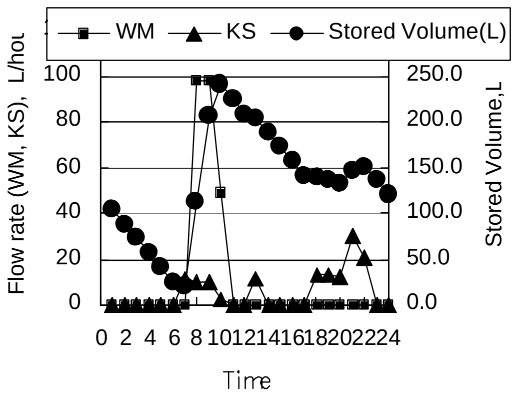

Figure 3: Model variation pattern of flow rate

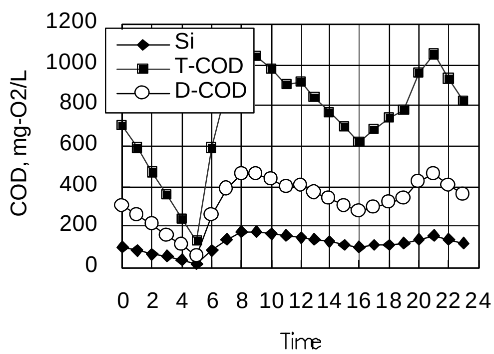

Figure 4: Estimated result of effluent from flow equalization tank

Figure 5 gives the simulated COD values in the effluent of bioreactor, showing that the required reaction time is about 5 hours. In the figure, Re shows the excess sludge withdrawal rate. Low Re value leads to the high suspended solid concentration in the reactor and then this gives higher total COD in the effluent when the reaction time is greater than 10 hours because we assumed a fixed performance in solid-liquid separation of the membrane.

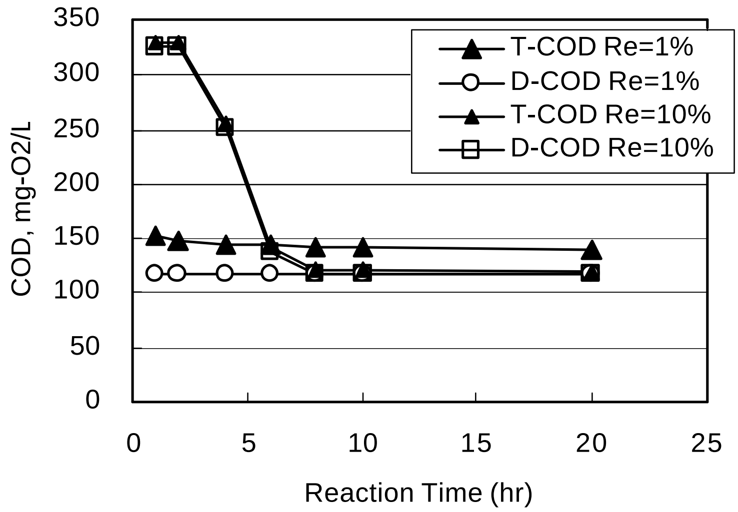

Figure 5: Calculation results of effluent of membrane bio-reactor

Conclusions

In designing the grey water treatment system, the information regarding the bio-degradability of the constituents and their reaction rate is essential. Characterization results showed that about 40% of organic materials in grey water were inert, slowly biodegradable part occupied 30-40%, and readily biodegradable organic matter was 20 – 40 %. The mathematical model was developed for simulation of grey water treatment system with flow equalization tank. The simulated results showed that the minimum reaction time required to treat slowly bio-degradable organic materials was about 5 hours in a membrane bio-reactor.

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Evaluation of key factors involved in the design of horizontal subsurface flow constructed wetlands*

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Keywords

Constructed wetlands, design, horizontal subsurface flow, wastewater

Abstract

This paper investigates the effect of hydraulic loading rate (HLR), aspect ratio, size of granular medium and water depth on the performance of horizontal subsurface flow constructed wetlands (SSFCWs) treating urban wastewater. Experiments were carried out in a pilot plant made up of eight parallel horizontal SSFCWs, each one with a surface area of 54-56 m^2. The system was sampled weekly from May 2001 to January 2003. The results indicate that HLR and water depth are two determining factors of the performance of the horizontal SSFCWs for most of the contaminants studied. Higher efficiency observed in shallower beds was related to the biochemical processes involved in the degradation of the organic matter, because it was observed that in shallower beds it was promoted more energetically favorable reactions.

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Introduction

Horizontal subsurface flow constructed wetlands (SSFCWs) are natural ecologically-engineered wastewater treatment systems. They are easy to operate, have low maintenance costs and do not produce large amounts of sludge in the secondary step. Moreover, they require less energy to operate than conventional mechanical systems, although they need more specific surface area. All these characteristics make horizontal SSFCWs especially suitable for the sanitation of small communities, ranging from single households to villages with few thousands of inhabitants. During the design of horizontal SSFCWs for secondary treatment, the most relevant parameters that need to be defined are: hydraulic loading rate (HLR), aspect ratio, size of the granular medium and water depth (Kadlec and Knight, 1996). Research into the effect of HLR on contaminant removal indicates that lowering HLR improves treatment efficiency (Maehlum and Stålnacke, 1999). Most of the HLRs used are within the range 10 to 100 mm/d. Studies of the influence of aspect ratio have demonstrated that system efficiency does not significantly depend on the shape of the system. For example, Bounds *et al.* (1998) found that there was no significant difference in TSS and COD removal in three parallel horizontal SSFCWs with aspect ratios of 4:1, 10:1 and 30:1. Different sized media within the range 10 to 60 mm (US EPA, 2000) do not appear to provide a clear advantage in pollutant removal, although the use of smaller media is normally recommended because the specific surface available for the biofilm per unit volume increases when the size of the particles decreases (Kadlec and Knight, 1996). There are no reports which clearly delineate the effect of water depth on the treatment efficiency of

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horizontal SSFCWs, so from practical experience, the depth is normally set at around 0.6 m in full scale projects (Cooper *et al.*, 1996). The objective of this study is to evaluate the effect of HLR, aspect ratio, size of the granular medium and water depth on the efficiency removal of organic matter, ammonium and ortophosphate in horizontal SSFCWs treating urban wastewater.

Materials and methods

The pilot plant used in this study treats part of the urban wastewater generated by the Can Suquet housing development in the municipality of Les Franqueses del Vallés (Barcelona, north-east Spain). The pilot plant consists of eight parallel horizontal SSFCWs (Figure 1) each one with a surface area of 54-56 m^2. The aspect ratio of the beds varies in pairs; for pair A, 1:1, for pair B, 1.5:1, for pair C, 2:1 and for pair D, 2.5:1. Furthermore, the size of the granular medium within each pair also varies. Type 1 beds contain a coarse granitic gravel (D_{60}=10 mm, C_u=1.6) while type 2 beds contain fine granitic gravel (D_{60}=3.5 mm, C_u=1.7). Average water depth for types A, B and C is 0.5 m, and 0.27 m for type D. Perforated manifolds running the entire bed width are used for the inlet (located on the top of the beds) and outlet (on the other side, located on the bottom and connected to a level control device). The pilot plant started operation in March 2001, when the beds were planted with common reeds.

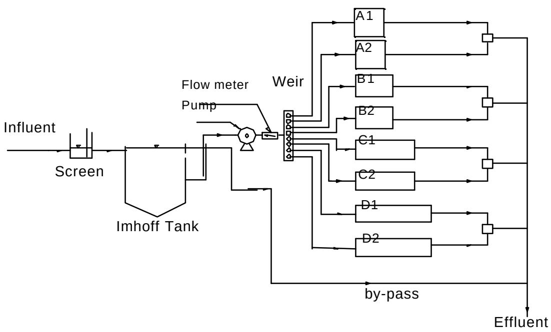

Figure 1: Diagram of the pilot plant at the Can Suquet housing development

The primary effluent is divided by means of a weir, and flows to the beds. In this study three HLRs were used: 20, 36 and 45 mm/d. Grab samples of the primary effluent (influent) and the effluents of all the beds were taken on a weekly basis from May 2001 to January 2003. COD, BOD_5, ammonium and ortophosphate were analysed immediately using conventional methods (APHA-AWWA-WPCF, 1995). Two additional sampling campaigns were carried out in summer 2001 to qualitatively evaluate the relative contribution of the different respiration pathways to the degradation of organic matter. In these campaigns electron acceptors (nitrate and sulphate) and organic matter were measured in the same manner used by Burgoon *et al*. (1991). Methane emissions were also estimated three times from type A and D beds during summer 2002 using funnels inserted into the gravel. A head-space method similar to that of Brix (1990) was used and methane was quantified using gas chromatography.

Results and discussion

The average (∀standard deviation) bed influent COD, BOD_5, ammonium and ortophosphate concentrations was 239 (∀87) mg/l, 143 (∀48) mg/l, 55 (∀12) mg N/l and 9.5 (∀3.0) mg P/l respectively. Figure 2 shows the average and standard deviation of the effluent's COD, BOD_5, ammonium and ortophosphate concentrations grouped according to the parameters tested.

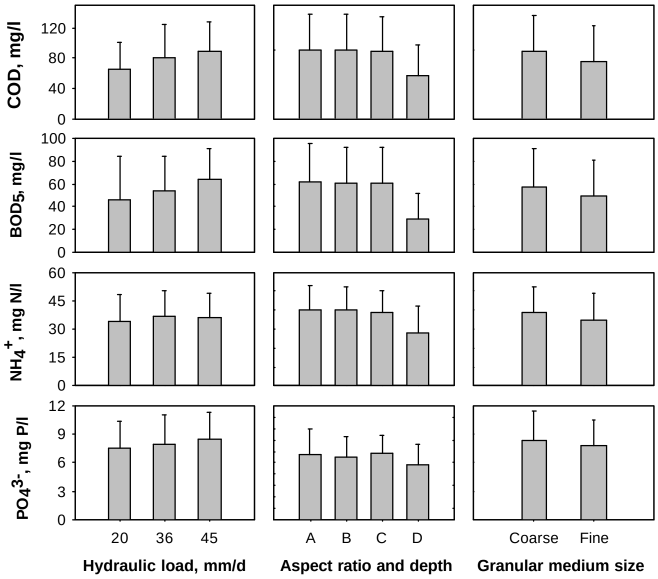

Figure 2: Average and standard deviation of the effluent's COD, BOD_5, ammonium and ortophosphate concentrations grouped according to the parameters tested.

As can be observed in Figure 2, of the four factors studied (HLR, aspect ratio, size of the granular medium and depth), only the first and the last yield clear differences in effluent concentrations of the contaminants measured. This finding is in agreement with previous works listed in the introduction with respect to HLR. HLR has an statistical significant effect on effluent COD (on average 67% removal for 20 mm/d, 62% for 36 mm/d and 57% for 45 mm/d) and BOD_5 (on average 64% removal for 20 mm/d, 58% for 36 mm/d and 54% for 45 mm/d), but not (significant) on ammonium and ortophosphate.

This is because the HLRs used were not low enough to reduce these two latter chemical species to a extent to put statistical differences into evidence. The beds with finer media have slightly lower effluent concentrations for all the contaminants tested. However, the differences are in general small and not significant (on average 83 and 71 mg/l for COD, 56 and 50 mg/l for BOD_5, 38 and 33 mg N/l for ammonium, and 8.4 and 7.9 mg P/l of ortophosphate for the coarse and the fine media respectively).

The results of this study indicate that water depth is a very important factor for contaminant removal in horizontal SSFCWs. As can be seen in Figure 2, for all contaminants tested the shallower beds (type D) produced systematically significant lower effluent concentrations. To our knowledge, this is the first time that a result like that is reported in the technical literature. In these beds it was found in the two additional sampling campaigns that denitrification was responsible for 20 to 30% of organic matter removal, but this process was not apparently present in the other beds because there was not ammonium removal during the trials (and therefore nitrate available for denitrification). Note that nitrate was not detected in the influent and the effluent of all beds, indicating that nitrate produced by nitrification was quickly consumed by the denitrification reaction (in special in beds D where there was evidence of ammonium removal). In fact, the importance of denitrification in beds D was evaluated by means of ammonium removal assuming that it was transformed to nitrate. The amount of organic matter removed by sulfate reduction was estimated to be higher in beds of types A, B and C (10-40% of the total organic matter) than in beds of type D (10-20%). Methane emissions were clearly higher in beds of type A (15, 17, 21, 27, 32 and 47 $mg/m^2.d$ -three measurements for each bed-) than in beds of type D (1, 4, 6, 6, 6 and 11 $mg/m^2.d$ -three measurements for each bed-). These results indicate that in shallower beds more energetically favorable reactions such as denitrification are important. In contrast, in deeper beds where these reactions are not significant.

HLR and water depth are both key factors in the performance of horizontal SSFCWs. From our data it can be seen that to obtain a BOD_5 removal of 90% and comply with the standards of the European Union Directive on wastewater treatment (Council of the European Communities, 1991), one must avoid exceeding an organic surface loading of approximately 6 g $BOD/m^2.day$

(for example, 20 mm/d HLR with an influent BOD_5 concentration of 300 mg/l) when using depths of 0.27 m, and 2 g BOD/m^2.day (20 mm/d HLR with an influent BOD_5 concentration of 100 mg/l) when using 0.5 m depths. With these loads ammonium and ortophosphate will not be adequately removed; the removal of these compunds requires more treatment units than a simple horizontal SSFCW, or operation at an impractical HLR.

Conclusions

The results of this study indicate that HLR and water depth are important factors controlling the efficiency removal of organic matter in horizontal SSFCWs. More efficient removal in beds with a lower water depth is related to the biochemical processes involved in the degradation of the organic matter, promoting more energetically favorable reactions in shallower beds. The use of shallower beds reduces methane emissions to the atmosphere. Note that methane has a higher global warming potential at an horizon time of 100 years (21) than carbon dioxide (1), and therefore shallower beds consequently have a lower impact on climate change.

Acknowledgements

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Phosphorus removal from domestic sewage and possibilities of recovery

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Introduction

Domestic sewage, for many years treated as waste, at present often are examined as potential source of nutrients. It is very important especially in case of phosphorus, which natural resources are limited, and its outflow to receivers causes eutrophisation and lowering their qualities. Commonly used methods of phosphorus removal from sewages do not give possibility of P-recovery and recycling. That is the reason why in local wastewater treatment systems some tests of filtration materials which could be implemented as a phosphorus trap are performing. Such media not only avoid P-migration to environment but also, P-saturated, are possible to be used as a fertilizer in agricultural production. The objective of this study was to determine P-sorption potential of preheated calciferous bedrock - Opoka (batch experiment) and fractionation of phosphorus trapped during percolation test.

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Methods

Batch experiments were performed to obtain P-sorption capacity of tested material. Duplicate 1 g samples of opoka were continually mixed for 15 minutes with phosphate solution (5 - 1000 mg PO_4/l) prepared from KH_2PO_4 at room temperature. The remaining phosphate concentration was measured in the filtrate spectrophotometically using ammonium molybdate method. Phosphorus sorption was calculated from the difference between initial and remaining value of phosphate concentration in solution. Apparent sorption capacity was estimated by fitting obtained data (treble repeated) to linear form of the Langmuir equation.

Short-term small column experiment. As a material used in study was powdered it was characterized by very low filtration ability. To perform percolation test it was mixed with peat (weigh relation 1:1). Domestic sewage (with average concentration 14.2 mg P-PO_4/l) were filtered through small column filled with mixture for 30 days. Sewage load averaged 40 mm per day.

To obtain total and plant available P content in filter selective extraction with 20% HCl and 0.05 M HCl was used respectively. Phosphate concentration was measured in the extracts spectrophometically using ammonium molybdate method.

Results

Sorption experiments based on short-time contacting do not accurately mirror the real sorption characteristic of material, however can be useful in comparing alternative materials as filtration media. P-sorption capacity obtained for opoka from batch experiment averaged 18 mg P per 1g of substrate.

Results obtained from column experiment showed that more than 90 % of discharged phosphorus was trapped in the filter, and the effluent concentrations did not exceed 1 mg P-

PO_4/l. Filtration media analyses showed that over 40 % of stopped phosphorus was in potentially plant available form.

Conclusions

High P sorption obtained in batch experiment could qualify substrate as an effective filter media for phosphorus removal from wastewater. It was preliminary confirmed by short-term column experiment. However, long-term test of material as a filter media for wastewater is necessarily needed. Low filtration ability of powdered substrate calls for use of other filtration material together. The use of peat treble increased filtration ability of substrate, however, increased also colour of effluent. Tests of other organic and inorganic filtration materials together with opoka are also needed.

High quality greywater recycling with biological treatment and 2-step membrane filtration

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Keywords

Greywater, low pressure reverse osmosis, microfiltration, recycling, sequencing batch reactor (SBR)

Introduction

Because of water shortage, it has been considered that treated wastewater can be used as a source of water (Asano 1998). By separating the flows of greywater and blackwater at source in households, it is expected that greywater treatment processes can be implemented with low operating costs and relatively simple technology since greywater contains very low nitrogen concentration (table 1). Therefore, greywater as a potentially reliable resource for water recycling is receiving more attention now. In this study, greywater treatment combing a biological SBR (Sequencing Batch Reactor), microfiltration and reverse osmosis have been investigated for reuse as tap water excluding direct human consumption. Separate systems for blackwater are needed in order to install integrated solutions.

Volume l/(p*year)		Greywater 25.000 - 100.000	Blackwater (without flush water) Urine ~ 500	Faeces ~ 50
Yearly Loads kg/(p*year)				
N	~ 4 - 5	~ 3%	~ 87%	~ 10%
P	~ 0.75	~ 10%	~ 50%	~ 40%
K	~ 1.8	~ 34%	~ 54%	~ 12%
COD	~ 30	~ 41%	~ 12%	~ 47%

Table 1: Typical characteristics of greywater and blackwater (Otterpohl, 2002)

Methods

Greywater treatment experiments have been conducted on laboratory scale (Figure 1). In the experiments, greywater was biologically treated in a SBR, microfiltration (MF) and reverse osmosis (RO) subsequently. SBR plus MF could also be realised as membrane-bioreactors. Greywater collected from the settlement Flintenbreite, Lubeck (Germany), which includes wastewater from kitchen sink, showers, laundry and personal hygiene etc. In the houses of this settlement, greywater and blackwater are separated at the source.
For elimination of organic substances and suspended solids, the SBR was operated by 3 cycles/day, exchange volume was equal to 50% of total SBR volume. Microfiltration (nominal pore size 0,1 µm) was applied in order to remove residual turbidity and pathogens, while RO was investigated for removal of residual dissolved organic and inorganic substances.

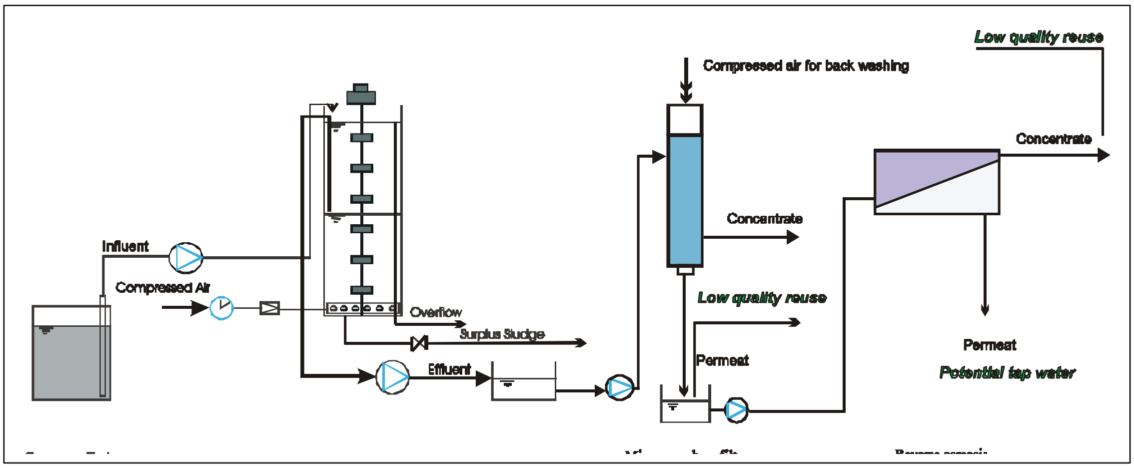

Figure 1: Scheme of greywater treatment experiment

Results

Results showed that the SBR process achieved consistent removals of about 85% of total organic carbon (TOC) and a final turbidity of less than 2 NTU. Greywater treated in the SBR was subsequently processed by microfiltration. E-coli and total coliforms have been eliminated totally and could not be detected in the effluent of microfiltration. Turbidity was less than 1 NTU. The typical parameters of greywater at the different stages of the treatment sequence are given in Table 2. After microfiltration, the quality of the effluent meets the requirements of EU Bathing Water Quality Guideline as well as the Guideline on the use of recycled greywater in buildings of the Berlin Senate Department for building and housing (SENBAUWOHN, 1995). However, the effluent of MF still contains relatively high concentrations of organic and inorganic substances. Therefore, it should be treated further in order to reach the high water quality for tap water.

Parameter	Unit	Influent SBR	Effluent from SBR	Effluent from MF	Effluent from RO
turbidity	NTU	119 ~ 164	< 2	< 1	< 1
TOC	mg/l	73 ~ 142	7.86 ~ 13.2	6 ~ 11	< 1
total-N	mg/l	8.73 ~ 13,1	< 5	< 5	-
NH_4-N	mg/l	2,5	< 0,16	< 0,16	-
NO_2-N	mg/l	< 0,15	< 0,15	< 0,15	-
NO_3-N	mg/l	< 0,5	< 0,5	< 0,5	-
total-P	mg/l	6,8 ~ 9.2	2.66 ~ 4.95	-	n.d.
E-Coli	1/100ml	$6.7*10^4$~$2.6*10^5$	100 ~ $2*10^4$	n.d.	n.d.

Table 2: Concentration in SBR influent and effluent and in MF effluent

In further studies concerning household reuse of greywater it was investigated whether low pressure RO (WEIL Industrieanlagen GmbH, Germany) could be operated technically and economically. The ratio of permeate to concentrate (**W**ater **C**onversion **F**actor, WCF) was about 1/5. The preliminary results showed that the TOC of permeate can be reduced to be lower than 1 mg/l and the conductivity of permeate to be lower than 100 µS/cm by RO. Because the WCF is very low, the conductivity of concentrate increased not too much, only to about 1000 µS/cm. It´s salt content is not harmful for some irrigation.

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Conclusions

The final effluent of the multistage process (RO permeate) meets the requirements of drinking water guideline of WHO. The RO concentrate showed similar characteristics as the MF effluent. RO permeate und concentrate can be reused separately for different purposes in household. The concentrate can be used e.g. for car washing, toilet flushing and garden irrigation. The permeate can be used for washing, shower and food preparation etc. With this concept tap water can be supplied locally, reducing freshwater demand by about 80%. Direct drinking water is not recommended and would require addition of salts. Drinking water could be supplied from excellent sources from bottles as it is practised around the world.

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Temperature effect on aerobic biodegradation of faeces using sawdust as a matrix

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Keywords

Aerobic biodegradation of feces, easily hydrolysable organic matter, slowly biodegradable organic matter, slowly hydrolysable organic matter

Abstract

Temperature is indubitably one of the most important factors affecting microbial growth and biological reactions. In this study, the effect of temperature on aerobic biodegradation of feces is described covering a wide range of temperatures that characterized mainly mesophilic and thermophilic processes. Results show that mesophilic microorganisms dominated the biodegradation of feces up to 40°C and thermophilic organisms were responsible of biodegradation of feces at higher temperatures; however, at 70°C the activity of them was remarkable diminished. The pattern of oxygen utilization rate (OUR) profiles was characteristically associated with the enzymatic activity of each group of microorganisms. Temperatures nearly to 60°C seem to be the optimum since the OUR was maximized at this temperature. Two fractions of slowly biodegradable organic matter were identified, easily hydrolysable organic matter (X_{Se}) and slowly hydrolysable organic matter (X_{Ss}).

Introduction

Temperature can exert an effect on biological reactions in two ways: by influencing the rates of enzymatically-catalyzed reactions and by affecting the rate of diffusion of substrate to the cells (Grady *et al*., 1999). There are three techniques commonly used to quantify the effects of temperature on biological processes. All of them are different ways of expressing the Arrhenius equation, which is only applicable over the range where the reaction rate coefficient increases with increasing temperature (Grady *et al*., 1999). For modeling and design of biological processes, the impact of temperature on the maximum growth rate is often described by an Arrhenius type function. Different type of expression to quantify the temperature dependence of microbial growth in composting systems was introduced by Kaiser (1996). Aerobic biodegradation of toilet wastes using sawdust as a matrix is an essential process on the Onsite Wastewater Differentiable Treatment System (Lopez *et al*., 2002a). An approach for modeling the aerobic biodegradation of feces was introduced by Lopez *et al*. (2002b); however in their model, temperature effect on kinetics of biodegradation process was not included. So that, in this study, the effect of temperature on aerobic biodegradation of feces is described covering a wide range of temperatures that characterized mainly mesophilic and thermophilic processes.

Method

Experimental device. Figure 1 shows the experimental device employed for performing batch tests. Four bioreactors, constructed of glass and steel, and provided with steel porous plate in

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the bottom for ensuring well distribution of air supply, were placed into water baths; sensors for oxygen, temperature and pressure were set before and after of each bioreactor, and an additional temperature sensor was also placed inside of it; all sensors were properly connected to a computer for monitoring. Air was supplied into the bioreactor continuously and air flow rate and pressure were controlled and kept constant by using a flow meter. Air was dried before measuring oxygen concentration by using silica gel. Bioreactors were submerged into water whose temperature was kept constant by using a temperature controller. Oxygen utilization rates were computed based on measurements of oxygen concentrations of air before and after the bioreactor.

Batch tests. Batch tests for seven different temperatures (from 20 to 70°C, two repetitions per temperature) were conducted. 20g-feces (dry basis) were properly mixed into the 100g-sawdust (dry basis) for ensuring uniform and completely mixed conditions. All mixtures were set up at 60% of initial moisture content by adding distilled water. Air at a rate of 100 ml/min was supplied in each trial for keeping perfect aerobic conditions; air flow rates and pressure were kept constant during the tests performance. Input and output oxygen and carbon dioxide (in some trials) concentrations were monitored every 20 minutes. Oxygen utilization rate and CO_2 production rate (CPR) in each trial were computed based on input and output oxygen and carbon dioxide concentrations. Batch tests were stopped approximately 1 week after starting them.

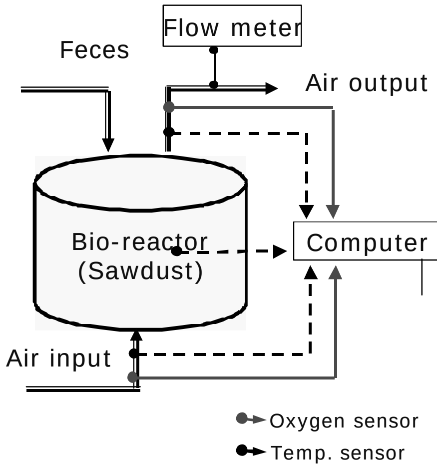

Figure 1: Schematic representation of the experimental device.

Results and discussion

OUR and CDP profiles. For easer interpretation, figure 2 shows only the OUR and CPR profiles obtained for temperatures 50 and 40°C; however, for all temperatures three stages were distinguished: a) *rapid increase stage* from the origin up to reach the peak (from point A to B), b) *rapid decrease stage* from the peak down to the beginning of stabilization of the profile (from point B to C), and c) *steady stage*, between points C and D. Higher OUR was observed at higher temperatures, up to 60°C.

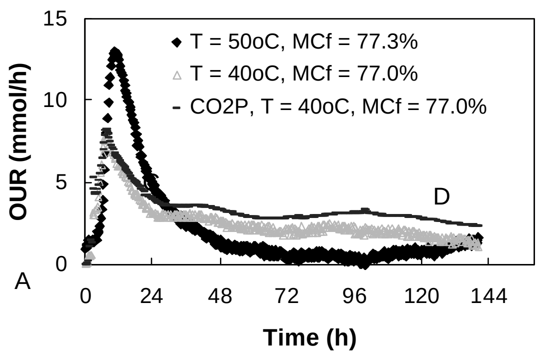

Figure 2: OUR and CO_2 production profiles for temperatures 50 and 40°C.

Analysis of all OUR profiles led to the following statements: at 70°C the enzymatic activity of microorganisms diminished remarkable, even, 12 hours after the beginning of the batch test the oxygen consumption was negligible. Regarding the *rapid increase stage* of OUR profiles within the range 20 to 60°C, it was found that oxygen utilization rate increased as the temperature increased. These results suggest that a) 60°C was the optimum temperature for degrading feces and b) Arrhenius equation is applicable to describe the effect of temperature on reaction rates due to OUR increased as the temperature increased.

The OUR peak reaching time decreased as temperature increased, especially from 20 to 40°C. Two different patterns were observed in the *rapid increase stage* of OUR profiles, one associated with temperatures up to 40°C where the peak reaching time decreased rapidly as the temperature increased, and the other characterizing temperatures higher than 40°C where the peak reaching time was almost the same.

Simulation of OUR profiles. By using the mathematical model introduced by Lopez *et al*. (2002b), OUR profiles for every temperature were simulated. Regarding the uncertainty associated with the impact of temperature on yield coefficient, most engineers assume it to be independent of temperature (Grady *et al*., 1999); thus, stoichiometric parameters, Y_H and f_{XI} were fixed as 0.63 and 0.1, respectively, and maximum growth rate of biomass (μ_H) was estimated for each temperature by using the Arrhenius equation. The Arrhenius equation commonly used in environmental engineering literature (Grady *et al*., 1999) is expressed as follows

$$\mu_{HT} = \mu_{H20}\theta^{(T-20)} \qquad (1)$$

where μ_{H20} and μ_{HT} are the maximum growth rates of biomass at 20°C and at temperature T, respectively, and θ is the temperature coefficient.

From the analysis of OUR profiles in the *rapid increase stage*, θ was estimated as 1.05; this value is similar to that (1.07) used by several researchers (Henze *et al*. 1987,1995, 1999; Gujer *et al*., 1999) for activated sludge treatment systems; then a μ_H value of 6 d^{-1} for 20°C and a temperature coefficient (θ) of 1.07 were adopted base on average values of kinetic parameters reported by them and regarding that the values of μ_H reported in composting systems are not well supported.

Simulation results for temperatures 50 and 30°C are depicted in figure 3. It was found that model predictions fixed much more properly to the experimental data as temperature increased, especially, for temperatures higher than 40°C. These simulation results are congruent if we consider that Lopez *et al*. (2002b) calibrated their mathematical model at 55°C, hence, acceptable quality of model predictions are expected in the thermophilic range of temperatures; however, for simulating experimental OUR profiles at temperatures lower than or equal to 40°C, model modifications were performed.

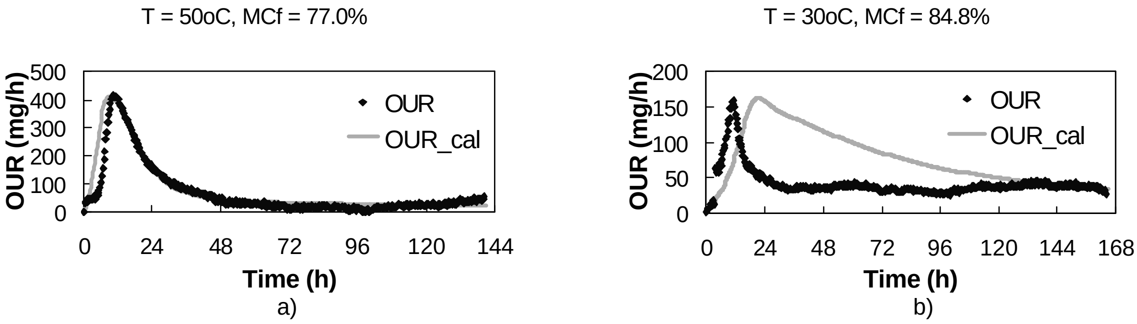

Figure 3: Simulation of OUR profiles for temperatures 50 and 30°C.

Improvement of model predictions in the mesophilic range. For this purpose, an analysis was made regarding that slowly biodegradable organic matter is constituted by two fractions, easily hydrolysable (X_{Se}) and slowly hydrolysable (X_{Ss}). To include these two fractions in the mathematical model, hydrolysis process, associated components and rate equations were modified. To apply the improved model, the fractions X_{Se} and X_{Ss} were estimated assuming that X_{Se} is associated with the *rapid increase* and *rapid decrease* stages and X_{Ss} is linked to the *steady stage* of experimental OUR profiles; therefore, the area under such stages of the experimental OUR profiles were determined and divided by the total slowly biodegradable organic matter (80% of the total COD of feces, reported by Lopez *et al.*, 2002c).

Kinetic parameters were determined by using sensitivity analysis and curve-fitting techniques, as described by Lopez *et al*. (2002b). Thus, simulation of experimental OUR profiles in the mesophilic range of temperatures was performed. Simulation results for the temperature 30°C are plotted in figure 4. It was found that the model predictions fitted successfully to the experimental data in all the mesophilic range making evident the importance of fractioning the slowly biodegradable organic matter into two fractions.

Conclusions

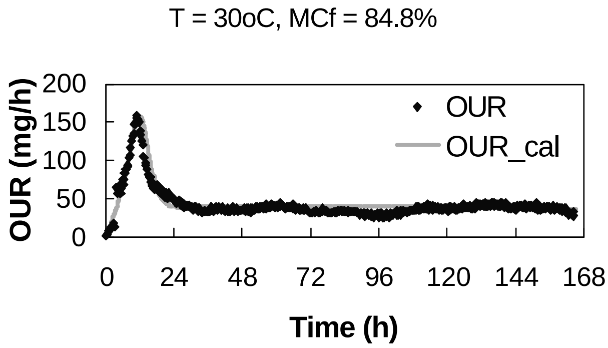

Figure 4: Improved simulation of experimental OUR profiles in the mesophilic range.

Three stages were characteristically observed in the experimental OUR profiles obtained from the batch test performance, *rapid increase*, *rapid decrease* and *steady stage*. Mesophilic microorganisms dominated the biodegradation of feces up to 40°C, whereas thermophilic organisms were responsible of feces biodegradation at higher temperatures. At 70°C the enzymatic activity of microorganisms diminished remarkable; even, 12 hours after the beginning of the batch test the oxygen consumption was negligible. Effect of temperature on aerobic biodegradation of feces was acceptably described by using the Arrhenius equation within the range 20 to 60°C. In the mesophilic range, the slowly biodegradable organic matter, which constitutes the feces, has been fractionated into two fractions for higher quality bio-kinetic model predictions, easily hydrolysable organic matter (X_{Se}) and slowly hydrolysable organic matter (X_{Ss}). Bio-kinetic model introduced by Lopez *et al*. (2002b) was improved by incorporating the effect of temperature and fractioning of slowly biodegradable organic matter; model predictions fitted properly to the experimental data.

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Palestinian experience with enhanced pre-treatment of black wastewater from Birzeit University using a UASB septic tank system

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Keywords

Anaerobic treatment, domestic wastewater, UASB reactors, treatment

Abstract

Successful implementation of the UASB (Anaerobic upflow sludge blanket) at pilot and full scale has produced very encouraging results that show its feasibility as a pre-treatment for black and domestic wastewaters. The economic advantages it offers, further encourages developing countries to become self-sufficient in this respect. In this contribution, the start-up of the UASB-septic tank system and its monitoring during this period was the main objective. A pilot scale UASB reactor with a liquid volume of about 400 L (h= 1.88m and f =0.265m) was fed with the black wastewater collected from the Faculty of Commerce at Birzeit University. During the start-up phase, the reactor was operated in a batch mode for six months and only shortly operated in a continuous flow node. The results obtained demonstrated that the system is quite effective in removing organic pollutants. The removal rate of the organic pollutants was mainly due to bio-physical process, which is sedimentation of the particles and its microbial degradation. Although, the microbial activity was yet slow it contributed to the total COD removal efficiency. The COD_{total} removal attained was approximately 80% in which the removal of COD_{ss}, COD_{col}, and COD_{dis} was 68%, 23% and 52% respectively. The UASB effluent has a good transparency with an elimination rate of 80% and 85% for TSS,and VSS respectively. This would facilitates a natural post- treatment (waste stabilization ponds), where photosynthesis and pH might increase. Based on the results obtained from this research study, the UASB-septic tank system offered practical advantages compared to conventional septic tanks through its small size, biogas collection and utilization, and elimination of odour problems. Furthermore, its ease of operation encourages its application in poor rural areas of Palestine.

Introduction

Conventional septic tank systems are world wide used for the house on site treatment of domestic sewage. The removal efficiency of these systems is however limited, morever have large volumes are generally applied. As the flow through systems is mainly horizontal, the purification is mainly due to settling of solids. The UASB- septic-tank is a promising alternative for the conventional septic-tank (Bogte *et al*., 1993 and Lettinga *et al*., 1993). The most important difference with the traditional UASB system is that the UASB-septic-tank system is also designed for the accumulation and stabilization of sludge. It differs from the conventional septic tank system by the upflow mode in which the system is operated, resulting in both improved physical removal of suspended solids and improved biological conversion. So UASB-septic-tank is a continuous system with respect to the liquid, but a fed-batch or accumulation system, with respect to the solids. Application of these modified septic tank systems, was

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studied under Dutch (low) and Indonesian (high) ambient temperatures. Zeeman and Lettinga (1999) recommend the use of modified UASB septic tanks for the improvement of the removal efficiencies especially for low temperature regions or regions with a period of short winter period, like Middle East. Therefore, this study will investigate the performance of UASB septic tank system. The black wastewater discharged from the Faculty of Commerce at Birzeit University will be tested.

The realization of the necessity to reconsider seriously the management of the existing water resources, either due to its scarcity or the concern of its pollution has motivated expertise in the water sector to search for alternatives. Consequently, the reuse of the domestic wastewater is a potential alternative for the semi arid country of Palestine, as well as many surrounding countries in the Middle East. The increasing urbanization and industrialization in Palestine have dramatically increased the amount of generated wastewater. With the very limited existing disposal systems throughout the country, Palestine is now threatened by this waste which my infiltrate and pollute its underground water resources unless measures are taken to alleviate this dilemma. Thus the new treatment process that offers a substantial promise is the Upflow Anaerobic Sludge Blanket (UASB) technology.

Complex wastewaters containing a high amount of suspended solids will limit the performance of a one phase anaerobic UASB system (Zeeman, 1999). The accumulation of these compounds in the sludge bed will reduce the sludge retention time (SRT) and the methanogenic activity of the sludge. This problem was perceived by Hulshoff Pol and Lettinga (1991) when they stated, ‘For the treatment of partially soluble complex wastewater the required removal efficiency of the SS should be given attention’. Thus with the implementation of this pre-treatment method, it is necessary to consider the strength of the wastewater. The wastewater in the West Bank is classified as a strong domestic wastewater due to the high concentration of pollutants such as COD, TKN, phosphorous, sulphate, ammonia, SS and VSS.

Materials and methods

Experimental set-up (UASB-septic tank)

The set-up of the UASB reactor is shown in Figure 1. A holding tank, preceding the UASB reactor, will serve as a balance tank and as a primary sedimentation tank. The incorporation of the holding tank will provide a partial removal of the solids, which will be accumulated and experience further stabilization. The reactor was inoculated with 200 litres of anaerobic sewage sludge from pilot anaerobic ponds treating wastewater from Birzeit University. The specific methanogenic activity was 0.07 g COD/g VSS.d. The inoculums characteristics and the operational conditions are shown in Table 1.

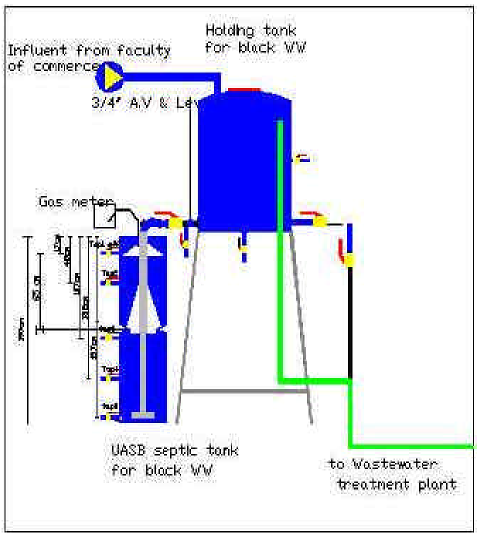

Figure 1: UASB septic tanks and holding tanks

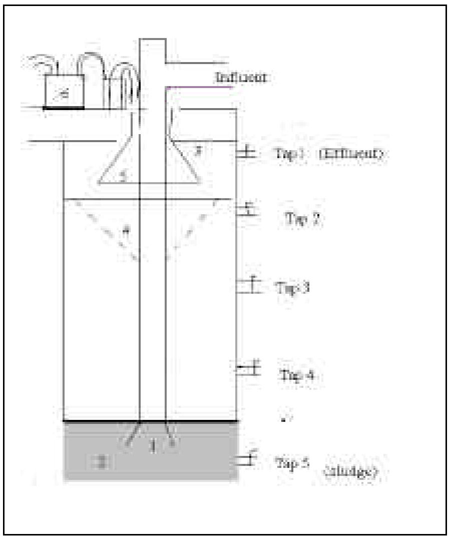

Figure 2: A schematic diagram of the 0.4 m^3 UASB-pilot plant

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Parameter	Unit	UASB septic tank-BZU
Hydraulic retention time	hr	16
Sludge concentration	kg VSS/m^3	13.9
Methanogenic activity	g COD/g VSS.d	0.07
Upward velocity	m/h	0.12

Table 1: Start-up conditions of the UASB septic tank at BZU

Results and discussion

Inoculation

According to the measured wastewater quality, the reactor needs to be started with a 1kg of inoculum. When inoculum of sludge of about 0.1-0.08 g COD/g VSS methanogenic activity is used (Lettinga et al., 1991). Although the seeding of the reactor was during the second week of April till the end of May, the actual monitoring period was during June and July were the ambient temperature range was from 22°C - 28°C. The influent sewage temperature was 24.54°C which was almost similar to the effluent temperature. The influent's pH was in the range of 8.0-8.3, and the effluent pH was about 7.5.

The COD_{tot} removal efficiency attained an average value of 76% considering the entire period of operation. The major contributor to the COD_{tot} was the removal of suspended solids. The average removal efficiencies for COD_{ss} was 91%, the COD_{col} was 71% and COD_{dis} was 43%.

With respect in the removal of the TSS and VSS efficiencies, the average removal efficiency was 58% and 53% for the TSS and VSS removal efficiency , respectively. Tap 5 contents a high concentration in Tss and Vss due to settling of suspended solids.

Parameters[+]		Black Wastewater Characteristics		
		Sample no.	Average	STD
COD	Total	20	1013	262
Suspended		5	784	162
	Colloidal	5	162	50
	Dissolved	5	155	143
BOD		6	458	109
NH_4^+ as N		10	21	2
Total P as P		6	11	3
PO_4^{3-} as P		8	10	3
TSS		11	715	285
VSS		11	401	212
TKN		3	41	3
pH		19	8.02	0.37
T_{ww}		19	28.8	2.2
Colour		Grey (fresh) – Black (old)		

[+]All unit in mg/l

Table 2: Characteristics of wastewater generated from the faculty of Commerce/ Birzeit university

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Conclusions and Recommendations

The UASB-septic tank system can efficiently perform as a pre-treatment unit during summer period. The average removal efficiencies for suspended COD (COD_{ss}), Colloidal the COD_{col}) and dissolved COD (COD_{dis}) were respectively 91%, 71% and 43%.

More research is required to monitor the reactor performance over the whole year especially during the winter period; and consequently the system should be optimised, e.g. amount of inoculums, desludging period, etc.

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Specific quantification of pathogenic and indicator organisms in digester samples using quantitative real-time PCR (qPCR)

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Keywords

Anaerobic digesters, cattle manure, indicator organisms, hygiene, pathogens, qPCR

Abstract

Pathogenic (micro)organisms present in environmental samples can be quantified by cultivation techniques. However, techniques of molecular biology may be applicable more efficiently. Cattle manure and digester samples were analyzed for pathogens and indicator organisms by Quantitative Real-Time Polymerase Chain Reaction (qPCR). Similar quantities were obtained in comparison to cultivation techniques. However, analysis by qPCR required less time and in some cases indicated higher values for distinct organisms. This might be due to the presence of cells that can not be cultivated but detected with qPCR, or to different specificities.

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Introduction

Anaerobic digestion of solid waste is considered as a profitable reuse technology that allows the recycling of end products. Biogas is produced and the digest may be used as fertilizer e.g. in agriculture. However an efficient hygienization step should be included in the process to prevent sanitary risks before applying the product as soil conditioner.

Pathogens and indicator microorganisms can be quantified by conventional cultivation techniques, but these exhibit serious disadvantages: they are frequently time and material consuming, cannot detect active but non-cultivable (ABNC) germs, and frequently lack adequate specificity. If indicator organisms are analyzed, results may not allow extrapolation for the behavior of recalcitrant pathogens.

Pathogenic (micro)organisms can be quantified by qPCR. This molecular technique offers a convenient rapid and specific alternative to conventional cultivation in various application areas, e.g. for hygiene monitoring of environmental samples, such as organic waste or wastewater.

The scope of a joint project of Bavarian research institutions and local water suppliers is to evaluate the potential of a three-stage anaerobic digestion process for the environmentally sustainable and economical control of pathogens. In the frame of this project, we develop and evaluate qPCR systems for the specific quantification of hygienically relevant microorganisms and viruses in cattle manure, digest, soil, and water samples.

Here we present selected preliminary results obtained from qPCR and parallel cultivation techniques.

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Methods

Cattle manure and samples from anaerobic digesters connected in series (mesophilic, thermophilic, mesophilic) were analyzed and quantified for pathogens and indicator microorganisms using qPCR on DNA-extracts. An optimized protocol for nucleic acid extraction from reactor samples was applied using a standard spiking technique and modified kit-based protocols (Lebuhn et al., 2003). This protocol greatly reduces coextraction of PCR inhibitors, such as humic acids and allows to asses the method detection limit. Cultivation based analyses (selective plating, MPN-analyses) were performed in parallel.

Results and discussions

According to Table 1, the development of bacterial numbers from manure and digester samples assessed by qPCR is consistent with results from cultivation. For fecal enterococci, qPCR results exceeded those from cultivation by a factor of 10 to 100. This may be due to the presence of ABNC cells that cannot be cultivated, or to dead cells, or to different specificities of the systems used. As expected, bacteria with relatively low tenacity (*E. coli*, enterococci) efficiently decreased in the fermenter cascade, whereas the spore formers and thermophiles remained constant (Tab. 1). Quantities of *Campylobacter jejuni* were at or below the detection limit of the system. In comparison to cultivation techniques, detection by qPCR can be performed in a short time (only 6 hrs) and it is cost effective. It also provides high sample throughput (96 measurements simultaneously), high specificity and sensitivity; and it allows the determination and quantification of ABNC cells. Our results suggest, that qPCR may substitute conventional cultivation routines.

Bacterium	**Cattle manure**		**Mesophilic digester 1**		**Thermophilic digester**		**Mesophilic digester 2**	
Bacterial group	QPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)
E. coli	1.0 - 1.3*10^{5}	3.0 - 4.6*10^{5}	3.19*10^{3}		<1.0*10^{2} - 1.96*10^{3}		1.11*10^{2}	
Fecal coliforms	4.0*10^{5}	n.d.		1.1*10^{3}		2.3*10^{1}		<3.0
Enterococcus faecalis, E. faecium	8.95*10^{4} 1.37*10^{6}		1.4*10^{3}		< 1.0*10^{2} 5.8 - 15.4*10^{2}		5.9*10^{2} 1.17*10^{3}	
Intestinal enterococci	3.5*10^{6}	2.9*10^{5}		1.3*10^{3}		4.0*10^{2}		1.0*10^{2}
Clostridium perfringes	n.d.		<1.0*10^{2} - 1.1*10^{3}		<1.0*10^{2} – 6.4*10^{2}		1.42*10^{3}	
Clostridium perfringes		5.5*10^{2}		n.d.		n.d.		n.d.
Bacillus cereus group	7.0*10^{3}		n.d.		5.1*10^{3}		4.6*10^{2}	
Bacillus cereus		2.0*10^{5}		2.0*10^{3}		<1		1.15*10^{3}
Campylobacter jejuni	0.8 - 2.6*10^{1}		n.d.		< 1.0*10^{2}		n.d.	

n.d.: not determined CFU: colony forming units MPN: most probably number

Table 1: Preliminary selected results from qPCR and cultivation analyses of different digestion stages of cattle manure

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Source separation of domestic sewage components and integrated management with organic fraction from MSW

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Keywords

Anaerobic co-digestion of food waste and domestic wastewater separated fractions, domestic wastewater fractions separation; greywater phytotreatment

Abstract

A pilot facility has been constructed at the University of Padua to investigate the scientific and technical aspects of a new approach to integrate wastewater and solid waste management. This paper presents the first results from a system that treats separated wastewater flows by the phytotreatment of greywater and the anaerobic co-digestion of food waste and faecal matter.

Introduction

The current discussion regarding the sustainable management of domestic wastewater and solid waste is based on concepts such as avoidance, source separation, recycling and reuse. On the one hand, a clear trend has been taken towards a systematic look at the different domestic wastewater fractions, foreseeing new strategies and potentialities for treatment and management of these fractions, and on the other hand, it is also recognised that there is a need to integrate the treatment of these fractions with the management of domestic solid waste, in the search for integrated sustainable solutions (Cossu et al, 2001). A pilot facility has been constructed in the IMAGE Department at the University of Padua with the purpose of studying the scientific and technical aspects of this approach. This paper looks at the first experimental results obtained and the further steps that are being taken in this direction.

Facilities description

The pilot facility consists of an experimental WC with a special source control device for the separation of urine (yellow water) and faecal matter (brown water), including individual flushing systems and a separate collection pipe for each fraction. Greywater (from the washbasin) is also kept separate from the other fractions. These three fractions flow to individual tanks that are equipped with mixers, level detectors and electrical automatic valves for periodic discharge. At the entrance of the toilet, a photocell system is installed to count the number of users. Thus, while greywater is conducted to a constructed wetland for phytotreatment, brown water is mixed with food waste and then treated in an anaerobic reactor at lab scale. In Figure 1 an scheme of the facilities is presented.

Characterisation of wastewater fractions

Source separation of wastewater fractions is a key element in this new approach which may contribute to a more efficient use of water, pollution control and nutrients recycling (Otterpohl et al, 1999). The results regarding quality and quantity of the separated wastewater fractions indicate that brown water has the highest contribution in terms of volume, solids, total phosphorus and organic matter; yellow water represents the main source of TKN, and in a less significant proportion, of alkalinity; finally greywater presents a high reuse potential given its low polluting loads. Figure 2 shows the contribution in percentage of each fraction for a range of water quality parameters.

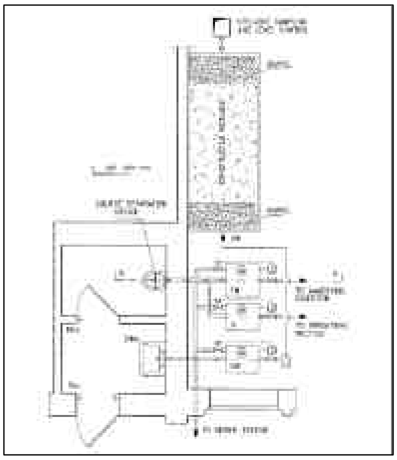

Figure 1: Plan view of the pilot facilities

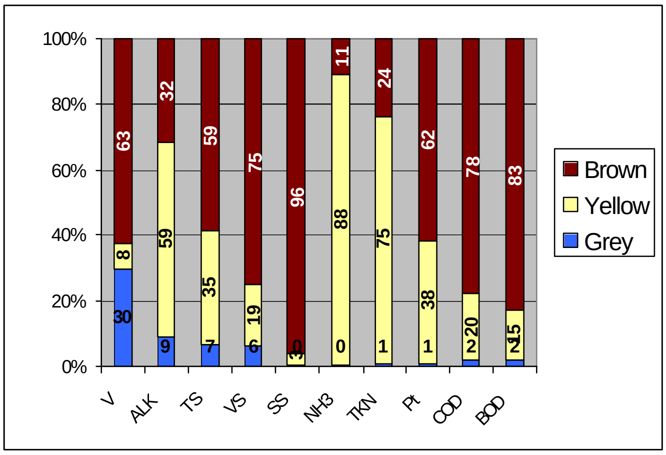

Figure 2: Load distribution of wastewater fractions

Phytotreatment of greywater

	COD	S.D.	NH_3	S.D.	TKN	S.D.	TN	S.D.	TP	S.D.
Alisma	69.2	18.2	87.4	9.5	76.0	11.3	-47.8	19.1	82.5	12.0
Calla	65.4	8.6	-306.5	212.1	-133.7	97.9	-141.2	90.7	-71.5	162.2
Iris	72.0	8.9	77.1	8.9	74.8	14.1	-43.9	46.4	73.9	19.9
Lobelia	74.5	7.5	-186.8	132.5	-71.6	65.2	-75.1	62.5	56.5	26.5
Lytrum	54.3	17.9	-375.0	375.0	-178.6	173.1	-182.7	169.8	-28.4	68.3
Mentha	68.9	6.9	-150.7	119.5	-142.2	95.1	-141.9	93.3	72.7	9.8
Thalia	82.1	3.0	83.0	3.6	84.4	5.6	72.2	10.5	94.3	3.0
Typha	75.8	4.1	48.4	23.4	47.0	24.6	41.0	27.1	65.9	17.0
Acorus	62.8	11.4	57.0	15.2	64.9	13.1	57.5	17.0	63.8	20.6
Canna	69.0	16.3	86.9	7.8	85.4	6.0	69.0	16.3	85.1	12.7
Lysimachia	63.0	9.5	-293.8	177.8	-36.6	67.2	-40.5	68.9	57.8	24.8
Eichornia	92.8	4.1	99.9	0.1	75.9	11.2	73.1	17.4	37.5	35.3
Lemna	89.3	13.3	99.9	0.2	99.1	1.1	72.0	40.6	53.5	33.6

Table 1: Removal efficiency of the individual species (%) and standard deviation

In a first phase of the survey dealing with the phytotreatment of greywater, 13 vegetal species were tested in pots. According to the data reported in Table 2 *Alisma* and *Iris* presented negative nitrogen removal, due to high nitrification and negligible denitrification. On the other hand during the research period the nitrate concentration decreased. *Thalia*, *Canna*, *Eichornia*, *Lemna* showed a total nitrogen removal efficiency of about 70%. Generally for the vegetated pots nitrogen removal was higher than for the unvegetated blank pot. The phosphorous removal efficiency was good for all plants, in particular for *Alisma* (82%), *Thalia* (94%) and *Canna* (85%). Considering the full set of contaminants, *Alisma, Iris, Thalia Typha, Acorus* were the species offering the best removal performance. Generally this was correlated with the higher evapotranspiration rates. Then, in a second phase of the survey, a horizontal subsurface constructed wetland (CW) was constructed. The CW is connected to the greywater collection tank and is composed of units, each 4.2m long, 1.0m wide, 0.9m depht and with a 1.5% slope. The same species tested in the pots were planted in the fist plot while *Phragmites australis* was planted in the second plot, with the intention of having a direct comparison this last well-known plant. The starting up phase was conducted from November 2002 to March 2003. Figure 3 and 4 show COD and MBAS removal performance respectively. These two parameters are of primary importance taking into account the characteristics of the greywater pr oduced in the washbasin of the experimental toilet. The outflow of both units meets the quality standards imposed by national Italian regulation and the WHO guidelines for wastewater reuse.

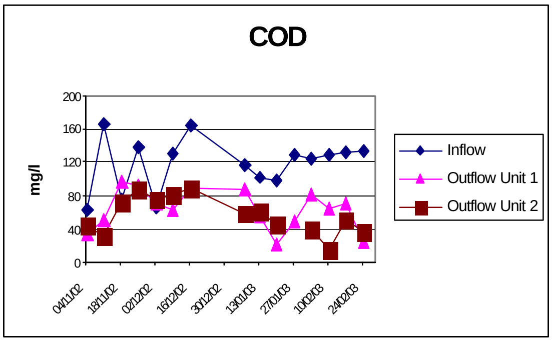

Figure 4: COD removal performance

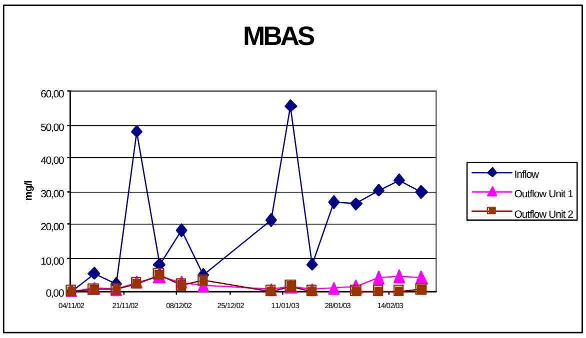

Figure 5: MBAS removal performance

Anaerobic co-digestion of food waste and wastewater fractions

Lab-scale test experiment has been carried out on the anaerobic co-digestion of food waste with different sewage fractions. The purpose of these tests is to investigate the technical and economical feasibility of a new integrated wastewater and solid waste management system in order to achieve the following strategic aims: a) reduction of putrescible organics in solid waste to be disposed off in landfills with a consequent reduction of landfill emissions; b) reduction of the problems related to large centralised wastewater treatment facilities; c) production of methane from anaerobic digestion as an alternative energy source. While food waste is home collected and shredded in a kitchen mill, brown and yellow wastewater fractions are separated and collected using the facility above mentioned. The reactors were monitored to measure organic solids degradation, gas production and bacteria growth under different ammonia concentrations and different temperatures. Ammonia concentrations were manipulated by varying the yellow water feed to the digesters. In a first run the temperature was set at 35°C, while in a second run the temperature was increased weekly by 2 °C reaching stable thermophilic conditions at 70°C. The results show good gas production (350-550 Nm3/t TS) with methane concentrations in the range 50-78%. Current tests are examining the performance of the digesters under various loading regimes.

Conclusions

In the light of an innovative approach to deal with wastewater and solid waste management that is based on separately treating the diverse fractions, a pilot facility has been constructed at the University of Padua, to study the scientific and technical connotations of this concept. In terms of the production of the diverse wastewater fractions, the results obtained in the experimental toilet show that while brown water contributes the highest proportion of volume, solids, total

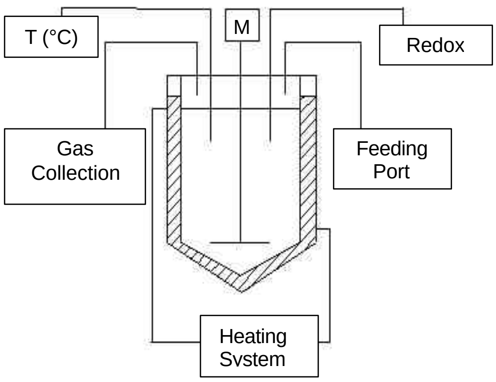

Figure 6: Schematic layout of reactor

		Phase 1		*Phase 2*	
		Food waste + Faeces	Food waste + Faeces + Urine	Food waste + Faeces	Food waste + Faeces + Urine
Parameters	Unite	Range	Range	Range	Range
N-NH3	(mg/l)	657-117	1089-603	351-97	824-549
TKN	(mg/l)	1638-469	2079-1162	1232-245	1169-574
P	(mg/l)	70,8-9,8	118,4-9,9	37,4-8,2	25-13,3
Soluble COD	(mg/l)	29914-4030	24214-8498	10164-3388	8422-4244
TS	(mg/l)	63255-11965	66435-16170	15579-9155	16045-8590
VS	(mg/l)	61105-10765	63505-14385	13895-8280	14040-7185
Alkalinity	(mg/l)	820-400	2900-960	1380-320	1900-860

Table2: Characteristics of feeding in laboratory test

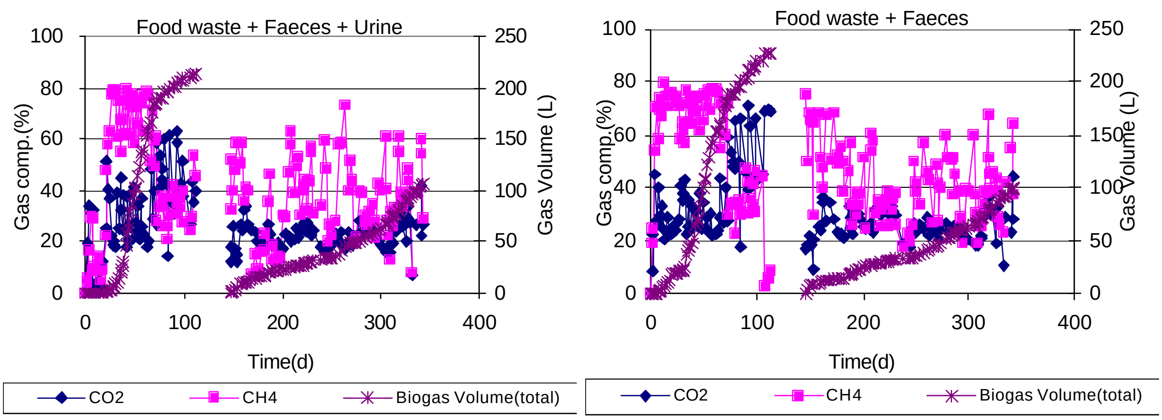

Figure 7: The total biogas production and composition during the test

phosphorous and organic matter, the main nitrogen contribution comes from yellow water. The initial survey on the capacity of some ornamental vegetal species to phytotreat greywater, has shown that Iris, Thalia Typh and Acorus were the species with the best removal efficiencies. The starting up phase of a constructed wetland for the phytotreatment of greywater was conducted. Ornamental vegetal species were used in one bed, while a second bed contained Phragmites australis only. The outflow quality of both units meets the national regulation standards for discharging to water bodies. The first outcomes dealing with the anaerobic co-digestion of brown water and food waste seem to be encouraging, with an acceptable removal of BOD_5 and COD and an elevated level of gas production.

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Treatment of phosphorous and bacteria by filter media in on-site wastewater disposal systems

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Keywords

Bacteria, filter, Polonite®, phosphate, recycling, sorbents

Abstract

Correctly designed infiltration beds or phosphorus traps are advantageous for the treatment of wastewater in areas with a low population density. The efficiency can be increased by replacing the commonly used sand with materials that have a higher sorption capacity. Some of these materials are capable of delivering the sorbed phosphorus (P) to plants if subsequently used in agriculture, thereby recycling P in crop production in a sustainable way. A long-term column study was performed using municipal wastewater. Columns were filled with seven different filter media. Polonite®, a product from the bedrock opoka, had the largest sorption capacity for P of the studied materials and its high pH resulted in a filtrate of good hygienic quality. No coliform bacteria was found in the effluent from four selected columns and the removal efficiency approached 99.5 %.

Introduction

The phosphorus (P) sorption capacity is one of the most important properties of a filter media for use in on-site wastewater systems. This is advantageous since the P-saturated material is proposed to be transferred back to agriculture as fertiliser, thereby closing the P cycle (Hylander *et al*., 1999; Hylander & Simán, 2001). However, the recycled material can only be used after taking into consideration the possible content of pathogens, toxic compounds and heavy metals. The lack of proper wastewater treatment in rural areas contributes largely to P pollution of surface waters. Since conventional methods of biological and physico-chemical P removal is not suitable for small-scale wastewater treatment plants, because they require skilled operators and are also complicated, alternative removal methods that are inexpensive and simple, are required and have been implemented in recent years. Ecologically based, on-site treatment systems, such as constructed wetlands and soil infiltration systems, have attracted attention as favourable methods for the removal of P (e.g. Vymazal *et al*., 1998). The efficiency of reducing the P content of wastewater is often increased by incorporating a suitable P-sorbing material in the soil profile, generally an Al, Fe or Ca compound (Mann & Bavor, 1993; Drizo *et al*., 1997). Trapping P in infiltration beds represents another valid strategy by substituting commonly used sand for a material with a large P-sorption capacity. Recent studies have been focused on reactive materials among which emerge Blast Furnace Slags, Ex-clay Filtralite, and others (Sakadevan & Bavor, 1998; Kløve & Mæhlum, 2000). Both in wetlands and in infiltration beds,

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the sorbing material has to be replaced when few unoccupied P sorption sites remain and its sorption efficiency decreases. In Sweden, most users of treatment systems are obligated to keep the P-concentration in the effluent below 0.5 mg/l. In this paper, results are presented from a large-scale column experiment where the phosphate sorption capacities of five different materials were tested. The research aims to develop high-efficient sorbents, which originate from natural material, e.g. bedrock, or from industrial by-products of no harm for the environment. The technical solution, i.e. the nutrient trap, is developed as well.

Methods

Nine columns (diam. 0.3 m, length 0.7 m) were filled to 0.5 m with five different media, two of them in duplicate. The media used were; sand, opoka, Polonite® , limestone, and two kinds of blast furnace slag, crystalline (C-slag) and amorphous (A-slag). The grain size was approximately the same for all of them (2-5.6 mm), except for sand (‹ 2 mm), limestone (2 mm) and one coarse fraction of slag (2-7 mm). Physical parameters of the materials are given in tab. 1. The phosphate attenuation capacities of the selected filter materials were studied under conditions of unsaturated intermittent flow of wastewater during 58 weeks at the Loudden wastewater treatment plant in Stockholm. The average load was 85 l/m²/d, i.e. corresponding to the load recommended by the Environmental Protection Agency for soil infiltration systems in Sweden. The wastewater, pre-treated in a septic tank, was discharged to each column every second hour throughout the day. Samples were taken weekly from the influent (after pre-treatment) and effluent water and were analysed on the content of orthophosphate using Flow Injection Analyser (Aquatec-Tecator Autoanalyser). The total P content of all filter materials was analysed at the end of the experiment from samples taken at each 5 cm level. Bacteria were analysed by standard methods on influent and effluent water among four of the columns when the experiment had lasted for 32 weeks. Samples were also taken from the superficial layer (0-5 cm) of the same columns for the analyses of bacteria content.

Sorption material [a]	Hydraulic conductivity (m/day)	Surface area ($m^2\ g^{-1}$)	Particle size (mm)	Column porosity (%)
A-slag	40.6	0.43	0.25-4	46.7
C-slag	15.9	0.50	0.25-4	45.5
C-slag[1]	1950	0.37	2-7	50.9
Limestone	238.5	0.57	1-2	46.4
Polonite	800	0.70	2-5.6	47.7
Opoka	1481	50.85	2-5.6	50.2
Sand	200	0.09	0-2	43.7

[a] A-slag = amorphous slag, C-slag = crystalline slag, thin;
C-slag[1] = crystalline slag, coarse.

Table 1: Physical parameters of sorption materials and column porosity at start of experiment.

Results

The incoming wastewater showed a large variation in the content of P (fig. 1). This is attributed to dilution caused by in-leakage of groundwater and stormwater to the sewer system. The column filled with sand did not remove P as expected. It followed well the variation in P-concentration of the incoming wastewater. The P removal capacity decreased successively in most of the filter media studied and passed the critical limit of 0.5 mg/l after a few weeks. One clear exception was Polonite®, which did not show any tendency for breakthrough. Total P content was largest in 0-5 cm layer of Polonite, where the content had increased from originally 0.2 mg g^{-1} to 1.3 mg g^{-1}. The bottom layer (40-50 cm) had the same content as the virgin material. It was unexpectedly followed by sand, which had a higher P content in its surface layer than revealed by its capacity to reduce orthophosphate from percolating wastewater. However, the underlying horizons had very low P content. Among the bacteria in incoming wastewater, 30 % were found to be coliforms and roughly 45 % were grouped as aerobic gram negative rods, from where some isolated colonies where identified as the genus *Acinetobacter.* The bacteria content was reduced efficiently in three of the materials studied, up to 99.5 % in the effluent of K3 and K7, columns containing silica-calcium material of very high pH (11.2-12.5). Opoka reduced the bacteria content with only 66 %. However, no coliform bacteria was identified in the effluent from the four columns (tab. 2).

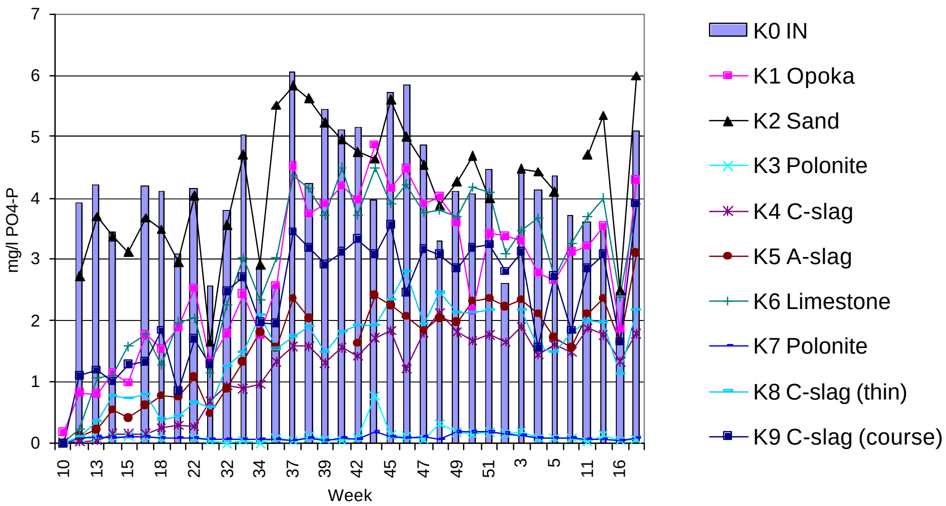

Figure 1: Influent and effluent concentrations of phosphorus during column experiment performed from w. 10 (2000) to w. 25 (2001). K1-K9; columns with different filter media.

Most of the bacteria content in the superficial layers of the materials were mainly soil bacteria. The content of *Bacillus spp*. was high. Species of the genus *Acinetobacter* were found in opoka, Polonite and sand. A group of red colored colonies were found in the Polonite and comprised 30 % of the total bacteria content there. The identification gave a 99 % reliability for *Serratia marcescens*, an enteric bacteria and normal inhabitant in natural environments.

Materia	Bacteria (cfu/ml)				Removal (%)
	Gram- aerobic rods	Gram+ facul-tative anae- obic rods	Other Enterics	Others	
Polonite	408	292	0	0	99.5
Sand	1748	184	92	276	98.3
C-slag (thin)	3236	2091	0	523	95.6
Opoka	35217	0	7826	1956	65.9

Table 2: Groups of bacteria and reduction in wastewater after treatment in four filter materials.

Discussion

The Polonite material was found to reduce efficiently the phosphorus content from the influent wastewater that was studied. In this product, prepared from opoka, the calcium carbonate is transformed to calcium oxide, which has a lager solubility product than calcium carbonate, leaving more Ca ions to react with P. Laboratory investigations show that the maximum sorption capacity of Polonite is 119 g PO_4^{3-} /kg material (Brogowski & Renman, unpubl. data). The high total P content in the surface horizon of sand originates from organic P. Part of this has been retained from the wastewater by the sand since it acts as a filter due to the fine texture. Another part originates from bacteria preferably living in the surface horizon of the column instead of in lower horizons. Several investigations done recently on different materials, by-products or natural, show that P is possible to trap efficiently (Johansson, 1999; Roseth, 2000; Agyei *et al*., 2002). High removal efficiency of bacteria was found in this study. Bacteria are more efficiently killed at high pH values. This could explain the highest reduction in the Polonite material. This is supported by the fact that a high percentage of the out coming bacteria from that material was spore forming bacteria, mostly belonging to *Bacillus spp.* By including more P reactive media in constructed wetlands and infiltration beds, the leakage from such systems can be significantly minimized. If the option is to recover the P resource as fast as possible, special traps must be designed where it is easy to manage the P saturated filter media for further use. Some of the materials are capable to deliver the sorbed P in crop production in a sustainable way (Hylander & Simán, 2001).

Conclusion

Using filter substrates is a possible technology for small-scale wastewater treatment. It can be applied for treatment of different kinds of wastewater, e.g. grey water. A high P sorption capacity and an efficient removal of bacteria was demonstrated for Polonite.

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Acknowledgements

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Session F

Hygienic agro-reuse

Chairpersons

Caroline Schönning (Swedish Institute for Infectious Disease Control, Sweden)

Joachim Clemens (University of Bonn, Germany)

Lectures

Separation of faeces combined with urine diversion - function and efficiency*
Björn Vinnerås, *Håkan Jönsson* (Swedish University of Agricultural Sciences, Sweden)

Urine, faeces, greywater and biodegradable solid waste as potential fertilisers*
Helena Palmquist (Luleá University of Technology, Sweden), *Håkan Jönsson*

The use of separated human urine as mineral fertilizer*
Jürgen Simons, Joachim Clemens (University of Bonn, Germany)

Integrated systems on biogas production, non-polluted agricultural production and sanitation in rural China
Yao Xianjung, Wang Hai (Ministry of Agriculture, China)

Composting with human urine: plant fertilizer approach*
Wantana Pinsem (King Mongkut's Institute of Technology, Thailand), *Björn Vinnerås*

Sewage sludge humification in a sequential conversion procedure
Joachim Pabsch, Holger Pabsch, Andreas Purrmann (IPP Consult GmBH, Germany)

Session F

Oral poster presentations

Adapting the nutrient content of urine and faeces in different countries using FAO and Swedish data*
Håkan Jönsson, Björn Vinnerås (Swedish University of Agricultural Sciences, Sweden)

Safe nutrient-removal from urban sewage
Florian von Sothen (University of Bonn, Germany)

Nutrient uptake by different vegetable plants from source separated human urine*
Kedar Man Prajapati (Department of Water Supply and Sewerage, Nepal), Deepak Raj Gajurel

Sanitation of blackwater and organic material*
Linda Malmén, Ola Palm (Swedish Institute of Agricultural and Environmental Engineering, Sweden), *Erik Norin*

Ecological sanitation: valorisation of waste sludge by composting for agricultural production
Amah Klutse, Cheick Tidiane Tandia (CREPA, Burkina Faso), *Jean Malomon Yadouleton, Henri Soclo*

Sustainable utilisation of human urine in urban areas - practical experiences*
Marie Adamsson, Zsofia Bán, G. Dave (Göteborg University, Sweden)

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[*]This paper has been peer reviewed by the symposium scientific committee

Poster presentations

The effects of sewage sludge application on the yields of berseem and forage maize in newly reclaimed soil
Ezzat M. Abd El Lateef (Field Crop Research Department, NRC, Egypt)*, J. E. Hall, S. R. Smith*

Effect of long-term application of wastewater on bioavailability of trace elements and soil contamination
Ezzat M. Abd El Lateef (Field Crop Research Department, NRC, Egypt)*, J. E. Hall, S. R. Smith*

Urine-separating toilet in popularising ecological sanitation in the peri-urban areas of Manipur, India
Rajkumar Dilip Singh (Government of Manipur, India)

Sustainability and optimisation of treatments and use of wastewater for irrigation in mediterranean countries
D.Xanthoulis et al. (Faculté Universitaire des Sciences Agronomiques de Gembloux, Belgium)

Investigation of constructed wetland performance considering water reusing
Ping Gui, Ryuhei Inamori, Wenchang Zhu, Motoyuki Mizuochi, Yuhei Inamori (National Institute for Environmental Studies, Japan)

The use of sewage fertiliser products on arable land - requirements from the farmers perspective
Pernilla Tidåker, Cecilia Sjöberg, Håkan Jönsson (Swedish University of Agricultural Sciences, Sweden)

Separation of faeces combined with urine diversion - function and efficiency*

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Keywords

Blackwater, faecal separation, nutrient recovery, nutrient recycling, urine diversion

Abstract

The main proportion of the plant nutrients in household wastewater is found in the toilet fraction, and originates from urine and faeces. Using a blackwater system, it is possible to collect these nutrient rich fractions. However, the nutrients in the blackwater are diluted by large amounts of flushwater, even if a low-flush vacuum system is used.

By using a combination of urine diversion and separation of faecal matter from the flushwater, it is possible to collect the majority of the nutrients in a much more concentrated form compared to blackwater systems. The efficiency of instant separation is higher than separation in a filter bag. The efficiency of the separation depends on the system design but if correctly designed and built, it is possible to separate 84% N, 86% P and 65% K from the faecal matter. In a system where 95% of the urine is diverted and the faecal matter is instantly separated, 93% of the nitrogen, 92% of the phosphorous and 87% of the potassium are separated into a fraction comprising half the volume of blackwater from a vacuum system.

Introduction

In household wastewater, the main contribution of nitrogen (N), phosphorous (P) and potassium (K) originates from the urine fraction followed by the faecal fraction (Fig. 1). The fraction with the lowest concentration of nutrients is the greywater (Vinnerås, 2002). On the other hand, the greywater fraction is by volume the largest fraction, normally between 10 and 55 m^3 per person and year. The urine fraction is considerably smaller, with a flow of approximately 0.5 m^3 per person and year, while the faecal fraction is even smaller containing only approximately 50 kg of material per person and year.

The nutrients excreted in the urine and the faeces reflect the composition of the food consumed, where those found in the urine are the majority of the metabolised nutrients and those found in the faeces are the majority of the non-metabolised nutrients. The nutrients consumed and excreted are in equilibrium for adults and almost so for children, although only approximately 2% of the nutrients consumed during the first 13 years of life are built into the body.

In a normal flushed toilet system, the nutrients in the urine and faeces are diluted by large amounts of flushwater, approximately 15-20 m^3 $p^{-1}y^{-1}$. Even in systems using vacuum, the nutrients are diluted by at least 2-3 m^3 of flushwater per person and year if the system is functioning correctly, otherwise more. It is important to keep the diluting water volume as small as possible in order to make it economically viable to recycle the plant nutrients in the toilet fractions. The highest concentration of the nutrients is obtained if the urine and the faeces are

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collected without flushwater. However, this is probably not a generally acceptable option in the Western world of today.

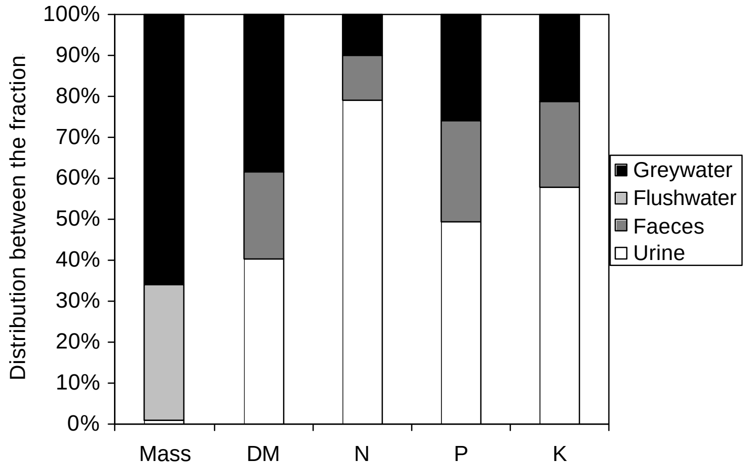

Figure 1: The amount of mass, dry matter, nitrogen, phosphorus and potassium in the different household wastewater fractions. The flushwater included represent the water usage of an average Swedish single flushed toilet (6l/flush). (Vinnerås, 2003)

However, it is possible to use a water-flushed toilet and collect the nutrients from the urine and the faeces in relatively concentrated form. The easiest way to collect the urine is to use a urine-diverting toilet (Fig. 2a-b), where the main proportion of the nutrients is collected with the urine in the front bowl of the toilet. The faecal matter should also be collected. As the faecal matter is normally solid, it is possible to collect it by solid-liquid separation after a short transport. To collect the faecal nutrients using this technique, the main proportion of the nutrients should remain in the faecal particles during the transport and separation.

a b c

Figure 2: a) The urine diverting toilet from Gustavsberg; b) the urine diverting toilet model ES from WostMan Ecology; c) the solid liquid separator from Aquatron, which uses gravitation, surface tension and a whirlpool effect to separate the faecal matter from the water.

For this type of separation there are mainly two different separation techniques used. The first is to use a filter bag where the faecal particles and the paper are captured and where the collected matter is used as a filter medium during the coming year. Then the material is dried and composted for a year before it is used as a fertiliser or soil conditioner (Gajurel et al., 2002). The other technique is to use a separator that employs a combination of whirlpool effect, surface tension and gravitation to separate the particles and the liquids (Fig. 2c) (Vinnerås et al., 2002a). With this method, the particles are instantly separated from the liquid, thereby avoiding any risk of continued extraction of the nutrients from the particles by liquid sieving through.

Objectives

The objective of this study was to compare different techniques for separating faecal nutrients from flushwater with regards to their separation efficiency for nutrients and solid matter. Another objective was to compare the nutrient recovery potential of systems based on faecal separation and urine diversion with that of blackwater systems.

Methods

The technique of whirlpool effect, surface tension and gravitation separator combined with urine diversion was investigated with respect to its separation efficiency of the plant nutrients nitrogen, phosphorus and potassium.

The Ekoporten block of flats in Norrköping, with 35 inhabitants, is equipped with this type of faecal separation in combination with urine diversion. The apartments are equipped with urine diverting toilets and in the basement of the four-storey building, two separators are installed to separate the faecal matter (faeces and toilet paper) from the flushwater. The amount of diverted urine was also collected and measured, which made it possible to estimate the amount of urine not separated, i.e. that was misplaced (Vinnerås & Jönsson, 2002a).

Several weak spots were identified in this full-scale system. Therefore, a follow up bench-scale study was performed. In this, the sewage system consisted of a one metre vertical pipe connected via a 90° bend to a one metre horizontal pipe, at the end of which was the separator. The faecal matter was manually introduced into the vertical pipe and it was immediately followed by four litres of flushwater (Vinnerås & Jönsson, 2002b).

After the bench-scale experiment, the system was scaled up in a pilot scale experiment. The vertical drop was increased to five metres and the 90° bend was replaced by two 45° bends, thereby smoothing out the change of direction. The faeces were introduced to the system via a urine-diverting toilet located at the top of the vertical pipe. Faecal matter was first deposited in the toilet, then toilet paper and ten seconds after application of the toilet paper the toilet was flushed (Vinnerås, 2003).

The efficiency of the separation was evaluated with respect to the distribution of faecal nutrients and dry matter between the separated solids (SepS) and the separated water (SepW).

Several different studies of the collection of diverted urine, in which the urine has been collected continuously for several weeks from households, have been performed (Jönsson et al., 2000; Vinnerås, 2002). These studies combined with the study in Ekoporten make it possible to predict the collectable amounts of nutrients in the different toilet fractions.

Results and discussion

Urine diversion

There are two different types of urine diverting toilets produced today. In the first type a small urine bowl is integrated in the larger faecal bowl, examples being the toilets WostMan Ecology model DS and the urine diverting Gustavsberg toilet (Fig. 2a). The other type is based on two more defined and separate bowls, examples being the WostMan Ekology ES (Fig. 2b) and the Dubbletten. All these toilets use some water for flushing. The toilets with integrated bowls (Fig. 2a) produce a somewhat more diluted urine mixture (Höglund et al., 1999) but no significant differences in amounts of plant nutrients collected have been detected for the double flushed toilets. However, with the single flushed toilet WostMan Ekology ES, which collects the faeces dry, a significantly higher collection rate has been observed (Andersson & Jensen, 2002). This is also an indication of the effect of collecting urine by using well-functioning toilets combined with motivated users (Table 1).

The main factors regulating the urine collection rate seem to be the function of the toilet and the motivation of the users (Jönsson et al. 1998; Lindgren, 1999). With the combination of well-functioning toilets and motivated users, it seems possible to collect over 90% of the urine excreted.

The different studies indicate a collection rate between 44% and 95% of the collectable urine. When only 44% was collected, the toilets had a high degree of malfunction and non-motivated users, i.e. the users were neither informed about the system and nor aware of why it was installed (Lindgren, 1999). In a system where more than 80% of the urine was collected, the toilets were also malfunctional but the users here were extremely motivated and had chosen the system themselves (Jönsson et al., 1998). These malfunctioning toilets were produced in early stages of urine diverting systems and later models have been improved significantly.

The different systems resulted in different efficiencies of nutrient collection from the urine. The collected urine during the different collection periods was compared to the amount expected according to the Swedish default value for urine excretion (Vinnerås et al, 2003). This made it possible to estimate the amount of nutrients missed during the collection. Corrections for the time spent at home were performed, making it possible to give the values for full time persons in the different collection areas (Table 1).

Area	Motivation	Function	Type	N (g p^{-1} y^{-1})	P (g p^{-1} y^{-1})	K (g p^{-1} y^{-1})
Swedish default value[1]				4000	365	1000
Gebers[2]	+	+	A	3830	250	820
Ekoporten[3]	0	-	A	2500	230	800
Understenshöjden[3]	+	-	A	3080	265	843
Hushagen[4]	0	0	B	2800	170	580
Miljöhuset[3]	-	-	A	1852	150	450

[1](Vinnerås, 2002) [2]Wost Man Ecology ES toilet
[3]Dubbletten toilet [4]Wost Man Ecology DS toilet

Table 1: The default values for nutrient content in the diverted urine fraction compared to the amount collected in the different areas investigated. The columns showing motivation and function use +, 0 and – for indication. The toilet type refers to Fig. 2

The collection of urine in Understenshöjden and in Hushagen is reported by Jönsson et al. (2000), and that in Miljöhuset by Lindgren (1999).

Faecal separation

The initial measurements in the full-scale system indicated good separation of the faecal nutrients when non-diverted urine had been accounted for. Approximately 60% of N and P, together with 45% of K and 13% of the total mass, were collected in the separated solids (SepS). The large mass collected came from large volumes of water collected in SepS, due to many flushes per person and day combined with poorly functioning separation of the water. Therefore, the dry matter content of SepS was only 0.2%. When the misplaced urine was not deducted from the faecal water, the nutrient separation efficiency was a lot lower as the main proportion of the urine nutrients are dissolved and thereby only 13% of the nutrients of the misplaced urine ended up in SepS and the rest in SepW.

Looking closer into the system, several different factors were identified as key factors influencing the composition of the separated solids: the amount of water separated into the solid

SepS fraction; the amount of misplaced urine; the number of flushes; and the degradation of the faecal particles.

The combination of influencing factors made it necessary to look into the function of the separator. A bench-scale system was then built in the laboratory to provide good control of the influencing factors. As no urine entered the system, the evaluation of separation efficiency of faecal matter was easier.

In the bench-scale experiment, the efficiency of the faecal separation was high. Approximately 69% N, 72% P and 68% K from the faeces were separated into the SepS fraction. The dry matter content of SepS was 10%, which should be compared with that of the faecal matter introduced into the pipe, 23% of dry matter.

However even with a drop of only one metre, the disintegration of the faecal particles was high. This was identified as being caused by the sharp angle involved when shifting from vertical to horizontal transport. This was changed when scaling up the system to pilot-scale. In this, two 45° bends were used to create a smooth 90° angle, which resulted in less disintegration of the particles, even after a 5 metre vertical drop and as a result the separation efficiency increased. Approximately 82% N, 86% P and 65% K of the faeces nutrients were separated into SepS in the bench-scale experiment. The probable explanation for the increased separation efficiency was the smooth bend.

As toilet paper absorbs a lot of water, an increased number of flushes with toilet paper was shown to result in a significantly increased mass of SepS. However, when the flushes were performed with water only, without toilet paper, the volume separated into SepS was just one to two teaspoons of water for each flush. Approximately 9% of the 4 litres used per flush ended up in SepS when toilet paper only was flushed. Even if the toilet paper affects the water volume in the separated solids, it does not affect the separation efficiency of the nutrients (Vinnerås, 2003). However, the use of toilet paper increased the wet mass in SepS three times compared to when only faeces were separated.

These three system evaluations indicate that the design of the system and the installation of the different parts have a major influence on the separation efficiency. When the transition from vertical transport to horizontal is made via a gradual bend, the disintegration of particles decreases, which increases the separation efficiency. If the system is designed correctly, of the faecal nutrients it is possible to collect approximately 85% of N and P, together with 65% of K in SepS.

Other alternatives for separation of the faecal matter from the flushwater involve filtration. This can be done in two ways, either as a continuous collection where the separated matter is added to the filter cake, thereby increasing the filter volume, or by using a filter where the filter cake is removed immediately after the separation.

The separation with increasing filter cake is used in separation systems using a rottebehaelter, where the faecal matter and the toilet paper are collected over a long period, up to a year. Then the material is left and matured for another year before it is used as a fertiliser or soil conditioner. During the collection, there is a risk that the separated material is degraded and its nutrients washed out by the passing water. Vinnerås & Jönsson (2002b) have also shown increased nutrient extraction as a function of the contact time between the faecal matter and water. However, in field studies performed by Gajurel et al. (2002) it was shown that during one month of collection and one and a half months of maturation, 60% N, 40% P and 20% K were collected in the solid fraction. The advantage with this filter method is the high dry matter content (on average 30%) compared to other separation methods, but a lot of nutrients are lost. If the retention time were to be increased, even more nutrients would probably be lost.

A smaller investigation with filtration of faecal matter and instant removal of the filter cake was performed as a laboratory-scale investigation by Vinnerås & Jönsson (2002b). In that study, 80% N, 72% P and 65% K were separated into the solid fraction. During the separation, the water content of the faecal matter increased from the initial 77% to 90%. This separation technique contains mechanical parts, which increases the risk of failure and the cost of the system. As neither the whirlpool, gravitation and surface tension separator nor the rottebehaelter have any moving parts, they are preferable for faecal separation. However, by using the filter technique with instant cake removal, it is possible to collect more of the faecal nutrients than by using continuous collection with a growing filter cake, e.g. rottebehaelter.

Collectable amount of nutrients

The combination of faecal separation and urine diversion is very promising for collection of the excreta nutrients in fractions of small volume that are easy to recycle. By using the urine diverting toilets, normally between 50% and 95% of the urine nutrients are collected. This has a major influence on the efficiency of the system, as the faecal separation can only separate the nutrients bound to, or contained in, particles.

The most efficient system from a nutrient recycling point of view is to use a blackwater system (Figure 3). However, normally these systems are highly technical, often using vacuum techniques. Another disadvantage of low flush systems is the problem of keeping the diluting water volume as low as possible. For example in mini flush systems, in reality between 2 and 4 litres of water are used after every visit instead of the few decilitres for which these systems are designed (Palm et al., 2002).

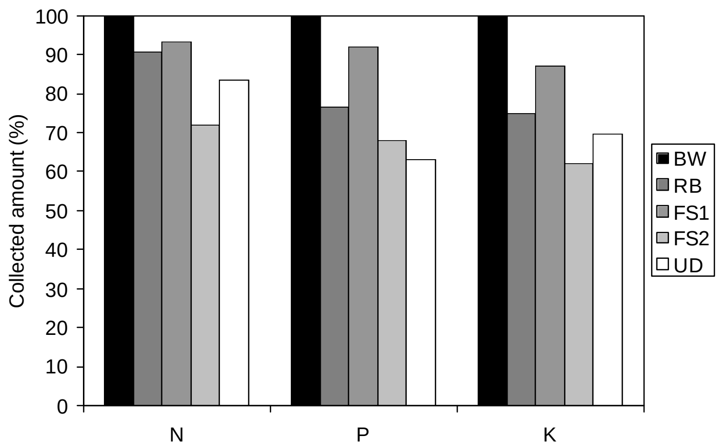

Figure 3: Estimation of the amounts of nitrogen, phosphorus and potassium collected depending on the type of system used, compared with blackwater collection, which is set to 100%. BW=Blackwater, RB=Faecal separation with rottebehaelter and 95% of urine diverted, FS1=Pilot-scale faecal separation and 95% of urine diverted, FS2= Faecal separation and urine diversion as in Ekoporten and UD=Urine diversion, 95%, only.

The scenario giving the highest nutrient recycling with faecal separation was the one where approximately 95% of the urine was diverted, as it was in Gebers (Andersson & Jenssen, 2002) combined with a separation efficiency of the faecal nutrients as in the pilot scale study (Figure 3; Vinnerås, 2003). In this scenario approximately 93% N, 92% P and 87% K were collected compared to a blackwater system.

When the faecal particles were collected in a rottebehaelter (Gajurel et al., 2002), combined with 95% of the urine being diverted, approximately 90% N, 77% P and 75% K were collected compared to a blackwater system. Compared to these results, significantly less nutrients were separated in Ekoporten (Figure 3), approximately 72% N 68% P and 62% K compared to a blackwater system (Vinnerås & Jönsson, 2002a).

The system with the urine diversion combined with faecal separation is not as sensitive as a blackwater system to the amount of flushwater used, except for the flushwater used in the urine bowl. The amount of separated solids is only slightly influenced by differences in the volume of flushwater used in the rear bowl, as it is the particles together with some water that are separated into the solids fraction (Vinnerås, 2002). When the whirlpool, gravitation and surface tension separator is used, only small amounts of water end up in the SepS fraction on flushing with water only. The main influencing factor for the water content in the SepS is the amount of toilet paper used, as the toilet paper absorbs a lot of water during the transport. This increases the water content three times compared to separation of faeces only (Vinnerås, 2003). The volume of the collected fraction is still smaller than that of blackwater systems (Figure 4). However, if the system does not function well, as is the case in Ekoporten (Vinnerås & Jönsson, 2002a), the amount of water collected in the SepS fraction can be very large (Figure 4). The amount of flushwater diluting the urine in the urine diversion scenarios was set to 0.08 litre per urination. The average flushwater volume used in Gebers was 0.07 l/flush (Andersson & Jenssen, 2002) and in Understenshöjden 0.09l/flush (Jönsson et al., 1998).

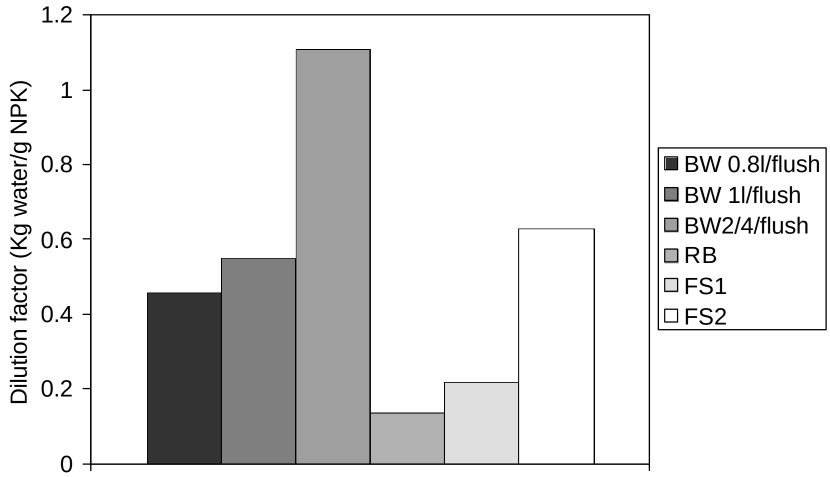

Figure 4: The amount of water collected per g of N, P and K depending on system used, BW=Blackwater systems with 0.8 litre/flush, 1 litre/flush and with 2/4 (2 litres/small flush and 4 litres per large flush), RB=Rottebehaelter urine diversion 95%, FS1=Urine diversion 95% and pilot-scale faecal separation, FS2=Urine diversion and faecal separation in Ekoporten.

The rottebehaelter and the whirlpool, gravitation and surface tension separator combined with well-functioning urine diversion gives almost as high nutrient separation as the blackwater system (Figure 3). A major difference is that the concentration of nutrients collected with a diversion and separation system is twice that of a regular blackwater system (Figure 4).

Conclusions

The preferable alternative for collection of the majority of the plant nutrients in household wastewater in relatively nutrient rich and concentrated fractions is to use a combination of urine diversion and faecal separation.

Continuous collection of the faecal matter in a filter bag, e.g. rottebehaelter, gives the smallest volumes to recycle of the systems compared. However, this system also gives significantly

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lower recycling of phosphorus and potassium compared to the whirlpool, gravitation, surface tension separator.

In a well-designed system based on faecal separation, up to 85% of the faecal nutrients can be separated. If this is combined with a well-functioning urine-diverting toilet, separating 95% of the urine, it is possible to collect 93% of the nitrogen, 92% of the phosphorus and 87% of the potassium from the toilet waste in fractions of small volume.

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Urine, faeces, greywater and biodegradable solid waste as potential fertilisers*

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Keywords

Wastewater fractions, urine, faeces, greywater, potential fertiliser, metals, nutrients

Abstract

To increase the knowledge concerning the flows and compositions of wastewater fractions, field measurements were performed on the Gebers wastewater system (80 residents), which source separates the flow into four fractions of urine, dry collected faeces, greywater, and solid biodegradable waste. The flows were 1.77; 0.22; 110 and 0.18 kg per person and day respectively. The chemical compositions were reported for the following compounds: TS, COD, BOD_7, N-tot, P-tot, K, S, Ag, B, Bi, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Pd, Pt, Rh, Sb, Se, Sn, Sr, Te, W, and Zn. The NPKS relationships of urine mixture, faeces, and biodegradable solid waste at Gebers corresponded well to the crop uptake of macronutrients, which make them to potential fertilisers from a plant nutrients point of view.

A ratio of hazardous elements vs. nutrients was calculated to evaluate the potential for nutrient recycling. The lower the quotient, the better quality of the fertiliser. Obtained ratios were compared to the analogous ratios for wastewater sludge and a chemical fertiliser. The ratios of 12 non-essential elements to phosphorus and nitrogen were lower in the urine than in all of the other fractions The fertilising potential for the sludge, greywater and biodegradable solid waste was questioned in the long term perspective due to higher ratios of hazardous elements contra nutrients than the plant uptake, which implies that an accumulation of these metals may occur in the fields. To reach a mass balance on the field the fertiliser should contain lower or the same ratios than the food. Since the food is the main source of the discussed metals in urine and faeces these fractions could be potential fertilisers, provided that external sources can be restricted.

Introduction

A water and wastewater system accounts for a large portion of the flows of both water and plant nutrients in an urban society. Most plant nutrients in wastewater originate from arable land and their flow is via food and human excreta into the wastewater system. To preserve its fertility, arable land needs to be compensated for the plant nutrients removed. Today, chemical fertilisers produced by fossil resources do mostly this. In the long-term perspective we cannot securely rely on fossil resources, while the recycling of plant nutrients from human excreta to

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*This paper has been peer reviewed by the symposium scientific committee

arable land could be another way of compensating soil fertility. Another important issue is that treated wastewater should be pure enough when it is returned to nature to not influence the ecosystem.

Stormwater, industrial discharges, and greywater are considered to be the main sources of pollution in conventional wastewater systems. Greywater is generally defined as household wastewater without any input from toilets, which corresponds to wastewater produced from bathing, showering, laundry, and the kitchen sink. While much information is available on the flow and composition, including hazardous substances, of mixed wastewater, reliable information is lacking concerning the flow and composition of its different fractions, urine, faeces, and greywater. According to Jefferson et al. (1999), Palmquist (2001), and Eriksson et al. (2002), published and reviewed literature focusing on the characterisation of greywater is very limited. The same applies to urine and faecal matter (Jönsson et al., 2000; Vinnerås, 2002). For the development and evaluation of source separating wastewater systems, reliable information is needed on the composition of the wastewater fractions. Increased knowledge concerning flows and composition, of both nutrients and hazardous substances, is necessary for assessing the quality of the fractions and the potential for nutrient recycling on arable land.

To increase the knowledge concerning the flows and compositions of wastewater fractions, field measurements were performed on the Gebers wastewater system. Gebers is a house consisting of 32 apartments, communal recreational facilities, kitchen, and dining hall, and is situated in the suburb of Skarpnäck nearby Stockholm, Sweden. Gebers has approximately 80 residents, many of them with environmental concerns, including their housing. The wastewater system of Gebers source separates the flow into three fractions of urine mixture (urine + small amounts of flush water), faeces (faeces + toilet paper collected dry), and greywater. The solid biodegradable waste is also source separated.

Objectives

This paper has two main objectives. The first is to analyse and describe the flow and chemical composition of the following four waste and wastewater fractions; urine, faeces, greywater, and solid biodegradable waste at Gebers. The four fractions cover the output waste streams from households. The second objective is to consider the potential of these fractions for nutrient recycling based on their ratios between hazardous substances and plant nutrients.

Methods

Selection of indicator substances

Today, more than 75,000 chemical compounds are present in the technosphere, with 30,000 of these being regarded as everyday chemicals that are regularly used in households (Palmquist, 2001). Due to the vast number of chemicals used in households, the high analytical costs of both organic and inorganic substances, and a limited analyses budget, a restricted number of indicator substances had to be selected for the investigation at Gebers. The choice of indicator substances was made by a group of experts. The base of the selection was ordinary wastewater variables supplemented by some hazardous organic and inorganic substances. Urine, faeces, greywater, and solid biodegradable waste were analysed for 29 metals (elements). The greywater was additionally investigated for the following organic compounds; polycyclic aromatic hydrocarbons (PAHs), poly chlorinated biphenyls (PCBs), phthalates, alkylphenol etoxilates, organotin compounds, brominated flame-retarding agents, and linear alkylbenzene sulphonate (LAS). A total number of 80 organic compounds were investigated but they will not be considered in this paper due to the restricted space.

The plant nutrients of most interest, when evaluating the recycling potential of the four fractions, are nitrogen, phosphorus, potassium, and sulphur (Swedish EPA, 2002). The four of these nutrients were measured.

Sampling

The sampling of source separated urine, faeces, greywater, and biodegradable solid waste from the households at Gebers was performed during three weeks in October 2001, divided into three periods of one week each. During this period samples of all four fractions were taken and their total mass flows were measured. In addition, during the whole period, the residents noted on a questionnaire how much time they spent at home each day. During the whole measurement period, residents were supplied with toilet paper. All samples were collected as weekly mixed samples, and were stored at -20°C until they were analysed. The solid biodegradable waste samples were ground and homogenised before they were sent for analysis.

The samples of greywater were collected proportionally to the flow. Equipment for automatic sampling was installed on the two outgoing sewage pipes from the house. For every 100 litres of greywater passing a ski board, 160 ml of sample was collected and stored in a refrigerator. The collected greywater from the two sampling points was mixed into daily samples, which were placed into -20°C. After 7 days, weekly samples were mixed from the daily mixed samples.

At Gebers, the urine is normally collected in 3 - 6 m^3 tanks in the basement of the house. During the sampling period the urine was instead piped into 3 - 25-litres plastic containers that were emptied manually twice daily into a 1 m^3 tank. At the end of each weekly measurement period, the urine was thoroughly mixed in a closed system before the samples were collected. Faeces were collected in separate bins for each of the 32 apartments; the bins were also emptied after each of the three sampling weeks. The faecal matter and the used toilet paper were mixed into a homogeneous slurry after an addition of deionised water, and then the samples were extracted. All solid biodegradable waste was collected and divided into representative samples twice weekly. These samples were later ground and homogenised before being divided into smaller samples submitted for analysis.

Analyses

Accredited contract laboratories were engaged for all the analysis work (SGAB Analytica, AnalyCen, ALcontrol). Two weekly mixed samples per fraction were analysed for TS, ash, COD, BOD_7, TOC, nitrate, and nitrite, and four weekly mixed samples per fraction for ammonia and Kjeldal-nitrogen. There were no accredited methods available for BOD_7 and COD for faeces and the biodegradable solid waste. Furthermore, two weekly mixed samples were analysed for each fraction during the first two weeks, and three samples during the last week for the total phosphorus (P_{tot}) and the elements K, Ca, Fe, Mg, Na, S, Ag, Al, B, Bi, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Pd, Pt, Rh, Sb, Se, Sn, Sr, Te, W, and Zn. The element analyses were performed by SGAB Analytica using ICP-AES/ICP-SMS. Accredited methods for the following element analyses were not available in urine; Ag, B, Bi, Fe, Hg, Pd, Pt, S, Sb, Se, Sr, and W (SGAB Analytica, 2002). For urine and greywater, the pH and conductivity was measured daily. Suspended solids (SS) and phosphate were measured on urine and greywater twice weekly (on fresh daily mixed samples).

Results

During the measurement period, residents were at home on average 15.3 hours per day. Thus, the measured flows of urine and faecal matter have been linearly extrapolated to the estimated flow during the whole day, i.e. during 24 hours. No extrapolation has been made for the flow of greywater or solid biodegradable waste. The reason for this is that the amount of showering, laundry, and cooking will only slightly be affected by the time spent at home, while the residents will most likely use other toilets when not at home.

Data for urine was denoted urine mixture, meaning that urine samples with flush water were included. The results from the faeces measurements are presented with toilet paper included. Table 1 gives the flows of ordinary wastewater variables, including seven heavy metals, in Gebers put forward as mass flows per person and year.

	Unit	Urine mixture	Faeces + toilet paper	Greywater	Biodegradable solid waste
Wet mass	kg	646	81[a]	40150	67
TS	kg	7.0	18.6[a]	14.6	16.5
BOD_7	g	1829	1223	7700	1051
COD	g	3720	1668	17500	2931
N	g	3830	710	510	324
P	g	250	250	220	57
K	g	820	280	350	182
S	g	230	78	584	33
Cu	mg	17.2	635	2370	162
Cr	mg	0.16	49	149	182
Ni	mg	4.2	82	241	89
Zn	mg	107	16940[b]	2255	675
Pb	mg	4.2	13.5	88	40
Cd	mg	0.08	5.7	5.5	2.5
Hg	mg	0.16	3.2	1.1	2.7

a) The use of toilet paper was: 8.5 kg TS per person and year

b) This value is probably partly due to corrosion from the galvanised pipes which were a part of the system

Table 1: Results from measurements of source separated wastewater fractions at Gebers. The results are given as a *mass flow per person and year*. Urine mixture means urine with flush water included. The faeces measurements are presented with toilet paper included.

	Urine mixture		Faeces + TP		Greywater		Biodegr. solid waste	
Unit	µg l^{-1}	Std dev.	mg (kg TS)$^{-1}$	Std. dev.	µg l^{-1}	Std. dev.	mg (kg TS)$^{-1}$	Std. dev.
Ag	0.03	0.01	0.64	0.40	0.265	0.007	0.022	0.011
B	969	9	7.8	0.7	49.7	11.7	10.6	2.2
Bi	<0.050	-	0.014	0.004	<0.050	-	0.017	0.010
Co	0.25	0.04	0.518	0.005	0.394	0.009	0.58	0.49
Mn	1.5[a]	-	100	3	33	3	63.4	24.1
Mo	44.4	1.4	2.24	0.04	1.10	0.03	0.83	0.18
Pd	<0.020	-	<0.020	-	<0.020	-	<0.020	-
Pt	<0.003	-	0.003	0.002	0.014	0.002	<0.020	-
Rh	<0.010	-	<0.020	-	<0.010	-	<0.020	-
Sb	0.17	0.05	0.060	0.002	0.189	0.025	0.045	0.025
Se	<20	-	0.60	0.03	0.177	0.011	<0.40	-
Sn	0.917	0.138	16	6	1.65	0.31	1.33	1.44
Sr	42.7	1.1	33.6	1.9	60.3	2.0	40.0	14.4
Te	0.02	0.01	<0.005	-	0.019	0.003	<0.09	-
W	0.099	0.012	0.062	0.017	0.079	0.002	0.005	0.000

[a] Based on two values only

Table 2: Rare elements in source separated wastewater fractions and biodegradable solid waste at Gebers. The results originate from the average values from the three (weekly mixed) samples for each fraction.

Additional metals, many of them considered as hazardous, were analysed in source separated wastewater fractions and biodegradable solid waste at Gebers (see Table 2).

Samples of urine were analysed for antibiotics resulting in concentrations below the detection limit 0.25 µg per litre (Johansson, 2002). 43 out of the 80 investigated organic substances were detected in the greywater. Substances from all the seven groups were found. Significant variations in the presence and concentrations of the investigated substances were observed over the three sampling weeks. These results are presented in greater detail in Andersson & Jenssen (2002).

Discussion

Ratios between hazardous substances and plant nutrients

For some of the substances, the relation between hazardous elements and the plant nutrients phosphorus and nitrogen were studied in the four fractions (Tables 3a and 3b). A ratio of hazardous substances contra nutrients is one way of evaluating the potential for nutrient recycling. The lower the quotient, the better quality of the fertiliser. Obtained ratios for the waste and wastewater fractions were compared to the analogous ratios for sludge from municipal wastewater treatment plants (WWTP) and a chemical fertiliser (Eriksson, 2001). The sludge ratios were calculated from the median values of selected metals vs. phosphorus and nitrogen from 32 Swedish WWTPs with less than 20,000 people connected (Eriksson, 2001). The reason for selecting these WWTPs was that mainly households are connected to those small WWTPs, making the comparison between the sludge ratios and the ratios for waste and wastewater fractions more adequate.

[mg / kg P]	Urine	Faeces	Greywater	Biodegr. solid waste	WW sludge[a]	Chemical fertiliser
Ag	0.08	48	52	6.2	141	<
Cd	0.31	23	27	44	37	0.24
Co	0.64	39	77	158	144	4.5
Cr	0.66	196	739	3220	926	37
Cu	68.6	2530	11550	2865	11520	6.9
Hg	0.65	13	5.3	4.2	29	0.04
Ni	16.6	330	1170	1581	480	22
Pb	16.9	54	425	710	963	2
Pt	<	0.2	2.8	<	5	0.03
Sb	0.45	4.5	37	12.4	48	0.2
Sn	2.4	1200	324	386	593	0.4
Sr	110	2520	11820	11090	3500	270
Te	0.05	<	3.7	<	5	<
W	0.26	4.7	15.5	25.4	89	0.2
Zn	426	67700[b]	12370	11940	16440	76

a) Values from Eriksson (2001). WW sludge refers to median values for WWTP with less than 20,000 persons connected. The chemical fertiliser refers to NPK-S 21-4-7

b) This high value was probably partly due to corrosion from the galvanised pipes, which were a part of the system

Table 3a: The flow of metals per kg phosphorus in the wastewater fractions urine, faeces, greywater, and biodegradable solid waste at Gebers compared to analogous ratios of WW sludge and a chemical fertiliser.

The total uptake of macronutrients of the crop is approximately 100 times larger than the total uptake of micronutrients (Hammar et al., 1993). The macronutrients are nitrogen, phosphorus, potassium, sulphur, magnesium and calcium. Of these, yearly additions are normally not needed of calcium and magnesium, since soils with acceptable pH values normally contain enough calcium and magnesium. When the pH value of the soil is too low, it is raised by additions of lime, which often also contains magnesium (Hammar et al., 1993).

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In most cultivation areas yearly additions are needed of nitrogen, phosphorus, potassium and sulphur. Thus, these four elements are of high significance when waste and wastewater products are discussed as potential fertilisers. The mass ratios between the four elements are also of importance, since different kinds of crops have different uptake of these substances. Compared to phosphorus, most crops take up 4-10 times as much nitrogen, 1-8 times as much potassium while the uptake of sulphur is 0.3-1 times the phosphorus (Hammar et al., 1993).

The composition of the waste and wastewater fractions, which are derived from food, matches these ratios well. Compared to phosphorus, the N:P:K:S relationships of urine mixture, faeces, greywater, and biodegradable solid waste at Gebers were 15:1:3:1, 3:1:1:0.3, 2:1:2:3 and 6:1:3:0.6. These ratios show that the urine mixture is a very nitrogen rich fraction, which makes it a potential fertiliser. It is also seen that the sulphur/phosphorus ratio falls within the range, 0.3-1, for urine, faeces and biodegradable solid waste, which correspond to the plant uptake of the S:P ratio (Hammar et al., 1993). For greywater though the S:P ratio is 3, which means that sulphur would be added in excess if greywater would be used for P-fertilising purposes. Surplus amounts of sulphur may have acidifying effects in the soil.

[mg / kg N]	Urine	Faeces	Greywater	Biodegr. solid waste	WW sludge[a]	Chemical fertiliser[a]
Ag	0.01	16.7	20.5	1.1	100	<
Cd	0.02	8.1	10.6	7.7	27	0.08
Co	0.04	13.7	30.5	27.6	103	1.5
Cr	0.04	69	292	562	658	12
Cu	4.5	889	4566	500	8184	2.3
Hg	0.04	4.6	2.1	0.74	20	0.01
Ni	1.1	117	462	276	342	7
Pb	1.1	19	168	124	684	0.7
Pt	<	0.08	1.1	<	4	0.01
Sb	0.03	1.6	14.6	2.2	34	0.07
Sn	0.16	417	128	67	421	0.13
Sr	7.2	892	4674	1936	2487	90
Te	0.003	<	1.5	<	3	<
W	0.02	1.6	6.1	4.4	63	0.07
Zn	28	24[b]	4891	2083	11684	25

a) Values from Eriksson (2001). WW sludge refers to median values for WWTP with less than 20,000 persons connected. The chemical fertiliser refers to NPK-S 21-4-7

b) This high value was probably partly due to corrosion from the galvanised pipes, which were a part of the system

Table 3b: The flow of metals per kg nitrogen in the wastewater fractions urine, faeces, greywater, and biodegradable solid waste at Gebers compared to analogous ratios of WW sludge and a chemical fertiliser.

The plants also require micronutrients such as boron, cobalt, copper, iron, manganese and zi nc (Hammar et al., 1993). Ratios for cobalt, copper and zinc in the waste and wastewater fractions are given in the Tables 3a and 3b. The mass flows of micronutrients in the urine and the faeces are likely to correspond to the mass flows of these substances in the food, due to the mass balance of the human body. Increased zinc values in the faeces indicate that they might have been contaminated by zinc from the galvanised pipes in the collecting system. The copper/phosphorus ratios for greywater and sludge, show that contamination of copper probably occur due to e.g. corrosion of the copper pipes for drinking water.

The other 12 elements in the Tables 3a and 3b are not needed by the plants and most of them can be toxic to soil microbes, plants, and animals including humans. Therefore, accumulation of these elements in the soil might be harmful in a long term perspective. Furthermore, the natural concentration of some of these substances, e.g. Ag, in the soil is very low, which means that also small additions rapidly increase the concentration in the soil. Table 3a and 3b show that the ratios were lower for urine than in the other waste and wastewater fractions. Several studies have furthermore shown that the fertilising effect of human urine is good (Kirchmann & Pettersson, 1995; Kvarmo, 1998; Richert-Stintzing, et al., 2001).

The ratios of the 12 non-essential elements to phosphorus and nitrogen are higher in the faeces than in the urine (Table 3a and 3b). If bound to particles or low solubility in the intestines liquids the elements, taken via the food, goes directly into the faeces, while the nutrients are metabolised and excreted via the urine (Birgersson et al.,1983). Normally the pollution level of the food equals the pollution that is removed from the fields, and to reach a mass balance on the field of these substances the fertiliser should not contain higher ratios than the food. Since the food is the main source of the discussed metals in urine and faeces these fractions could be potential fertilisers, provided that external sources of hazardous elements can be restricted.

According to the Tables 3a and 3b the ratios of WW sludge in general are higher than for urine and faeces. The same applies for the greywater, which makes them to difficult fractions when it comes to their fertilising potentials. Receiving a lot of chemicals and residues from our daily activities e.g. personal care products, washing powders etc. makes them doubtful from a chemical risk point of view. The ratios for the solid biodegradable waste were also generally higher than for urine and faeces, which partly might be due to pollution from peels and contamination form surfaces e.g. some chromium might come from stainless steel surfaces. All in all the potential as fertiliser for food production for the fractions WW sludge, greywater and biodegradable solid waste must be questioned in the long term perspective due to higher ratios of hazardous elements contra nutrients than what the plant uptake can counter balance.

Conclusions

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The flows of source separated urine, faeces, greywater, and biodegradable solid waste from the households at Gebers were 1.77; 0.22; 110 and 0.18 kg per person and day during the three weeks of measurements. The chemical compositions were reported for the following compounds: TS, COD, BOD_7, N-tot, P-tot, K, S, Ag, B, Bi, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Pd, Pt, Rh, Sb, Se, Sn, Sr, Te, W, and Zn in the Tables 1 and 2.

The NPKS relationships of urine mixture, faeces, greywater, and biodegradable solid waste at Gebers were 15:1:3:1, 3:1:1:0.3, 2:1:2:3 and 6:1:3:0.6. Except for greywater this corresponded well to the crop uptake of macronutrients, which make them to potential fertilisers from a plant nutrients point of view.

The ratios of the 12 non-essential elements to phosphorus and nitrogen were lower in the urine than in all of the other waste and wastewater fractions. To reach a mass balance on the field of these substances the fertiliser should not contain higher ratios than the food. Since the food is the main source of the discussed metals in urine and faeces these fractions could be potential fertilisers, provided that external sources can be restricted. The fertilising potential for the fractions WW sludge, greywater and biodegradable solid waste must be questioned in the long term perspective due to higher ratios of hazardous elements contra nutrients than what the plant uptake can counter balance, which implies that an accumulation of these metals may occur in the fields.

The content of both inorganic and organic hazardous substances in wastewater fractions is difficult to relate to a comprehensible reference frame due to the lack of knowledge. Even in such a small and well-defined wastewater system as Gebers, the diffuse sources to the chemical flow are difficult to keep track of, which also show how difficult it is to keep fractions unpolluted in our chemical society. The obtained results, for both the more well-known and the *new* compounds, are important pieces for accomplishment of substances flow analyses for the material flows within different types of wastewater systems.

Acknowledgements

This study was financially supported by the Mistra-programme Urban Water, Stockholm Water Company (SWC), and the Swedish Water & Wastewater Association (VA-Forsk); all are gratefully acknowledged. Further, the authors are grateful to Ms Åsa Andersson and Ms Annika Jenssen, who did considerable parts of the sampling and data processing as parts of their master thesis work. The authors would also like to express their gratitude to Ms Cajsa Wahlberg and Mr Klas Öster (SWC), Dr Niclas Paxéus (GRYYAB), and Dr Magnus Johansson (Umeå University) for their advice and technical assistance. Further, the authors are grateful to the residents at Gebers, who bravely endured the inconvenience that followed the three weeks of wastewater sampling.

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The use of separated human urine as mineral fertilizer*

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Keywords

Fertilizer, field experiments, urine

Abstract

Human Urine contains most of the macro nutrients e.g. nitrogen humans excrete. Thus, separated human urine may be used as mineral fertilizer. In two field and one greenhouse experiments we compared the nitrogen availability of urine with mineral and/or organic fertilizers. On grassland we applied urine, slurry and a slurry urine mixture in two dosages (sum: 110 NH_4-N ha^{-1}). On arable land we applied to winter barley mineral fertilizer, urine and a slurry urine mixture in three dosages (sum: 170 NH_4-N ha^{-1}). On grassland and arable land, the urine plots tended to remove higher N amounts from the soil. However there were no significant differences between different treatments. In the greenhouse experiment we applied acidified urine with pH 4, urine with pH 8 and mineral fertilizer to Lolium multiflorum/italicum. The plots treated with urine showed higher N removals compared to the mineral fertilizer plots. Urine N may substitute N from mineral fertilizer. Due to the low N content in the urine we suggest to apply the urine with slurry. Treatments like acidification of urine could be buffered in a slurry with a high alkalinity.

Introduction

Urine has a high content of nitrogen, phosphorus and potassium. Thus urine has the potential to be used as a mineral fertilizer. Only few studies have been performed with urine as fertilizer such as (Johannson, 2000), (Fittschen & Hahn, 1998), (Kirchmann & Pettersson, 1995). Comparative studies with one substrate in different management systems are missing so far. We compared yields and N availability from separated urine with other organic and/or mineral fertilizers on grassland and arable land. We did not focus on antibiotics or endocrine disruptors that may prohibit urine spreading in agriculture.

Materials and methods

Urine: From the experimental site „Lambertsmühle“ in Germany separated human urine was used. The macro nutrients and pH of the urine are listed in table 1. In the storage tank the urine was acidified with sulfuric acid to reduce microbial contamination and ammonia emissions. Compared to undiluted human urine the urine in the separation tank showed lower N concentrations that are similar to animal slurry.

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*This paper has been peer reviewed by the symposium scientific committee

	N_{tot}	NH_4^+	P_{tot}	K^+	pH
Urine “Lambertsmühle”	1.4	1.2	0.15	0.5	1.8*
Undiluted urine	6.7	0.4	0.5	1.8	8.1

Table 1: Chemical composition of human urine from the “Lambertsmühle” used in the field experiments. The composition is compared to undiluted human urine [g l^{-1}], *: the urine was acidified with sulfuric acid.

Sites: The two sites (sandy loam) were next to the Lambertsmühle. Physico chemical parameters of the arable land are listed in table 2.

	texture	pH	P_2O_5 (mg/100g soil)	K_2O (mg/100g soil)	MgO (mg/100g soil)
arable land	sandy loam	6.5	17	19	15

Table 2: Soil parameters of arable land

On grassland we applied urine (pH 4.8), cattle slurry and a mixture of urine/ cattle slurry (50% NH_4^+ from each substrate). The plots were fertilized twice (first application: 60 kg NH_4^+-N ha^{-1}, second application: 50 kg NH_4^+-N ha^{-1}) and harvested thrice. Arable land with winter barely was fertilized in three dosages (first application: 60 kg NH_4^+-N ha^{-1}, second application: 60 kg NH_4^+-N ha^{-1}, third application: 50 kg NH_4^+-N ha^{-1}). We used urine (pH 4.8), mineral fertilizer (CAN) and a mixture of urine/cattle slurry (50% NH_4-N from each substrate). On both sites control plots received no fertilizer.

At each site we used a randomized block design with four treatments and four replicates. We compared the yield and N-removal.

To calculate the N-availability of the fertilizer N uptake of control plot were subtracted from the fertilized plots. Statistical analysis was performed with SPSS10.

In a greenhouse experiment the plant availability of urine-N was tested with Lolium multiflorum/italicum on a silty soil (table 3). Acidified urine (pH 4) and urine with a pH similar to untreated urine (pH 8) were compared with mineral fertilizers (CAN) at two dosages (1 and 2 g mineral N per pot with 9 kg soil).

texture	pH	N_{tot} (%)	P_2O_5 (mg/100g soil)	K_2O (mg/100g soil)
silt	6.3	0.08	6.7	4.8

Table 3: Soil parameters of the greenhouse soil

Results

Grassland: There were no significant differences in the yield from fertilized plots (figure 1). The urine used was acidified and thus no damages due to high pH on plant surfaces occurred.

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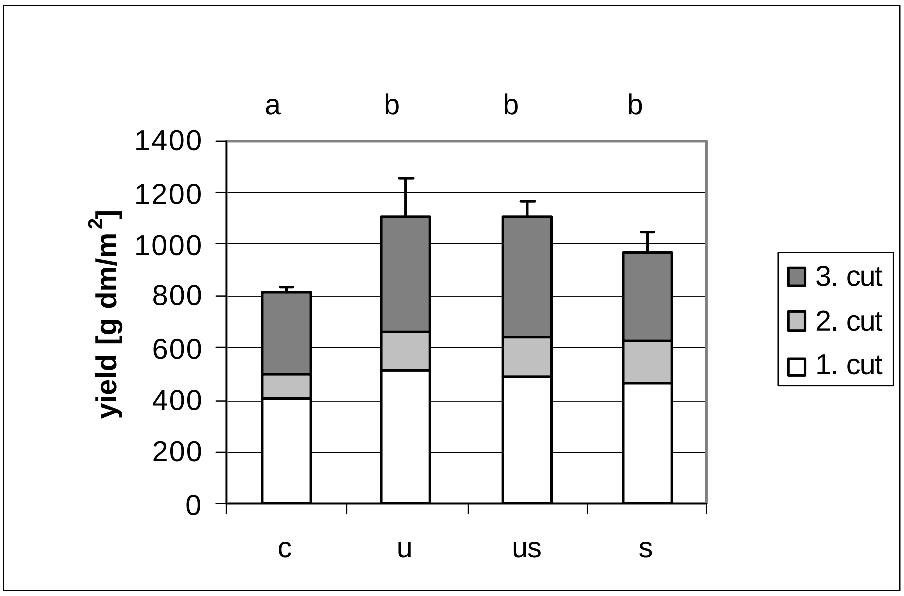

Figure 1: Yields from grassland, 1., 2. and 3. cut [g m^{-2}]; c: control; u: urine, s: slurry; u/s: mixture of urine and slurry.

The N removal was highest from plots that received either urine or a mixture of urine and slurry (figure 2), probably due to the acidified urine or mixture. N availability from urine was higher compared to slurry but again there were no significant differences (figure 3).

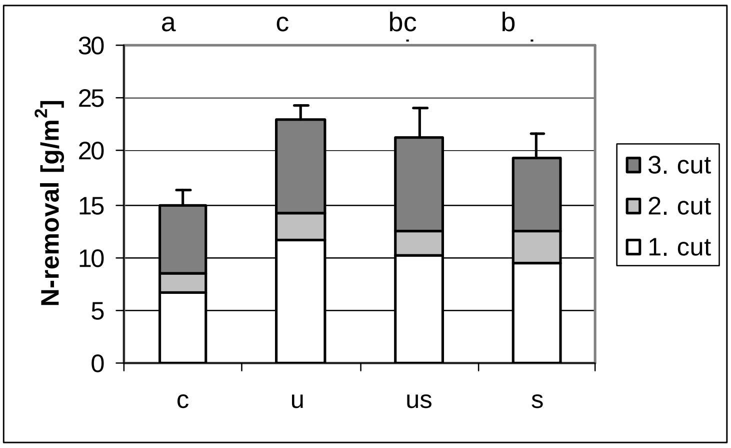

Figure 2: N-removal from the different plots (grassland); c: control; u: urine, s: slurry; u/s: mixture of urine and slurry.

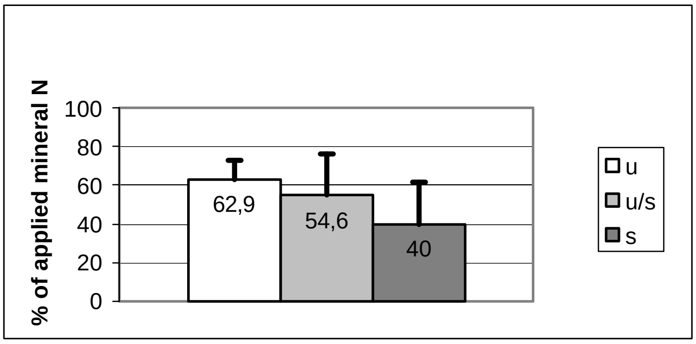

Figure 3: N-availability of the fertilizer used (% of the applied amount of mineral N) in a plot experiment (grassland); u: urine, s: slurry; u/s: mixture of urine and slurry.

Arable land: The barley yields from plots fertilized with urine or urine/slurry were higher compared to plots fertilized with mineral fertilizer (figure 4).

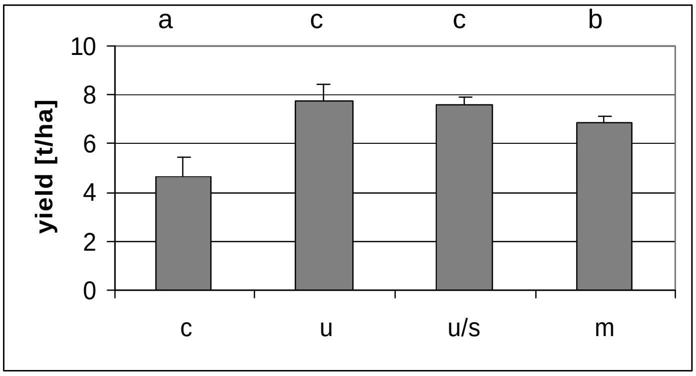

Figure 4: Yields from arable land (barley), yield [t/ha]; c: control; u: urine; u/s: mixture of urine and slurry; m: mineral fertilizer (CAN).

The N availability from the urine was higher compared to the other treatments (figure 5). The application of urine went along with an "irrigation" of the plots because of the low N concentration of the urine. Probably the higher yields were induced by this additional application of water on the urine plots since the soil was quite dry when we fertilized the plots.

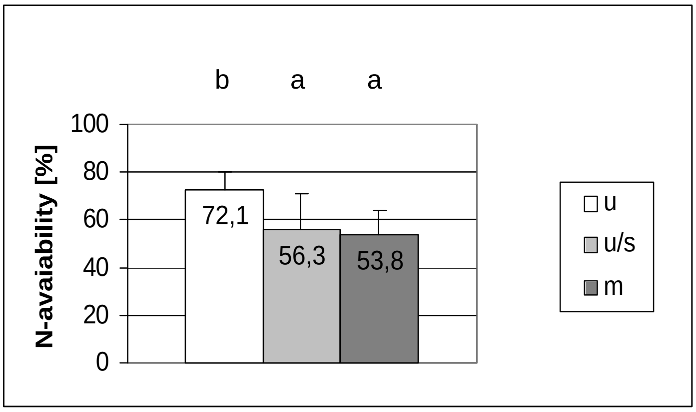

Figure 5: N-availability of the fertilizer used (% of the applied amount of mineral N) in a plot experiment (arable land; barley); u: urine; u/s: mixture of urine and slurry; m: mineral fertilizer (CAN).

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Greenhouse study: After the first cut the yields from untreated urine (U_8) tended to be lower compared to those from the other fertilizers (figure 6). This may be due to losses of ammonia (high pH of the urine). Also the yields from pots that received high urine amounts (U_4II and U_8II) were lower compared to those with low urine dosage (U_4I and U_8I), probably due to a higher input of sodium chloride. At the end of the experiment there were no significant differences within the groups with low and high N gifts.

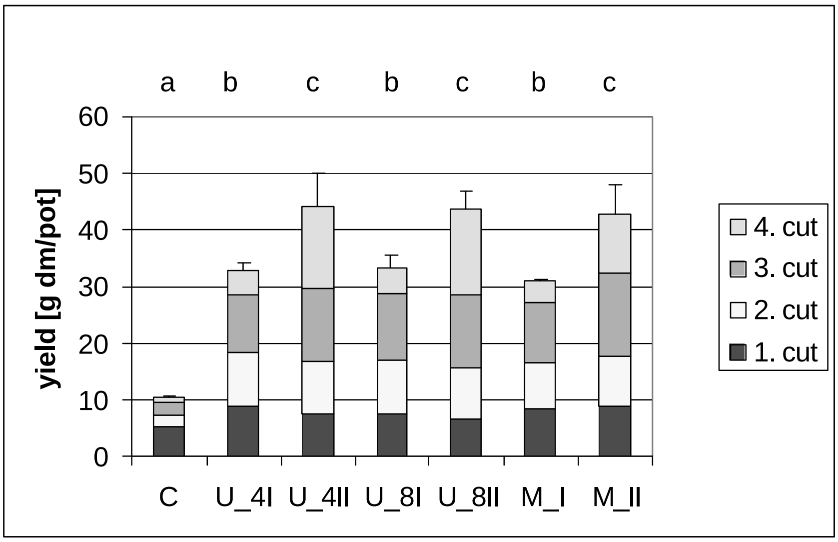

Figure 6: Yields from the greenhouse pot experiment (Lolium multiflorum/italicum)[g dm/pot]; c: control; u_4I: urine with pH 4 and 1 g NH_4^+-N; II: 2 g NH_4^+-N; _8: pH 8; m: mineral fertilizer (CAN).

The N availability from the fertilizers were in a range of 71.9 to 90.1 % of the applied mineral N (figure 7).

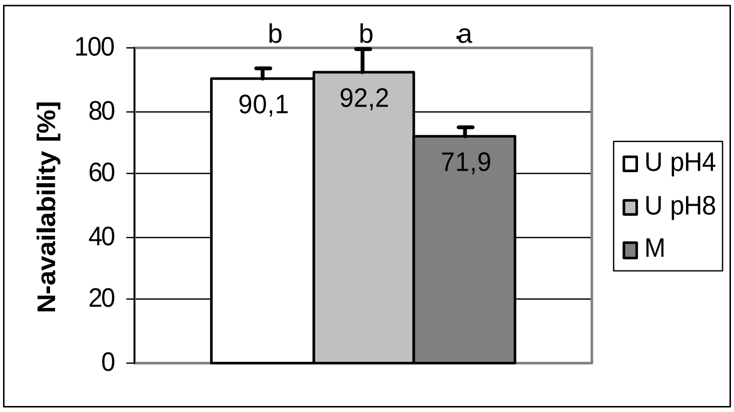

Figure 7: N-availability of the fertilizer used (% of the applied amount of mineral N) in a pot experiment (Lolium multiflorum/italicum); u: urine, m: mineral fertilizer (CAN).

Conclusions

Urine seems to be a suitable mineral fertilizer if the urine is acidified (pH<5) in order to reduce ammonia losses and plant damage. It should not be use in excess to avoid yield losses due to high inputs of sodium chloride.

We suggest to mix urine with animal slurry since application technologies for animal slurries are suitable for urine application, too. In such a case, urine acidification even to a very low ph (as in our field experiments) does not lead to plant damage because slurry has a high buffer capacity due to its high alkalinity.

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Integrated systems on biogas production, non-polluted agricultural production and sanitation in rural China

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Keywords

Agricultural production, biogas, integrated system, sanitation

Abstract

This paper introduces three typical biogas systems that take anaerobic fermentation of human and animal "wastes" as the key technology and integrate biogas production with agricultural use of digested effluent and sludge, and sanitation. These popularly disseminated systems in China practice the theory of "closing the loop" and achieve great significant benefits on promotion of renewable energy utilization, improvement of farmers' living environment, increase of farmers' revenue from saving their expenditure on commodity fuels by biogas, and improvement of agricultural products by using organic fertilizer instead of chemical fertilizer.

Regarding with the population who are engaged in agricultural production, China is surely named as the biggest agricultural country in the world. The 2002' statistical yearbook[1] states that by the end of year 2000, there were 853.7 million rural populations, 66.57% of the total national population, much higher than 42.38% of the global average. On the other hand, the animal husbandry in either intensive farm or domestic scale, the animal husbandry is developed rapidly. However, contradicted with the increase of rural population and animal husbandry, the human urine and excreta and animal manure trend to be less and less effectively used, which worsens the rural opening environment and the quality of surface and underground water. Consequently it results in the spreading of infectious diseases. In year 2000 the chemical fertilizer application was 327.0 kg/hectare as a national average and to achieve a near-term high productivity, farmers shift to apply more and more chemical fertilizer, even traditionally, Chinese farmers used to apply human urine and excreta and animal manure for agricultural production. It was estimated that only 35% of the total fertilizer input was from organic fertilizer (Li Qingkui, 1998) and the utilization rate of human urine and excreta was less than 30% (Li Qingkui, 1998).

To solve the contradiction between more output of human and animal "wastes" from increasing population and expanding animal breeding and their less agricultural use is a systematic subject which concerns with multiple factors such as theoretical research on ecological circulation of matters, technical solution, financial feasibility, and social acceptance, etc.. Likely, there are some existing activities happening in China to take care of the treatment and re-use of the "wastes" in terms of improvement of toilet structure, handling approaches of "wastes", as well as from the point of end use or disposal. Currently, wide-spreading systems integrating "wastes" from toilet and animal houses with their agricultural use after appropriate treatment and taking the anaerobic fermentation as the key linkage in China sound prospective as a model of "closing the loop".

[1] 2002 Statistical Yearbook issued by the Chinese Ministry of Agriculture

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Household biogas-integrated systems were originally developed and used mainly for energy production (biogas) in early 80's when the whole state faced a strong competitive demand on energy sources with the dramatic economic development after opening to the outside world and reform. Then the systems are improved gradually to be an integrated system with multiple functions along with the change on energy, agricultural production, rural development, as well as macro economic development. Consequently according to the statistics from the Ministry of Agriculture, the systems had been extended to over 9.57 million households accumulatively by the end of 2002 and 857.4 in operation in that year.

The experience shows that the systems are with multiple functions including clean energy production, sanitation, as well as green farming:

- Biogas - clean and renewable energy to replace coal, LPG, as well as firewood;
- Green farming - use of digested organic effluent and sludge;
- Sanitation - Improvement of living environment by avoiding open disposal of the wastes, elimination of flies production etc.

The systems experience the theory of "closing the loop". Urine and excreta from human beings, animal dung, and sometimes organic garbage from farm households are flowed to a biogas digester which produces biogas for both domestic use as household cooking and lighting and production use like biogas lamps in greenhouses as carbon fertilizer. The digested effluent and sludge then are used for agricultural plantation such as vegetable, cereal, and orchards. All the agricultural products are consumed by human beings and animals.

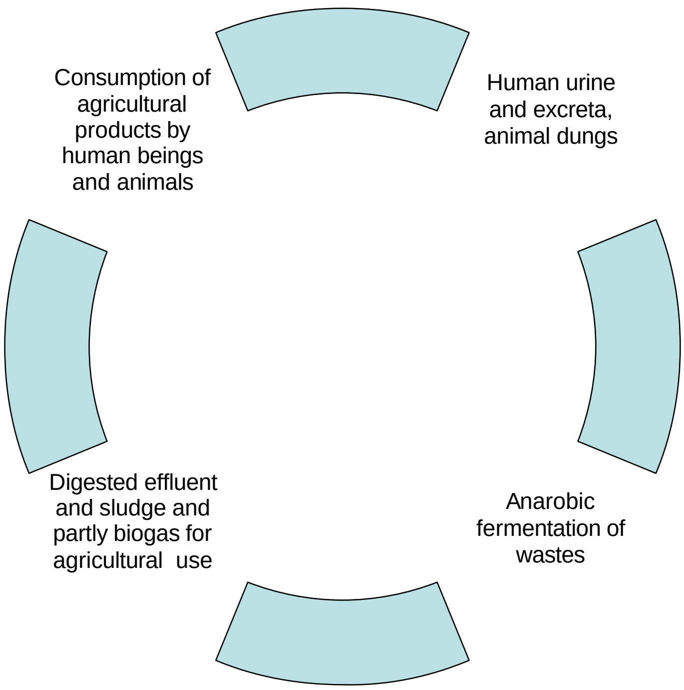

Figure 1: "Closing-Loop" of the integrated biogas system

Varying on various features of climate, agricultural production structure, availability of resources, as well as social behaviors in different regions in China, there are three major typical models in China. Shortly, there are named as "four-in-one" in cold Northern China, "pig-biogas digester-orchards" in southern China with more tropical climate, and "five components integration" in Northwestern China with dry climate.

I. "Four-in-one" model in cold Northern China

The system is consisted of the following essential components: a solar greenhouse facing the south with a area of around 200 – 600 m², a 20 m² animal house at its western or eastern side of the greenhouse, a 1 m² toilet, and a biogas digester with a volume of 6 m³ underground the animal house.

The northern model integrates the biogas digester, animal house, toilet, and the agricultural plantation in a closed solar greenhouse which keeps the digester, animal house, and plantation with an appropriate temperature and humidity to make the biogas production, animal raising, and plant growth possible in cold winter in Northern China. The greenhouse is constructed with a well-insulated wall as the framework at the northern side and usually adopts plastic film for sunshine transfer at the side facing south. The test done by Liaoning Rural Energy Office shows that even when the outside temperature is minus 20 °C, the inner temperature can reach over 10 °C, which enables the biogas production and agricultural plantation. Meanwhile, the animal breeding also helps to raise the greenhouse temperature. Measured by Liaoning Rural Energy Office, ten pigs weighing over 50 kg in pigpen inner a 100 m² enables the greenhouse temperature raise 1°C, and ten pigs weighing over 100 kg 1.5 °C. Carbon dioxide produced from exhale of pigs and combustion of biogas inner greenhouse increases the temperature of greenhouse and provides the plants as carbon fertilizer. On the other hand, the photosynthesis of plants provides sufficient oxygen for animal breath. The digested effluent and sludge from biogas digester is used as fertilizer for plants, which replace the application of chemical fertilizer and enable the vegetables and fruits certificated as non-polluted products.

All the system components form a well-circulated loop of energy and material flows (Fig 1).

A integrated system with a greenhouse covering 667 m², in which 494 m² of agricultural plantation land, a 8 m² biogas digester, a 20 m² pigpen, and a 15 m² room for farmers' stay, costs around US$ 1,840 as primary investment. With a yearly incremental revenue of around US$ 635 from sale of plants and pigs and save of chemical fuels and fertilizer, the dynamic investment recovery period is less than three years when taking 10% as the discount rate.

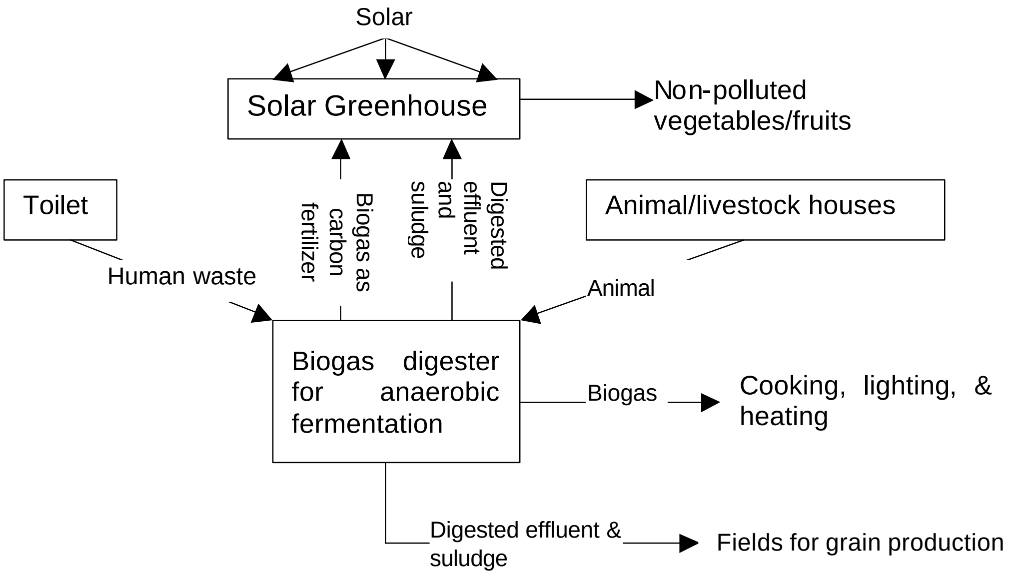

Figure 2: Sketch of "four-in-one" model in Northern China

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II. Pig-biogas digester-orchards"model in Southern China

The typical model on integrated biogas system for tropical southern China is normally consisted of the following essential components: an animal house (pigpen) covering 20 m^2 with 4-5 pigs in stock normally, a 8 m^3 biogas digester, and 0.33 hectare of orchard land or vegetable land. Similarly with the northern model, the digested effluent and sludge are applied for fruit or/and vegetable production, and the biogas for household cooking and lighting. Additional to that the toilet is connected with the inlet of digester, in some modern styles, the digested effluent can even be used to flash the toilet, which saves the water consumption. The improved orchard land, reconstructed pigpens, nearly built digester, and reformed sanitation toilet costs around US$ 585. With direct saving of cooking fuels and electricity by biogas, saving of chemical fertilizer by organic fertilizer, and incremental income from more and better quality fruits (vegetables, etc.) and pigs, the total revenue from the biogas integrated system is estimated as US$ 280, which makes the invested recovered in about two years.

More importantly, the replacement of firewood by biogas in southern China has a significant role on local ecological improvement. It is estimated that one biogas integrated system with a warm climate in Southern China can produce 450 m^3 of biogas. It is equivalent to the yearly growth of 0.35 hectare of firewood forestry.

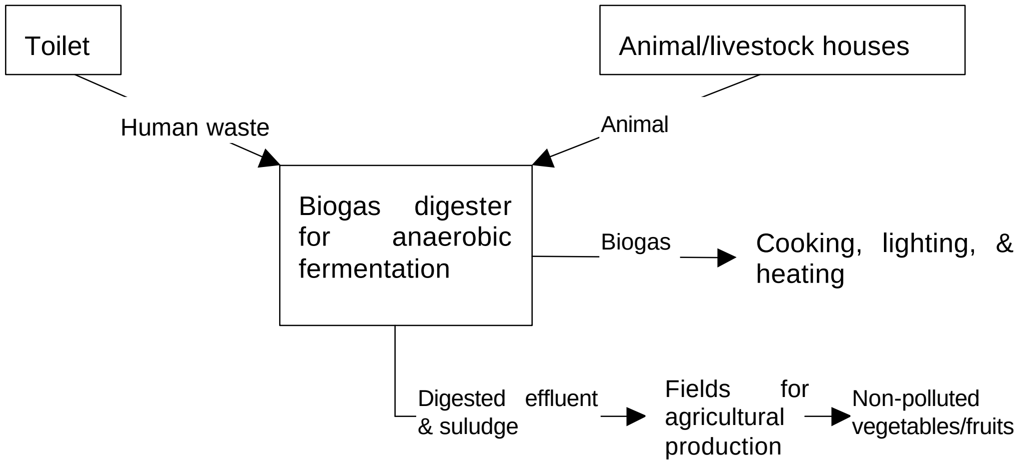

Figure 3: Sketch of "pig-biogas digester-orchards"model in Southern China

III. "Five components integration" model in Northwestern China

Considering the dry climate in North-western China, based on the availability of arable land, the system integrates 0.33 hectare of orchard land, a stay room for orchard care persons, 8 – 10 m^3 covered water tank, a 10 – 20 m^2 pigpen covered with plastic film in winters for 4 – 6 pigs in stock or sheep house, a 8m^3 biogas digester under the pigpen, and a toilet into one system. The biogas digester is the core which combines the plantation with the animal breeding, and the domestic life with the production. The water tank for saving rainfall in rainy seasons for the whole-year-around consumption provides water for not only human beings, animal or/and livestock, and biogas digester, but also production use of plantations.

The whole system including the improvement of orchard land and construction of a orchard care room, a 20 m^2 solar pigpen, a water tank, and a 8 8m^3 biogas digester costs US$ 646 in local price level. A yearly saving of fuels by biogas use and of chemical fertilizer by organic fertilizer application and a yearly incremental income from fruits or/and vegetable production and pig breeding account for US$ 256 in average. Consequently, the primary investment can be recovered in three years.

IV. Comprehensive utilization of products from the systems

Biogas for carbon dioxide in greenhouses

The content of carbon dioxide in atmosphere is around 0.03%. While biogas combustion in greenhouses can increase its content to over 0.1%, which accelerates the photosynthesis of plants, then their yields. Table 1 shows the impact of different contents of carbon dioxide to plants in greenhouses.

Content of CO_2 (%)	Celery		Cucumber yield (kg/m^2)
	Height of plant (cm)	Weight of single plant (g)	
0.02 – 0.03	44.9	7.8	7.8
0.08 – 0.11	66.8	12.5	10.3

Table 1: Impact of carbon dioxide increase by biogas combustion in greenhouses (Source: Zhou, 1999)

Fertility of digested effluent

For the anaerobic fermentation is a complex biochemical process, the contents of digested effluent vary with the differences of raw materials, rotation time, fermentation technique, etc.. Table 2 shows a test on its fertility.

Digested effluent	Whole C (mg/ml)	Whole N (mg/ml)	Whole P (mg/ml)	Whole K (mg/ml)	NH_3- N (mg/l)	Rapid effective P (mg/l)	Rapid effective K (mg/l)
Number of samples	135	133	74	75	74	78	78
Maximum content	4.82	0.99	0.98	3.90	971	315	3,900
Minimum content	0.42	0.09	0.10	0.38	24	4.95	375
average	2.03	0.39	0.37	2.06	295.5	73.32	1,758.3

Table 2: Fertility contents of digested effluent (Source: Yuan, 2001)

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Conclusions and recommendations

The experience on integrated biogas system application in China shows that the different models designed on various local natural and economic conditions fit the local demands. They practice the theory of closing the loop by integrating biogas production by anaerobic fermentation with “wastes” treatment and agricultural utilization, by taking the “wastes” as valuable resources for agricultural use, and contributing to the improvement of sanitation condition in rural China.

However, in the current systems, there is no separation between urine and excrete in human wastes, and the animal waste is mixed with all the human waste from toilets. After anaerobic fermentation with normal-temperature (without any external heating input and the fermentation temperature varies upon the surrounding environment), the digested matter is applied for agricultural use without any further hygienic treatment. Therefore, it is recommended that there is urgent need on systematic studies on pathogen killness effectiveness in normal-temperature anaerobic fermentation and on safeness of agricultural use of digested effluent and sludge, such as their application on plantation. Specially, there is a use of digested effluent and sludge for animal breeding like pigs or/and fish. In this issue, a joint work between international and national efforts and a joint team composing expertises from different sectors including resource management, energy, health, sanitation, etc. should be fully encouraged.

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Composting with human urine: plant fertilizer approach*

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Keywords

Composting, fertiliser, human urine, plants, nutrients, temperature

Abstract

The purpose of this study was to collect the nutrients contained in human urine (nitrogen, phosphorous and potassium) by composting with grass leaves and fruit peel and to increase the compost activity by decreasing the C:N ratio. Compost temperature was used as an indicator of compost activity.

The tests demonstrated the importance of the structure in the material for good aeration of the compost, as ground raw material maintained lower temperatures than non-ground. Adding urine increased the nutrient content of the compost. Some of the nitrogen was lost as ammonia emissions but there was still more nitrogen and presumably more other macro- and micro-nutrients in the compost after urine addition. Addition of approximately 10-15% urine to the wet weight of the compost material increased the compost reaction and rendered a higher top temperature of the treatment. Thus, adding urine to the compost process can render better sanitised and stable mature compost in a shorter time period compared to when no urine is added.

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Introduction

Most of the nutrients in household wastewater come from human urine, approximately 80% of nitrogen and more than 50% of phosphorous and potassium (Vinnerås, 2002). However, urine only contributes 1% of the volume of household wastewater (Figure 1).

The nitrogen and the phosphorus are potential pollutants that have to be removed in the wastewater treatment plant. Most toilets in Thailand are water closets. The household wastewater is normally treated in septic tanks, located underground at each house, and discharged to the closest water recipient, groundwater or surface water.

In this kind of water-borne system, there are mainly two preferable solutions: 1) Large sewage treatment plants; and 2) Decentralised, source separating systems that recycle the nutrients and keep the pathogens out of the water.

In this region, large-scale wastewater treatment is not an economical option, except for the central parts of larger cities.

The overflow of these septic tanks finds its way to the nearest canal or possibly seeps and contaminates the underground water. This results in contamination by chemicals and microorganisms, leading to disease transmission and difficulty in locating clean drinking water.

*This paper has been peer reviewed by the symposium scientific committee

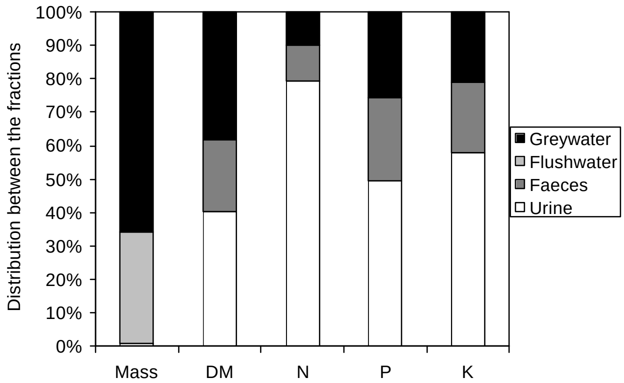

Figure 1: The amount of mass, dry matter, nitrogen, phosphorus and potassium in the different household wastewater fractions. The flushwater included represent the water usage of an average Swedish single flushed toilet (6l/flush). (Vinnerås, 2002).

In the near future, the cost of clean drinking water production will increase to levels not affordable for increasing parts of the community.

Separating urine right from the source and treating it in a small volume would be an easier option but in view of its nutrient value, it is even wiser to use this urine as plant fertiliser and gain the extra benefits to the economy and the environment. Taking the proposed new Swedish norm (Table 1), the amount of urine produced per person and year is 550kg, which in terms of nutrients represents 4.0kg N, 0.365kg P and 1.0kg K (Vinnerås, 2002).

		Urine	Faeces	Toilet paper	Greywater	Biodegradable waste
WM	Kg	550	51.5	8.9	36500	80.3
DM	Kg	21	11	8.5	20	27.5
BOD_7	g	-	-	-	9500	-
COD	g	-	-	-	19000	-
N	g	4000	550		500	550
P	g	365	183		190	104
K	g	1000	365		365	82
Cu	mg	37	400		2900	549
Cr	mg	3.7	7.3		365	137
Ni	mg	2.6	27		450	82.3
Zn	mg	16.4	3900		3650	700
Pb	mg	0.73	7.3		350	275
Cd	mg	0.25	3.7		15	2.7
Hg	mg	0.30	3.3		1.5	0.25

Table 1: The proposed norm for composition of the different fractions of household wastewater and biodegradable solid waste per person and year

The urine from the 14.000 students at King Mongkut's Institute of Technology, North Bangkok, corresponds to 56 tons of nitrogen, 5.1 tons of phosphorous and 14 tons of potassium per year. This urine is enough to fertilise 400-500 hectares.

Getting people in Thailand to accept application of human urine as a fertiliser is not easy. The main issue is the sociological difficulty, as the common belief is that human excreta are dirty and a disease transmission pathway. Approved sanitisation methodology by storage at temperatures above 20°C for six months is one of the keys to this barrier (Höglund et al., 1999, 2000, 2002). Other difficulties in implementing these systems are of a more practical nature: 1) There is no urine source separating toilet seat available in the sanitary products market in Thailand. 2) Urine is liquid and to transport this volume to the farm or application site is costly. Evaluating the energy consumption for transport compared to wastewater treatment and production of mineral fertilisers, it is still economical to transport the urine 200km (Jönsson et al., 2000).

One way to tackle the transport of these large volumes could be to trap the nutrients of the urine in a biological process by composting with carbon-rich organic waste. The nitrogen in the urine would increase the biological processes as the energy production increases, which would increase the temperature of the compost. The higher temperature achieved would make the compost safer, as pathogens and weed seeds would be killed by the treatment (Vinnerås et al., 2003). It would also be possible to capture some of the nutrients chemically by precipitation, e.g. adding Mg^{2+} to the urine precipitates struvite (NH_4MgPO_4). However, this kind of chemical treatment would only make it possible to capture the phosphorus and some of the nitrogen, while the major proportion of the other nutrients would still remain in the liquids. When using the urine in the compost, some of the nitrogen would be lost while the major proportion of the other nutrients, both macro- and micro-, would remain in the compost.

Composting

Composting is a biological decomposition of organic biodegradable material. As a result of the compost process a dark, soil-like material is formed. The degradation mainly occurs by the enzymatic digestion of material by soil microorganisms. Composting can be both aerobic and anaerobic, depending on the local conditions. Different conditions such as temperature and oxygen content lead to different microorganism concentrations, but the end product from the treatment is more or less the same. However, aerobic treatment can give rise to higher temperatures, due to more exothermic reactions. Anaerobic treatment gives a smaller final volume, as less organic material is used for construction of cell matter compared to in aerobic treatment.

The composting of organic matter can occur in different temperature ranges. Psychrophilic bacteria work in the lowest temperature range -18 to +13°C. Psychrophiles give off a small amount of heat as a by-product of their work, and this causes a rise in the ambient air temperature in the pile. Mesophilic bacteria act in a mid temperature range 21-32°C. Above that temperature, between 40°C and 93°C, the thermophilic bacteria are active.

In a normal aerobic composting process, the temperature first rises to about 35 °C, during which time the pH drops to approximately 4. After a few days with a temperature of about 35 °C, the pH increases and as a result of that the thermophilic bacteria increase their activity, which results in a rapid rise in temperature (Smårs et al, 2003). This high activity, optimal activity, occurs at approximately 55°C (Haug, 1995), and if it can proceed for a few days, much of the available organic material is degraded. This degradation leads to poor structure and a decrease in the temperature. Turning the compost material constructs new pores for the aeration and creates new contact areas for the microorganisms to find more easily degradable carbon. These two factors produce another increase in the temperature of the compost.

Diversity of composting materials

The diversity of the raw materials used is the key factor to good compost. In addition to major plant nutrients such as nitrogen, phosphorous and potassium, plants need several trace elements too. The more diverse the material composted, the more likely it is that these elements can be returned to the plants. Using a diversity of materials also increases the chances of having a suitable carbon-nitrogen ratio in the compost material. The C-N ratio in the compost directly affects how well the materials are composted. It is the term used to describe how much carbon a material contains relative to nitrogen. Microorganisms metabolise carbon for energy, and nitrogen for reproduction. The microorganisms use these two elements in the proportions of about 25-30 parts carbon to one part nitrogen. With this ratio in the substrate, the microorganisms can work and reproduce quickly if other factors such as aeration and moisture also are adequate. However, most materials available for composting do not have this ratio. Therefore, different materials need to be mixed into the compost to get a good mixture and C:N ratio. For example, mixing 50% by weight of brown tree leaves (C:N=40:1) with 50% grass clippings (20:1) results in a fast decomposing blend, with a 30:1 ratio. The C-N ratio of matured compost should not exceed 20, as a lot of carbon is lost during respiration by the microorganisms (Haug, 1995). During this process, a considerable amount of nitrogen, 40-60%, is also lost due to gaseous emissions.

Objectives

The main objective of this study was to determine the effects on the compost process of biodegradable household waste when the nitrogen content was changed, both on a small scale (1 litre) and pilot scale (200 litre).

Another objective was to see the dependence of the compost temperature when using different turning intervals. The final objective was to monitor and evaluate the effect of the nitrogen content in the matured compost using the different mixes and turning strategies.

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Materials and methods

Materials

The urine was collected in a urinal installed at the Department of Industrial Chemistry. The urinal was connected via a plastic pipe to a small collection tank that was emptied every second day into a larger storage tank.

Two different sets of composters were used in the tests. Initially, small scale composting was

a b c

Figure 2: a) the urinal for collection of urine, b) the 1 litre urethane foam compost reactors, c) the 200 litre plastic compost reactor.

carried out in approximately 1 litre urethane foam compost reactors (Figure 2). For the larger scale tests, 200 litre compost reactors were used, one of plastic (Figure 2) and one of iron.

The composting material used in the tests consisted of grass, leaves and fruit peel as the carbon source. To get a good structure in the compost, chopped coconut husk and coconut fibre was used as an amendment. The collected human urine was used as the nitrogen source. To get a good initial microbiological population in the compost material, old, mature, compost was also added.

Eight sets of experiments were performed in the small compost reactors. The material composted was a mixture of 500g fruit peel, 50g coconut husk amendment, 130g old compost and varying amounts of urine (0, 50 ,100 ,150g). When different amounts of urine were added, the moisture content was adjusted by water addition to a level corresponding to the highest urine addition (150g). Two different sets of fruit peel were used, one where the peel was ground into small pieces and one where it was added as it was, in larger pieces. The composts were tuned/mixed every day and the temperature was monitored during the tests.

During the pilot scale composting in the 200 litre reactors, a mixture of 14 kg fresh grass, leaves and fruit peel was mixed with 2kg coconut amendment, 10kg old compost and different amounts of urine (0, 1, 3, 6kg). When different amounts of urine were added, the moisture content was adjusted by water addition to a level corresponding to the highest urine addition (6kg). Two different turning regimes was tested for the compost reactor, one reactor was turned every day and the other every third day. During this experiment, the temperature and the difference in nitrogen content in the final product was tested.

The nutrient content in the matured compost was analysed for its content of nitrogen, phosphorous, potassium and organic carbon. The nitrogen was analysed using the Kjeldahl method. Phosphorus was analysed by spectrophotometer (420 nm). Potassium was analysed using ICP-EAS. The total organic carbon was analysed using the Walkley-Black method (oxidation with $K_2Cr_2O_7$ in conc. H_2SO_4 followed by titration with $FeNH_4SO_4$ using o-phenolphthalein ferrous sulphate as indicator).

The buffering capacity of the matured compost was investigated as the pH of the mixture of 90% distilled water and 10% compost was monitored when 0.5M HCl was added. The buffering capacity of the compost was compared to the capacity of distilled water, and presented as the difference in HCl consumption for decreasing the pH from 7 down to 4.

During the 3 weeks of composting, the leachate was collected and the pH was monitored every second day.

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Results and discussion

In the small sale composting reactors, two different structures of the material were tested; ground and non-ground fruit peel and different amounts of added urine. A tendency towards a higher temperature was found in the tests with non-ground material (Figure 3). The main reason for this was probably an effect from the better structure attained in the reactors with non-ground fruit peel. The higher structure resulted in better aeration of the material and thereby higher activity.

The different addition regimes of urine indicated that addition of 14% urine by wet weight to the mixture gave the best effect. This clear tendency was evident in reactors with both ground material and non-ground material.

Initially, the two pilot scale reactors were compared for their heat loss; both reactors had only small amounts of insulation. The results showed that there were high losses of heat from the reactors, even when the surrounding air temperature was between 25 and 30°C. No significant difference was found between the two construction materials, plastic or iron, of the reactors

(Figure 4). However, there was a tendency to be colder in the iron reactor, probably due to less insulation.

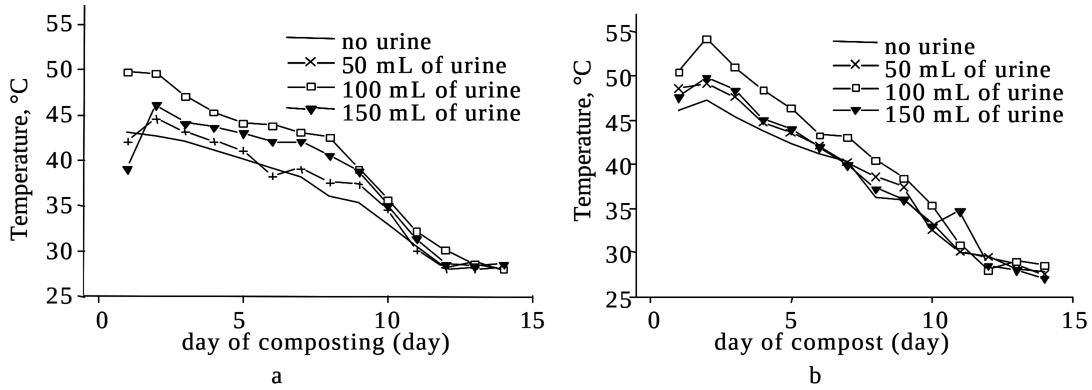

Figure 3: Temperature over time with different urine additions to pilot-scale compost reactors with a) ground and b) non-ground fruit peel.

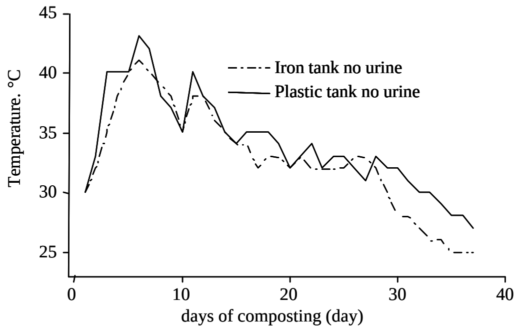

Figure 4: Effect of composting reactor construction material (iron or plastic) on compost temperature

Adding urine to the compost material gave a higher increase in temperature and a higher final temperature compared to the material to which no urine was added (Figure 5), although there were no significant differences in temperature of the compost between 1 litre and 3 litre addition of urine. The addition of urine also resulted in a more rapid process, so the urine composts were faster to reach the ambient temperature (Figure 5).

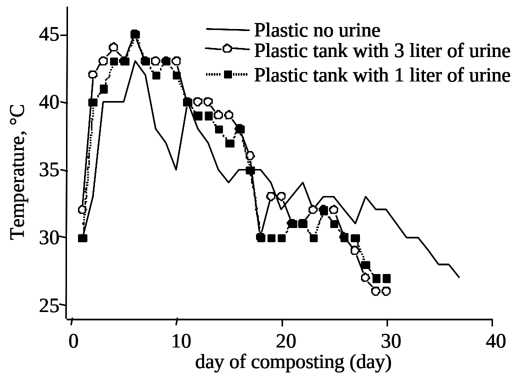

Figure 5: Effect of addition of 1 or 3 litres of urine to compost on temperature in the compost reactor.

Comparing the two different turning regimes for the compost every day to turning every third day, both the treatment temperature and the duration of treatment differed (Figure 6).

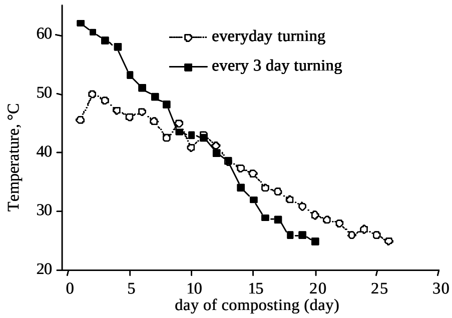

Figure 6: Effect of turning frequency on compost temperature.

When compost is turned every day, the material is cooled down to such extent that it is not possible for it to reach as high temperatures as a compost turned every third day. On the other hand, frequent turning of the compost material is important in maintaining a good structure for aeration and in creating new contact surfaces between the material and the microorganisms. Therefore during high activity phases, the compost should be turned more often than during low activity phases.

The total amount of nitrogen in the compost when greater amounts of urine were added increased somewhat (Fig. 7). The different turning regimes (1 day per turn and 3 days per turn) gave a significant difference in the amount of available nitrogen in the mature compost. The lower turning rate resulted in a significantly higher amount of nitrogen remaining in the compost.

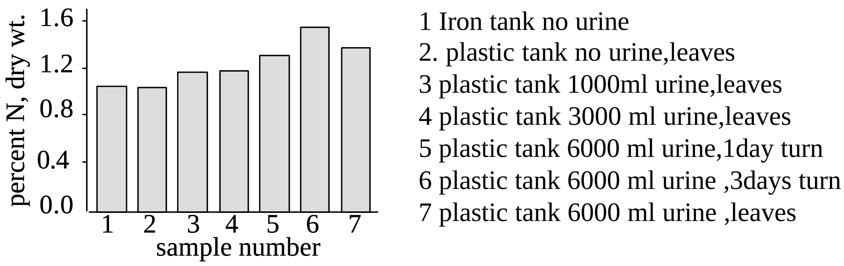

Figure 7: Nitrogen concentration in the matured composts with different urine additions and turning regimes.

In the compost mixes to which urine was added, the C/N ratio decreased compared to the no urine mixtures. This was mainly due to higher nitrogen content (Figure 7) combined with higher degradation of the organic material. Looking more closely at the different dosages of nitrogen in the compost process, the addition of 3 kg urine to the reactor had a major effect on the degradation of organic matter (Figure 8), especially since the concentration of nitrogen in the matured compost was similar to that in the compost that received only 1 kg (Figure 7). However, this indicates that the high degradation of organic matter was accompanied by a major loss of nitrogen, probably as ammonia emissions that can affect the environment in terms of eutrophication or acidification.

The highest addition of urine (6kg) with the lower turning frequency resulted in a higher amount of nitrogen in the end product, but a comparison of Figs. 7 and 8 shows that the lower turning rate tended to give a higher degradation, probably due to the higher activity in the material as indicated by the higher treatment temperature.

The pH in the compost leachate remained quite stable during the whole composting process within the range 7.96 - 8.03.

The buffering capacity of the compost material was significantly higher compared to that of the distilled water, so adding the compost to soil as a fertiliser would improve both the fertility of the soil and its buffering capacity.

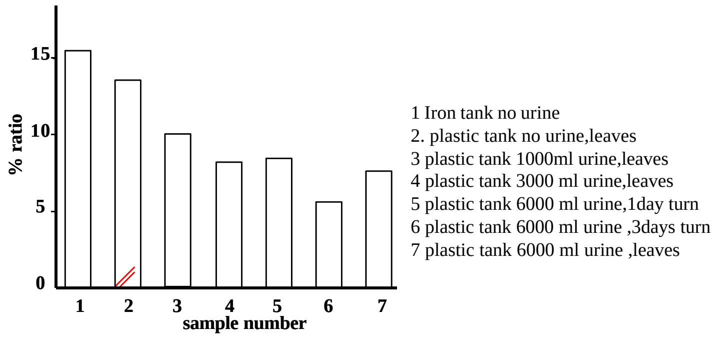

Figure 8: Carbon/nitrogen ration of the matured composts with different urine additions.

Conclusion

The small-scale treatments showed the importance of the structure in the material for composting, as the ground material did not reach as high temperatures as the non-ground one.

Addition of urine increases the nutrient content of compost. Even though some of the nitrogen may be lost as ammonia emissions, the compost still contains more nitrogen and presumably more other macro- and micronutrients too.

The addition of approximately 10-15% urine to the wet weight of the compost material increased the compost reaction and produced a higher top temperature of the treatment. Thus, adding urine to the compost process renders better sanitised and more stable mature compost in a shorter time period compared to when no urine is added.

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Sewage sludge humification in a sequential conversion procedure

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Keywords

Conversion, fertilising, sewage-sludge, soil-conditioning

Introduction

The reuse and disposal of sewage sludge has become of great interest all over the world. Intending to improve the acceptance ipp-consult has developed a system to convert sewage sludge to a substrate similar to humus (humification or conversion of sewage sludge). In a PPP-measure ipp-Consult has been contracted by GTZ to introduce this process in Egypt, where it had to be adjusted to the Egyptian climatic, social and economic conditions.

Project background

The drying of the sewage sludge in drying beds is the most common method in Egypt and also appears as the most efficient technique due to the normally short drying intervals. However the morphological, chemical and hygienic quality of the dried product is insufficient.

The content of nutrients in the sewage sludge is high, 1 kg of dry matter in Egypt contains for example an average of 17 g of nitrogen, 10 g of phosphorus, and many other micronutrients. These nutrients get lost from the nutrient cycle, if sewage sludge is simply disposed, i.e. dumped or burned, and not re-used. Therefore, sewage sludge should be regarded as a resource of nutrients and soil conditioner which can be used as a high-quality organic fertiliser in agriculture. Fresh sludge contains, besides harmless germs of the intestinal flora, also pathogens.

In Egypt the use of sewage sludge is legally restricted (Egyptian Sludge Regulations; Decree 214/1997), and these regulations are difficult to be complied with. Quality characteristics, which are important and indispensable, were taken from the American guidelines (Clean Water Act, Part 503, 1993), but their realisation was not sufficiently considered. According to these guidelines, sewage sludge can only be applied on arable land, if its hygienic qualities are proved by a corresponding analysis. Expensive analyses of the microbiological parameters have to be effected on a regular basis at the expense of the plant user and/or of the purchaser. Furthermore, a number of bureaucratic obstacles make the legal sale and the re-use of sewage sludge more difficult.

Project targets

Primary target of the project „Sewage sludge conversion in Egypt“ is the long-term improvement of the environmental situation with respect to sewage sludge and to establish an effective and sustainable method to gain a product of high quality from sewage sludge in the project locations El Minia and Nawag. The training of local experts shall provide a multiplication effect, which enables operators of waste water treatment plants of other communities to apply and integrate the method in their sludge treatment system. Furthermore, the product shall be used in agriculture as a fertiliser and soil conditioner.

Aimed results

After completing the project, technically and socio-economically acceptable solutions should be elaborated, tested and applied, which are transferable to other climatic regions in Egypt.

The method of sewage sludge conversion should known by other treatment plant operators as well as authorities of other regions within Egypt.

The correct application of converted sewage sludge as a high quality fertiliser should be known by farmers in the region of the project locations El Minia and Nawag. The awareness among the farmers, participating experts and treatment plant operators with respect to the interrelations between agriculture, environmental protection and soil protection should increase.

Course of the study

The project, which was initiated in March 2001, was executed during a period of 17 months. The study was divided into phases. Phase I (3,5 months) mainly served for organisatory tasks (selection of locations, permissions) and for first large scale experiments at the locations Tanta and El Minia. After some dissatisfying results, the experiments were continued in a bigger programme on a small scale in Nawag (Phase II: 3,5 months). Here, it was possible to determine the plant species to be used as well as the methods of operation. In Phase III (6 months) the results of the previous phase were tested with respect to their transferability on large scale in Nawag and El Minia. The fourth and last phase (4 months) of the project served for the execution of several agricultural experiments and field tests and the presentation of the project. The presentation of the project and information of the farmers was based on the execution of a socio-economic field study. The information campaign covered the local region as well as the governmental basis.

Present situation – problems of the dried sludge

The fast drying of sewage sludge in hot and dry climate has the disadvantage that the hydrolytic and microbiological decomposition as well as the microbiological conversion of organic and inorganic substances is minimized. After a few days, the humidity is not sufficient for the survival or the reproduction of microorganisms. If the dried product is applied in agriculture offensive odours may occur.

Disadvantages are often the big size and hardness of the lumps, the low water storage capacity, the low hygienisation rate and the low microbiological conversion of the organic substances during the short drying period.

The agricultural experiments with dried sludge in El Minia and Nawag showed that the product has high contents of substances which have harmful effects on plants. This substances lead to lower germination rates and to a slower development of the plants. The hygienic analysis showed a general decrease of pathogenic germs, but after a drying period of some months the product still contains, a high risk potential with respect to salmonellae and Helminths. All these disadvantages can be avoided with a well operated conversion system.

Basic knowledge about sewage sludge conversion

Sewage sludge conversion with grass

The principle of the conversion of sewage sludge is based essentially on the development of an environment in the sludge which differs considerably form the environment which appears in the drying sludge. The development of leaves and roots support the reproduction and development of micro-organisms which can also be found in natural soils. This mainly happens because of the dying and of the regeneration of root-cells, the aeration and the chemical compounds (root-exudates), which are emitted by the roots of the plants.

Sewage sludge is filled in layers of 30 – 40 kg TS/m² into so-called conversion polders. These polders usually have a usable depth of 1 m. A minimum filter layer of 20 cm of sand above 20 cm of gravel should be provided. Between the filling of each layer the sludge should dewater through air-drying and drainage.

After the completing of the fillings, the sludge dewaters until first cracks appear on the surface. The establishment of an environment similar to soil provides different decomposition processes in the sludge, which are comparable to the generation of humus or the composting of sewage sludge. Apart from the additional aeration, the penetration of roots has the effect of loosening up the sludge which is preventing the creation of large lumps during further drying.

After the complete development of the grass and the conversion of the first layer, the next layer of sludge can be filled in. With each further layer, the above described process will be repeated until the polder is filled (40 – 50 cm). The already developed environment in the lower layers probably plays an important role in the conversion of the next layer. Also the grass, which is not harvested, has an important influence by providing a structure and additional aeration of the fresh sludge after the filling. After the completing of 4 – 5 cycles, the product can be used.

Sewage sludge conversion with reed

In contrast to the conversion with grass, the reed species "Phragmites australis" is planted in polders with depths of 1 m – 1.5 m. For a better development, the filter layer (comparable with the filter layer of the grass conversion polders) is covered with a layer of soil (20 cm). At first, the reed develops a complex root system, after that, with the increasing height of the sludge, a rhizome system is developing.

The rhizomes begin to grow at the vegetation points when they are covered with sludge. This development provides the additional aeration of the sludge and supports the development of an environment which is similar to a natural reed location. Through the metabolism of the reed, the organic substance in the sludge is mineralised. The processes are comparable to the conversion with grass. The difference is that reed can grow also in anaerobic environments. The reason for this is that reed can transport oxygen from the green parts of the plant to the root zone.

The filling can be carried out in relatively short intervals. Normally the polders are used for 5 up to 10 years without emptying. Therefore, the method is continuously in contrary to the discontinuous conversion with grass, however the product contains a lot of reed roots and straw is only partly decayed.

Operational differences of sludge conversion compared to Germany

Conversion with grass

The most important difference to the operation of sludge conversion polders in Germany is the necessity of irrigation and the application of other grass species. Already the experiments in Nawag during the second phase have shown, that the regular irrigation of the sludge is indispensable for the germination and development of the grasses especially during the first weeks of growth. Especially in the germination phase the process is very sensitive. The use of pre-germinated seeds as well as the covering of the surface with straw is recommendable to support the germination.

The operation of a conversion facility in Egypt requires more attention than a comparable plant in Europe. Another difference is the use of tropical grasses for the process.

For the safe and functional operation of a sewage sludge conversion plant (SSCP) it is necessary to fulfil the following requirements:

- Existence / Installation of an irrigation system or irrigation facility. This can be treated waste water or liquid sludge in limited charges.
- Detailed schedule for the operation and maintenance of the polders
- Homogenous quality and sufficient biological stability of the sludge
- Sufficiently trained and motivated personnel

Experiences in El Minia and Nawag have shown that the process of conversion is sensitive especially in the first 2 weeks after seeding. The germination of the grass seeds on sludge of low biological stability need regular irrigation. A necessary post-stabilisation of the sludge leads to delays in the process and more space required.

Conversion with reed

The experiences in Nawag have shown, that the reed is less affected by the stabilisation grade of the liquid sewage sludge. For this reason, the required stabilisation is minor in comparison to the conversion with grass. Nevertheless, it is necessary to work with lower loads in the case of a low biological stability, which results in a reduction of the possible annual load.

The necessary and strict fulfilment of the loadings is a disadvantage of this method because it is not possible to react flexibly to high overloads and plant damages. Another disadvantage of the method is the necessity to chop up the final product to prevent the development of reed plants after the application on the field. This is dangerous, especially in Egypt, because the agricultural field are mostly irrigated by flooding which is an optimum condition for reed to sprout again.

For the operation of the sewage sludge conversion with reed, the following requirements must be fulfilled:

- The upper filter layer (sand) in the polder should contain sand of the quality 0/2. Coarse sand leads to negative results
- The outlets of the polder drainage should be equipped with valves to provide the possibility to inundate the polder for some days during the growth of the reed
- A detailed schedule for the operation and maintenance is indispensable
- A homogenous sludge quality and a sufficient grade of biological stabilisation of the liquid sludge are desirable.

Results of investigation - quality of the products

Morphological and aesthetic quality of the products

For the evaluation of the results a comparison between the products of the well-known and practiced drying of sludge and the conversion of sludge was made:

Dried product	Converted sludge
The structure shows large lumps	The structure is crumbly and looks like soil penetrated with roots
The colour is black-grey	The colour is mainly brown
Faecal odour develops after moistening	Only the odour of soil can be noticed
The sludge attracts flies, larvaes and ants	

Table 1: Average morphological and aesthetical appearance

pH-value, content of salt, organic substance

Parameter	Dried product	Converted sludge
PH-Value	6 - 7	5,8 – 7,18
Chloride	1,94 %	0,435 %
Sulphate	2,09 %	0,378 %
Electrical Conductivity	9,15 mS/cm	0,99 mS/cm
Volatile Solids	52 % - 75 %	36 % - 46 %

Table 2: Average pH-value, content of salt, organic substance (Nawag)

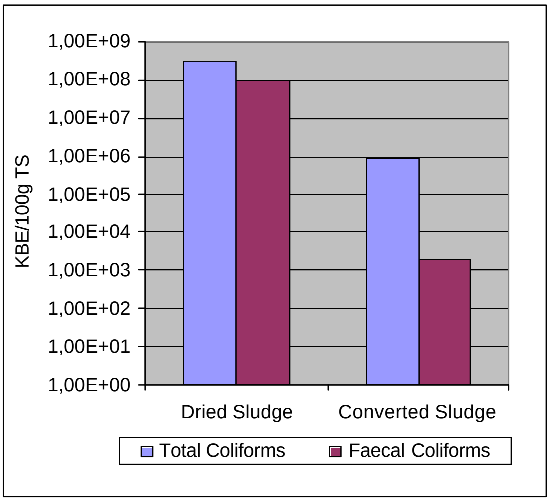
Plant nutrients

Parameter	Dried product	Converted sludge
Total Nitrogen	2,4 %	2,9 %
Total Phosphorous	0,5 %	0,6 %
Potassium	0,2 %	0,4 %
Magnesium	0,3 %	0,8 %

Table 3: Average concentrations of plant nutrients

Hygienic and microbiological qualities of the product

The efficiency of the reduction of coliform germs, faecal coliforms, salmonellae and helminth eggs is very different. The method of sludge conversion has evidently a strong hygienisation effect whereas the majority of the germs survive during the simple air drying of sludge.



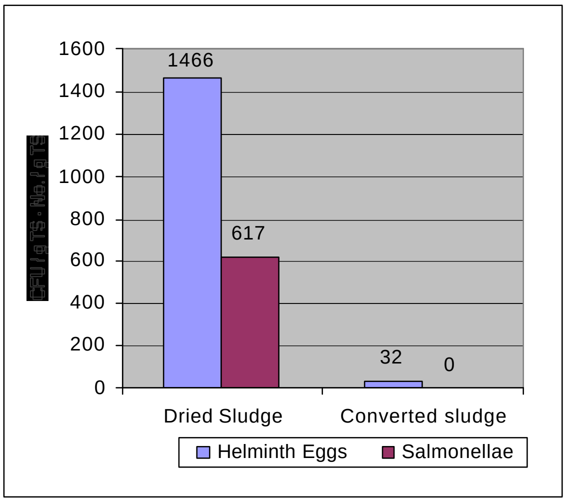


Figure 1 (left): Contents of Total Coliforms and Faecal Coliforms (Nawag)

Figure 2: (right): Contents of Salmonella and Helminth Eggs (Nawag)

Indicator for the contents and formation of humin-nutrient complexes is the micro organism Actinomycetis. Also here notable differences are observable.

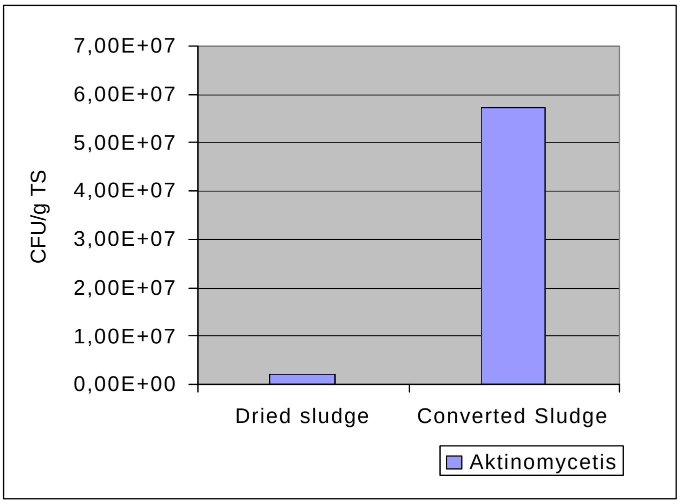


Figure 3: Contents of Salmonella and Helminth Eggs (Nawag)

Agricultural experiments

The agricultural experiments in Nawag and El Minia were initiated to examine the quality of the converted sludge. At the same time, the suitability of the dried sludge was examined under the same conditions to give hints referring to its characteristics as fertiliser and soil-conditioner. The experiments showed evidently that with respect to both objectives of examination (germination rate and yield) the application of converted sludge is preferable compared to the use of air dried sludge. The germination rates in the sand were so low, that the aimed minimum number of plants per plot often was not achieved.

Especially the results on pure sand in Nawag obviously indicate that the availability of nutrients in converted sludge is adapted to the demand of the plants compared to the instantly available nutrients in dried sludge is potentially dangerous for the cultivated plants (Over-fertilization). The figure below shows the development of the plant Ladyfinger (Okra) in sand with different additions of dried and converted sludge.

Figure 4: Development of Ladyfinger on sand (f. l. t. r.: with 30l dried sludge, 10l dried sludge, 30l converted sludge, 10l converted sludge and without any soil conditioners)

Field study: agricultural application of sewage sludge

The results of the study show that the application of sewage sludge is known by the majority of the farmers. Furthermore, the study reveals that dried sludge is applied in Egypt and that the demand is increasing. Concerning the application of the converted sewage sludge product, the study draws the conclusion that the use can be supported by information and advisory campaigns, above all because the time needed from the first perception to the adoption of a method is up to 4 years. Most of the interviewed farmers prefer the application of sewage sludge products for the cultivation of crops and are interested in expanding the use of these products. Main limits are the high prices and the lack of supply. The majority of the farmers is willing to visit and participate in campaigns and experiments according the topic and to transfer their knowledge. With respect to the product "converted sludge", the majority of the farmers is willing to use "converted sludge" immediately.

Conclusion

The aim of the project, the introduction of an effective and lasting method to produce high-quality sewage sludge in El Minia and Nawag, has been achieved. In Nawag, the treatment methods "sewage sludge conversion with grass" and "sewage sludge conversion with reed" were tested and applied for a period of 9 months.

The sewage sludge conversion with reed is assessed as less suitable since operational errors may quickly cause a failure in the process which cannot easily be corrected. Furthermore the reed roots within the product are feared by the farmers.

Regarding the morphological, aesthetic and hygienic characteristics, the generated sludge product, has significant advantages after a conversion period of only 2.5 months compared to the comparable dried substrates. If this technique is operated correctly, all hygienic risks, which may be caused by sewage sludge, can be reduced to a minimum.

The chemical-physical qualities of the dried sewage sludge and of the converted product could not only be determined by the analyses effected but also by the comparison of the two substrates for the agricultural use. The results indicated that the use of converted sewage sludge, even in high concentrations, has nearly no negative impact on the vegetation. Therefore, the use of converted sewage sludge might be very successful, particularly on sand, to improve the soil. Continuous applications of converted sewage sludge would also cause an accumulation of organic substances and therefore an improvement of the physical qualities of the soil of which, consequently, a lower demand of irrigation water will be the result.

Besides the quality of the crop products, there are also direct financial benefits due to an improved plant health and therefore lower expenses for fertilisers and plant protectives.

The socio-agricultural field study, carried out in July 2002, showed that the majority of the Egyptian farmers know about the possibility of using dried sewage sludge. The dried sewage sludge is used in Egyptian agriculture, however, the demand is much higher than the supply. The problems mentioned by farmers and transport companies may be solved or reduced by using the sewage sludge conversion method. Moreover, there is a considerable interest in the converted product among the interviewed farmers. The converted sludge may be successfully brought to market by means of corresponding advertising during information campaigns or by individual consulting.

Adapting the nutrient content of urine and faeces in different countries using FAO and Swedish data*

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Keywords

Plant nutrients, excreta, urine, faeces, composition, diet, countries, regions

Abstract

In a sustainable society, the plant nutrients in excreta need to be recycled to arable land as fertiliser. New source separating sewage systems are promising in this respect. To evaluate these and further develop them, their nutrient recycling should be quantified. To do this, default values on the plant nutrient content of urine and faeces are needed. This paper presents a method for calculation of such default values from easily available statistics on the food supply and default values were estimated for five countries. The estimated values were compared with those reported for one country. The agreement was good for nitrogen and phosphorus. Values of the total nutrient excretion were calculated and apportioned between urine and faeces. Urine contained most of the nutrients, but its proportion of the total nutrients varies due to varying digestibility of the diet, making precise estimation hard.

Introduction

Since the nutrients in excreta originate from arable land, recycling of them as a fertiliser is an important task for the sustainable sewage systems of the future. To evaluate the nutrient recycling potential of different source separating sewage systems, the composition of the different incoming sewage fractions needs to be known. The nutrient content of urine and faeces, which contain most of the plant nutrients in sewage, essentially equals that of the food consumed. Therefore, the default values for the composition of urine and faeces differ in different countries, due to differing food consumption. The objective of this study was to develop a method to estimate default values for the nutrient content of excreta in different countries and regions of the world.

Methods

A proposal for new Swedish default values (Vinnerås et al., Submitted) has been developed. The proposal is based on the average Swedish food consumption combined with several studies of the amount and composition of urine and faeces produced. As an example, the amounts and composition of all urine, faeces, greywater and biodegradable waste produced at Gebers, a house with 80 inhabitants, were measured during three consecutive one-week periods (Palmquist & Jönsson, 2003). The proposal for the new default values (Table 1) is based on measurements of the excreta produced during more than 3500 person days in different residential areas in Sweden.

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Based on these values, default values were calculated for other countries. The calculations were based on the mass balance for the human body and on readily available statistical data on the food supply (FAO, 2003). The mass and composition of the adult body is fairly constant. In the human body, nitrogen mainly accumulates in proteins, i.e. in muscles, phosphorus in bones and muscles, and potassium in nerves and muscles (Nationalencyklopedin, 1993). Thus, adults do not accumulate any new plant nutrients in their bodies. Our calculations on the average weight gain and the average diet of children between 3 and 13 years of age show that children accumulate only a few percent of the nutrients consumed.

Parameter	Unit	Urine	Faeces	Toilet paper	Blackwater (urine+faeces)
Wet mass	kg/yr	550	51	8.9	610
Dry mass	kg/yr	21	11	8.5	40.5
Nitrogen	g/yr	4000	550		4550
Phosphorus	g/yr	365	183		548
Potassium	g/yr	1000	365		1365

Table 1: Proposed new Swedish default values (Vinnerås et al., submitted)

The amount of nitrogen in food is linearly correlated with its protein content. In fact, generally the amount of protein in food is calculated from analyses of its nitrogen content. Therefore, the nitrogen content of the excreta was calculated from the protein content of the food supply. Statistical analysis of the composition (LV, 2003) of 180 food stuffs (staple foods, vegetables, meats and fishes) showed that the contents of phosphorus and potassium are better correlated with the content of protein than with the origin (animal or vegetal) or the energy content. The analysis also showed that vegetal food stuffs on average contained approximately twice as much phosphorus and 5.6 times as much potassium per gram of protein as animal ones. Therefore, the amount of phosphorus in the excreta was calculated according to the sum of the animal and two times the vegetal protein supplied and the amount of potassium according to the sum of the animal protein and 5.6 times the vegetal protein supplied. Table 2 gives both the input and the results of these calculations performed for China. In the Swedish measurements, the nutrient excretion was measured both for urine and faeces and approximately 88% of the nitrogen, 67% of the phosphorus and 73% of the potassium was excreted via the urine (Table 2). In the calculations we assumed that the urine in all the different countries has the same proportions of the nutrients as in Sweden.

Country, year, type	Energy cal/cap day	Protein g/cap day	N kg/cap, yr	Pkg/cap, yr	K kg/cap, yr
Sweden, 1992,total	3052	98	4.6	0.5	1.4
Vegetal	2026	34			
Urine			4.0	0.4	1.0
Faeces			0.5	0.2	0.4
China, 2000, total	3029	86	4.0	0.6	1.8
Vegetal	2446	56			
Urine			3.5	0.4	1.3
Faeces			0.5	0.2	0.5

Table 2: Example showing the input and results when the proposed Swedish default values were recalculated for China

Results

To adapt the proposed Swedish default values to other countries, the FAO (2003) food supply statistics for Sweden were compared with the corresponding food statistics of the other countries (Table 3) and the relevant values for the total excretion and its distribution between urine and faeces were calculated using the method described above. The results of these calculations are presented in Table 4.

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The most recent available statistics, those for the year 2000, were used for all the countries except Sweden. For Sweden, statistics for 1992 were used, since measurements and calculations on the Swedish diet in 1992 are important inputs to the proposed new default values (Vinnerås et al., Submitted).

Country	Tot energy cal/cap, day	Vegetal energy cal/cap, day	Tot protein g/cap, day	Vegetal protein g/cap, day
Sweden[a]	3052	2026	98	34
China, Asia	3029	2446	86	56
Haiti, West Indies	2056	1923	45	37
India, Asia	2428	2234	57	47
South Africa, Africa	2886	2516	74	48
Uganda, East Africa	2359	2218	55	45

[a]The data for Sweden are for 1992, since the default excretion values were developed for this year.

Table 3: Food supply (crops primary equivalent) in the different countries in the year 2000 (FAO, 2003)

Country	Nitrogen kg/cap, yr	Phosphorus kg/cap, yr	Potassium kg/cap, yr
China, total	4.0	0.6	1.8
Urine	3.5	0.4	1.3
Faeces	0.5	0.2	0.5
Haiti, total	2.1	0.3	1.2
Urine	1.9	0.2	0.9
Faeces	0.3	0.1	0.3
India, total	2.7	0.4	1.5
Urine	2.3	0.3	1.1
Faeces	0.3	0.1	0.4
South Africa, total	3.4	0.5	1.6
Urine	3.0	0.3	1.2
Faeces	0.4	0.2	0.4
Uganda, total	2.5	0.4	1.4
Urine	2.2	0.3	1.0
Faeces	0.3	0.1	0.4

[a]The data for Sweden are for 1992, since the default excretion data were developed for this year.

Table 4: Calculated estimation of the excretion in the different countries

Discussion

It is important to remember that the calculated estimation of the excretion was based on national statistics, while the excretion from an individual, a family or a block of houses depends on the actual diet of the persons involved. In many countries, differences in diet are very large between different population strata and this is reflected in the excretion.

From experience, we know (Vinnerås et al, submitted) that there are large uncertainties involved when measuring urine and faecal excretion. Many measurements of excreta have been carried out at large institutions and have only involved a limited number of persons, often only one fraction, one sex and persons with a limited age variation. Therefore, the value of these measurements is limited for determining reasonable default values. This is the reason why we based the proposed Swedish default values for excreta both on large studies of the diet and on several large measurements of the urine and faeces excreted by people at home. By measuring in apartment houses, men, women and children were included in the measurements.

The human metabolism is similar all over the globe and comparable statistics on food supply are, via FAO available for most countries. Therefore, reasonable default values can be calculated for the average excretion in different countries. To arrive at better default values, large measurements of the excretion from representative population groups are needed. This is shown for example by Ago et al. (2002), who report the average yearly total excretion of nitrogen, phosphorus and potassium in China as 4.4 kg of nitrogen, 0.5 kg of phosphorus and 0.8 kg of potassium. Comparing this with the calculated values in Table 4, the nitrogen and phosphorus values agree well, considering the difficulty in getting representative population samples and good statistics on the food supply in such a large country. For potassium the difference is quite large, 56%. One possible reason for this is that all vegetable foods have been lumped together in our calculation, even though the potassium content per gram of protein is about ten times higher in potatoes (staple food in Sweden) than in rice (staple food in China). Luckily, potassium is rarely the most limiting nutrient.

The distribution of nutrients between urine and faeces depends on the digestibility of the food. Digested nutrients leave the body via urine, while undigested matter leaves via faeces. Highly processed vegetal foods and animal foods are generally easy to digest and the proportion of such foods is higher in Sweden than in the other countries in Table 4. Therefore, higher proportions of the nutrients are to be expected in the faeces in those countries. This difference in digestibility is reflected in the amount of faecal matter produced, about 50 kg per person and year in Sweden (Table 1) and about 115 kg in China (Gao et al, 2002). Therefore, it is not surprising that Gao et al. (2002) also report a larger proportion of nitrogen (30%) and phosphorus (56%) in the faeces than the Swedish default values. However, the proportion measured in the faeces also depends on how successful the urine diversion system is. If a small proportion of the urine is mixed with the faeces instead of being diverted, then the amount of nitrogen, and also phosphorus, found in the faeces increases drastically. The proportion of urine not diverted depends very much on the toilet and on the dedication of the users. In our measurements, the proportion of misdiverted urine has varied between 5% and 50%.

Conclusions

The method presented enables the calculation of reasonable estimations of the plant nutrient excretion from the human body, just by use of easily available statistics on food supply. The uncertainty of the estimation seems small for nitrogen and phosphorus and large for potassium. The estimated excretion is the average value and the actual excretion can, depending on diet, vary very widely between individuals, families and population strata. Of the excreted totals, urine contains by far the largest proportion of nitrogen (70-90%), phosphorus (45-80%) and potassium (75-95%). The actual proportions measured depend on the digestibility of the diet and on successful diversion of all urine (100%) from faecal matter.

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Safe nutrient-removal from urban sewage

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Keywords

Crystallisation, endocrine substances, heavy metals, P-removal

Abstract

Different P-recovery-technologies for sewage are more and more discussed, while the use of sewage sludge on farmland is more and more criticised due to heavy metal and organic pollutants in the sludge. Three kind of technologies are described. Only the recovery from sewage sludge ash seems to be safe by now. Especially concerning the precipitation with lime and the crystallisation processes no data is available concerning the transformation of endocrine substances into the crystals and the tertiary sludge. Although the crystallisation-process is e.g. very promising concerning running costs further research is necessary on these basics.

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Introduction

A lot of waste water treatment plants were built up in the last decades. E.g. in Germany and other EU-countries they are nearly all run with mechanical and biological treatment technology, most of them also with P-elimination. Due to sewage sludge decrees and waste water control the content of pollutants in sewage and sludge was reduced drastically. But there are still heavy metals left and especially organic pollutants and the endocrine substances are causing trouble. Therefore new approaches are necessary to remove nutrients like phosphates from sewage for using it as a fertiliser on farmland in order to close the nutrient-loop.

In industrialised countries, but also in developing countries, more and more people are living in urban areas. Their sewage is entering into waste water treatment plants by being mixed with waste water from the commercial sector, which is in most cases responsible for the pollutant-input. But this input can in most cases not be avoided during the next years. But nevertheless it is important to find solutions for saving also these nutrients instead of wasting this resource. But it must be done in a safe way.

Methods

Three major methods of separate P-recovery from waste water do exist.

- P-precipipation with lime by producing a tertiary sludge at the end of the waste water treatment process
- Recovery from ash, by burning sewage sludge first in a mono-incinerator
- P-crystallisation

First of all soluble phosphates can be removed by precipitating them not into the sewage sludge, but into a saleable tertiary sludge, which must be stored and treated separately from the primary and excess sludge. Especially in case lime is used for transforming the phosphates into calcium-phosphates, they can be used without further treatment in the agricultural sector. This technology is not a new approach at all, but it was not often installed at waste water treatment plants in the past.

Another technology is the removal from sewage incineration ash. A mono-burning plant is necessary, because in case of co-burning, e.g. with brown-coal, P-content in the ash is too low for the removal. A lot of chemical substances are necessary to dissolve the P afterwards, especially in case it has been eliminated by iron or aluminium instead of using a Bio-P-technology. Although most of the chemical substances can be removed during an ion-exchange-process, the process-water contains in most cases a lot of salt.

Last not least there is the so called crystallisation-technology. By adding magnesium-precip-itants, struvite (MAP = magnesium-ammonium-phosphate) is produced in a crystallisator, a fluidised bed-reactor (Gaastra et al., 1998). This procedure can run in a side-stream- or full-stream-process. Side stream includes some advantages. For example only 60 % of the precipitants are needed to safe 90 % of the phosphate, that are removed during a full-stream process. PH, Mg/P-ratio, MAP-concentration in the reactor and the hydraulic retention time of the reactor are important operational factors of the MAP system. Due to the fact, that magnesium-precipitants are quite expansive, attempts with sea water (Kumashiro et. al., 2001) have been made, because sea-water contains magnesium and also sodium. The latter is stabilising the pH in the crystallisator.

Economical aspects

Besides technical aspects, first economical estimations have been made for full scaled operation plants. P from phosphate rock cost in Europe at about 0,40 €/kg (cif-price harbour Europe). Costs for recovering phosphates from the ash of former sewage sludge are at about ten times higher. But concerning the side-steam- crystallisation-process the costs are only 0,5 – 0,8 €/kg P (Buer et. al., 2002). Especially taking the economical situation in developing countries into account one has to add, that these cost will in most cases not lead to a further increase of imports whereas, imported phosphate or phosphor-rock has negative effect concerning the im- and export-balance sheet.

Concentrations of nutrient and pollutants in the recovered products

First of all it need to be mentioned that a very low concentrations of polluting substances is an essential demand on the produced products. Burning sewage sludge and recovering P from its ash is quite safe concerning organic pollutants which are destroyed during the burning process (in case of a modern emission-control-technology), but it is still an end-of-pipe-technology. And, last not least, it is very expensive.

Basically, the mentioned technologies offer the possibility to recover phosphate even from such kind of waste water, where a use of sewage sludge e.g. for agricultural purposes is impossible due to high pollutant concentration in the waste water. Especially the crystallisation-process does not allow a crystallisation if there is a high concentration of non-typical elements in the surrounding of the seeding material. Table 1 shows data concerning the heavy metal contents of struvit from Japan. Unfortunately the pollutant concentrations in the waste water were not mentioned.

d.m.-content (%)	N (%)	P (%)	K (mg/kg)	As (mg/kg)	Hg (mg/kg)	Cd (mg/kg)
41,8	5,5	12,5	565	0,7	<0,003	not detectable

Table 1: Concentration of MAP-granulats from Kitakyushu/ Japan Source: Kumashiro et al., 2001

Especially if one takes the results from phosphate rock into account this a good result, showing that contamination can be avoided with this technology. But further research is necessary to find out, whether it is possible for example for endocrine substances to find a place in these crystals, because they might not be excluded during the crystallisation-process, like for example cadmium or other “macro”-pollutants.

Conclusions

Table 2 is characterising the P-recovery-technologies by comparing them concerning their important „benchmarks“.

	Precipitation with lime	Crystallisation main-stream	Crystallisation side-stream	Recovery from ash
P-recovery-rate	40 - 65 %	65 - 70 % %	60 – 65 %	90 %
Running costs	middle	middle	low	High
Technical effort for installation	low - middle	high	high	extremely high (if no incinerator yet exists)
Final product	Calcium-phosphate	Struvit	Struvit	Depending on the technology Thermphos: P_4
Possibility of trans-formation of organic pollutants into re-covered P-product	Maybe possible, further research necessary	Maybe possible, further research necessary	Maybe possible, further research necessary	Not possible

Table 2: Characterisation of different P-recovery-technologies

On the one hand, the actual contamination of sewage in nearly every urban area of developing countries is too bad for using that sewage sludge for agricultural purposes. But besides that, there is even a discussion in developed countries like German, whether there should be a ban of sewage sludge from urban areas on farmland, due to hazard pollutants like endocrine sub-stances.

On the other hand it is necessary to close the nutrient-loop. And due to the high percentage of urban sewage on the total amount, it is necessary to find ways, how the nutrients can be removed from urban sewage without transferring the polluting substances. Some very promising attempts have yet been made, but a future-target must include series of analytic tests especially on organic pollutants and the endocrine substances in special in order to find out, whether they are able to make their way into the crystals (and the tertiary sludge). In case this happens in serious concentrations, this would maybe even go against the initiation of these new technologies on waste water treatment plants. Research on especially this item is necessary.

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Nutrient uptake by different vegetable plants from source separated human urine*

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Keywords

Nutrient uptake, plant bio-mass growth rate, source separated human urine, vegetable plants

Abstract

In this paper nutrient uptake efficiency of different plants were studied. For this purpose source separated human urine in varying dilution was treated with different species of vegetable seeds. The growth of the plants was observed for 15 to 20 days experiment cycle. Five experiments were conducted in batch basis. Results showed that plants such as Green Pea, Black gram, Broad bean had high nutrient uptake efficiency**.** As media solution and effluent still contained traces of nutrients (NPK). Source-separated human urine can be further diluted for total nutrient recovery.

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Introduction

Human urine contributes large amount of nutrients to the household wastewater (Esrey et al., 1998; Jönsson et al., 1999; Larsen et al. 1999; Otterpohl, 2001). High levels of these nutrients uptake are possible with separate collection of human urine at source. Human urine is relatively sterile and can be reused without further treatment (Wolgast, 1993). However, due to faecal contamination, pathogens have been found in human urine-collected separately with means of separating toilet; but in low concentration, which will pose low hygienic risk of using human urine as a fertilizer, if it is stored at least for 6 months before being used in agriculture (Jönsson et al., 1999, Hellstroem and Johansson, 1999). Moreover, human urine has low concentration of heavy metal. Therefore, separately collected human urine can be used as fertilizer for growing vegetables. The main objective of this paper is to study feasibility of nutrients uptake by vegetable plants from source separated human urine. This will help to develop a sustainable treatment process for household wastewater as well as reducing the dependence on chemical fertilizers. In this paper, nutrient uptake efficiency of different plants is presented.

Methods and materials

For the experiment a temporary urinal was constructed, the outlet of which was connected to a collection tank whose outlet was again connected to a mixing tank. The outlet of the mixing tank was connected to culture chambers of 90*60*45 cm size. All the outlet points were installed with valves to control the flow. The chamber was filled with approximately 60 liters of gravel and

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pebble media of 5-10 mm size and coarse sand to cover up to 11 centimeters of the chamber. Prior to commencement of the experiment, the medias were washed thoroughly. After the completion of every experiment, the media was washed continuously stirring the media 3-4 times and water drained in each wash. New media was introduced only in the fifth experiment.

Different species of vegetable seeds of cress, spinach, tintel, mustard, 2 varieties of Rayo (rape), green pea (Botanical name Pisum Sativum), black gram (Botanical name Cicer Arietinum) and broad bean (Botanical name Vicia Faba) were allowed to germinate in the laboratory for two days and placed on the plant culture chamber. The seeds, which germinated were only taken and rest excluded. The germinated seedlings were planted on the chamber. The growth of the plant was observed for 15 to 20 days experiment cycle. Five experiments were conducted. The plant species taken for different experiments and climatic condition during the experiment is as shown in the Table 1.

Experiment No.	Vegetable Plant Type	Climatic Condition
1	Cress, Spinach, Tintel, Mustard, Rape, Green Pea, Black Gram, Broad Bean	Direct sunlight available maximum of 2 hours a day
2	Cress, Spinach, Tintel, Mustard, Rape, Green Pea, Black Gram, Broad Bean	Same as in exp. 1
3	Green Pea, Black Gram, Broad Bean	Same as in exp. 1 and 2
4	Black Gram, Broad Bean	No Direct sunlight available at all
5	Broad Bean	Same as in exp. 4

Table 1: Plant species and climatic condition

The source-separated human urine was collected in the collection tank a day before the experiment and is diluted to required concentration in the mixing chamber. The dilution of human urine and nutrient loading were done as shown in Table 2.

Experiment No.	Human urine Volume Loaded (Litre)	Dilution Ratio	Nitrogen Loading Rate (g/m^2)	Phosphorous Loading Rate (g/m^2)	Potassium Loading Rate (g/m^2)
1	12.0	1:10	10.7	2.4	3.7
2	12.0	1: 6	4.2	0.1	3.5
3	14.2	1:15	7.7	0.5	13.7
4	18.0	1:15	6.2	0.3	6.4
5	15.0	1:10	6.2	0.2	1.6

Table 2: Dilution and nutrient loading rate

The influent and effluent were analyzed for Nitrogen (N), phosphorous (P) and potassium (K). The effluent sample was drawn in every 5th day–except for experiment 2- for which only final effluent was drawn. At the end of the experiment, the plants were weighed, dried and analyzed for NPK. The process was conducted on batch basis i.e. human urine was loaded for one time just before planting of the seedlings.

Results and discussion

The uptake efficiencies of different plants are as shown in Table 3. Nitrogen uptake was in the range of 68 - 91%. Highest uptakeefficiency was achieved in experiment 3 for broad bean, black gram and green pea with 1:15 dilution. Phosphorous uptakewas in the range of 63 - 96%. Highest uptake efficiency was achieved in experiment 1 for Cress, Spinach, Tintel, Mustard, Rape, Green Pea, Black gram, Broad bean with 1:10 dilution. Also in experiment 3 phosphorous uptake was about 92%. Potassium uptake was in the range of 59 - 85%. Highest potassium uptake was in experiment 3 for broad bean, black gram and green pea with 1:15 dilution.

Experiment No.	Influent Characteristic (mg/L)			Effluent Characteristic (mg/L)			Uptake Efficiency (%)		
	N	P	K	N	P	K	N	P	K
1	479.6	108.8	165	57.3	3.4	n.a	88.1	96.9	n.a
2	197.6	4.6	155.3	59.7	1.7	n.a	68.2	63.0	n.a
3	291.4	19.7	521.2	26.0	1.6	75.0	91.1	91.9	85.6
4	184.8	9.4	191.0	33.5	0.9	72.9	81.9	90.4	61.8
5	222.1	7.1	59.3	61.8	0.9	24	72.2	87.3	59.5

Note: The uptake efficiency is based upon initial volume. n.a. means not available.

Table 3: Characteristics of influent and effluent

The NPK content of the dehydrated plant bio-mass is shown in Table 4. Maximum nitrogen recovery was made in 33.3% of loading value in the fourth experiment with broad bead and black gram, Maximum Phosphorous recovery was made in 50.0% of loading value in the third experiment with broad bead, black gram and green pea. Maximum Potassium recovery was made in 45.2% of loading value in the fifth experiment with broad bead.

	Nitrogen		Phosphorous		Potassium	
Experiment No.	Uptake By Plants (mg)	% Of N Loading	Uptake By Plants (mg)	% Of P Loading	Uptake By Plants (mg)	% Of K Loading
1	57.6	1.0	11.1	0.9	77.0	3.9
2	332.8	14.8	15.9	28.8	261.0	14.0
3	192.8	4.7	139.8	50.0	509.9	6.9
4	1107.9	33.3	55.3	32.7	1000.5	29.1
5	991.2	29.8	7.1	6.7	402.1	45.2

Table 4: Plant uptake of nutrient and percentage of loading rate

In the successive experiments, the plant species were selected depending upon mass of plant growth. Higher growth varieties were retained and low yielding plant in terms of plant bio-mass growth were excluded in the later experiments. In the fifth experiment only one species i.e. Broad bean (Botanical name Vicia Faba) was planted. Maximum plant bio-mass growth was achieved in experiment 4 with broad bean and black gram with 1:15 dilution (Table 5)

Experiment No.	Duration of Experiment (days)	Mass Of Plant Growth (g)	Mass Of Plant Growth Per Unit Area (g./m^2)	Mass Of Plant Growth Per Unit Area Per Day (g/m^2/day)
1	15	12.1	22.3	1.5
2	15	65.2	120.7	8.0
3	15	185.6	343.7	22.9
4	20	234.2	433.7	21.7
5	20	108.2	200.4	10.0

Table 5: Plant bio-mass growth rate

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From the results it showed that plants Green Pea, Black gram, Broad bean had high uptake efficiency. Results also showed that up to 33 % of Nitrogen, 50% of phosphorous and 45% of potassium were utilized by vegetable plant.

In all experiments, influent pH, which was at stronger alkaline state had been changed to lower values (Table 6). Electrical conductivity also changed from higher to lower values, signifying low ion concentration in effluent (table 6).

Experiment No.	Influent pH	Effluent pH	Influential EC (mS/cm*)	Effluent EC (mS/cm)
1	12.4	9.2	2.9	1.9
2	8.6	8.3	2.4	1.5
3	9.0	8.1	3.5	0.3
4	8.7	7.9	0.8	0.2
5	9.3	8.5	1.2	0.6

** Electrical Conductivity (mS/cm) – millie-Siemens per centimetre*

Table 6: Change in pH and EC in wastewater

Conclusions

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The source-separated human urine can be used for the vegetable plants particularly broad bean, black gram and Green Pea. There was still unutilised NPK found in the media solution. With the applied dilution, effluent still contains traces of NPK. Therefore, further dilution of source-separated human urine can be applied for total nutrient recovery. In future studies, actual nutrient uptake by vegetable plants from source separated human urine and chemical fertilizers in soil media with different dilution or loading rate in the same condition can be investigated in terms of bio-mass growth.

The system is based on reuse of valuable nutrients, giving rise to a sustainable treatment process with vegetable plants. It can reduce the dependence on chemical fertilizers, which will save foreign currency needed to import the fertilizers in the developing countries like Nepal.

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Sanitation of blackwater and organic material*

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Keywords

Batchwise aerobic thermophilic treatment, blackwater system, hygienisation, organic waste, small scale treatment plant, wet composting

Abstract

The municipality of Sund in Åland (Finland) is a rural area with small villages surrounded by the sensitive Baltic Sea, where an EU-Life demonstration project is being carried out. The overall objective is to move the most concentrated fraction of wastewater from the coastal area to batch-wise treatment, followed by agricultural use as an organic fertiliser. The aim of the treatment is to stabilise and sanitise the material. Treatment of two batches has been monitored. The maximum temperature in treatment of the first batch (A) was 55°C, and in the second batch (B) a temperature of 62°C was reached. Microbial analyses have been carried out. The results indicate that the wet composting process reduce indicator bacteria sufficiently, but additional batches have to be evaluated before conclusions can be drawn.

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System description and methods

Blackwater together with grey-water septic sludge from about thirty households and two tourist camping areas is treated together with food waste from the camping areas and energy-rich organic material from a nearby potato-chip factory. The collection concept is based on the use of extremely efficient water-saving toilets, with separate systems for the blackwater and greywater in the households. Greywater from the households and camping areas is infiltrated in soil filter beds (Malmén et al, 2002).

The treatment consists of a batch-wise aerobic thermophilic process (wet composting process), where the materials reach at least 55°C during a minimum of 10 hours. Aeration is supplied by an immersed ejective aerator. The maximum batch volume is 290 m^3. After sanitation and stabilisation by the treatment, the slurry is used in agriculture as an organic fertiliser.

Aerobic thermophilic treatment (wet composting) has traditionally been used for treatment of sewage sludge and liquid manure. Nowadays the method has also become interesting for treatment of organic waste and blackwater, and development in this field has mainly taken place in Norway and Sweden (Skjelhaugen, 1999; Skjelhaugen and Sæther, 1994; Norin et al, 2000, Norin, 1996). The main advantages with the wet composting process are that a sanitation and stabilization of the material is reached, while there is hardly any losses of plant nutrients during treatment. The treatment process takes place in a closed reactor and the outgoing air is cooled,

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resulting in NH_3 from the air returning to the reactor with the condensation. Aerobic conditions are maintained by active supply of oxygen. Generally, the material for treatment should have a dry matter content of between 3-10 % (Skjelhaugen and Sæther, 1994).

To reach a sanitation, it is recommended that the material shall remain at a temperature of at least 55°C for at least 10 hours, in a reactor where all of the material is being totally mixed (Lundeberg et al, 1999). The reactors of the treatment plant contain equipment for continuous measurement of the temperature in the material during treatment. This has enabled an evaluation of whether the hygienic demands regarding time and temperature in the treatment process have been reached. The material in the two batches was sampled before, during and after treatment using a sterile sampler. Sampling was done while stirring equipment was operating in order to have a homogenous batch. The samples were transported in a cooled box to laboratory within 24 hours. The selection of analyses to be carried out was decided in accordance to recommendations from the Swedish National Veterinary Institute, SVA.

Results and discussion

Temperature graphs from the treatment of two batches can be seen in Figure 1 and Figure 2 respectively.

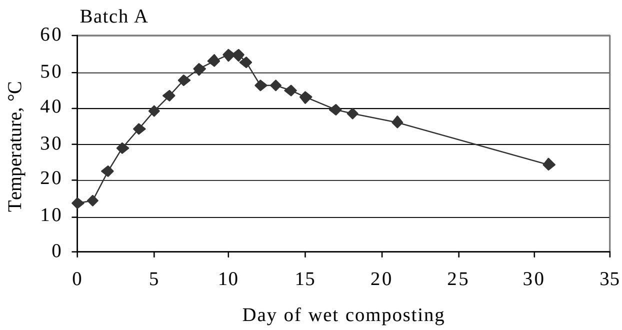

Figure 1: Temperatures during the wet composting process of Batch A in October 2001. The aerator and the stirring device were turned off on day 21.

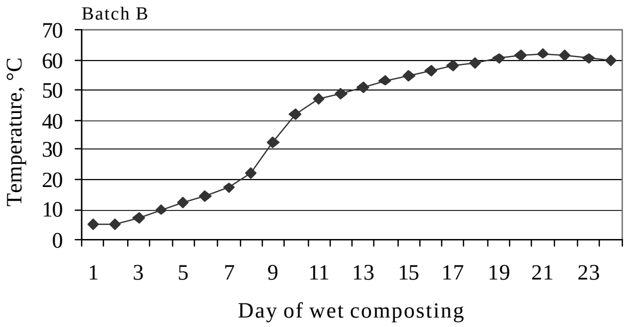

Figure 2: Temperatures during the initial phase of the wet composting process of Batch B, April 2002. The aerator and the stirring device were turned off on day 23.

The first batch to be treated in October 2001 (Batch A), consisted of approximately $120m^3$ blackwater and greywater sludge (DM 0,4%) and $12m^3$ of potato peelings (DM 32%). By starting the aerator and stirring device, the aerobic thermophilic treatment (wet composting) of the batch was started. The temperature of the material in the reactor was about 14 °C at the start. The heat developed by the aerobic bacteria and frictional heat from the machines in the reactor made the temperature of the material rise to 55°C after 10 days. The temperature remained at 55°C for 10 hours, before it started to get lower again (Figure 1). The pH-value in Batch A was 7,2 before treatment; 8,7 after 10 hours treatment at 55°C and 8,9 after six months storage following the treatment.

During ten weeks, from February to April 2002, 130 m^3 of blackwater and 22m^3 of potato peelings were pre-storaged, without any further addition of material to the reactor. The process of wet composting Batch 2 was started in April 2002, when the temperature of the material in the reactor was about 5°C. During treatment the temperature rose to 55°C after 14 days. It increased further, and reached a maximum of about 62°C after another six days. In total, the temperature in the treated material remained at more than 55 °C for about two weeks, before it dropped (Figure 2). The pH-value in Batch B was 5,5 before treatment after ten weeks of pre-storage, and after 24 hours treatment at > 55°C it was 6,2.

The difference between Batch A and B regarding the reached maximum temperature, is most likely explained by the larger amount of potato peelings in Batch B, and hence a larger amount of BOD. Since the blackwater does not contain much energy, it is important to ensure a sufficient load of BOD by adding the potato peelings.

The results from the microbial analyses can be seen in table 1.

	Coliform bacteria (37°C)	Thermotolerant coliform bacteria (44°C)	*E. coli*	*Enterococcus* spp.	*Clostridium* spp.	*Campylobacter jejuni* and *coli*	EHEC	*Salmonella* spp.
Unit	CFU/g					Affirmative/non affirmative		
Batch 1								
Rawmaterial before treatment								
2001-10-09	3 500 000	200	200	7 300	5 600	non aff.	non aff.	non aff.
Treated material (wet composted), after 10 hours at >55 degrees Celcius								
2001-10-18	< 10	< 10	< 10	< 100	400	non aff.	non aff.	non aff.
Treated material, stored 2 months after treatment								
2001-12-13	< 10	< 10	< 10	< 100	420	non aff.	non aff.	non aff.
2001-12-13	< 10	< 10	< 10	< 100	390	non aff.	non aff.	non aff.
Treated material, stored 6 months after treatment								
2002-04-29	< 10	< 10	< 10	< 100	360	non aff.	non aff.	non aff.
2002-04-29	< 10	< 10	< 10	< 100	500	non aff.	non aff.	non aff.
Batch 2								
Rawmaterial before pre-storage								
2002-02-10	1 300	< 10	< 10	3 000	6 500	non aff.	non aff.	non aff.
Rawmaterial after 10 weeks of pre-storage and just before treatment								
2002-04-21	<10	<10	<10	470	150 000	non aff.	non aff.	non aff.
2002-04-21	<10	<10	<10	450	140 000	non aff.	non aff.	non aff.
Treated material (wet composted), after 24 hours at >55 degrees Celcius								
2002-05-05	<10	<10	<10	< 100	100	non aff.	non aff.	non aff.
2002-05-05	<10	<10	<10	< 100	<10	non aff.	non aff.	non aff.
Treated material, stored 4 months after treatment								
2002-09-08	< 10	< 10	< 10	< 100	50	non aff.	non aff.	non aff.
2002-09-08	< 10	< 10	< 10	< 100	100	non aff.	non aff.	non aff.

Table 1: Microbial analyses of two treated batches (1 and 2) of collected rawmaterial (blackwater, potato peelings and greywater septic sludge).

All of the examined micro-organisms in the rawmaterial was almost completely reduced by the treatment, with exception of the spor forming bacteria *Clostridium* in the first batch. This is expected, since reduction of spor forming micro-organisms requires a higher temperature. According to previous studies at SVA (the Swedish National Veterinary Institute), spor forming

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bacteria have been found after pasteurization (Bagge et al, 2003). This has not given rise to any further investigation or demands for measures to be taken. Spores from *Clostridium* exists in the ground. Some of the spor forming bacteria are pathogenic, which makes the sanitary risk difficult to estimate, since there is a lack of knowledge in the area. The experiences from a Norwegian aerobic thermophilic treatment unit, treating sludge from a wastewater treatment plant, show that Salmonella and thermotolerant coliform bacterias are reduced if the amount of organic material is sufficient (Nybruket et al, 2003).

From studies of other treatment processes it is known that there is an obvious risk for re-contamination and re-growth of both indicator bacteria and pathogens during handling and storage of the processed material. However, no re-growth was observed for any of the two batches, during the storage after treatment. Neither did the pH-value in the material change much during storage after treatment. This indicates that the main part of the easily degradable organic material was consumed during the composting process, which makes a re-growth of micro-organisms more difficult.

Conclusions

The results indicate that the wet composting process reduce indicator bacteria sufficiently. Normally, this also means that conventional pathogens are reduced sufficiently. But, since treatment of only two batches has been monitored additional batches has to be evaluated before conclusions can be drawn.

From a hygienic safety point of view, a batch treatment is preferable to a semi-continuous process, which is often selected. In a batch process the treated material will be exposed to higher temperatures over considerably longer times than in a semi-continuous process.

From a technical point of view the system is a success. The project has faced no major technical problems. As a result the Government of Åland is discussing the introduction of the system in other places.

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Ecological sanitation: valorisation of waste sludge by composting for agricultural production

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Keywords

Composting, fertiliser, reuse, sanitation, waste sludge, yield

Abstract

Pit latrine sludge endangers health and environment if not treated. Nevertheless, even when this is the case, treated pit latrine sludge is seldom reused. Physical and chemical and bacteriological analyses of stabilised and dehydrated pit latrine sludge from SIBEAU lagoon treatment plant in Benin shows a high content of nutrients, such as nitrogen and phosphorus in stabilised sludge; which are indispensable for agricultural production. A one-year field experiment investigated the effect of stabilised pit latrine sludge on biomass production. It came out that stabilised pit latrine sludge had a positive effect on biomass production of e.g. tomatoes, when compared to chemical fertiliser and control. Dehydrated pit latrine sludge is usable, without any further treatment, as a fertilising agent or after its composting. The interest of composting is two-fold; 1. Increase the availability of nutrients in sludge; 2. Reduce the pathogen content in sludge. This is attained when temperature during composting is raised to 60°C.

Introduction

In both West and Central Africa, sludge coming from latrine pits is handled in a rather chaotic manner. This often endangers the lives of humans and environment. Because of this situation, CREPA (the Regional Centre for Water Supply and Sanitation) instigated a research programme to explore for possible solutions to handle this sludge. The results of this work illustrated that in order to ensure a sustainable management within urban, peri-urban and rural environments, a strategy is required. Such strategy must integrate latrine sludge as a resource to improve people living conditions, for example, by increasing agricultural production. This study presents the current state of valorising dehydrated latrine sludge from the treatment lagoon of the Benin's Industrial Company for Water and Urban Sanitation (SIBEAU) in Cotonou, Benin.

[1] *Centre régional pour l'Eau potable et l'Assainissement à faible coût*

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Method

Methodology used in this study based on a participatory approach (questionnaire, focus groups, interviews, and meetings), to inform and take into consideration the opinion of all stakeholders in the research project. Different stakeholders involved in the research made decisions concerning the experimental site, the installation of composting units by consensus.

A physical, chemical, bacteriological, and parasitological characterisation of different fertilising agents, soil, and water was made.

The effect of the different fertilising agents on the biomass production of different fruits and vegetables was tested by evaluating the mass, quality, and quantity of fruits and vegetables produced either per plant or per square meter.

Fertilising agents used were 1. Dried sludge, 2. Dried sludge mixed with solid waste, and 3. Chemical fertiliser. Yields were compared to a control where no fertilising agent was used.

Results

Soil, fertilising agent, and water characteristics

Soil in the experimental site in Benin offers an example of typical poor soil found in the littoral zone in West Africa. It has a high content of sand, with a high infiltration rate and an acid pH (5.5). The organic matter, carbon, and nitrogen content were low in the soil, and the C/N ratio was 10. This indicated that the soil was highly mineralised and weathered.

Dehydrated sludge had a pH close to 7 with humidity content of 10.3% and a dry matter content of 89.7%. The C/N ratio showed that the organic matter in the sludge was in an advanced state of decomposition, which indicated that the nutrients in the sludge were more or less available to the plants.

Water used for watering during the experiment came from well and contained faecal contamination indicator organisms.

Effect of fertilising agent on plants: dehydrated sludge and chemical fertiliser.

Plants	Performance indicator (weight in gramme)	Type of substrate		
		Dehydrated sludge	Chemica fertiliser	control
Célosie (25 plants/m^2)	Biomass / m^2	925	575	567
Lettuce (25 plants/m^2)	Biomass/ m^2	650	591,5	567
Amaranth (25 plants/m^2)	Biomass / m^2	866,5	741,5	508, 25
Grande morelle (25 plants/m^2)	Biomass / m^2	2032, 5	3174,5	1360,25
Tomatoe (04 plants/m^2)	fruits / m^2	104	100	20

Table 1: Agronomic performance of fertilisers on plants

Table 1 indicates that yield obtained with dehydrated sludge was higher than yield obtained with a control (fig. 1, fig. 2, fig. 3 and fig. 4). This is also the case when we compare yield obtained with dehydrated sludge to the results obtained with chemical fertilisers, except for "grande morelle", where chemical fertilisers gave a higher yield than dehydrated sludge. For tomatoes, similar results were obtained with both dehydrated sludge and chemical fertiliser, whereas we noticed less leaves and fruits on the control plant.

Figure 1: célosie (dehydrated sludge as fertiliser)

Figure 2 : célosie (control: without fertil.)

Figure 3: papaya (control: without fertiliser)

Figure 4: papaya (dehydrated sludge as fertil.)

Residual toxicity

Metal contamination was identified on the plant fertilised with sludge mixed with solid waste. However, the level of contamination was lower than the thresholds for toxicity.

Compost experiment

Three different types of composts were produced: sludge + solid waste, sludge + wood shavings, sludge + leaves from the acacia tree). The swath have a size of 6m×2m×1.5m. The choice of carbon source for compost was made basing on composting techniques used in the region.

Composting maturation results

Maturation process was followed for 60 days. Parameters investigated during compost maturation were pH, humidity, organic matter content, and the C/N ratio. Composting took place during the rainy season. A heavy precipitation was noted in October 2002; and this did not allow for humidity control. Moreover, temperature did not reach above 55°C.

Compost characteristics

Compost	pH	Humidity (%)	Organic mat er	C/N
sludge + solid waste	6,93<pH<7,25	45,52	31,72	12
Sludge + wood shavings	6,69<pH<7,20	31,48	9,92	13
sludge+ acacia leaves	6,34<pH<7,15	28,32	11,24	18

Table 2: Compost characteristics after maturation

Compost maturation was achieved after approximately 60 days. A progressive decrease in the C/N ratio was noted during the composting process. The final C/N ratio for the sludge + solid waste, sludge + wood shavings, and sludge + acacia tree leaves were 12, 13, and 18 respectively. A high C/N value was observed for sludge + solid waste; but the trend reversed towards the end of the process for Sludge + Wood sawing and Sludge + Acacia Tree leaves. The presence of lignite in the two last composts whose biodegradation kinetics is relatively slow may explain this situation.

Ongoing experiments on cultures

Ongoing experiments to test the comportment of some speculation vis-à-vis the compost amendments and to compare their performance with those of other substrates and chemical fertilisers, agronomic values, residual toxicity, parasitological and bacteriological data.

Conclusion

Yields revealed interesting agronomic qualities concerning residual sludge. Improvements with a supplementation in structuring matters (solid waste, wood sawing, Acacia leaves) enable a further enrichment of soils both for vegetables and fruit cultures.

Not only does soil amendment with sludge enable an increase of their productivity, but it also contributes in accelerating plant vegetative cycles. For a better valorisation of sludge in agriculture or gardening, it must be sufficient to control the toxicity factor of sludge and agricultural products from a chemical, bacteriological, and parasitological viewpoint. An estimate of the gross product per hectare of gardening operations is needed for each type of culture.

Sustainable utilisation of human urine in urban areas – practical experiences*

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Keywords

Aquaculture, ecological engineering, struvite, urine, zeolite, urine separation

Abstract

After several years of research on utilisation of nutrients in human urine an opportunity to build and use a greenhouse aquaculture demonstration plant appeared in the new science centre Universeum, in Göteborg, Sweden. The challenge for this project is to recycle all the nutrients in urine collected from the staff and the visiting public (about 500 000 visitors during the first year) and to demonstrate its value as nutrient with different eco-sanitation technologies on site. The nutrients are collected by the use of 26 urine-sorting toilets (estimated 100-300L urine per day, 50% diluted). Part of the urine is treated directly by the aquaculture food chain (algae-zooplankton-fish). Another part will be concentrated by chemical precipitation (struvite) and adsorption to minerals (zeolite). The main part of the urine is to be spread in agriculture. This multiple use of the source-separated urine favours a sustainable recycling of nutrients in urban areas, and it also demonstrates the usefulness of human urine as a nutrient source for the visitors. Furthermore, any eco-toxicological concern by its use can be directly investigated in the aquaculture food chain on site, opening possibilities for interesting research projects in the future. This paper will present a brief description of the site, the ongoing projects, and some practical experiences.

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Introduction

The Universeum science centre

Universeum science centre located at Korsvägen in Göteborg, Sweden, was inaugurated in 2001 (Wallin, 2002). The science centre is an educational platform and an excellent forum to tempt youngsters (in ages between 7-19 years old) to develop a better understanding and a direct experiment of sciences by visiting this building (Ervik, 2003).

In the business plan for Universeum, demonstrations of science and technology from an ecological perspective was emphasised and the building was identified as a resource for communicating this perspective. Environmental ambitions were developed into system requirements. During the design process, a reference group of researchers gave advice on goal settings, system design and specific details (Wallin, 2002).

Ecological engineering and the wastewater system

Ecological engineering was defined in 1971 by Howard T. Odum as the management of nature for human use (Odum, 1971). The synthesis between ecology and technology (eco-technology) requires a combination of basic and applied research as well as interdisciplinary teams for its

*This paper has been peer reviewed by the symposium scientific committee

proper application (Jensen et al, 1992; Mitch, 1991). Because of the complexity of nature a broad professional knowledge is required when creating ecological engineering systems .

After the Brundtland convention (1987), and environmental meetings (e.g. Rio, 1992) fundamental terms as "Agenda 21 ", "life cycle assessment" and "recycling", are stated and widely acknowledged, which has focused the practical local action on new technical developments towards local system for wastewater treatment. This has lifted environmental issues to a higher priority in decision-making processes, and also brought fundamental thinking on local scales to all levels in the society, people are involved. The future work with sustainable development in Sweden is following 15 environmental goals (http://www.environ.se). Two of these goals are “No eutrophication” and "A sea in balance with living coast and archipelago". These goals are especially important for urban areas producing enormous amounts of wastewater and discharging large amounts of nutrients to water recipients through agricultural runoff and wastewater treatment plants.

Figure 1: The Universeum exterior autumn 2001, view from the main entrance. Photo Zsofia Ban.

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The discovery of nitrogen as a major cause of eutrophication, especially in the marine environment, has intensified the research on nitrogen removal from sewage water. Further demands on nutrient removal cause treatment plants to be rebuilt or extended (Mattsson, 1997). More than eighty percent of the nitrogen in sewage water from households originates from human urine (Adamsson, 1999). Therefore, source separating of urine could be a complement to decrease nitrogen discharge to estuaries.

Four aspects need to be considered for wastewater treatment methods (Jenssen et al 1992; Jonasson 1993):

- health aspects,
- recipient aspects,
- cost efficiency aspects and
- recycling aspects.

By using separating systems, the nutrients could be used as a resource directly after toilet disposal and appropriate hygienic stabilisation (i.e. storage) and thereby reduce the nitrogen load in incoming water to coastal sewage plants. The value of human urine as fertilizer or soil conditioner in agriculture is well known in Sweden (Jönsson et al., 2000; Johansson, 2000). However, its use can be controversial regarding different stages of urine management (storage, transports, spreading and overall aspects of hygiene). In recent years, research made at Göteborg University have shown that nutrient recovery in crystalline form to obtain a slow-release soil conditioner known as struvite [Mg (K, NH4)(PO_4) •6H2O] can be an ecologically and environmentally desirable way (Ban, 1998; Lind, *et al*.,2000). Human urine could also be used in an aquaculture approach (Adamsson, 2000). After several years of research on utilisation of the nutrients in human urine in a constructed food chain (Adamsson, 1999), the possibilities for demonstrating this technique became a reality at Universeum science centre.

The objectives of this paper are (1) to describe the technique of aquaculture and the initial research on crystallisation based on sorted human urine from Universeum, (2) to share some practical experiences from the operating toilet system at Universeum and (3) to discuss if new techniques like collecting of urine and crystallisation (struvite) could be a solution for sustainable utilisation of human urine in urban areas.

Methods

Collecting urine

The majority of the nutrients (N and P) are collected by the use of 26 urine-sorting toilets (system called "Dubletten", developed by Bibbi Innovation & Co AB). The front bowl is connected to a separated pipe, which collects urine into two storage tanks (volume of 6m^3 each). The back bowl is flushed to ordinary sewage system and the sewage plant for Göte borg city, with exception of 7 toilets on the personal floors. The faeces from these 7 toilets are connected to a sludge separator (3 chambers with a total volume of 12m^3) and this effluent could be used in the aquaculture or be transported to the ordinary sewage system.

The total urine volume collected per year is estimated by number of visitors and a dilution factor of 50% (about 1.2-1.5dl flushing volume according to the manufacturer of the toilet, see http://www.dubbletten.nu/english-presentation/WCdubbletteneng.htm).

Chemical and microbiological analysis have been made on the urine from the storage tanks by using a water-lifter (small plastic container on a wooden stick) directly placed into the manhole of the tanks, filling a glass bottle (1L), which were transported in a cool box (+4°C) directly to an accredited laboratory.

The aquaculture-principles (Figure 2)

The diluted urine is pumped [1] from storage tanks to a ble nder [2] (about 50L) in the water treatment centre (aquaculture). From this blender the solution flows by gravity to four cylinders (1m^3 each) which contain microscopic algae [3] (i.e. *Scenedesmus acuminatus*). Using photosynthesis, these algae assimilate the nutrients from the urine. The overflow of algae runs to each of four separated 1m^3 large concrete aquaria (replicates), were the algae are eaten by zooplankton, water fleas (*Daphnia magna*) [4]. The aquaria also contain a plastic foam (1m * 0,7m * 0.1m) with a pore size of about 0.1-10mm, which is aerated. The function of this is to act as a biofilter with an attached nitrification bacterial community. The water containing water fleas flows by gravity down to a 6 m^3 (water volume) large tank with small tropical fish (Guppy) [5]. These fishes fed on *Daphnia* sp. and are in turn harvested to become food for larger fish in some of the other aquaria in the building. The water runs down to a series of small pools [6] were water plants are cultivated. Not only these plants, but the roots of the rainforest trees are able to take up nutrients which still remain in the water. Then the water is

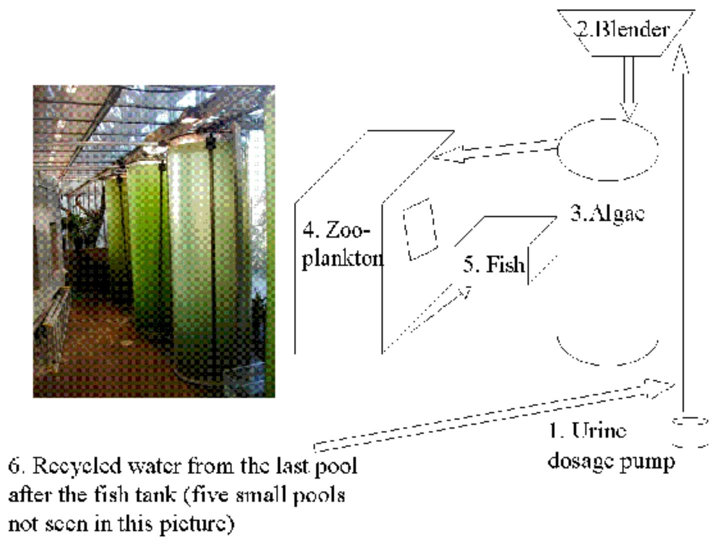

Figure 2: The aquaculture system at Universeum.

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returned to the blender by a pump. In the blender, new urine is added. The water flows in a closed loop system, which is technically operated only by a dosage station for urine and the pump station in the final pool [6]. Biomass production of zooplankton has been recorded as well as pH, dissolved oxygen, total nitrogen, ammonia, nitrate and nitrite in order to monitor the nutrient flow and locate functional problems within the system during one month the first year (Barone, 2002). Urine from the storage tank in the aquaculture has also been sent for chemical and microbiological analyses.

The struvite process and mineral adsorption

Lind *et al*. (2000) showed that by addition of small amounts of magnesium oxide (MgO) to human urine most of the phosphorous (95-99%) and part of the nitrogen (20-50%) can be recovered as a precipitate. Crystalline struvite [Mg (K, NH4)(PO_4) •6H2O] was the major component of the precipitate, which also contained montgomeryite [$Ca_4MgAl_4(PO)_4(OH)_4$ *12H_2O], brucite [$Mg(OH)_2$] and epsonite [$MgSO_4$ *7H_2O]. In this way also 22-64% of K and 2-5.6% of Ca was recovered. Additional mineral adsorption steps improved the nitrogen recovery. Natural zeolites and wollastonite showed excellent adsorbent qualities in contact with ammonia solutions as well as in tests with human urine (Ban, 1998). When struvite crystallisation and mineral adsorption was combined 64-80% of the nitrogen (as ammonia) was recovered together with 95-99% phosphorus, (Lind *et al*., 2000).

The experiments with Universeum urine were based on the combination of two steps:

a) *dephosphatisation* using different amounts of MgO for struvite crystallisation

b) *mineral adsorption* using different amounts of zeolite for improved nitrogen removal.

Human urine was collected from the urine tanks at Universeum and transported immediately in closed plastic cans to the laboratory for testing. The urine was directly used for the experiment, without freezing or further storage.

The mineral zeolite (with high clinoptilolite content originating from Mad, Hungary, and a grain size of 1,2-2mm) was used in its natural form. MgO and zeolite was added to the urine in a series of batch tests.

The contact time of the experiment was 72 h at room temperature (20°C), which is more than enough for both struvite formation and ammonium adsorption processes (Lind, 2000). A short, manual stirring was made once daily. After 72 hours the supernatant was decanted and analysed for total-P and total-N (Spectrophotometer DR 4000, Hach-methods 3036 and 2558). Figures 3 and 4 show the results of the experiments.

Results and discussion

Sorted human urine at Universeum

Collecting system

Since these systems are new, some technical problems were expected. Most of them were related to pipe dimensions and slopes and the design of the toilet seat. This has caused some additional work for the maintainers and cleaning staff at Universeum during the first year. Due to educated and interested staff at Universeum, these toilets have, in spite of their non-optimal design, been well maintained and are, in most cases, accepted and appreciated by the visitors. There are areas in the building that are more critical than others (i.e. more visited) like the entrance hall, where in high seasons, very frequent cleaning by staff is necessary. This was not always possible, which has lead to some complains from visitors of odours and blockages of the front bowl used for urine (paper jam, etc.).

Nutrients in collected urine:

Total N varied between 2 and 6g/L in collected urine (see Table 1 and Figure 3) and total P varied between 0.13 and 0.85g/L (see Table 1 and Figure 4).The reduction of *E.coli* in stored human urine occurs within a few days. Therefore, also other indicator organism should be used when evaluating hygienic risks from sorted human urine prior to its use as nutrient source (Jönsson, 2000; Höglund, 2001).

Table 1. Chemical and microbiological data for two samples of sorted human urine (about 50% diluted by flush water) at Universeum, Göteborg Sweden. Sample 1 was taken directly from the incoming water to the storage tanks. Sample 2 was taken when the urine enters the blending tank in the aquaculture. This means that the urine in sample 2 has been stored further for at least 1 week at 26 ± 2ºC.

Parameters	Method	Unit	1	2
pH	SS 028122-2.Titro		9.2	8.7
BOD (7)	SS 029143-2	mg/l	1200	290
COD (Cr)	Hach	mg/l	2100	1200
Total Nitrogen	TRAACS	mg/l	2200	2700
Ammonium-N	TRAACS	mg/l	2300	2700
Total Phosphorous	TRAACS	mg/l	130	150
Potassium	ICP-AES	mg/l	840	930
Cadmium	ICP-MS	mg/l	< 0.0004	<0.0004
E. coli	SS 028166-1	cfu/100ml	>160000	<2
Heterotrophic bacteria, 20 C, 2d	SS 028171-1	cfu/ml	>300000	>300000
Coliform bacteria, 35 C	SS 028166-1	cfu/100ml	>160000	<2

The aquaculture

Research at a laboratory scale and in a small greenhouse system (Adamsson, 1999; Adamsson, 2000) showed that *Scenedesmus acuminatus* and *Daphnia magna* can grow and reproduce with human urine as nutrient source. Then the reduction of nutrients through the aquaculture system ranged 36-97% for nitrogen and 67-98% for phosphorous. The results from the first 18 months of operation of the aquaculture system at Universeum have shown that the critical step is the zooplankton production. This is mainly due to high temperature, low food quantity (lack of light for photosynthesis) and ammonia toxicity (Adamsson, not published; Barone, 2002). One aim is to increase the urine concentration (more nutrients) in the blender to produce more algae to improve *Daphnia* production. This must, however, be combined with acceptable pH value in the system to decrease the risk for ammonia toxicity to *Daphnia* (Adamsson, 1999). A complete evaluation of the production and reducti on efficiency of this pilot scale system is so far unknown, although, a study based on one month performance of the plant (Barone,2002), indicated that the nitrogen concentration was reduced after the aquaculture steps, and the major part of nitrogen was in form of nitrate, indicating that both nitrification and nitrogen reduction was efficient.

The struvite process and mineral adsorption

The addition of MgO increased the initial pH value from 8.9 to 9.3 (data not presented here). Total-N and total-P reduction after addition of small amounts of MgO respective zeolite to human urine collected from the urine tanks is shown in Figure 3 and 4.

Nitrogen reduction:

a) The tot-N reduction from human urine is highly dependent of the amount of MgO added and of the stoichiometric conditions for *struvite* precipitation (molar ratio of 1:1:1 and weight ratio N:Mg:P of 1:1.7:2.2). Human urine contains an excess of ammonium relative to phosphate and with Mg added and a phosphate recovery of nearly 100% just a part of ammonia is recovered as struvite. Theoretically, the maximum part of the total N that can be captured in the struvite structure is 38% from Universeum urine.

b) The further nitrogen uptake by *zeolites* depends on the ion exchange property of the mineral, the amount used, the grain size and contact time (Lind, *et al.,*2000). The clinoptilolite type of zeolite used here has good ammonium absorbent capacity (Lind, *et al.,* 2000) but the struvite precipitation itself slightly reduces the end-pH of the urine tested and during the adsorption process to the zeolite a competition may occur between H-ions and NH_4-ions for the exchange sites in the mineral structure. The simultaneous precipitation and mineral adsorption processes are complex processes and a clear picture of the tot-N uptake due only to the zeolite was investigated earlier (Lind, *et al.,* 2000). A deeper discussion about the processes using concentrated urine is under publication elsewhere. However, an additional of 30-85% total N reduction (from remaining amounts after struvite precipitation) due to zeolite adsorption was found in this study (Figure 3).

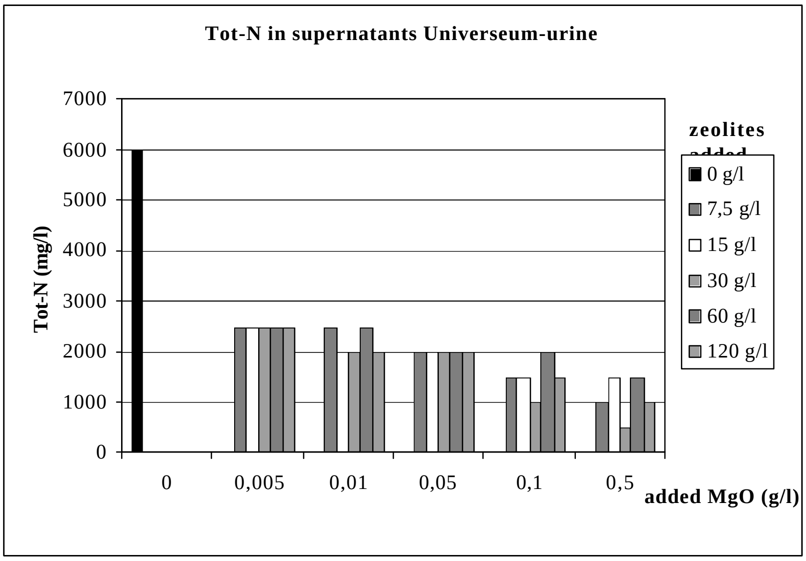

Figure 3: Total-N reduction in urine from Universeum by addition of MgO and zeolite.

Phosphorus reduction:

a) The stoichiometric ratio (molar weight based) Mg:P is 1.71: 2.21 for *struvite* precipitation for urine containing 0.85 g P/l. According to our experiments 0.5 g MgO per litre urine is sufficient to get a tot-P reduction of 95-98% in combination with zeolite, because the zeolite is a good phosphorus adsorbent.

b) The natural *clinoptilolite type of zeolite* has also a good tot-P adsorption capacity. When tested with human urine. This process is mainly due to the possibilities for chemisorption on the Ca-, Fe- or Al-oxide sites in the zeolite structure (under publication elsewhere).

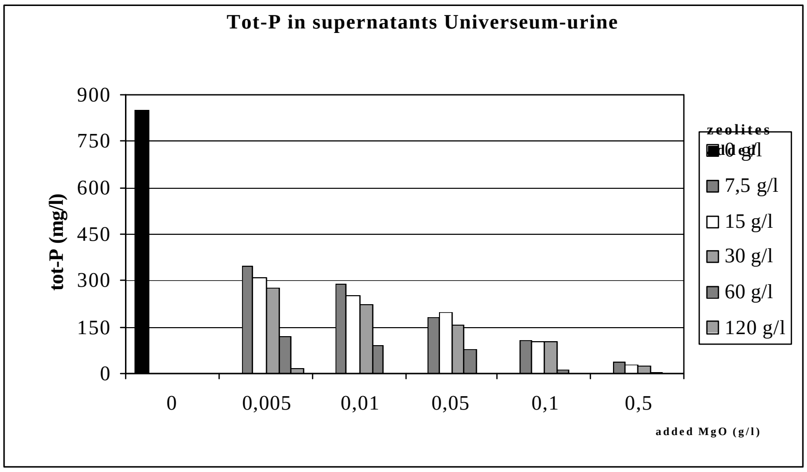

Figure 4: Total-P reduction in urine from Universeum by addition of MgO and zeolite.

Previous test results with combination of struvite precipitation and further ammonium uptake by zeolites have also demonstrated a 64-80% ammonium uptake together with a 98-100 % phosphorus uptake from human urine (Lind *et al*., 2000). Process optimisation at Universeum is in progress.

Sustainability and future work

Wastewater is a resource and should, therefore, be treated as such. However, its use has important hygienic aspects that has to be considered. The aquaculture technique is perfect as a demonstration pilot plant and for educational purposes regarding understanding the scientific background behind eutrophication, and could also be used for research on bioaccumulation and biomagnification of different elements in the organisms living in aquatic environments. But the aquaculture technique as such has only a limited potential as a commonly used wastewater treatment technique, even if it can be used in combination with other techniques. The most realistic and interesting approach on utilising the nutrients in human urine in urban areas is, therefore, simple collection in storage tanks. The urine fraction must then be transported to farmers to close the loop between urban and rural areas for further use in agriculture. This transport could be environmentally improved by using the struvite process, and in this way decreasing the transport of water. Therefore we are looking forward to construct a pilot plant for mineralization of N and P from human urine at Universeum in the near future. The research is at experimental level, mostly at laboratory scale, and a holistic approach including a system evaluation is necessary.

Modern society will probably continue to have some large-scale wastewater plants that were constructed during the 70ths and forward for many years to come. This is not a question of either having large and efficient conventional systems or small scale, expensive, low functioning systems, to meet the future demand on sewage systems. This is about how to use the best technologies in combination to meet the areal restrains of large cities and to recycle materials in an as environmentally friendly way as possible to reach a sustainable society for coming generations, and also considering aspects of what is acceptable from the users point of view.

This multiple use of the source-separated urine from one facility demonstrates a possibility for a sustainable recycling of nutrients between urban and rural areas and it also demonstrates the usefulness of human urine as a nutrient source for the exhibition visitors. Furthermore, any eco-toxicological concern including endocrine disruption, can be investigated in the aquaculture food chain, opening possibilities for interesting research projects in the future.

The Universeum ecological wastewater system is a demonstrating plant and a research site in an educational environment that is visited by people of all ages and professions. It is a good starting point for discussions and debates on future sustainable utilisation of human urine and wastes in general in urban areas.

Conclusions

- Urine collection and the utilisation of its main nutrients (N and P) have been practiced for two years (2002-2003) at a science centre (Universeum) in Göteborg, Sweden.
- Problems relating to the function of urine-separating toilets and mineralization of the nutrients have been addressed and partly solved.
- Ecological recycling is demonstrated in an aqua cultural food chain (algae-zooplankton-fish).
- Mineralisation of N and P by precipitation as struvite and adsorption to zeolite have been tested at a laboratory scale with recoveries of 30-85% of the total nitrogen and 95-98% of the total phosphorous in the collected urine.

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The effects of sewage sludge application on the yields of berseem and forage maize in newly reclaimed soil

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Key words

Egypt, nutrients, reclaimed soil, sewage sludge, trace elements, yields

Abstract

Two large-scale field trials with fodder crops (berseem and maize) were established under centre pivot irrigation on a reclaimed desert soil in the Western Desert, near Sadaat City, Egypt, comparing the use of air-dried raw sewage sludge with normal farmer practice. The application of sludge improved crop yields and strong residual benefits were observed in subsequent years. The nutritional quality of these animal fodders was also improved by sludge applied to this deficient soil, with useful increases in nutrient and trace element concentrations. There were no increases in heavy metal concentrations.

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Introduction

The newly reclaimed soils in Egypt are characterised by low fertility and poor moisture retention. Since animal manure is no longer readily available, other materials such as sewage sludge should be tested and used to meet soil nutrient and organic matter requirements. Sludge use in agriculture is widely regarded as the best practicable environmental option but is untested under Egyptian conditions (Smith *et al*., 1995).

Cairo produces large quantities of sludge (0.4 million t dry solids y^{-1}), and the preferred management option is beneficial use in agriculture. The Cairo Sludge Disposal Study (1995-99) was a 4 year demonstration programme, funded through the European Investment Bank, to evaluate how sludge can be reused practically and safely, particularly on newly reclaimed desert land.

This paper reports on one of the 30 arable and fruit field trials conducted during the study (Smith *et al*., 1999). The aim of this trial was to evaluate the effect of sludge on forage yield and quality in a fully mechanised large-scale field trial on calcareous sandy reclaimed desert soil.

Materials and methods

Two large-scale field trials were conducted under centre-pivot irrigation system on a private farm at km 100 on the Cairo-Alexandria Desert Road, under a rotation of fodder and cereal crops. Fertigation is normal farmer practice and large plots were established with and without sludge addition to assess direct, residual and cumulative effects. Only the fodder crops are considered in this paper. The first trial was carried out on berseem, while the second trial was with forage maize (*Zea mays* L.).

In 1995/96 winter season, berseem (Egyptian clover *Trifolium alexandrinum* L.) was grown on a centre pivot area of 30 ha. Half the area was treated with 24 m3 ha^{-1} of air-dried raw sludge prior to sowing and the rest untreated. Three cuts of berseem were made, yields assessed from 10 large randomly selected quadrats. Foliage was analysed for nutrients and trace elements.

In summer 1996, fodder maize was grown on a second pivot area (15 ha). The area was similarly divided and treated with 48 m^3 ha^{-1} of sludge. In summer 1998, maize was grown again and assessed for residual effects of the sludge applied two years previously.

Results and discussion

Soil and sludge quality

The soil type was a well-drained Typic Calciorthid (Aridisol), with contents of CaCO3 5%, gypsum 0.6%, organic matter <1%, with pH 7.5 and electrical conductivity of 3 dS $m^{-1.}$ The soil had only recently been brought under cultivation and previous crops had been poor due to the difficult soil conditions.

The chemical analysis of sludge from Abu Rawash WWTP used in the field trials is summarised in Table 1. The nutrient concentrations are typical for Egyptian sludges and heavy metal concentrations are well within prescribed quality limits (Decree 214, 1997).

Units: nutrients %, other elements mg kg^{-1}		
Determinand	Mean	±95% confidence
N	1.61	0.49
P	0.57	0.28
K	0.23	0.07
Fe	1.90	0.40
Mn	286	145
Zn	656	301
Cu	168	51
Cr	36.6	30.6
Pb	102	62.3
Cd	2.57	0.70
Ni	51.3	32.3

Table 1: Chemical analysis of sludge

Crop yields

The mean yields of berseem at each cut are presented in Table 2. There was no significant effect of sludge on berseem yield at the first cut when mean yields were13.2 and 12.5t ha^{-1} for the untreated (normal farmer practice) and the treated areas respectively. However, in the subsequent cuts, the yields from the sludge-treated area were significantly greater than the yields from the untreated area: the latter declined with each harvest to 5.0t ha^{-1} at the third cut, compared to 10.1t ha^{-1} from the sludge treated area. The maintenance of yields in successive harvests in this way is of significant benefit of sludge for the farmer. Overall, the results show that sludge applied at 24 m3 ha^{-1} increased crop yields from 27.8 to 37.8t ha^{-1}, an increase of 25%.

Treatments: FP farmer practice; SS sludge 24 m^3 ha^{-1}						
	Cut 1		Cut 2		Cut 3	
	FP	SS	FP	SS	FP	SS
Mean	13.2	12.5	9.6	12.2	5.0	10.1
p	>0.05		0.033*		<0.001***	
LSD	ns		2.4		2.6	

Table 2: Yields of berseem (t FW ha-1).

Treatments: FP farmer practice; SS sludge 48 m3 ha^{-1}		
	FP	SS
	First season (sludge applied)	
Mean	6.43	16.9
P	0.004**	
LSD	6.77	
	Fourth season (residual effect)	
Mean	12.7	17.0
P	0.008**	

Table 3: Yields of maize (t FW ha^{-1})

The yields of forage maize from the second trial in the first season are given in Table 3. The sludge-treated area produced a significantly higher yield ($P < 0.004$) than the untreated area; 16.9t ha^{-1} compared to 6.43t ha^{-1}, 160% increase. The yields generally were rather poor. The establishment of arable crops on newly reclaimed land can be variable due to the difficult soil conditions, particularly if seed is sown too shallow where it is more at risk of desiccation. The addition of the organic matter in the sludge may assist in moisture retention and improved seedling survival.

Maize was grown on the same area two years after sludge was applied. Yields were overall were much greater than for the first crop, presumably due to the intervening effects of cultivation and fertilisation. Nevertheless, significant residual effects on yield were observed on the sludge treated area (Table 3), presumably due to addition of organic matter and slow-release nutrients.

Crop quality

Table 4 summarises the nutrient content of the berseem (means of three cuts). The concentrations of the heavy metals Cr, Co, Cd, Pb, and Ni were below detection limits. There were only a few statistically significant beneficial effects due to the sludge application on N, P and K contents of berseem, bearing in mind that all of the crop received fertiliser by fertigation. However, the concentrations of Fe, Mn, Zn and Cu were generally significantly greater in the berseem grown on the sludge-treated area than the untreated area. Since the yields of the sludge-treated plot were also generally much greater, the total off-take of these nutrients would be substantial. Thus, in terms of plant and animal nutrition, sludge improved herbage quality since these elements are often deficient in such alkaline soils. Even so, Zn and Cu content of berseem on the sludge-treated plot only reached the adequacy levels for the ruminant nutrition.

It has been reported from similar trials through this study that frequent applications of sludge to reclaimed soil will increase soil fertility and can reduce inorganic N fertiliser requirements. Four to six consecutive applications at the suggested rates of addition (48m3 ha^{-1} for raw sludge and 24m3 ha^{-1} for digested sludge) can reduce inputs of inorganic N fertilisers by 50 %. Ameliorating the marginal physico-chemical properties of reclaimed soils for crop production demands large and frequent inputs of organic matter and plant nutrients. To satisfy this requirement, sludge can be applied regularly to reclaimed desert soils. All crops may be treated within a rotation provided that due diligence is given to balance K supply with inorganic fertilisers and that the sensitivity to N of certain crops, such as sesame and legumes, is considered. FYM can be used as an effective source of K and, if inorganic K fertilisers are not available, alternate dressings of sludge and FYM should be applied to balance NPK inputs to soil.

Units: nutrients % DM; trace elements mg DM kg^{-1}		
	Farme practic :	Sewage sludge
N	1.77	1.75
P	0.22	0.19
K	0.98	1.03
Fe	62.2	80.9
Mn	29.8	30.7
Zn	17.4	22.9
Cu	5.76	6.45

Table 4: Quality of berseem (means of 3 cuts)

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Conclusion

Sewage sludge has important cumulative and residual value for field crop production on reclaimed desert soils. Yields of crops grown on land treated previously with sludge may be increased by 10 - 20% compared with normal farmer practice. The addition of heavy metals to the soil during the trial was very small from a single application of sludge and had minimal effect on crop and soil concentrations. The calcareous nature of most Egyptian soils and the relatively low concentrations of heavy metals in Cairo's sludges Smith et al., 1995; 1999) means that it is unlikely that heavy metals from sludge will pose a significant threat, even in the long-term.

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Effect of long-term application of wastewater on bioavailability of trace elements and soil contamination

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Key words

DTPA extraction, citrus, Cu, Cd, leaf concentration, soil concentration, toxicity, Zn

Abstract

As part of a four year study evaluating the practicability and value of sewage sludge use in Egypt, soil and plant surveys were carried out on a citrus plantation, irrigated with Cairo sewage since the 1920s, in order to evaluate the long-term accumulation of heavy metals and their bioavailability. While total and DTPA soil concentrations correlated well, no relationship could be found between soil and plant tissue concentrations, despite elevated levels of heavy metals in the soil.

Introduction

Cairo is now served by six large wastewater treatment works which produce significant quantities of sludge. The preferred option is to use this in agriculture, particularly on reclaimed desert land which is inherently deficient in organic matter, nutrients and trace elements. However, there are concerns about the long-term accumulation and potential effects of heavy metals, and as part of the Cairo Sludge Disposal Study, a number of field trials and surveys have been carried out.

The Gabal El Asfar Farm is a fruit plantation on reclaimed desert land north of Cairo. It has been irrigated with sewage for over 80 years and there are concerns about the contamination of the site by potentially toxic heavy metals. The site provides a possible model of the potential long-term effects of heavy metals on crops for sewage sludge-treated soils in Egypt.

Materials and methods

The heavy metal contents of citrus leaves and fruit (orange and mandarin) and total and DTPA extractable concentrations in soils were measured in samples collected from different areas of Gabal El Asfar Farm during two surveys of the site in 1997.

Results and discussion

Total and DTPA concentrations of heavy metals in the surveyed soils showed significant enrichment by long-term irrigation with sewage effluent. For example, the maximum total concentrations of Zn and Cu were 530 and 366 mg kg^{-1}, respectively, representing a potential risk to crop yields (Table 1). The maximum Cd concentration detected was 9 mg kg^{-1} and Cd may be a potential risk to the human food chain from uptake into staple crops grown at the farm. The concentrations of DTPA extractable metals were also increased by sewage application and were significantly correlated ($P<0.001$) with the total contents of Zn ($r=0.81$), Cu ($r=0.89$), Ni ($r=0.88$), Cd ($r=0.73$) and Pb ($r=0.62$) (Figure 1a).

Element	Survey 1		
	Minimum	Maximum	Mean
Zn	180	530	331
Cu	50	117	84
Ni	1	51	22
Cd	1	9	3
Pb	5	70	23
Cr	80	230	154
	Survey 2		
Zn	32	143	95
Cu	7	366	67
Ni	10	92	45
Cd	0.2	4.6	1.6
Pb	16	290	70
Cr	2	376	89

Table 1: Total heavy metal content (mg kg^{-1}) of soil at Gabal El Asfar Farm

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However, crop analysis showed no relationships were apparent between tissue content (Table 2) and the corresponding total and DTPA extractable concentrations in soil for the elements determined (Table 3 and Figure 1b). Leaf Zn and Cu concentrations were in the low (16-24 and 3.6-4.9 mg kg^{-1}, respectively) to optimum (25-100 and 5-16 mg kg^{-1}, respectively) ranges for citrus. The other heavy metals were within normal ranges.

Whilst DTPA is widely used in nutrient diagnosis assessment, it has not provided a reliable indication of the bioavailability of potentially toxic elements to citrus in reclaimed desert soil.

	Fruit (Survey 1)			Leaves (Survey 2)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Zn	0.4	2.6	1.1	1.2	150	27.8
Cu	0.1	0.5	0.3	1.0	9.4	3.8
Ni	0.1	1.2	0.4	0.8	10.0	4.3
Cd	0.02	0.1	0.07	<0.1	0.2	0.1
Pb	0.2	2.1	1.0	0.5	30.0	12.4
Cr	0.4	3.6	2.0	0.2	4.1	2.0

Table 2: Heavy metal content (mg kg^{-1}) of citrus at Gabal El Asfar Farm

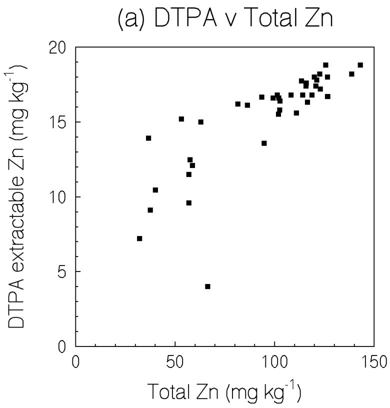

Figure 1a: Relationships between total and extractable Zn in soil at Gabal El Asfar Farm (Survey 2)

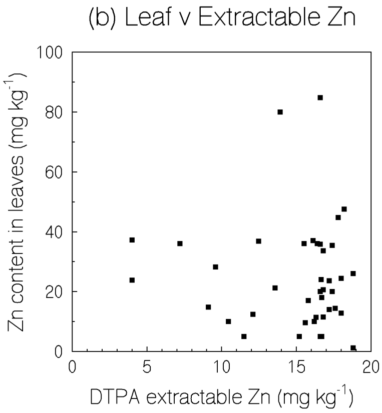

Figure 1b: Relationships between extractable Zn in soil and Zn content of citrus leaves at Gabal El Asfar Farm (Survey 2)

	Fruit		Leaves	
Zn	-0.11ns	0.03ns	-0.01ns	0.05ns
Cu	0.27ns	-0.03ns	0.36ns	0.24ns
Ni	0.06ns	-0.35ns	0.38ns	0.18ns
Cd	0.39ns	0.35ns	0.35ns	0.47ns
Pb	0.24ns	-0.24ns	-0.10ns	0.04ns
Cr	0.09ns	0.01ns	0.01ns	-0.05ns

ns: not significant at P=0.05

Table 3: Correlation coefficients (r) of relationships between metal concentrations in soil and citrus at Gabal El Asfar Farm

This study has contributed to a broader understanding of the behaviour of heavy metals in reclaimed sandy and calcareous desert soil which is the principal ‘market’ for sludge in Egypt. As part of the Cairo Sludge Disposal Study (Smith et al., 1995: 1999), funded through the European Investment Bank, this has contributed to the development of Egyptian standards for sludge use in agriculture (Decree 214, 1997).

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Urine-separating toilet in popularising ecological sanitation in the peri-urban areas of Manipur, India

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Keywords

Eutrophication, Imphal, Loktak lake, urine-separating toilet

Abstract

To popularise the beneficial aspects of the fertilizing utility of human urine to the general public of Manipur state and also to make a step toward checking the deteriorating environment of Imphal city by protection of water bodies, a urine-separating toilet has been introduced and demonstrated at Kangla a locality of Imphal city. The harvest of potatoes and chilies when urine is used as fertilizer are very good and comparable to the harvest which are fertilized with chemical fertilizer.

Urine-separating toilet at large may be adopted by the general public of Manipur state with awareness programme through print and electronic media and active involvement of NGOs.

Introduction

Manipur is the north-easternmost state of India adjoining with Myanmar. It is a hilly state whereas the central part consisting 10% of the total area of 22,327 sq. km. is the Imphal valley where 70% of the state's population of two million plus are inhabited. Traditionally by and large Meitei the people of the valley are orthodox. They consider human excreta as untouchable in any form whether dry or wet; raw or composted. Even in recent times one should necessarily take bath after toilet.

The two main rivers viz, Imphal and Iril flowing through the capital city Imphal are the main source of water for half the inhabitants of the city. The two rivers and river Nambul also act as open drains to which all the used water of the city are merged. The polluted river water ultimately join the Loktak lake to the southwestern side of the valley. Loktak lake is the biggest fresh-water lake in the north-eastern India. The socio-cultural civilization of the valley of Manipur has been flourished around this lake in its pristine time. But because of unchecked end-point disposal of all human activities including heavy loading of nutrients to the lake, the quality of the lake and its surrounding area has been deteriorating. Eutrophication is going on in the lake resulting in excess growth of aquatic weeds and floating mass of vegetation.

Even though the people of Imphal look neat and clean the traditional method of disposal of human excreta has not been so hygienic. Septic tank without soak-pit and pit latrine are the usual disposal system of human excreta. In the periphery most of the latrines are open-pit type. Sewage from the septic tank without soak-pit are directly discharged to the open drains which again flows mainly to any of the three rivers. But with the recent introduction of training programmes for capacity and capability building to the users in the sector of water and sanitation conducted by Human Resource Development Cell, sanitary latrine like two-pit pour-flushed latrines are becoming popular in the peri-urban areas of Manipur. People started taking interest in disposal of human excreta in a safer way.

The concept of urine-separating toilet (Ecological Sanitation–ecosan) was introduced by the author to groups of knowledgeable persons of Imphal city sometimes in the month of October, November 2001. One of the group started a pilot project on urine-separating toilet at a place known as Kangla about 10 km northeast of Imphal. A liberal minded family has been selected to adopt urine-separating toilet. In the household of 7 member family, three members the husband, wife and daughter were fully convinced about the benefits of ecosan specially the fertilizing utility of urine.

Methods

The three member team of the household started collecting urine by squatting on a tray kept in the toilet specially in the evening time. The urine was immediately transferred into a 5-litre plastic jerkin. The jerkin was kept closed and stored for a minimum of 10 days without dilution. 2.5 to 3 litres of urine can be collected in a day. All the collected urine were stored to be used as fertilizer later.

150 potatoes plants of JYOTI variety were planted on an ordinarily prepared bed during the first week of November, 2001. When the plants were of about 15 cm height and four leaves were sprouted from the stem, soils were scooped by THANGJOU (local contrivance) about 5 cm away from each plant and 200 ml stored urine without dilution was administered in the depressed area near the stem. After urine was poured the soils were made again flat as before. During the same time another bed with sprinkled DPA (Diammonium phosphate) was also prepared for planting another 150 potato plants of the same variety. Urea and potash were used as fertilizer on these plants at the same time when urine was put on the other bed.

Figure 1: Administering store-urine to the potato plants

Again in the first week of Jan, 2002, 200 plants of Chillies of "MEITEI MOROK ASHAANGBI" variety were planted on an ordinarily prepared bed. When the plants were about 25 cm high 150 to 200 ml stored urine without dilution was administered in the same manner as in the case of potato plants. Chillies are usually planted without any additional fertilizer otherwise the stems are bent and most of the plants are spoiled. As the stems of the urine fertilized chilli plants are growing faster spikes are provided to support the bending stems. During the same time another 200 plants of the same variety were planted on another ordinarily prepared bed without any fertilizer.

Results

During the third and fourth week of Feb, 2002 the potatoes were harvested. It has been found that the urine-fertilized-plants have 10 days longer time with green leaves before the leaves were wilted than the ordinarily fertilized-plant with DPA, urea and potash.

In case of chillies also the urine fertilized-plants have10-15 days longer time with green leaves. Harvesting started from the first week of July to the middle of August. Results of the harvest of both potatoes and chillies are summarised in the following table.

Crops	Variety	One time undiluted store - urine dose on each plant	Harvest
Potato	Jyoti	200 ml	Very good, produce are as good as that of fertilized plants with DPA, urea and potash
Chilli	Meitei Morok Ashaangbi	150 – 200 ml	20% more than the ordinarily planted chillies without fertilizer

Table 1: Result of the harvest of potatoes and chillies fertilized with store–urine

Conclusions

No one in the neighbourhood was informed about the urine fertilization on the potato and chilli plants and no complaint of anything sort including smell had come up from the neighbourhood. Even the older members of the same family were not informed less they might object because of religious believes and other orthodox views. In the Meitei society the first harvest of any plant is offered to the Almighty God and it is unthinkable for an orthodox Hindu Meitei to offer urine-fertilized potatoes or chillies to the Almighty. Nevertheless the harvest of both potatoes and chillies were very good without any extra cost and the family members were very happy. One toilet model with separate arrangement for urine collection tray has already been started functioning in the same locality after the successful story.

Awareness programmes with practical demonstration to show the beneficial aspects are essential to take-up ECOSAN activities in the area. Government efforts like advertisement in the radio, T.V. and newspaper are important steps to overcome the orthodox believes of the society. Active involvement of NGOs working in the field of water supply and sanitation is also necessary for widespread popularisation of ecosan in Manipur.

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Sustainability and optimisation of treatments and use of wastewater for irrigation in mediterranean countries

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Keywords

Epuvalisation, nitrogen fertilization, wastewater reuse, wastewater storage, wastewater treatment, wetlands

Abstract

The aim is to find long term solutions to the general problem of wastewater reuse, in accordance with specific needs and environmental conditions in Mediterranean countries. Low cost technologies for wastewater treatment are investigated. Free Water Systems with and without recycling, mixing olive oil wastewater with municipal wastewater or fresh water, achieve good results especially for BOD removal. The maturation and seasonal storage of wastewater prove the positive effect on decontamination rate. The epuvalisation system tests the purification efficiency of different hydroponics plants and reveals that mentha and celery are among the most robust and best suited ones. Irrigation techniques compatible with sustainable agriculture are studied for what concerns their impact on the irrigation system itself, on the soil/plant complex, as well as complementation irrigation for cereal crops and optimization of nitrogen fertilization under irrigation with wastewater. The study of performances of irrigation equipment using wastewater demonstrates that the drip irrigation system with integer emitters gives the best yields and optimal hydraulic working. The need of controlling the leaching of nutrients and contamination of soils and water leads to several recommendations in order to reduce the risk of nitrogen pollution as well as the cost of supplied water.

Introduction

The two aspects experimented in the frame of the INternational COoperation project – INCO (FP4) - financed by the E.U., are wastewater treatment, to obtain a effluent which can be reused in agriculture, and irrigation techniques, which are compatible with sustainable agricultural practices. The goals are to produce, in a sustainable way, crops irrigated with wastewater treated by low cost technologies adapted to the Mediterranean environment and adequate for producing advanced treated effluent. The success of this initiative results from the collaboration of Mediterranean countries research teams and European Union laboratories.

New technologies are developed for the treatment of wastewater from small settlements, villages and towns, in order to produce water suitable for irrigation. Traditional wastewater treatments have not succeeded due to the high costs of both construction and maintenance as well as to the need of highly specialized personnel for their supervision.

The use of wastewater for irrigation may potentially have adverse impacts on both the environment and the public health, mainly depending on the wastewater characteristics, degree of purification, method and location of use and irrigated crops. Soil, groundwater and surface water pollutions are the most important disadvantages of wastewater use. However, sound scientific planning and effective management of the irrigation or fertilization regime according to water and nutrient requirement of selected crops can minimize these disadvantages to the level of environmental insignificance. Selection of crops is one of the most powerful means to protect public health. Flowers, particularly those which are dried, industrial crops or crops consumed after transformations open new perspectives on wastewater use since they can be used on profitable and sustainable bases.

Material and methods

The technology developed for wastewater treatment by the Free Water Systems (FWS) consists of parallel basins or channels with permeable bottoms soil, emergent vegetation and shallow water depth. Pretreated wastewater is applied continuously and a further treatment occurs as water flows slowly through the stems and roots of the emergent vegetation. Among all the aquatic systems, the FWS are considered the most appropriate to obtain reclaimed wastewater for irrigation (Tchobanoglous, 1987 and Angelakis and Tchobanoglous, 1996). Various ponds configurations, including recycling or not, with various BOD loading rate, and selected indigenous aquatic plant species tests the efficiency of FWS for treatment of municipal and olive oil wastewaters.

Epuvalisation, the biological treatment of wastewater based on the principle of hydroponic crops, is a system well in use in temperate countries as a tertiary treatment, producing an effluent available for unrestricted agricultural reuse, producing greenhouse or decoration flowers, seaside windbreak plants, etc. Thanks to the gravity flow of the liquid to be purified, and an abundant aeration, the microbial flora acts like a bacterial bed. It mineralizes matter in solution and the plants, by their root system, act as a filter which retains the matter in suspension and pathogen micro-organisms. (Xanthoulis, 1996, 1997, Dumont, 1999) The transposition of the technology to Mediterranean countries has to face the problem of the too high temperature, which is lethal for both the rooting system of the plants and the bacterial bed in the channels, and also induces a lack of dissolved oxygen. The efficiency of the regional plants species are tested; flowers produced under irrigation are compared for their quality between irrigated one with water produced by epuvalisation and four other sources of water, added or not with fertilizers.

One of the disadvantages of wastewater reuse for irrigation is its microbiological quality. To avoid contamination of the crops by irrigation, the most influential factors on bacterial indicators die-off, together with the practice of long term storage of wastewater before irrigation, are identified. The bacterial decontamination time needed under various climatic conditions and with different basin depths and capacities are determined. The maturation and the seasonal storage of effluent are evaluated by means of the wastewater characteristics, under different storage basin management modes (M.Raïs, D.Xanthoulis, 1999). The products obtained (eg citrus and olive trees, eggplants) from crops irrigated with clear water and with wastewater treated by storage are compared for their microbiological qualities. Irrigation with wastewater also encounters problems with the irrigation systems themselves. The behavior and performances of micro irrigation systems are modified when wastewater, instead of conventional water, is used. The impact of wastewater is tested on drip irrigation, sprinkling and modernized furrow irrigation systems; emitters and filtration performances in laboratory are compared with results obtained in the field (Chenini, 2000). The influence of nitrogen and salts contents in the recycled wastewater has a capital importance on the growth of plants and the yields they achieve. The response of chickpeas to water application and the response curve of the plant yield to water level is studied in Israel. Nutrient and water regime management, alternations between well water and treated wastewater, to optimize the use of nitrogen, are tested to find solutions to the Moroccan problems of high electrolytes concentration in the well water.

Results

Preliminary results of pre-treatment processes, before entering the Free Water System, show a removal efficiency of BOD of 90% and 40% for Olive Oil Wastewater (OWW) and Municipal Wastewater (MWW) respectively. In the unit mixing OWW with fresh water without recycling, the Total Suspended Solids (TSS) and BOD concentrations of the effluent range from 282 to 663mg/L and from 225 to 750mg/L, respectively. In the other units, including recycling and units mixing OWW with MWW, the TSS and BOD concentrations of the effluent range from 68 to 501mg/L and 95 to 365mg/L, respectively. Briefly, a BOD removal efficiency of 77% is obtained with recycling and 51% without.

Celery is grown in epuvalisation channels at water flow rates of 400 and 300L/hour. A decrease of 45% and 37.5% in suspended solids is observed (from 40ppm to 22 and 25ppm), one also observes a decrease in nitrates from 85ppm to 62 and 64ppm respectively but no effect on the BOD removal (from 97mg/l to 94 and 95mg/l). From the results of Gerbera flower production per plant it is shown that freshwater produces significantly more flowers per plant than the other water qualities; fertilization has a significant effect on flower production for both freshwater and borehole water but no significant effect on wastewater irrigated plants. In general freshwater produces better quality flowers in terms of flower height, weight and especially diameter, without the application of fertilizers. In the case of wastewater treatments, there is a significant difference in the quality of flowers with and without addition of fertilizer, whereas, in the case of freshwater, there is no significant difference between the two treatments. In the case of borehole water there is a significant increase only in flower weight with the application of fertilizer but no significant effect on flower height or diameter.

For the Long Term Storage, the trend curves of the microbiological decontamination rate, with respect to the evolution of the faecal coliform concentration in the water of basins with different depths, exhibit the same behaviour and are close to each other, illustrating a similar decontamination effect. Thus the volume of stored water has little influence on decontamination progress. The results for the bacteria indicators during a seasonal storage prove that long term storage improves the bacteriological quality of the water. The mean rate for the faecal germs tends to decrease till values undetectable with the analytical method being used. The comparison of results obtained from plots irrigated by means of reclaimed wastewater with and without storage basin has not shown a significant effect on bacterial quality of the yield. The study of performances of the irrigation equipment using wastewater shows that the drip irrigation system (integer emitters) is the system giving the best yield and the optimal hydraulic functionning.

The influence of nitrogen and salts in recycled water on the growth of chickpeas shows that increasing the application of nitrogen under form of fertilizer gives lower yields than those obtained in the control treatment. High salts content decreases the symbiosis and nodule formation on the roots of plants. Increasing nitrate concentration sharply reduces the uptake of molybdenum which, in turn, reduces nitrate assimilation by the plants. A few promising species, suitable for early and late planting, that respond to irrigation with yield increase, are identified. For wastewater management, one of the most important parameters to be carefully considered is the irrigation scheduling. When properly managed, treated wastewater has the benefit of reducing environmental degradation. Alternating saline well water with treated wastewater reduces the nitrogen leaching and increases the nitrogen efficiency. The results show that treated wastewater does not only supply major nutrients (N, P, K) but also contains micronutrients and soluble organic substances which stimulate growth and increase the total yield. Efficiency of water use on sweet pepper improves with increasing nitrogen application. Since treated wastewater is rich in nitrogen, it therefore increases total fruit yield and increases water use efficiency, as already reported by many investigators (Hussain Al-Jaloud.H, 1995). Increasing the water regime irrigation by 20% reduces the nitrogen efficiency for all treatments (Xanthoulis, 2001).

Conclusions

New alternative wastewater treatments are successfully investigated, producing water suitable for irrigation without restriction, opening new perspectives for wastewater reuse in Mediterranean countries.It is now proved that a proper irrigation management, with attention drawn to a good equipment, applications adapted to the plants growth stages, respecting quantities depending on the soil and wastewater characteristics, cultivating species more resistant, irrigating in alternation with fresh water, are new agricultural practices that may improve yields and products quality, without using conventional water, already in deficit for domestic and industrial uses in Mediterranean countries.

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Investigation of constructed wetland performance considering water reusing

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Introduction

With the development of economics, water needs rose rapidly. At the same time, water resource was destroyed because of serious water pollution along with economic development. Water shortage has become a worldwide crisis.

In China, more than 300 cities face the problem of water shortage, moreover, more than 50 cities with population higher than one million are in very serious water shortage now. It was estimated that total water shortage has reached 11 million cubic meters per day, and as a result more than 120 billion RMB of industrial production value was influenced. On the other hand, lack of efficient way for water treatment, only 70% of the industrial wastewater and less than 15% of the domestic wastewater is treated now. Low-level wastewater treatment deteriorates the water environment and sharp the water shortage crisis furthermore.

To be benefit to the whole environment and considering the concept of Ecological Sanitation, besides sanitation itself, disposal of wastewater and sewage before the water is discharged into environment or development the reuse technology are also important aspects.

Ideally, ecological sanitation systems enable the complete recovery of all nutrients from faeces, urine and greywater to the benefit of agriculture, and the minimisation of water pollution, while at the same time ensuring that water is used economically and is reused to the greatest possible extent, particularly for irrigation purposes.

Constructed wetland is just anticipated to be a potential ecological engineering act to ameliorate dispersed point source pollution and improve the environment. The most important, from one aspect, the effluent can be considered to be reused for irrigation, on the other side, the nutrient can be absorbed by aquatic plant and then recycled for paper making or recycled as fertilizer after they are composted.

To optimize the operation of constructed wetland, orthogonal designed experiment is introduced to investigate the influence of several key factors of constructed wetland to the performance of pollutants removal. The feasibility of application of constructed wetland to treat domestic wastewater directly, and the feasibility of using effluent for irrigation are discussed.

Method

Considering the variables those will influence the performance of constructed wetland and gas emission, four species of hydrophytes, two types of media, two values of water level and hydraulic loads were used. The designed mixed level orthogonal experiment arrangement was shown in Table 1 and the schematic figure of the experimental facility was shown in Figure 1.

Trail No.	Factors			
	Plant Species	Media Type	Water Level(cm)	Hydraulic Load (cm/d)
1	*Cyperus alternifolias*	Sand	10	10
2	*Cyperus alternifolias*	Gravel	-10	5
3	*Vetiveria zizanioides*	Sand	10	5
4	*Vetiveria zizanioides*	Gravel	-10	10
5	*Typha Orientalis*	Sand	-10	5
6	*Typha Orientalis*	Gravel	10	10
7	*Phragmites australis*	Sand	-10	10
8	*Phragmites australis*	Gravel	10	5

Table 1: Assignment of the factors in the orthogonal experiment

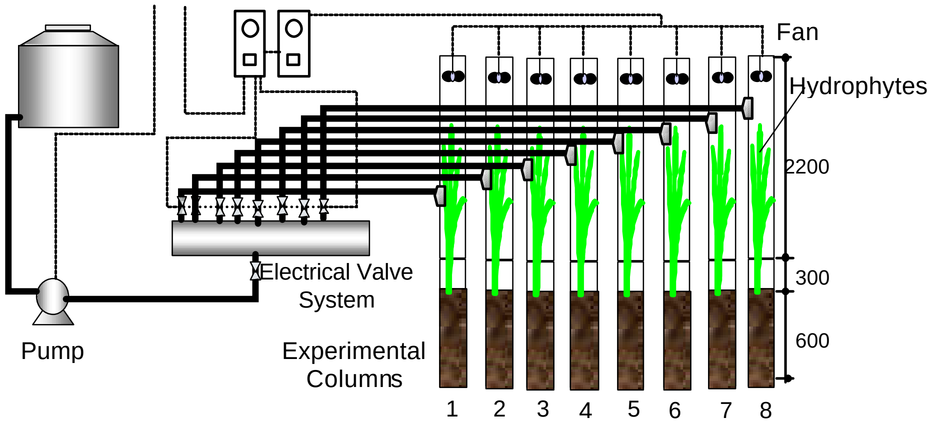

Figure 2: Schematic diagrams for orthogonal designed experiment facilities

Results

For NH_3-N removal, all these four factors showed obvious influence on the results. Increase of hydraulic load decreases the removal rate of NH3-N. Sand media achieved higher NH_3-N removal than grave due to the higher specific surface area for microorganism's growth in it. Veteveria and Phragmites got better NH_3-N removal than the other two types of plant. Water level of 10cm lower than media surface achieves higher NH3-N removal.

The same tendency was found among the results for COD and T-N removal, but the difference that was found is not obvious. This is supposed to be due to the high ability of COD and T-N removal for these systems during the experiment period and the difference was not shown.

But if consider the potential influence of system effluent to result in algae bloom, Plant species seemed to be very significant to influence it. Plant Cyperus alternifolias and Phragmites australis were recognized to be good for Algae growth control.

Conclusions

Considering pollutants removal, the extreme deviation for hydraulic load is highest and it means it influence the performance the most. The next is water level. Influence of plant and media type is very closed to each other. But consider algae growth potential of effluent, plant species was recognized to be most important.

The use of sewage fertiliser products on arable land – requirements from the farmers' perspective

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Keywords

Farmers, fertilisers, on-site treatment, sewage products, source separation

Abstract

The aim of this paper was to discuss farmers' requirements for using sewage products as fertilisers on arable land. A questionnaire followed up with interviews was used in a watershed area close to Stockholm. The study also included calculations of the cost to farmers of handling different sewage products. Farmers were most interested in source-separated human urine and precipitated septic tank sludge originating from on-site treatment. A high concentration of plant nutrients was important for farmers, as well as good hygiene quality of the product and a low content of heavy metals. However, the most important factor for farmers was that the expenses for e.g. collection, transporting, storage and spreading were covered.

Introduction

In Sweden, interest is growing for small-scale and source-separating wastewater systems from which the sewage products can be recycled as fertilisers in agriculture. One reason for this is the recommendation from the Swedish Farmers' Organisation (LRF) not to use mixed sewage sludge from conventional wastewater treatment plants on arable land. The Swedish food industry is also very reluctant to buy agricultural products grown on fields fertilised with sewage sludge. Several environmental systems analyses have also found that source-separating systems are more environmentally friendly than conventional (e.g. Bengtsson *et al.,* 1997; Kärrman *et al.,* 1999; Jönsson *et al.,* 2000). Local recirculation systems also decrease the need for transportation, and thus air emissions. However, finding arable land on which to spread the products has been identified by urban authorities as a serious obstacle to the introduction of systems for recycling the sewage products from on-site treatments. This problem also remains for sewage fertiliser products acceptable to the food industry.

Why is there such a low demand from the agricultural sector for these sewage fertiliser products? What are the requirements of farmers as regards the systems and the sewage fertiliser products? How can systems, in which for example farmers act as entrepreneurs, be designed? In order to answer these questions, a study was performed in the watershed area of 'Oxundaån' close to Stockholm (Sjöberg, 2003). In this area, which includes five municipalities, different projects aimed at improving the water quality have been initiated. As 90% of current on-site treatment plants in this area are considered to be operating insufficiently, the urban authorities concerned have an interest in alternatives to the current wastewater systems.

Methods

Initially, a questionnaire was sent out to all 180 farmers in the area, involving 6800 hectares of arable land. Answers were received from 50 of the farmers, corresponding to 70% of the arable land in question. Eleven of the farmers were further selected for interviews, based on their interest in taking part in future systems for recycling of sewage fertiliser products. These interviews were organised in a semi-structured way consisting of both quantitative and qualitative parts. In both the interviews and the questionnaire, questions were posed concerning farm production, as well as farmers' attitudes towards different sewage products originating from on-site treatment and their willingness to act as entrepreneurs within these systems. The on-site sewage systems considered were urine separation, blackwater separation, chemical precipitation in the septic tank, package treatment systems and filter beds. These products were selected as they give a high reduction in nitrogen and/or phosphorous and enable a high degree of recirculation. Information on the different systems was sent out to the farmers beforehand. The study also included calculations of the costs relating to the handling of different sewage products; i.e. transportation, storage and spreading operations.

Results and discussion

More than 50% of the farmers were positive towards the use of sewage products from the neighbourhood. Five of these, holders of 1100 hectares in total, were highly interested in starting a closer cooperation with the community by handling and using different sewage products as fertilisers. These 1100 hectares correspond to the area required for spreading urine from 16.000 individuals, precipitated septic tank sludge from 25.000 individuals or blackwater from 16.000 individuals. The most interesting fertiliser products from the farmers' perspective were source-separated human urine and precipitated sewage sludge from septic tanks originating from on-site treatment (Figure 1).

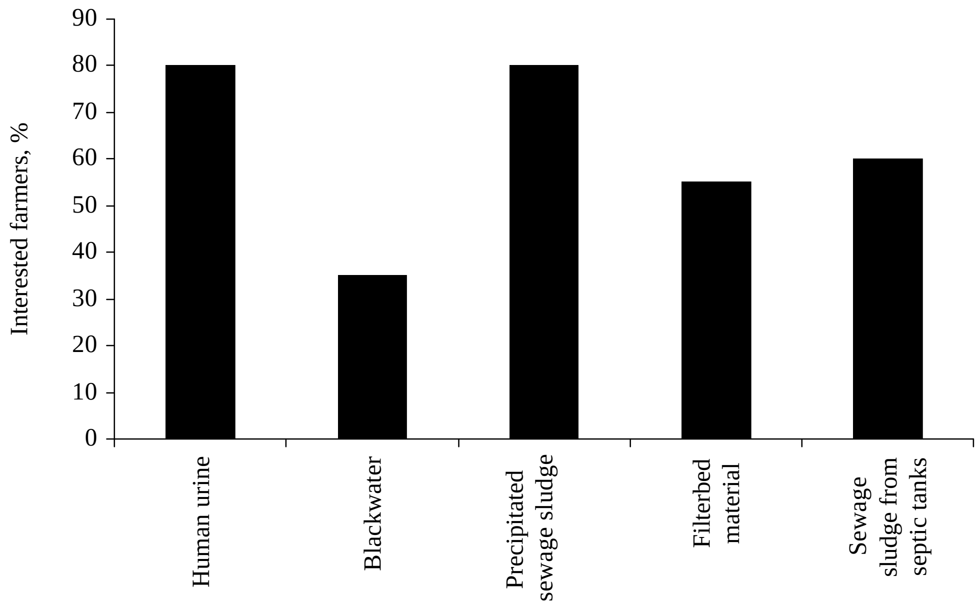

Figure1: Degree of interest of farmers in different fertiliser products from on-site sewage systems.

A high concentration of plant nutrients was a key issue for the farmers. The main advantages with source-separated human urine were its high content of available nitrogen and the fact that the spreading could be extended in time, since it can be spread both before sowing and in the growing crop. A phosphorus-rich product, such as precipitated sewage sludge from septic tanks, could on the other hand be spread during less busy seasons, e.g. the autumn, which can minimise the risk for soil compaction. Both source-separated human urine and sewage sludge from septic tanks involve relatively small volumes to handle, compared with e.g. blackwater, a fact that was also highlighted as important by the farmers. However, different machinery is required for handling different products depending on the characteristics of the products.

Good hygiene quality of the product was pointed out as important, as well as a low content of heavy metals (Fig. 2). According to the farmers surveyed, the amount of heavy metals in sewage products must be low enough not to give rise to an accumulation of these in the soil. In cases where the farms were situated close to residential areas, possible odour during the spreading operation could be another obstacle.

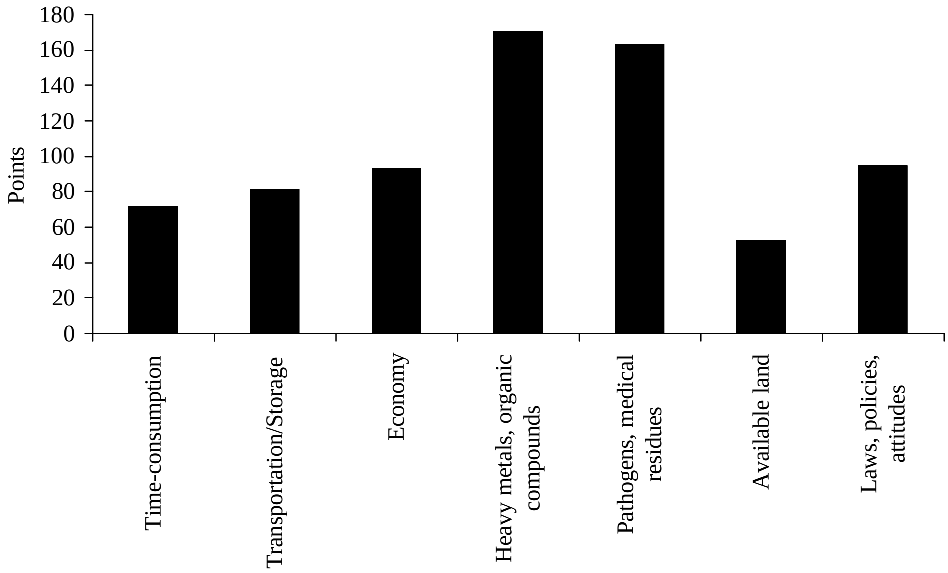

Figure 2: The evaluation of factors regarded as obstacles for using sewage products from on-site sewage systems among the farmers who responded to the questionnaire. The points came from a ranking system where the highest points were given to the alternative regarded as the most difficult obstacle.

Utilising plant nutrients in sewage products is more interesting for farmers specialising in crop production than for farmers specialising in milk and meat production, as those often already have a surplus of plant nutrients on their farms. Existing spreading equipment on farms handling manure might, however, be an economic and practical advantage for animal farms. From an environmental point of view, sewage products should be used on farms specialising in crop production, as the plant nutrients in sewage products can replace mineral fertilisers on such farms.

The farmers stressed the importance of acceptance for these sewage fertiliser products from the food industry as well as the authorities and neighbours. It is therefore an advantage if the farmers or the farmers' organisations become involved in an early stage of the planning of such systems. Some farmers wanted the responsibility for the whole chain, including collection, storage and spreading, while others only wanted to let their land for spreading the products.

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However, an absolute prerequisite for the farmers' involvement was that the expenses for e.g. collection, transporting, storage and spreading should be covered. Today, it is not unlikely that the cost of the spreading operation will in itself exceed the value of plant nutrients in the sewage products. Spreading under poor soil conditions might also give severe soil compaction. For urine, the economic value of the plant nutrients corresponds approximately to the cost of spreading concentrated urine, without any flushwater mixed in. In this study the cost of collection, storage, sanitation and spreading of source-separated urine was 120 SEK per person and year. The corresponding cost was 1100 SEK for blackwater and 200 SEK for precipitated sludge. The value of the fertiliser products was between 5 and 22 SEK per person and year. Although the farmers surveyed said that lack of time was an obstacle today to becoming involved in sewage fertiliser recycling, they would consider making other priorities if the economic compensation was high enough.

Conclusions

- Farmers interested in using sewage products as fertilisers can easily be identified by strategic methods.
- Several different sewage fertiliser products might be of interest for agriculture. The machinery required for handling the different products differs depending on the characteristics of the product.
- Farmers seem to be most interested in source-separated human urine and precipitated septic tank sludge.
- The quality of the sewage product regarding e.g. hygiene and heavy metals must be high and guaranteed through continuous analyses.
- It is important to involve farmers and other actors, e.g. the food industry, at an early stage when planning new recycling wastewater systems in an area.
- The sewage products represent an economic value corresponding to their concentration of plant nutrients. However, in most cases the farmers must be compensated for the costs related to e.g. collection and transportation and even spreading.

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Feasibility studies

Chairpersons

Amah Klutse (CREPA, Burkina Faso)

Christine Werner (GTZ, Germany)

Lectures

Sanitation concepts for separate treatment of urine, faeces and greywater
Anton Peter-Fröhlich, Isabelle Kraume (Berliner Wasserbetriebe, Germany), *André Lesouëf, Lionel Gommery, Laurent Phan, Martin Oldenburg*

Ecosan modules - adapted solutions for a medium sized city in Mali
Kerstin Bark, Martin Oldenburg (Otterwasser GmbH, Germany), *Waltraud Keipp*

Planning of an alternative wastewater concept for two villages in North-Rhine-Westphalia (NRW), Germany*
Michael Becker, Silke Geisler, Brigitte Sprengler (Emschergenossenschaft/ Lippeverband, Germany)

Finding of ecosan potentials - general aspects of a project example in Yemen
Martin Oldenburg (Otterwasser GmbH, Germany), *Bernd Kaltwasser, Andreas Koch*

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Source-oriented sanitation in rural regions
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Energy, water supply and waste water treatment for the Werbellinsee-project (ex. „Pioneer Republic Wilhelm Pieck")
Harald Kraft (Ingenieurbüro Kraft, Germany), *Andreas Schiller*

SWAMP - Sustainable water management and wastewater purification in tourism facilities
Klaus Bahlo, Susanne Lehwald (Ingenieurbüro AWA, Germany)

Sanitary systems in Ouagadougou, Burkina Faso: Current practices and future potential
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Zero emissions concept for Water and Wastewater Management, Project Rügen, Germany
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Poster presentations

Possibility of sustainable sanitation in Japan
Shinji Miura, Masaya Kobayashi, Katsuyoshi Ishizaki (Nagasaki University, Japan), *Naoko Nakagawa, Zhen Liu*

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*This paper has been peer reviewed by the symposium scientific committee

Sanitation concepts for separate treatment of urine, faeces and greywater

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Keywords

Decentralised wastewater systems, faeces, greywater, separation toilet, urine, vacuum separation toilet.

Abstract

In order to define the experiments for testing new, sustainable sanitation concepts a pre-study has been done. This study includes a cost comparison between two new sanitation concepts with gravity and vacuum separation toilets and the conventional system. It could be demonstrated that the new sanitation concepts may have cost advantages depending on the situation. This was a further motivation starting a pilot project in Berlin/Brandenburg testing the above mentioned toilet systems under realistic conditions. The operation of the gravity separation toilets concept will start in the summer 2003.

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Introduction

World-wide serious problems with water in relation to quantity and quality are recognized as a challenge for the next decades. These problems can not only be solved by maintaining the existing drinking and wastewater techniques and concepts which are in use in industrialised countries.

Thus new techniques and concepts for drinking water preparation and supply and wastewater discharge and treatment should be additionally developed. This more sustainable approach should consider the reuse of treated water as well as the recycling of the nutrients if possible. Furthermore the energy consumption for wastewater discharge and treatment should be minimised. Such techniques and concepts are already available and in use, but further developments and validations are still necessary.

These are the reasons why Berliner Wasserbetriebe (BWB) and Vivendi Water (VW) launched this research-project in the framework of the Kompetenzzentrum Wasser Berlin (KWB).

The main goal of this project is the development of new sustainable sanitation concepts which have significant advantages according to ecological as well as to economical aspects compared to the conventional systems (end-of-pipe-system), which are mainly used in industrialised countries.

The new sanitation concepts should represent a relevant solution for:

- remote areas, where the connection to a central system (e.g. big pipe networks) wouldn't be technically or economically feasible,
- rapidly growing suburbs in developing countries,
- countries with scarce water resources and
- it should be a contribution to the sustainable development with the recycling of nutrients and water.

Methods

The project is divided into two phases (***Phase I,*** pre-study and ***Phase II***, pilot project). ***Phase I***, a theoretical approach, has been finished at the end of 2001.

- **A literature based project review**, patent reviews and a collection of informations about the various projects were made. Furthermore existing projects with separate treatment in Germany, Denmark and Sweden have been visited. These informations and detailed economic investigations have been the prerequisite for continuing the project.
- **Cost comparisons between a conventional and two new sanitation concepts** for an intended new housing estate in the federal state Brandenburg near Berlin have been made. The housing estate should be realised stepwise from 672 up to 5,000 inhabitants within the next 10 years. For the economic calculation three different sanitation concepts have been compared for different cost levels:
  - **Conventional sanitation concept:** Conventional flush-water toilets with stop bottom, one sewer system, normal gravity sewer system for the area, pumping station with transport sewer to the existing sewer network, system operated by the public supplier.
  - **Separation sanitation concept (gravity, composting of faeces):** Gravity separation toilets, collection and storage of the urine, transport to the farmer nearby and utilisation in agriculture, faeces transported by a gravity sewer system, aerobic treatment in a compost separator, utilisation of the compost in the horticulture on the area, transport of greywater in gravity sewer system, treatment in a constructed wetland, transport to the receiving water.
  - **Separation sanitation concept (vacuum, digestion of faeces):** Vacuum separation toilets, gravity urine transport, storage of the urine, transport to the farmer nearby and utilisation in agriculture, faeces transported by a vacuum sewer system, common treatment with bio waste in a biogas plant, biogas utilisation by the equipment of the energy concept, transport of the digested sludge to the farmer nearby and utilisation in the agriculture, transport of greywater in gravity sewer system, treatment in a constructed wetland, transport to the receiving water.

The comparison of these three sanitation concepts has been considered for four scenarios which are shown in table 1.

	Inhabitants	Water Operator *
Scenario 1	672	Local company
Scenario 2	5,000	Local company
Scenario 3	672	Berliner Wasserbetriebe
Scenario 4	5,000	Berliner Wasserbetriebe

* This determines the costs of the "conventional" system and the costs for drinking water in all scenarios

Table 1: Scenarios for the cost comparison of the three different sanitation concepts

A decision based on an economic point of view should consider three aspects:

- Costs of the investment
- Costs of the reinvestment
- Operation costs

The cost calculations are made under the following assumptions:

- Lifetime of the project: 50 years
- Duration of the components depending on their lifetime. Reinvestment after the end of the lifetime.
- Real interest rate: 3.5% per year
- Maintenance costs are calculated as a percentage rate of investment. Personal costs are taken in consideration separately.
- Operation costs divided into costs for
  - personal equipment
  - maintenance
  - water and wastewater
  - electricity
  - others equipment

The specific costs for water, wastewater, connection fees, energy and other costs are based on the informations of the local company or of the Berliner Wasserbetriebe. With these assumptions and informations the costs for the whole project period are calculated as total project costs. The total project costs (Projektkostenbarwert) are the sum of money which is necessary for financing the whole project (investment, operation, reinvestment; see figure 1) for the assumed lifetime based on today's cost level.

The calculations have been realised with the German guideline "Dynamische Kostenvergleichsrechnung" (dynamic cost comparison calculation) published by the "Länderarbeitskreis Wasser LAWA", a working group of all federal countries in Germany concerning water management) (LAWA, 1998). This method can also named as a lifecycle analysis.

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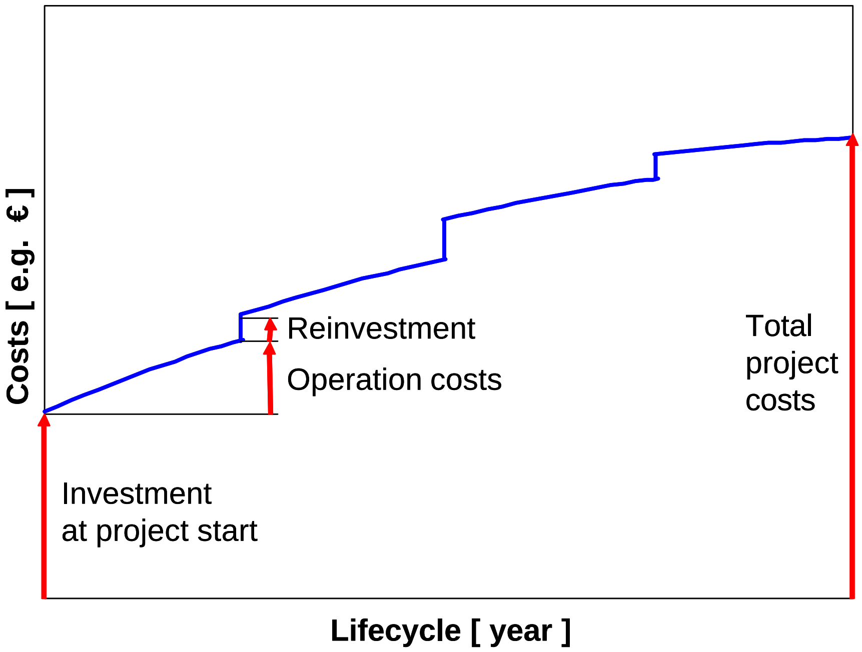

Figure 1: Demonstration of the total project costs (Projektkostenbarwert)

Results

a) Literature survey and visits

The main results from the pre-study are:

- 17 new sanitation projects already exist in Western Europe (Table 2).
- The activities in relation to new sanitation concepts are increasing all over the world.
- The separation of urine, faeces and greywater based on the use of new toilet bowls, has proven to be feasible and accepted by the users (Johansson, 2001; Hellström and Thurdin, 1998; Swedenviro, 2001).
- Once urine is separated from the faeces, several configurations exist, differing between them by the collection and transport system chosen and the treatment of the three effluents (faeces, urine, greywater) (Otterpohl *et al.*, 1999).

No.	Project Name	Country	City	Project Start (year)	Toilet Installation	URL Project	Responsible Organisation
1	Hamburg-Allermöhe	Germany	Hamburg	1990	Composting toilet		
2	Hamburg-Braamwisch	Germany	Hamburg	1992	Composting toilet	www.oekologische-siedlung-braamwisch.de	Ökologische Siedlung Braamwisch e.V.
3	Kiel-Hassee	Germany	Kiel	1992	Composting toilet		Ökologische Siedlung Hassee
4	Öko-Technik-Park Hägewiesen	Germany	Hannover	1992	Solitar vacuum toilet	www.oeko-technik-park.de	BauBeCon AG mit Stadtwerke Hannover AG
5	As	Norway	As	1992	Drying toilet		
6	Ecological Village Björnsbyn	Sweden	Björnsby near Lulea	1994	Separation toilet		NLH (Norrbottens Läns Hushallningssällskap - the Agricultural Society of Norrbotten County)
7	Bielefeld Waldquelle	Germany	Bielefeld	1995	Composting toilet		
8	Palsternackan	Sweden	Stockholm	1995	Separation toilet		
9	Understenshöjden	Sweden	Stockholm	1995	Separation toilet		
10	Freiburg Vauban	Germany	Freiburg	1998	Vacuum toilet	www.vauban.de	
11	Gebers	Sweden	Skarpnäck	1998	Separation toilet (Drying toilet)	www.iees.ch/cs/cs_4.html	Fastighetsägare, BRF Konditorn, Gebersvägen 24, 128 65 Sköndal
12	Kiel-Vieburg	Germany	Kiel	1998	Composting toilet		
13	Hyldespäldet	Denmark	Kopenhagen	1999	Separation toilet		
14	Mön Museum	Denmark	Mön	1999	Separation toilet		
15	Wohnsiedlung Flintenbreite	Germany	Lübeck	1999	Vacuum toilet	www.flintenbreite.de	infranova GmbH & Co. KG, Flintenbreite 4, 23554 Lübeck
16	Lambertsmühle	Germany	Burscheid	2000	Separation toilet		Wupperverband
17	SolarCity Linz-Pichling	Austria	Linz	2001	Separation toilet		SBL Stadtbetriebe Linz

Table 2: Existing new sanitation projects in Western Europe

b) Cost comparison

The cost comparison between the conventional and new sanitation concepts shows that the new sanitation concepts have not only ecological advantages but can also have economical advantages (see below). The cost advantage is very depending on the specific conditions of the housing-estate. For the chosen example (see methods) cost advantages occur in the most cases of the new sanitation concepts. For the demonstration, the results only from the best and the worst scenario (*Scenario 2* and *Scenario 3*) are shown in figure 2 and figure 3, respectively.

Scenario 2 (figure 2) shows, that both new sanitation concepts are cheaper compared to the conventional system after 3 and 9 years, respectively. The results from *Scenario 3* (figure 3) demonstrate only the benefit of the new sanitation concept with gravity separation toilets compared to the conventional system right from the project start.

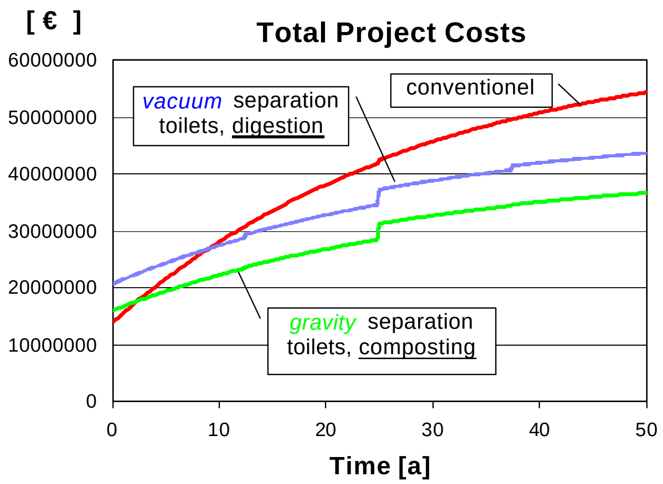

Figure 2: Total project costs for the conventional and the new sanitation concepts (*5,000* inhabitants); cost basis: *local company*

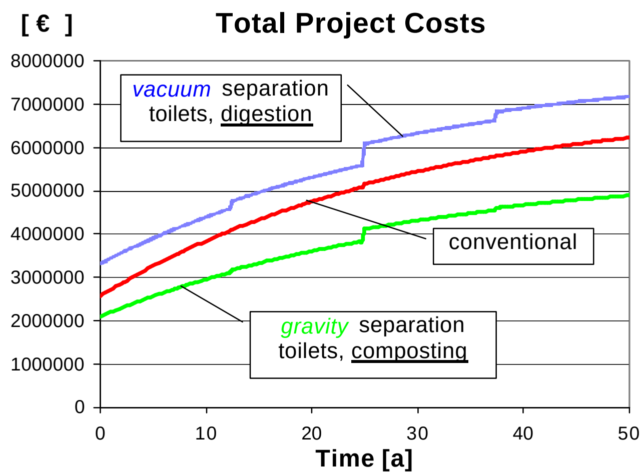

Figure 3: Total project costs for the conventional and the new sanitation concepts (*672* inhabitants); cost basis: *Berliner Wasserbetriebe*

The results from this cost comparison were an additional motivation for the start of a pilot project testing

- gravity separation toilets and
- vacuum separation toilets

in conjunction with different treatment configurations. The pilot project started in the year 2002 (***Phase II***). The new sanitation concepts will be tested in existing buildings (office building and apartment house) of the Stahnsdorf WWTP owned an operated by the Berliner Wasserbetriebe. The realisation of the new sanitation concept in the office building takes place in the frame of a general restoration of this building. For the apartment house a stepwise realisation of a new sanitation concept is intended.

The general process scheme for the new sanitation concepts in the office building and in the apartment house can be seen in Figure 4.

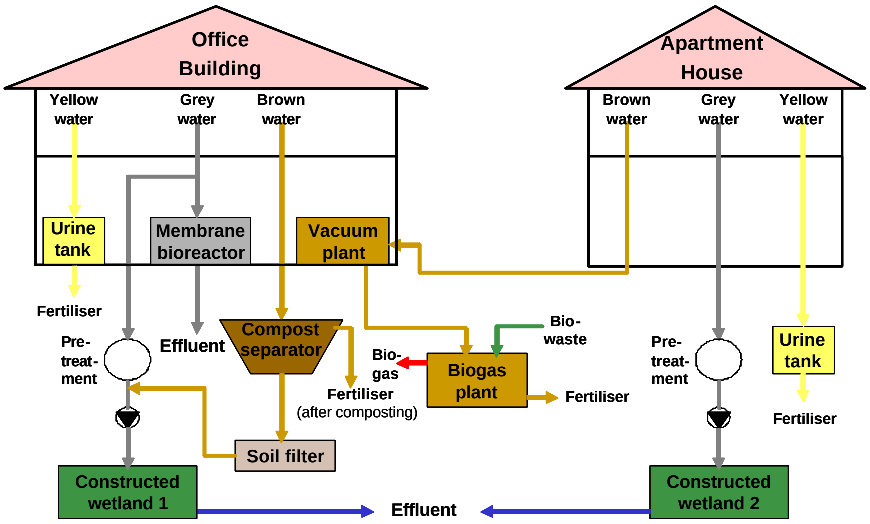

Figure 4: New sanitation concepts with *gravity* separation toilets in the office building and with *vacuum* separation toilets in the apartment house of the WWTP Stahnsdorf

In the new sanitation concept for the office building gravity separation toilets (10 toilets) will be used. Five waterless urinals are additionally provided in the men toilets. The faeces will be drained and composted. The filtrate from the compost separator will be treated with a soil filter before mixing it with greywater. The greywater passes a septic tank before the treatment in a constructed wetland. In parallel to the constructed wetland a membrane bioreactor will also be tested for the greywater treatment. The urine will be stored in tanks. Different methods will be tested for the handling and treatment of the urine before using it as fertiliser. The methods will be adjusting different pH-values during the storage of the urine, extraction of the nutrients etc.

For the new sanitation concept for the apartment house (15 flats) vacuum separation toilets are taken into consideration. This type of toilet is under development. In this concept the urine and the greywater are discharged transported by gravity and the faeces by a vacuum system. Each flow is also treated separately. The urine will be treated as mentioned above. The faeces will be digested together with ground bio waste. The digested sludge is also a fertiliser, e.g. for farmlands. The biogas can be used either in gas cookers or in a combined heat and power unit (CHPU). This topic will not be tested in this project. The greywater passes like in one case of the office building a septic tank before the treatment in a constructed wetland.

Since the dish washing powders has a high content of phosphate (often more than 30 %) and dishwashing machines are more and more common, for both concepts, a phosphate precipitation could also be necessary for the greywater treatment.

The treated greywater can be used e.g. for irrigation in general. In this project the effluent of the membrane bioreactor will be investigated for the different options of utilization as water on a lower quality level than drinking water.

These two sanitation concepts are technical options belonging to the new approach, others are possible, e.g. composting of the faeces together with bio waste in cases if production of biogas is not wished.

The kind of greywater treatment for both new sanitation concepts will differ depending from the special situation. For large settlements an activated sludge tank etc. could be a more appropriate solution than a constructed wetland. But the size of an activated sludge tank for

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greywater treatment can be much smaller as for municipal wastewater treatment due to the far lower load of COD, Nitrogen etc. (Otterpohl, 2001).

Conclusion

The results from the pre-study of this project enhanced the motivation for realising a pilot project testing gravity and vacuum separation toilets.

Although the cost comparison showed higher costs for the new vacuum sanitation concept compared to the gravity sanitation concept and although the operation is likely to be less simple, it may be an appropriate solution especially in cases with water shortages. The flush water consumption will be about 6 l/(p•d) compared to about 15 l/(p•d) for the gravity separation toilet or about 25 – 40 l/(p•d) for the conventional toilet with stop bottom.

Important objects of this pilot project (***Phase II***) are:

- Increasing of the knowledge of design and installation of new sanitation techniques based on separation technologies
- Experience of the operation of new sanitation concepts by investigation of the various modules of the separation concept in different conditions

In accordance to the schedule of this pilot project the start of the operation of the gravity concept in the office building is planned for summer this year (2003).

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Ecosan modules - adapted solutions for a medium sized city in Mali[1]

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Keywords

Desiccation of faeces, urine separation, composting with urine, “grey water gardens”, agricultural use of human excreta

Abstract

Based on the specific situation in Koulikoro, Mali, a sanitation system was developed that did not require inhabitants to make essential changes in their customs. It has the following components:

- Separate collection of faeces
- Separate collection of urine
- Separate grey water treatment
- Agricultural field trials

The investment costs for the proposed alternative decentralised waste water disposal system are estimated to about € 1.8 million for the city of Koulikoro. Operating costs can be disregarded since the decentralised sanitation facilities could be maintained by the inhabitants themselves.

The construction of a centralised underground sewage network with waste treatment ponds would add up to € 32 million because of the difficulty presented by regional rock layers. Annual operating costs would amount to about € 140,000. Koulikoro's annual communal budget is only € 200,000 and the average monthly income of a family is €100.

The practical experiences made in Mali with different ecosan modules show clearly that practical solutions are available and that the economic advantages of the ecosan concept are obvious. Next to ecological, agricultural and hygienic advantages, the substantially reduced need for capital investment plays an important role.

Introduction - specific conditions in Koulikoro, Mali

Koulikoro, the capital of the second region of Mali, was equipped with a central water supply system in the 1970s which was then extended about 20 years later, with financing by the German financial aid agency (KfW). Providing assistance to drinking water supply projects was and still is one of the priorities of international development assistance. In order to achieve sustainability the water tariff system should be able to meet costs. But in reality most central water supply systems in developing countries are not able to cover even operation and maintenance costs. This burdens already weak public budgets. Consequently the question of

[1] Initiated and technically / financially supported by the GTZ ecosan project, Eschborn

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waste water treatment, which should be an integral part of any water supply system is not even considered. Central water supply systems result in increased water consumption and consequently in increased waste water as well. The overall aim of drinking water supply projects is to reduce water borne diseases; However, the opposite occurs because the increased waste water is not treated. This subverts the intention to satisfy the basic needs of the population by even increasing the risk to water borne diseases.

As in many places, this happened also in Koulikoro, leading to open waste water flows / run outs throughout the city, exposing everyone to potential diseases and especially children. The Koulikoro municipality cannot afford to construct and maintain a central waste water collection and treatment system. A low cost approach to waste water treatment is seen as the only possibility for improving the current situation. To resolve this problem the approach ecosan was seen as the most appropriate solution by GTZ (German Agency for Technical Cooperation).

As a first step, the initial situation in Koulikoro was researched, and revealed the following: non existence of a central collection / treatment system for waste water; only about 3% of the households have water flush toilets and septic tanks which means that the reminder have traditional latrines; about 25% of the households are equipped with functioning soak pits or so called "puisards" (collection and infiltration pits for waste water).

Most (67%) of the 26.000 inhabitants live in spacious (300 to 400m²) compounds. The average household size is 10 persons, who are normally sharing one sanitation facility - used as shower and latrine.

Most of the inhabitants of Koulikoro are Moslems, which means that anal cleaning is done with water. In the case of traditional latrines this water is drained into the pit together with the faeces and urine. The water from showering and urinating drains into soak pits outside the shower area or drainage pipes that lead into the rain water canals. A study has shown that most of the soak pits in Koulikoro are poorly designed and managed as they are simply open holes outside the compound.

Agriculture in and around Koulikoro is an important economic activity but is made difficult as the soil is sandy and poor in nutrients (typical Sahel condition).

Methods and solutions to solve the existing problems

In order to identify the best solutions for the specific problems of Koulikoro, qualitative studies have been carried out and the results have been discussed with local decision makers, the local administration and the population. As a result the following technical solutions have been elaborated and carried out:

1. Separate collection of **faeces** through two-chamber desiccation latrines including an integrated drainage system for anal washing water => dried faeces are used as fertilizer and for soil improvement in agriculture
2. Separate collection of **urine** (in single households and central facilities):
   - as liquid fertilizer for food crops
   - as dried fertilizer
   - for "watering" of organic material (either from solid waste or agricultural residues) in order to enrich the compost and to enhance the composting process
3. Separate **grey water** treatment for single or neighbouring households in order to:
   - use it for watering of plants and moisturizing of yards
   - directly irrigate household vegetable gardens within the compounds
4. **Agricultural field trials** for sorghum and cotton to study the fertilizing capacities of the different kinds of waste and waste water at the Polytechnic Institute for Economic Studies based at Katibougou, Koulikoro.

1. Desiccation latrines - practical experiences

In Mali, and therefore in Koulikoro, traditional sanitary installations consist of one outdoor fenced bathing and toilet area with a pit latrine underneath and a drainage system conducting grey water either into a soak pit, a rain water drainage canal or simply into the street. Urine is more often evacuated with grey water than with faeces due to urination in the shower area. Traditionally, latrines have one pit. When these pits are full, they are covered with soil. The family, then, constructs a new latrine on another site within the compound.

This strategy is no longer viable due to two reasons: Compounds are continually divided to accommodate expanding families and the municipality is providing smaller plots in the new development areas.

More and more families are obliged to empty their latrines instead of closing them and moving to a new site. To make the situation worse the municipality cannot provide appropriate treatment and the private sector is not equipped to do this type of work. In general latrines are emptied manually and the untreated contents left on the streets or behind the yard for days or even weeks. This potentially spreads pathogenic germs through direct contact or through vectors such as animals and insects.

Under the local climatic conditions (high average temperatures, long dry and short rainy seasons), the two-chamber desiccation latrine is the most simple and most appropriate solution. The two chambers are used on an annual rotational basis. However since the Moslem population uses water for anal cleaning, a considerable amount of water drains into the latrine chamber and prevents the proper desiccation of the faeces. This problem was solved by two measures:

a) Introduction of a drainage system in the desiccation chambers. The bottom of the chambers is sloped and covered with a gravel layer. All liquids are drained directly into the bottom of a basin (which is filled with gravel and earth) located outside the chambers in order to avoid all direct contact with the contaminated water. In addition the basin is planted in order to facilitate evapo-transpiration of the liquid.

b) Desiccation is further enhanced by use of aeration pipes and the use of black iron lids that increase the drying process and make it easy to empty the chamber.

Sanitation tests (on nematode eggs and coliformes) have shown, that the hygienisation of faeces through drying is satisfactory after six months. To avoid any risk the chamber size is designed to be used for one year. This guarantees that dried faeces can be handled safely and easily. In addition the one year treatment period conforms to the agricultural production cycle in Mali.

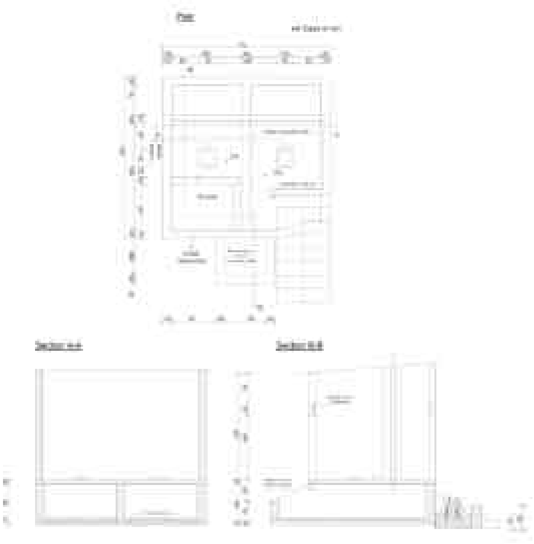

Figure 1: Model ecosan installation

Figure 2: Emptying of a ecosan latrine

2 a. Drying of urine - practical experiences

The separate collection of urine in single households and in public buildings has been tested and proven satisfactory. Under semi-urban conditions, not all households are engaged in agriculture and therefore don't see any need for urine as fertilizer. However, once enough households are equipped with urine separation latrines, the collection and use of urine on a large scale could become economically attractive for small private enterprises. With regard to public buildings the latrines of a catholic priest seminary were adjusted to collect large quantities of urine in one place. Drainage pipes were installed to divert urine from latrines pits into a barrel. This case of the catholic priest seminary was a real 'success story' (Christian culture – dry anal hygiene).

A problem in promoting urine for crop cultivation is that the use of any liquid as fertilizer is not known in Malian agriculture. To promote its use would require considerable awareness raising efforts and the acquisition of new equipment by farmers.

In order to simplify the handling, storage and application of urine as fertilizer, tests were carried out by sun-dried urine. Within two days each litre of liquid can be transformed into around 9 grams of powder. However this method must be improved upon in order to be economically viable.

Figure 3: Low-tech urine desiccation - tests

Figure 4: The product - fertilizing urine powder

2 b. Enriched composting with urine- practical experiences

The best way to use urine presently in Mali is for enrichment of compost of urban solid waste. Most household solid waste in Koulikoro is very poor in nutrients. What little organic material is in it is eaten by ruminants. Household waste mainly consists of sand and dust form sweeping.

The poor household waste can be transformed into valuable compost with the application of urine. The application of urine has three advantages: it saves water, it provides missing nutrients to compost and it enhances the composting process. Urine enriched compost proved to be a good fertilizer and soil conditions in agricultural tests carried out by the local university.

Figure 5: Urine collection in a public facility

Figure 6: Urine composting

3. 'Grey water gardens' - practical experiences

70% of Koulikoro households do not have appropriate facilities to treat and evacuate grey water, therefore, this issue was addressed by the implementation two different technical solutions: a gravel filter at the household level and a "grey water garden".

The treatment of the grey water / urine mix through gravel filters (gravel and sand are locally available) is functioning. Its efficiency depends on the filter size. However, the construction of a gravel filter is more expensive than the construction of a "grey water garden" and therefore it is only justified with a pronounced need for treated grey water for watering purposes at the household level.

The second solution which has been implemented, is the "grey water garden". Its immediate benefit to improve the nutritional situation of the household members was most appreciated by many families in Koulikoro. From an ecological point of view, the management of grey water should if possible take advantage of a planted aerobic system; this should preferably be a plant-based utilization system. The idea behind is: "grow it away, don't throw it away" (Del Porto). Therefore the grey water garden design should encourage high-rate aerobic processes and the reuse of the nutrients in grey water to feed the micro organisms living in the soil. During this process the nutrients are transformed in such a way that the plants can use them easily. As a result pollutants are transformed into plant nutrients.

Grey water from showers presents its challenges from the soap and fibre used for cleaning the body, because it causes very often problems with clogging. In addition the amount of sand and dust, which is transported through shoes and wind into the system has a heavy burden on the filters and the holes of the distribution pipes and the void spaces in filters and soil of the planted beds.

In order to introduce grey water into the irrigation system it is necessary to remove all particles in it that could clog the perforated pipes.

Therefore grey water is first decanted and filtered to reduce solids like fibre, sand and dust. After that the water is drained into the walled garden by subterranean perorated pipes. "Breezer" pipes are incorporated to create an aeration effect.

Very good experiences have been made with the cultivation of above ground plants such as okra, bananas, baobab, pepper and papayas. In particular the baobab leaves are rich on vitamin A and C and are very much appreciated by women.

Figure 7: Grey water garden before planting

Figure 8: Planted grey water garden

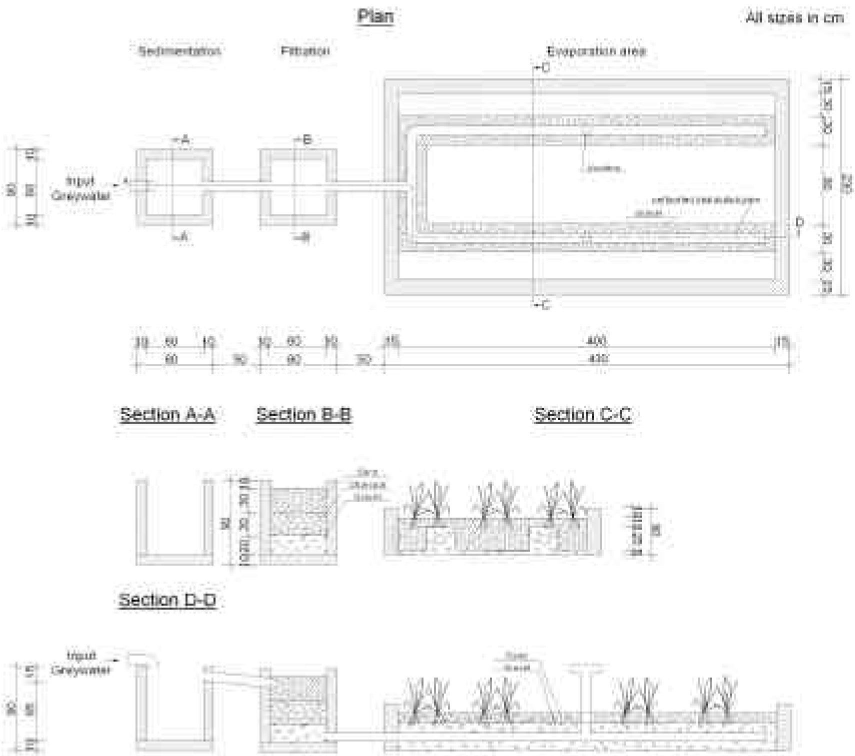

Figure 9: Construction principle of a 'grey water garden'

4. Effects on agriculture - preliminary results

A serious problem in the Sahel region is the degradation of soil, even leading to desertification. The reduction of natural soil fertility has been primarily caused by agricultural overexploitation and the insufficient return of nutrients to the soil. Chemical fertilisers are too expensive for most farmers; in the medium-term, these fertilisers also contribute to even more deterioration of soil quality (acidification).

Existing estimates and calculations show that the treated excreta of one adult in Koulikoro could supply hygienically safe nutrients for about 400 to 500 square meters of arable land. The marketing of nutrients from faeces and urine must be controlled by regular analysis to check nutrient content and to monitor disease-causing agents such as worm eggs and bacteria.

In cooperation with the Institut Polytechnique Rurale, the local agricultural university, the project conducted a series of tests with different groups of nutrients (dried faeces, dried and liquid urine, compost watered with urine, traditional compost, inorganic fertilisers, and varying mixtures of these groups).

Preliminary results are very promising and indicate that the use of urine provides similar results in yield compared to the use of inorganic fertilisers, and that the use of dried faeces has a positive influence on plant growth and soil quality. Urine, as a nutrient-rich fertiliser, can replace inorganic fertilisers. However, introducing its use would need to take the cultural acceptance of human fertiliser into account. The field trails on sorghum and cotton have shown that the combined use of faeces and urine-enriched-compost can lead to an increase in production of more than 100 % not to count the long-term effects on soil improvement.

However, these results need yet to be confirmed through a longer field trial programme. Unfortunately projects are often designed in a way that these longer-term needs of agricultural research cannot be easily accommodated.

Conclusion - lessons learned

The lessons learned from these practical experiences can be summarized as follows:

- The use of dried faeces is applicable in Moslem countries. The problem of anal washing water can easily be solved though an appropriate construction, which incorporates a direct drainage system.
- The use of urine as a starter for composting (household waste or agricultural residues) is an ideal approach in countries with water shortage and a promising alternative to the direct use of liquid urine.
- Efficient methods for solar urine water desiccation have still to be developed, especially with regard to the “harvesting” of dried urine.
- The method “grey water garden” for the treatment and use of grey water is an appropriate solution for families with sufficient space in their compound.

The agricultural field trials have only been carried out for a period of two years. Since concluding results can only been drawn after a minimum of three years of testing only tendencies can be provided.

The combination of sanitation and reuse of human waste in agriculture / gardening is a promising approach for both agricultural development and sanitation.

The Malian experience of the ecosan approach has shown that it is vital to adapt the technical and organizational solutions to the particular agricultural / socio-cultural and economic environment. Some alternative solutions that can be combined in different ways (modular approach) have been tested as pilot projects. The implementation of full-scale ecosan solutions in at least parts of a semi-urban area is still far from being achieved.

A successful implementation of ecosan would need a steady and efficient external support (experienced man power and financial resources) on the spot at least for a certain initiative period of time. This is unfortunately not the case in Koulikoro, which has as consequence a steady deterioration of the first facilities build.

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Planning of an alternative wastewater concept for two villages in North-Rhine-Westphalia (NRW), Germany*

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Keywords

Alternative drainage systems for rural areas, ecosan concepts, source separating systems

Abstract

In recent years it has become obvious that - under the aspect of sustainability - the structures of our present drainage systems, which consist in the main of combined sewer systems, must be reconsidered - in spite of the undoubted efficiency of these in densely populated areas. Indeed several investigations have shown that - particularly for communities in rural areas - there are more sustainable systems for dealing with wastewater than the combined sewer system. However there is an absence of practical examples. Accordingly the Lippeverband resolved to go into the findings, which have been purely theoretical up to the present time, taking as a basis a concrete situation: For two villages in the rural district of Welver in North Rhine-Westphalia, Germany, a detailed planning - regarding storm- and wastewater separately - with different scenarios is implemented. For the wastewater treatment four scenarios are investigated. The first scenario contains a central, the second a semi-central and the third a decentralized solution. The last scenario will expectedly work with a partial stream separation. All scenarios are compared under economical and ecological aspects. The actually planned stormwater concept implements as one possibility a direct discharge of non polluted stormwater into tributaries. A decentralised storm water management in responsibility of the land- and house-proprietors is also possible. The result of the investigation is that there are indeed realizable alternatives to the systems currently used in villages and other residential areas.

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Introduction

Under the aspect of sustainability our present drainage systems - above all the combined sewer system - need to be reconsidered. The mixing and diluting of wastewaters leads to an immense cleaning effort and to watercourses being polluted to an unnecessary extent while at the same time valuable nutrients such as nitrogen and phosphorus are lost. Storm water, which is polluted to only a low extent, is collected and expensively cleaned, while the renewal of the groundwater is reduced through the storm water being led off in this way. Against this backcloth and within the framework of the AKWA 2100 research project (AKWA 2100 = Alternatives to the municipal water supply and sewage disposal system; Hiessl et al. 2003), the Emschergenossenschaft and the Lippeverband were investigating together with other institutions long-term scenarios for modifying the communal wastewater disposal system in such a way that the above-mentioned weak points of the present system are compensated for. It has been shown that there are indeed systems which are more sustainable than the present method of disposing of wastewater via combined systems. This passes in particular for communities in rural areas which have at their disposal adequately large areas for alternative communal water manage-

*This paper has been peer reviewed by the symposium scientific committee

ment infrastructures and for which at the same time the wastewater would have to be transported over long distances to bring it to a central wastewater treatment plant. The viability of these theoretical results of the research project is currently being checked with the aid of a concrete plan taking as an example two villages of the community of Welver in Germany's North Rhine-Westphalia. For these two villages an alternative wastewater concept is being prepared. It is based on comparing a number of variants under economic and ecological aspects (see chapter 3). The objective is to obtain a wastewater disposal concept which is practical and acceptable for all involved parties and which satisfies the requirements of sustainable development.

Catchment area and starting situation

The two villages of Stocklarn and Berwicke, which together form the subject of the investigation, have together 576 inhabitants. Thereof 279 live in Stocklarn and 297 in Berwicke. The catchment area of Berwicke is 12 hectares, that of Stocklarn 13. The levels of sealing are 63 % and 43 % respectively. There is regular agricultural traffic in both villages. The Soestbach, a moderately polluted stream which always carries water, flows through the village of Berwicke. The Dorfbach which can run nearly dry in dry periods flows through the village of Stocklarn. There is still no regulated system for disposing of wastewater in either village. At the present time the storm water is led via surfaces and ditches as well as sewers requiring remediation into the watercourses. The wastewater is cleaned with the aid of mechanical or, as the case may be, mechanical-biological domestic wastewater treatment plants. The effluents therefrom are also led via the sewers to the bodies of water. The present plan for a central sewer system for the two villages with a central wastewater treatment plant drafted in 1996 has been deferred in view of the actual activities of the Lippeverband. Regarding wastewater treatment 85 % (Berwicke) and 72 % (Stocklarn) of the domestic wastewater treatment plants are mechanical ones being in part already excessively old and needing to be remediated. On the other hand the newer biological systems are almost all in a good state. The following table gives an overview of the present state of the wastewater treatment plants in the two villages.

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	Stocklarn	**Berwicke**
Mechanical treatment: multi-compartment tanks	38	50
Biological treatment: Technical systems with aeration of the wastewater Near-to-nature systems (planted constructed wetland, infiltration)	7 8	1 8
Systems no longer capable of being remediated	45 %	42 %
Systems needing to be remediated	34 %	35 %
Systems in a satisfactory state	21 %	23 %
Total number of systems evaluated	53	59

Table 1: Evaluation of the state of the existing small wastewater treatment plants

It has to be established that the number of biological treatment systems is very small; moreover the majority of the systems for leading off and treating the wastewater are in a poor state means that at present the existing watercourses - and here in particular the Dorfbach in Stocklarn which is dry in the summer - are subjected to a high level of material pollution.

Investigation of the possible variants

The separation of storm water and domestic sewage is strived for in all variants. Accordingly the storm water concept described in the following section passes for all the different sanitary sewage variants (see section 3.2).

Storm water

At the present time the storm water in the villages of Stocklarn and Berwicke is led into the relevant watercourses regardless of the degree to which it is polluted. In order to improve the quality of the watercourses and to bring the elimination of storm water up to the present state of arts, different categories of pollution of the storm water are considered in the new storm water concept.

- Category I : Unpolluted storm water ? no treatment necessary
- Category II : Slightly polluted storm water ? treatment necessary in general, exceptions possible on a case-by-case basis
- Category III : Heavily polluted storm water ? treatment absolutely necessary

Since the soils permit only a low level of infiltration, the targeted infiltration of storm water into the ground via the organic soil zone in a deliberate manner is not possible. The storm water is led into the Soest- or Dorfbach. Therefore a treatment is necessary in the majority of cases for the runoffs from areas assigned to categories II and III before the storm water is led into the Soest- or Dorfbach. Table 2 provides an overview of the classification of the areas via which storm water runs off and which have an effect on the necessary/possible treatment measures for the storm water runoffs.

Category		Areas assigned to category	Treatment or discharge
I	Unpolluted	Roofs and yard areas of residential buildings	No treatment, direct discharge: • direct discharge into gravel-filled trenches • discharge into ditches • discharge into pipes
II	Slightly polluted	Roads with low levels of motorized traffic Farmyards, farm tracks and roads between communities	No treatment necessary Treatment along the roads by infiltration in trough-type gravel-filled trenches (20 cm build-up of ground)
III	Heavily polluted	Farmyards where animals are kept and where liquid manure is handled Through roads with high levels of traffic	Treatment by infiltration through 20 cm A-horizon Discharge through drainage system, in particular with chokes (gravel-filled trench bodies)

Table 2: Classification of the areas via which storm water runs off and which have an effect on the treatment measures

The storm water should be allowed to run off as natural as possible. For that the following elements are used in accordance with local customs: open ditches, trough-type gravel-filled trenches (with choke device) and pipes (where open ditches are not possible). Where a building has an undamaged system for leading off the storm water from the roof and yard areas this should be retained. This concept fulfils the requirements of the technical and legal sets of regulations applied in Germany for the treatment of storm water and the discharging of this into watercourses (ATV-DVWK instruction sheet M 153, BWK instruction sheet M 3) (ATV-DVWK 2000, BWK 2001).

Wastewater

For the preparation of the sanitary sewage concept, a variant with a source separating system (separation of urine) based on AKWA 2100 was investigated in addition to variants with central, decentral and semi-central solutions (see table 3). In all variants the diversion of storm water and the treatment of wastewater were considered separately.

Variant	Classification	Description
1	Central	Central collection and transporting of wastewater to one central wastewater treatment plant per village
2		Central collection and transporting of wastewater to one central wastewater treatment plant for the two villages
3	Decentral	One wastewater treatment plant for each property
4	Semi-central	Appropriate grouping together of properties and connection of these to a central wastewater treatment plant for each group
5	Source separating system	Separate capturing of urine and extensive treatment of the wastewater

Table 3: Overview of variants

Variant 1: Central variant with one wastewater treatment plant for each village

With variant 1, all the sanitary sewage from each of the two villages is led off and treated in the particular village's own separate wastewater treatment plant. The treatment objective is the targeted elimination of nutrients by nitrification and denitrification. For this purpose an SBR system (sequence batch reactor) constructed of prefabricated parts with chemical phosphate precipitation is provided. The storage and treatment of the sludge is carried out in a sludge draining bed. The systems are constructed in a modular manner to facilitate matching to any changes in loading states in the future.

The sanitary sewage is brought to the wastewater treatment plant via sewers. Since the existing sewers are in need of remediation and their course is unknown in part, the assumption is made that all sewers must be replaced. The sanitary sewage is conveyed in general in gravity lines. However not only in Berwicke but also in Stocklarn the wastewater that has been collected will have to be pumped via a pressure pipe to the respective wastewater treatment plant. The treated wastewater is discharged into the Soestbach in Berwicke and in Stocklarn into the Feldbach, a larger watercourse, into which also the Dorfbach flows. The wastewater treatment plants can be operated by the local authority or by a third party.

An advantage of this variant is the opportunity for central charging so that the principle of solidarity can be applied for the complete village. In addition it can be coped with variations in loadings while the cleaning output remains stable. However all existing small wastewater treatment plants must be given up. Accordingly high investment costs will be necessary for the owners of some of the larger properties for the diversion of the sanitary sewage from their properties. A "let the causer pay" system of distributing costs will hardly be possible. In addition ground would have to be purchased for the lines taken by the sewers.

Variant 2: Central variant with common wastewater treatment plant

In technical and organizational terms and also in terms of advantages and disadvantages, variant 2 is the same as variant 1. However with variant 2 the wastewater in Stocklarn is not pumped into the village's own wastewater treatment plant but via a pressure pipe to the wastewater treatment plant in Berwicke treating the sanitary sewage from both villages. For that it is dimensioned appropriately greater.

Variant 3: Decentral wastewater disposal

Variant 3 provides the retention and technical enhancement of the present decentral waste-water treatment system (small wastewater treatment plants). With one exception the existing systems with biological stages are in a good state and can continue to be used. Existing systems will be evaluated and in part integrated into the concept. Where the systems are in a good state, the biological stage can be retrofitted in a cost-favourable manner. The minimum system size is laid down as 4 PEs (population equivalents) independently of the present number of inhabitants. The existing lines for the diversion of the treated wastewater will be in part retained; in part it will be diverted via the elements of the storm water system.

Systems for elimination of nutrients, e.g. SBR systems, fixed bed reactors with feeding back for denitrification or planted constructed wetlands with feeding back to the primary clarifier will be retrofitted. No process will be prescribed. Instead requirements will only be placed in terms of the cleaning performance. The treated wastewater will be discharged into the Soestbach respectively the Dorfbach. Whereas discharging into the Soestbach will be possible without any problem in Berwicke, it is probable that the requirements in respect of the quality of the water in the Dorfbach at Stocklarn could only be maintained when membranes are used to clean the wastewater. This would considerably increase the expense of this variant.

The wastewater treatment plants can be operated by the owners themselves. However this requires that each owner takes on a high degree of responsibility himself. Experience indicates that proper maintenance will only be carried out in practice when the owners are required to conclude a maintenance contract with a sewage disposal service provider. The faecal sludge is removed in accordance with requirements. This matter will also be laid down in a maintenance contract.

The advantages of this variant are that costs are distributed in accordance with the "let the causer pay"-principle and that the inhabitants make their own contribution. Nevertheless this can lead to high cost loadings in individual cases. However there is potential for costs to be saved where a number of properties are connected to one system. Moreover the systems can be matched optimally to the local situation and circumstances. But the maintenance of the systems and the removal of the faecal sludge mean that the running costs increase. In addition, the expenditure for operating the systems increases, e.g. the cleaning performance of small SBR-systems falls if the system is underutilized. Furthermore targeted P-elimination is not possible. However it has to be said that the elimination of nutrients achieved by the decentral systems will be adequate - depending on the receiving watercourse.

Variant 4: Semi-central disposal of wastewater

Variant 4 provides the semi-central diversion of the wastewater via new networks of sewers, that will have to be constructed, and a semi-central arrangement of small wastewater treatment plants. It is provided that 4 wastewater treatment plants should be constructed in each village, each with a capacity of between 22 and 143 PEs (population equivalents). The different plants being positioned in each village with the objective of keeping the line lengths low. Here too systems for eliminating nutrients, such as SBR systems, should be applied. The sludge must be stored temporarily, transported away and treated. Possibly each village should have its own sludge draining bed. The sewer network and the wastewater treatment plants should be operated by the local authority or a third party. In an analogous manner to variants 1 and 2, costs will be covered via a system of contributions and charges.

The construction of 4 semi-central plants for each village will reduce the variations in loading so that the plants will run in a more stable manner than decentral plants. In addition, there is potential for costs to be saved relative to variants 1 and 2 through the shorter line lengths.

Moreover further savings in costs are possible since the shorter lengths of the lines mean that they can be laid at lesser depths. Compared with the first two variants operating costs will be higher. Moreover the necessity of transporting away the faecal sludge increases running costs like in variant 3. Similarly targeted P-elimination is not possible.

Variant 5: Wastewater concept with further source separating system

Variant 5 supplements Variant 4 about the consistent separation, collection and use of urine with its content of nutrients. The remaining wastewater, which then contains a low level of nutrients, is treated in biological membrane systems. The use of these membrane systems can only be considered at the present time in semi-central systems as a result of their capital costs. With this variant it is provided that the urine is collected and stored in decentral urine tanks and then utilized in agricultural operations. However the concept for emptying the urine tanks as well as for the further treatment of the urine is still open at the present time. The sludge arising will also be stored, transported away and treated. The semi-central sewer network and the membrane systems can be operated by the local authority or a third party. Refinancing is carried out by contributions and charges.

The obvious advantage of this variant is the reduction of the discharge of nutrients into the receiving waters. The separation of urine diminishes the emissions of nitrogen und phosphates into the streams. In addition the use of the membrane technology reduces the level of germs discharged into the watercourses. With a suitable concept, the nutrients separated off can be used in place of fertilizers. However the effects of endocrinally active substances have still not been adequately clarified. If a decision was made in favour of this variant, conversion of the existing systems could be carried out in stages. However converting of the sanitary systems and the construction of a second line system in the houses would be necessary. Accordingly realization of this variant would depend on its acceptance by the population and would take a relatively long period of time.

Comparison of the variants

Costs

When considering the present value of project costs for the two villages (LAWA 1998), variant 4 with its semi-central wastewater treatment concept demonstrates small advantages over the two central-concept variants 1 and 2 (see Fig. 1). The decentral wastewater treatment concept (variant 3) leads to relatively high present values of project costs as a result of the higher running costs and the lower service lives of the components. Variant 5 is very cost intensive as a result of the additional systems needing to be installed for separating off the urine flow. However, when deciding which variant should be realized for which village, not only the costs but also - in the sense of sustainability - the ecological and social aspects should also be evaluated. Accordingly the results of the comparison of the total emissions for nitrogen are presented in the next section.

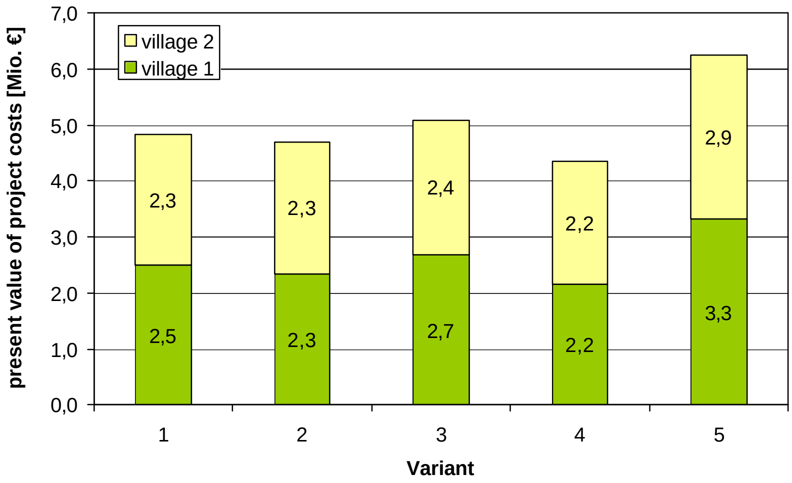

Figure 1: Present value of project costs for the two villages

Total emissions

Comparison of the variants under the aspect of the emissions of nitrogen as a significant ecological indicator identifies that variant 5 with its source separating system gives the best result (see Figure 2).

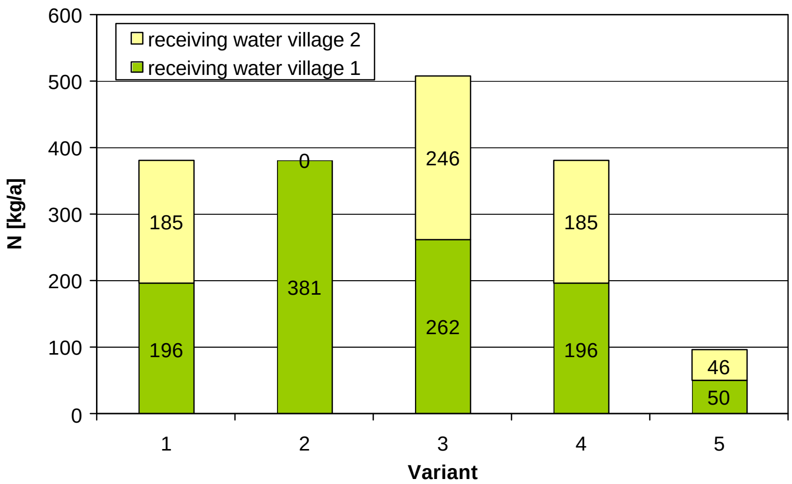

Figure 2: Simplified consideration of the emissions of total nitrogen

This can be explained by the fact that the urine contains more than 75 % of the communal nitrogen so that separating off of the urine holds back a large part of the nitrogen. The total nitrogen emissions of variants 1, 2 and 4 are close to each other, there being a difference only in the distribution of emissions. Here the reason is simply that variant 2 provides that all the emissions pass into the Soestbach at Berwicke while with the other two variants the emissions are divided up between the Soestbach and the Dorfbach. The decentral concept, variant 3, shows the worst result in respect of emissions. Here the reason lies in the fact that the small wastewater treatment plants are significantly less efficient at eliminating nutrients than the wastewater treatment plants provided for the central and semi-central variants.

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Preferred variant

Under ecological aspects, variant 5 with its source separating concept shows clear advantages over the others. On the other hand variant 4 must be preferred if solely economic reasons are to be considered. If one considers that variant 5 represents a technical further development of variant 4, then the solution suggests itself of realizing the semi-central concept, variant 4, with the option of introducing urine separation house by house over an appropriately extended period of time. Together with the concept for the storm water, one would then have for the long-term a flexible wastewater disposal system that makes sense in terms of sustainability. However discussions that have been held with the inhabitants of the two villages as well as with the relevant decision-makers indicate that a great deal of persuasion work needs to be carried out if the variant with a source separating system is to be realized.

Conclusion

The investigation of the feasibility of alternative wastewater concepts for the two villages of Berwicke and Stocklarn of the rural district of Welver has shown that indeed there are realizable alternatives to the systems currently used in villages and other residential areas. However, in regard to economical and ecological aspects, the decentral solution with its small wastewater treatment plants represents the worst alternative to the present system because of its present costs and the technical systems that accordingly come into question. If, on the other hand, the semi-central solution is chosen, one keeps open in addition the urine-separation option, which - if realized in full - would lead to an enormous reduction in the polluting of the watercourses with nutrient and which - at the same time - provides the opportunity of producing an alternative fertilizer.

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Finding of ecosan-potentials – general aspects of a project example in Yemen

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Dry toilet systems, faeces, greywater, urine separation

Abstract

In the framework of an ongoing water supply and sanitation program for four mid-size towns in Yemen, potentials for the introduction of the EcoSan approach are identified on the basis of visits and discussions with authorities and the population. EcoSan potentials are identified as possible in existing buildings and especially in new areas planned for a university and dwelling areas.

Introduction

The Ecological Sanitation (EcoSan) approach can – under certain framework conditions - be regarded as a realistic alternative to conventional sanitation systems from an ecological as well as from an economic perspective. In this context all partners involved in the "Provincial Towns Program II" for the "Water Supply and Sanitation in the towns Al Shehr - Ja'ar - Jiblah and Zinjibar in Yemen", namely the Yemeni National Water and Sanitation Authority, NWSA, the Kreditanstalt fuer Wiederaufbau, KfW, and the consortium of the consultants MVV-IGIP-ERM-NCO-GHAYTH decided to identify the potentials for incorporating the EcoSan approach in the sanitation components of the program. To this end, a fact finding mission started, in which suitable pilot areas had to be identified in the above mentioned four towns, which would provide potential for the implementation of EcoSan technologies.

In this lecture, the main results of the first fact-finding-mission are presented, for one town in detail and only very briefly for the other towns. It should be stressed, however, that these results are still of preliminary nature and have to be appraised in more detail in the course of the planned follow-up missions. This is particularly the case with regard to economic viability of the different technologies proposed and the acceptance of EcoSan solutions by the target population.

Methodology

The scope of work for the first fact-finding-mission included the analysis of the settlement structures with respect to the applicability of EcoSan technologies, of the prevalent socio-cultural situation, the assessment of the potentials for the use of nutrients from waste water and

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faeces, including the potentials of agricultural wastewater reuse and particularly the potential acceptance of EcoSan-technologies by the population to be served and the analysis of the potential economic impact as compared to conventional sanitation approaches.

As methodology applied for the analysis of the local situation with respect to EcoSan concepts, all four towns were visited and interviews were conducted with the relevant local stakeholders. On the basis of maps potential town areas were jointly inspected and individual houses were visited and discussions held with the population.

As a result, possible areas for the implementation of EcoSan technologies were identified and considered for the development of EcoSan concept proposals.

Results

Present situation and expressed needs

Although the local population often appeared to have a limited knowledge about the importance of cleanliness and (personal) hygiene, people are worried about their sanitary situation.

The main concerns expressed in this regards are:

- Cesspits are insufficiently covered, which can cause death of children, who fall into the hole while playing around;
- Great suffer by sleep disturbances because of the mosquitoe-bites;
- Great suffer by the constant foul smell and the obligation to live in this contaminated environment;
- Very little maintenance of the sanitation system, which had been designed in the seventies without any further improvement and which is insufficient to cater to the needs of a steadily increasing population.

Water used for anal hygiene is usually pale or tap water. Both men and women use the same method for cleaning themselves over the toilet bowl.

Families asked for their preferences for future toilets and bathrooms in the course of interviews conducted gave different answers: Most of the men wanted full flush toilets, technically well designed and well maintained; furthermore safe drainage systems, wider diameter pipes for the wastewater disposal. Furthermore more spacious toilets and bathrooms, full flush drainage systems and floors with tiles, shower and wash-hand basin are wanted. The wastewater should be disposed through pipes into the main drainage system. No floods of water should be seen in the streets, or near the houses where children play and easily become infected.

However, nowadays the vast majority of all houses have a connection to the water distribution system and have been converted to high standard ceramic full or poor flush toilets. Apart from the rural villages, there is no town zone in any of the four towns visited, in which any significant number of dry toilets would still be in use. The ceramic flush toilets already set the common standard. Any new approach has to meet the indoor standards of tiled bathrooms regarding cleanliness, odour, aesthetic look, etc.

Traditional sanitation methods are no longer considered modern or up-to-date and accordingly, families are aiming at “western standards” as the latest in development, unaware, that in industrialized countries, experts are shifting away from the water consuming full flush toilets and from huge treatment plants to ecologically sound and economically viable technologies.

General attitudes to the EcoSan approach

Elements of the EcoSan Philosophy are all but new to Yemen. In fact, separation of liquid and solid elements of wastewater have traditionally been elements of domestic waste water management and have heavily influenced typical Yemeni architecture in the past. Dry toilets and separation of urine and faeces have been found in operation in two of the cities visited and are widespread in rural areas. The use of dried faeces or sludge from cesspits as agricultural fertilizer is common in rural areas. In certain areas, there is a market value for cesspit sludge that is sludge trade is practiced.

It turned out in the interviews conducted with the local population, that people understood and recognized, that EcoSan technologies nowadays are as proper, bright, aesthetic, functioning, non-smelling and clean as the bathroom facilities they had in mind. There was a clearly expressed readiness to switch to the EcoSan system, provided, that this switch is linked to economic benefits like:

- reduced water bills,
- reduced fees for waste water treatment,
- sale of nutrients and soil conditioner.

Potential of EcoSan-concepts in the visited towns

The town of Jiblah (population 2001: 13.845) is characterized by a strictly confined settlement area of high density. Located on the back of a rock, it is enclosed by two wadis and a mountain slope at its back. Very narrow streets provide only limited access for modern construction equipment and digging a sewer system in the rocky underground of the city seems to be extremely difficult and costly. As a result of the difficult situation, the architecture traditionally provided for dry toilets in which domestic waste water and urine were separated from faeces, which were collected in a storage underneath the toilet, whereas the liquids were led outside the house in the path to infiltrate or dry.

Actually 92 houses still dispose of these traditional system, many of them in poor condition, though. The faeces are collected in the storage, at a few houses together with animal excrements and on a place in front of the house beside the street. This storages are emptied either from outside or from inside the house. Typically the storages are closed with stones. However, important to notice is the fact, that there is no general objection against these traditional elements of EcoSan like urine/faeces separation and that at least some of the owners of the houses with the traditional system are willing to upgrade and continue the use of the system, if a hygienically, technically and economically acceptable high standard solution is provided.

This was confirmed by the local authorities, which in general were very open minded with respect to the EcoSan approach. For them it is to a certain extend also an appreciation of their traditional know how and outstanding architecture and engineering of the past.

For an upgraded system in the existing buildings of the densily populated towns, there are several options:

a) The dry toilet system

In the bathrooms, the traditional, old facilities should be exchanged to most modern separation facilities, made from white ceramics or fiberglass, easy to clean and in the typical Yemeni design, which integrate the urine separation and lead the urine via a small pipe into a urine holding tank. Solids fall down into a storage, which needs to be modified to meet modern hygienic standards (ventilation, closed but with controlled access for emptying). Application of additional material for supporting the drying process (e.g. ash, sawdust or wood shavings, soil etc.) is recommended to improve the effectiveness of the dehydration process. Also included should be a cleaning place next to the toilet for anal hygiene and body cleaning after use of the toilet. The washing water needs to be collected separately.

The urine storage facility can be either designed as an individual in-house installation or as a joint storage facility for a couple of houses. The storage facility could be a container of a volume, large enough for intermediate storage. Outside the settlement area, close to agricultural lands, there should be one or several tanks, large enough to store the urine from the participating households for the period between the applications of urine as fertilizer to the fields.

Also for the dried faeces from the participating households, there should be a defined area, on which the faeces will be further treated to improve their value as soil conditioner and to destroy faecal contamination. The greywater will have to be discharged from the premises in smaller sewer pipes, since there is only very limited space for on-site treatment. Free of the main solid fraction, transportation in small pipes is fairly easy and no blockings should occur.

b) Flushing toilet with urine separation

The system is similar to the dry toilet system except for the fact, that a flushing but urine separating toilet bowl will be used. The consequences are: Water from washing, showering, cleaning, body hygiene will be mixed with faeces and discharged via regular sewer pipes. Only urine separation and its use as high value fertilizer remains from the system described above. Except for this, the system is equal to all the components mentioned above.

The remaining advantage here is the saving of flushing water for urine flushing only (that might make up to a saving of 30% or more of the water bill!) and the reduced amount of wastewater generated. At the same time, however, the household is equippe d with what is considered most luxury flushing toilet facilities, which is likely to contribute to an increased willingness of households to adapt such a solution. Additional water and cost savings can be realized if the flush water can be replaced in part by rainwater that is collected on the roof und used as flushing water.

c) Flushing toilets with urine separation but without use of urine as fertilizer

Again, the system is similar to b), however, it does not make any use of the separated urine. Urine will be discharged with the other wastewater in the sewer pipe. The only advantage is the saving in water consumption and accordingly in waste water generation (and reduced cost for both).

Main supporting facts for the choice of these houses are the existing traditional facilities and the acceptance, willingness and know how of the house owners/families to operate such a system. The few individual houses may play a key role as model houses for other town areas, documenting the high standard of bathroom furniture for EcoSan systems. It could thus be demonstrated that there does not have to be a difference in standard between the EcoSan and the conventional sewer approach. In addition, savings of recurrent costs for water and waste water bills could be demonstrated on household level. The parallel existence of both approaches within one city area allows for direct comparison of the individual household`s recurrent costs for water and sanitation. However, when comparing the economic viability of the alternative systems, investment and maintenance costs and their impact on household budgets will also have to be taken into account.

Obstacles to the EcoSan approach increase with the scope to which it will be implemented. The dry toilet and urine separation (option a) requires some kind of organization for the collection of urine and faeces (regular emptying of the storage facility and distribution of marketable components). A service (best to be carried out by potential users of nutrients and soil conditioner, i.e. farmers or farmers cooperative) needs to be established and its function must be guaranteed to avoid failure of the approach.

Potential for the re-use of urine and/or faeces sludge as fertilizer seems promising as agricultural land is located around the city on the right and left banks of the wadi and there are huge cultivated areas in the terraces located alongside the right and left banks of the Wadi.

However, due to the few individual houses, which could possibly be transferred to modern EcoSan model houses, the amounts of collectable waste might be to small to establish collection facilities and an organization for its agricultural use. The quantities need to be determined in detail to make a decision on its feasibility in the next phase of the project.

Its slightly easier, if only urine is collected separately (option b)), but nevertheless, more or less the same difficulties apply as for option a).

Only option c) does not require any additional operation or services and as such should not cause any problems in operation and sustainability. However, this is the option with the smallest ecological impact, since only water consumption and waste water generation can be reduced (no separation and direct reuse of any nutrients or soil conditioner, no effects on the load for the treatment plant, no major effect on costly investment for sewer lines). The reduction in water consumption and wastewater generation, however, might be significant.

The EcoSan-Potentials of the choice a) and b) are summarized in the table:

	Toilets with urine separation (Type can be chosen by the house owners)	
Potentials	Dry	Flush
Water saving	+++	+
Water saving by rainwater harvesting	0	+
Use of faeces	+	0
Use of nutrients	+	+

Figure 1: EcoSan-potentials for the two different systems proposed

The houses with the EcoSan elements could eventually function as multipliers, not only for Jiblah, but also for other similar areas in Yemen – and there are a lot.

Additional areas for the introduction of EcoSan installations are identified in two other towns:

The town of Zinjibar (population 2001: 19.851) is in the coastal plain area in the south of Yemen. It is expanding rapidly in circles around the town center. The town center is confined and of high density. Wastewater is disposed of by means of rudimentary sewer lines, discharging into wadis and by cesspits, which are supposed to be emptied if overflowing.

However, there is a huge compound earmarked for the construction of a new university complex. This project might be very suitable for a comprehensive EcoSan approach, since it might be possible to plan a system from the scratch and to integrate it in the architectural design and infrastructure planning from the very beginning. It might be possible to design a system, which is independent from any other public system and might be operated by the university on its own. It could include the full range of technologies from individual to public separation toilets, on compound treatment and use of nutrients and organic material.

An integrated EcoSan-concept for this area may contain a full range of sustainable elements like:

- Urine separation and utilization as fertilizer on the surrounding farmlands
- Solid and liquid separation combined with the soilization of the sludge
- Greywater treatment for irrigation use for greenlands on the university area.

This system has to be operated by the university on its own, so the benefits can be demonstrated significantly. Well implemented and operated, it could serve as a model case for future infrastructure planning of new town zones. Linked to a university, it also might be understood as advanced system with a vision in the future and as such reduces reservations of individuals re the new approach. Although there is apparently high potential for realization of a full fledged EcoSan approach at this location, it needs to be mentioned that the implementation period of the university project is still unclear and that at this stage, no discussions have been held with officials of the university project with respect to their views and acceptance of the idea.

The other town Al Shehr (population 51.889 in 2001) is a boosting town and is also located in the flat lands on the coast. A defined, densely populated old core is surrounded by circles of newly settled areas with decreasing density towards the outer zones. The growth of the city seems to be structured and planned.
The community of Al Shehr district is – with reference to the other program towns – comparatively wealthy and a large number of houses are spacious and well furnished. The community is very religious and the houses are clean. Contrary to the other areas the population is fully aware about the importance of cleanliness and hygiene.

The enormous development speed of new zones at Al Shehr opens a new dimension of fully integrating the EcoSan approach into confined areas.

One approach could be to cooperate with a dwelling company or a single investor who plans to develop a specific area and to build a number of similar houses. In contrast to other areas this approach seems fairly realistic, because various company are planning to settle and to construct dwelling houses for their employees.

In such a case, planning of an EcoSan system can start from scratch and include all necessary infrastructure and management elements to make the most of the approach and to secure its comprehensive functionality. So confined areas can be served independently by an EcoSan concept. The integration of the EcoSan approach into the planning process from its beginning allows for the most possible realization of the economic potential of the approach. The officials of the urban planning section of the baladia have expressed their support in establishing a cooperation between the project and a potential investor.

The conceptional approach can achieve the full range as for the university extension project in Zinjibar.

Rural communities in the periphery of the towns visited already use elements of EcoSan to a large extend. Lower level income households use dry toilets, some of them outdoors in separate buildings or simple structures, some integrated in the architecture of the houses. Higher level income households with brick houses have flush toilets and cesspits. An integral EcoSan concept for a rural area is only possible with an "homogeneous" support of all inhabitants of the village.

Though there is a potential for EcoSan technologies, a successful implementation of EcoSan systems can only be expected, if the high hygiene standards of the individuals are met. However, a change to separation toilets would in almost any case mean a major investment on in-house installations. In urban areas only flushing separation toilets are likely to be accepted. In-house investments would include new toilet facilities in all bathrooms and installation of separate pipes, all at the expenses of the house owner. Therefore private investments will only be made, if economic benefits from water savings materialize for the individual in an adequate span of time and if liquidity of the household is sufficient to finance the necessary in-house investments. In this regard, further information has to be generated in the course of the planned future study phases.

EcoSan can replace conventional systems, but it is very difficult to operate the two different systems in parallel, because this would always mean, that more or less two full systems would have to be implemented and run at he same time --- and at the investment and running costs of two systems. The full advantages and benefits of EcoSan can therefore only be materialized in areas, which do not dispose of any sanitary infrastructure at all and which can be served independently.

In consequence, the next study phases for the EcoSan component of the Provincial Towns Program II will focus on:

1. Development of EcoSan Concepts for the selected pilot areas;
2. Detailed feasibility study for the selected pilot areas and the technologies chosen including a thorough cost-benefit analysis and economic comparison of alternatives.

Conclusion

Important elements of the EcoSan approach are traditionally established in Yemeni culture. The Yemeni dry toilet is an integral element of historic architecture and goes hand in hand with separation of faeces from urine and water. A significant number of houses in old urban centers continue to use this type of toilet. In certain rural villages, the dry toilets and separation of urine and water is common in almost each household. Also widespread is the use of dried faeces or sludge from wastewater treatment plants in agriculture as soil conditioner and fertilizer.

Accordingly, the officials and persons talked to in the four towns and the surrounding villages were generally open-minded about the EcoSan approach. The philosophy was clear to them and the potential benefits understood.

However, nowadays the vast majority of all houses have been converted to high standard ceramic full or poor flush toilets. Apart from the rural villages, there is no town zone in any of the four towns, in which any significant number of dry toilets would still be in use.

The most important conclusion therefore is:

Though there is a potential for EcoSan technologies, a successful implementation of EcoSan systems can only be expected, if the high hygiene standards of the individuals are met and EcoSan systems are not perceived as being synonymous to a low standard of development.

Secondly:

In urban areas only flushing separation toilets will be accepted.

Today, there are most modern ceramic or fiberglass toilet bowls, which would meet these standards and at the same time, separate the materials.

However, a change to separation toilets would in almost any case mean a major investment in in-house installations. The investment includes new toilet facilities in all bathrooms and installation of separate pipes, all at the expenses of the house owner.

Therefore:

Private investments will only be made, if economic benefits from water savings, reduced wastewater bills and – in some cases – income generation from marketing of urine and organic matter as fertilizer materialize for the individual in an acceptable timespan and if households dispose of sufficient liquidity to finance the necessary in-house installations.

Potentials for economic benefits may be realized by:

- Reduction of water consumption (lower water bill)
- Reduction of wastewater generated (lower waste water bill)
- Utilization of treated greywater for irrigation (lower water bill, higher yields)
- Utilization of high quality nutrients from urine as fertilizer (lower fertilizer bill, higher yield)
- Utilization of organic matter and nutrients from faeces as soil conditioner and fertilizer (higher yield)

Whereas the savings in the water and waste water bill can be achieved immediately through the installation of flushing separation toilets (saving of flushing water for urine), the realization of the other potential benefits requires further installations like urine holding tanks, greywater treatment facilities, treatment for faeces and the implementation of some kind of management structure to operate the system. In addition, marketing of urine and organic matter as fertilizer may need some time to be established on a profitable scale. As such, the EcoSan approach is comparable to conventional wastewater management, which also requires the same, but centralized and in bigger scale.

EcoSan can replace conventional systems, but it is very difficult to operate them in parallel, because this would always mean, that more or less two full systems would have to be implemented at he same time - at the cost of two systems.

This holds particularly true for already settled areas, which already have conventional household installations and possibly a public infrastructure. Since not all houses would switch at the same time – or at all, there needs to be the conventional system to serve these households and at the same time, an EcoSan system would have to be implemented, which also requires a minimum number of households to be connected to make it functional. However, once the conventional system is in place already, it makes only little sense to invest in additional treatment facilities and operations, just to realize some fringe benefits like nutrient values and crop yields on individual basis. Low prices for artificial fertilizer in Yemen emphasize this statement even more.

The full advantages and benefits of EcoSan can therefore only be materialized in areas, which do not have any infrastructure at all and which can be served independently from the conventional sewer system to be established.

These are defined areas, which can be planned and developed from scratch as EcoSan Concept Areas, in which then all elements work hand in hand.

Areas with existing infrastructure can only partially benefit from EcoSan

Rural communities in the periphery of the towns visited already use elements of EcoSan to a large extend. Lower level income households use dry toilets, some of them outdoors in separate buildings or simple structures, some integrated in the architecture of the houses. Higher level income households with brick houses have flush toilets and cesspits. An integral EcoSan concept for a rural area (e.g. Mansura near Jiblah) is only possible with an "homogeneous" support of all inhabitants of the village.

However, for both there is significant potential for improvements with respect to both, the design of the facilities and the use of the valuables.

Source-oriented sanitation in rural regions

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Keywords

Source separation, decentralized treatment, demonstration project

Abstract

Urine and faeces make up over 80% of all nutrients in household waste water, but form only 1 to 2 volume percentage of this waste water flow. In source-oriented sanitation, toilet waste water is collected separately with much less rinse water and treated separately. This keeps the nutrients concentrated, and it becomes possible to recover and reuse them as fertilizer. The purification of household waste water becomes simpler and more robust with this concept. The investment costs for the implementation of source-oriented sanitation in rural regions are estimated at circa 15% higher than those for an IBA class-III system (small waste water treatment plant). However, implementation of source-oriented sanitation in the rural regions as a Dutch demonstration project offers an interesting opportunity, based on a better effluent quality and circa 25% lower operational costs. This would be a first step in a potential future shift of waste water purification towards "resource management".

Source-oriented sanitation

Our current waste water collection system is characterised by extensive dilution of the waste. Concentrated toilet waste water, circa 1.5 liter per inhabitant per day, is mixed with rinse water of drinking water quality and slightly contaminated waste water (bath, shower, washing machine, etc.) to approximately 125 liter water per inhabitant per day. Together with the same quantity of rainwater, this is transported via the sewer system to the central water purification plants. Despite the small proportion of toilet waste, the costs of the current waste water treatment with its strict effluent standards are determined to a large extent by this small flow.

An alternative, source-oriented approach in which waste water is collected separately at the house level can result in a more efficient sanitation system in which part (or possibly all) of the waste water treatment would be done locally. The main starting point for source-oriented sanitation is the separate collection and treatment of toilet waste water at the house level (figure 1). Urine and faeces make up over 80% of all nutrients in the household waste water, but form only 1 to 2 volume percentage of this waste water flow (figure 2, refs. 3 and 6).

Figure 1: Source-oriented separation and treatment of household waste water flows

Figure 2: Volume and distribution of contaminating components across different household waste water flows

By collecting urine and faeces separately, the remaining waste water flow is almost completely free of nutrients and can be more easily purified, the water quality improved, and the social costs reduced. By keeping urine and faeces concentrated, it also becomes possible to recover nutrients from waste water and re-use them as fertilizer. This will lead to savings of finite natural

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resources, like phosphorus and potassium (refs. 1 and 5). Waste water purification changes thereby into “resource management” and can contribute to sustainable economic and ecological development.

In various regions in the Netherlands, grey water is collected separately and treated, as in De Drielanden in Groningen, the borough Lanxmeer in Culemborg and the EcoPark in Emmeloord. In a broadly based research project (EET / STOWA), a varied consortium of Dutch universities and companies is currently conducting research into these concepts, in which technical, constructional and social-economic aspects are being studied. Although research is being done into source-oriented sanitation in the Netherlands, there is still no concrete application of the separate collection and treatment of toilet waste water.

Source-oriented sanitation in rural areas

In this article, we shall treat the question of whether the implementation of source-oriented sanitation concepts could form an alternative for the connection of lots in rural areas to the sewage system or to IBAs. Currently, there are still about 200,000 lots without a sewage connection in the Netherlands, most of them in rural areas. From 2005 no unpurified discharges are permitted from these lots. It is expected that about 100,000 lots still have to be connected to the sewage system. For the remaining lots, an IBA will be installed.

In the Environmental Management Act it states that local authorities are responsible for the efficient collection and transport of waste water. Local authorities can be granted exemption from this responsibility. A cost comparison between the connection to the sewage system and the deployment of suitable IBAs (individual treatment systems for waste water) can be used to determine the best solution (sewage system or IBAs) for a particular area. In many provinces, agreements have been concluded about so-called assessment sums per sewage connection. If the sewage system in a certain area can be installed for less than the assessment sum, then the area will have a sewage connection. If the costs are higher, then deploying IBAs can form an alternative. The assessment sums vary according to the area between € 7000 and € 11,000.

If a local authority has indicated which discharge outlets will not be considered for sewage connection and if the province has granted exemption from the responsibility for those outlets, then the Act applies to the one doing the discharging. That person must meet the effluent standards set by the WVO household waste water discharge decree, for which the district water board ensures compliance.

Source-oriented sanitation concepts in rural areas

Developments in toilet systems and transport technology allow toilet waste to be transported without or with very little water (refs. 4 and 7) while maintaining the comfort that we are used to with conventional toilets. The quantity of rinse water in the toilet is thus reduced by more than 85%. In the concepts examined, use is made of these toilet systems in which urine and faeces, whether separated or not, are transported to a storage volume measuring several cubic meters for an individual household. Periodically, the urine and faeces are transported by truck to a central collection point for further treatment. For a demonstration project, processing in an existing sewage water purification plant is being considered.

The remaining (grey) waste water makes up most of the total volume, but contains only a small proportion of the total quantity of nutrients (figure 2). This waste water can be simply and robustly treated on site with a simple purification system (eg a biorotor or helophyte filter). The constant good effluent quality (table 1) can be discharged without problems on site into the surface water.

Quality of the water to be discharged

According to the effluent quality to be achieved, the IBA systems are divided into three classes, I, II and III. The systems that are considered class III should meet the strictest effluent standards. The current effluent standards for a sewage water purification unit and for the class-III IBA systems are compared in table 1 with the feasible effluent quality for alternatives based on source-oriented sanitation.

	IBA III	SWPU	Source-oriented sanitation
CZV (mg/l):	< 100	< 50	< 50
Total N (mg/l):	< 30	< 10	< 2.2
Total P (mg/l):	< 2	< 1	< 0.15*)

*) to remove P it may be necessary to add a small quantity of $FeCl_3$

Table 1: The current effluent standards (mixed sample) for a IBA-III system and a sewage water purification unit compared with the feasible effluent quality in concepts based on source-oriented sanitation (refs. 1, 2 and 4)

The separate removal of toilet waste water prevents nutrients, drug remains, hormones and most pathogens from reaching the surface water.

Costs

An initial estimate of the costs of source-oriented sanitation is reproduced in table 2. The indicative investment costs for the source-oriented sanitation concepts examined are circa 15% (or € 1150) higher than those for the IBA class-III systems. The excess costs are almost entirely determined by the relatively expensive toilet systems.

The indicative operational costs of source-oriented sanitation is substantially lower, by circa 25% or € 95 per year, than those for the IBA class-III system. This is due to the lower energy use and the greater simplicity and robustness of source-oriented sanitation. As the treatment system is relatively simple, we also expect that the necessity for effluent control will be reduced.

	Source-oriented sanitation	IBA III
Investment costs (€):		
Average purchase of IBA class-III (5-6 ve):		4800
Toilets (2x) + vacuum system:	2450	
Total storage system:	1000	
Helophyte filter:	2500	
Installation costs for total system:	3200	3200
Total investment costs:	9150	8000
Operational costs (€/y):		
Energy:	10	65
Collecting + processing (feces/urine or sludge):	150	150
Maintenance:	100	140
Total operational costs:	260	355

(based on references 7)

Table 2: Indicative investment and development costs including tax of IBA class-III systems and alternatives based on source-oriented sanitation for a household of six people

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Conclusions and recommendations

The investment costs of source-oriented sanitation concepts in rural areas are circa 15% higher than for IBA class-III systems. The simplicity and robustness result, however, in circa 25% lower operational costs and in a better effluent quality. In addition, it is possible to recover and re-use nutrients and reduce the rinse water use by more than 85%.

Based on the findings described in this article, a demonstration study for the implementation of source-oriented sanitation concepts in rural areas seems to offer an interesting opportunity. An initial step can be taken toward a potential future shift in waste water purification towards resource management and a contribution made to sustainable economic and ecological development. The Rijnland District Water Control Board is currently studying the possibilities of carrying out such a demonstration project in collaboration with the foundation Lettinga Associates, Foundation for Applied Water Management Research (STOWA) and the North Holland District Water Control Board.

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Energy, water supply and waste water treatment for the Werbellinsee-project (ex “Pioneer Republic Wilhelm Pieck ’)

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Keywords

Decentralized, energy, integrated, rainwater, renewable, re-use, wastewater

Abstract

In recent years new water management and treatment technologies have been developed and demonstrated in projects. This is true especially for singular concepts using either rainwater management technologies or wastewater treatment in different locations. No experience exists in the operation of integrated decentralised installations including the potential for energy generation. The goal of the research is to gain experience in comprehensive design and implementation of singular technologies aiming at quasi-autark concepts requiring only a minimum of public water, waste and energy management services. Theses concepts should prove to function in different types of settlements and urban structures as well as various regional conditions and demands.

The aim of the research and development component of this project is to demonstrate the functioning of a comprehensive approach under technical, socio-cultural, economic and legal aspects by integrating individual technologies that reflect the state of art. For wastewater management it is proposed to use anaerobic sewage treatment, membrane technology, natural purification procedures as well as faces and urine separating technologies. For water conservation, water saving devices as well as rainwater harvesting and wastewater processing and recycling is envisaged. For solid waste management garbage separation, composting it and incineration is considered. The recovered nutrients from wastewater treatment and solid waste management shall be used for landscaping horticulture on site and for agriculture in the vicinity of the project site. For the supply of energy, block heating generation plant technology that uses renewable energy resources shall be adopted. The operation and maintenance of all the above installations would be run by one operating authority.

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The present situation

The Werbellinsee project (see figure1), offers place for about 1.100 visitors in around 30 guesthouses. The project was founded by the former German Democratic Republic in 1952 and was named after its founder and the first president of the German Democratic Republic, ”Pioneer Republic Wilhelm Pieck”. Today the project site is used for recreation by the youth (European Meeting Place for Young People), sport, vocational education and international meetings. The area of 200 ha at the marvellous Werbellin lake is covered by 100 ha of forest. The Werbellin lake extends over 10 km in length and 1 km in width. The project site is located within the Uckermark Biosphere Region. The built up area is protected under the monument protection law and comprises of 42.000 m² floor area. The project was designed by Richard

Paulik[1]. At present the heating is provided by a contracting company via a heating network. Waste water is pumped through a 30 km long sewer to a waste water treatment plant. Power and water as well as solid waste management are provided externally by public institutions. The reconstruction of parts of the existing technical infrastructure is planned under the framework of the original autarkic concept of water and energy supply as well as management of solid and liquid wastes.

Aims and objectives

The aim of reconstructing parts of the technical infrastructure is to revive the original autarkic concept of water and energy supply and management.

The research and development project will demonstrate new concepts, technologies and products for minimising wastewater, separation of faeces, urine and water and reusing treated wastewater. Furthermore the potentials of reuse of rainwater can be demonstrated. The decentralised generation of electricity and heat will include the use of organic wastes and leftover wood from logging activities.

The project comprises of the following elements:

1. Drinking water supply by rehabilitating the existing deep ground water wells on the site
2. Minimising wastewater by modern sanitation technologies (separation toilets, dry toilets, separation of urine and faeces, urine will be used for soil improvement)
3. Remaining wastewater being treated at the treatment plant on the project site (anaerobic treatment of sludge, trickling filter, rootzone treatment and membrane technology) for reuse in irrigation and toilets
4. Rainwater run-off collected in cisterns of different dimension for drinking water substitution (baths, toilet flushing, washing machines) and for groundwater recharge
5. Anaerobic treatment of organic waste (especially from the restaurants), use of methane gas and sludge from waste water treatment for energy production
6. Block heating and power generating plant that produces energy from renewable resources (methane gas, chopped wood, wood pellets)

Wastewater management

Together with the reconstruction of the wastewater treatment plant water saving technologies will be installed. To allow a comparison between different systems the houses will be equipped with different toilet types such as separation toilets and urinals without flushing, Gustavsberg water saving systems, 1 / 2 / 4 litre WC, hybrid toilet systems with water separator connected to a composting facility (for smaller buildings) and Clivus multrum compost toilets. At the project site a separate sanitary and stormwater drainage system already exists and shall be integrated with the proposed infrastructure. Organic wastes from canteens and faeces separated from sewage will be treated in decentralized methane reactors. The urine will be collected and treated separately and used as fertilizer. The wastewater yield of 1.900 population equivalents will be 285m³/d and ca. 104.000m³/a. About 20.000m³/a of purified wastewater will be used for supplying a nearby moor, thus about 76.000m³/a will remain for re-use.

[1] Richard Paulick, born 1903, affiliated with BAUHAUS since 1924, founder of Socialist Labour Party in 1933, emigrated to Shanghai, 1942 professor for architecture at the University of Shanghai and 1945 town planning director of Shanghai, 1949 member of Institute for Construction under Hans Sharoun, among other works architect of parts of Karl-Marx-Avenue in former East Berlin

Rainwater harvesting

Rainwater run-off from roofs amounting to 13.000 to 25.000m³/a will be stored in cisterns after being purified. The capacity of the cisterns will vary between 5 to 300 m³ according to the roof areas to be connected. Each cistern will be equipped with a filter, a pumping device and a drinking water connection for top-ups. Water from the rainwater cisterns will be used for drinking water substitution (baths, toilet flushing, washing machines) and for groundwater recharge. The run-off from pedestrian pathways and roads will be between 25.000 and 50.000m³/a will be collected in infiltration trenches. Rainwater run-off will not be discharged into the Werbellin Lake.

Water supply

The water works at the project site were shut down in 1996. The existing filter tanks will be cleaned, and the pumps, fittings, filter materials (for removing ferric oxide) and backwashing equipment will be renewed.

For irrigation of the intensively used sport fields, for green areas and gardens around 32.000 m³/a in a year with average precipitation and around 60.000 m³/a in a dry year will be needed The total demand of 67.000m³/a in a wet year can be completely provided for by using purified water from the treatment plant. In a dry year the demand rises to 95.000 m³, hence 13.000m³ of rainwater and 6.000m³ drinking water will have to be added to purified waste water.

The demand for process water for toilet flushing is estimated to be 35.000m³/a. In dry years around 13.000m³ of drinking water has to be added

For other purposes (household, small industry) process water from the cisterns is available. In a wet year the demand of around 17.000m³/a can be supplied in this way. Surpluses will be used for the recharge of groundwater.

Solid waste management

Organic waste from canteens and faeces separated from sewage will be treated in decentralised methane reactors. The compost from toilets together with organic waste from the gardens will be composted and used on site for horticultural purposes. The sludge from the purification plant can be used either for energy generation or for composting in order to close the loop within the project site.

Power generation and heating

Energy has to be supplied for buildings with a total floor area of 42.000m². At present a demand of about 3.500kW is estimated for heating purposes.

For a decentralised heating and electricity supply for the project site, a Block Heating and Power Generating Plant (BHGP) will be setup using methane gas from the wastewater purification plant and the methane reactors. The methane gas will be burnt and converted into heat and electricity. For peak demands, chopped wood will be additionally used as a renewable resource for energy production. Wood exists in sufficient amounts in the region. The use of solar energy is not suitable due to the dense tree canopy on the site.

The BGHP technology consists of a boiler which will be heated by a special burner. The hot combustion gas is used to heat thermo-oil in a heat exchanger. By introducing a new technology, the ORC-process, the heat of the thermo-oil is used to support a low temperature steam circulation, which is driving a condensation turbine for generating electricity. The operating medium for the ORC-generator is silicon oil, which has a boiling temperature of 80ºC. This enables a higher degree of efficiency compared to a traditional steam power station. Since the steam generator is heated indirectly, no supervision of the BGHP is necessary and maintenance required for this system is low. Only one person is needed to run the BGHP.

The annual demand for electricity supply is estimated to be 2.000 MWh/a. By installing a block heating and generating plant (BHGP) the energy costs can be reduced by 60%. By using energy conserving techniques of the building renovation, the maximum energy demand for heating will be reduced to 50%. The annual operating time of the BHGP is estimated to be 5.000 hours. This will be sufficient for the generation of 2,500 MWh/a. The electrical output of the BHGP will be 500kW. Management and regulation of peaks will reduce the power demand peaks to a maximum of 700 kW and contribute to a significant reduction of costs.

Operating authority concept

Operation and maintenance of the installations for energy production and for water and waste management in the project area of Werbellin lake would be run by one operating authority. This can be done by a corporation founded for this particular purpose or by an institution experienced in operating at least parts of the new technology. Whoever shall operate these installations, will have to be trained, as such technologies and their integrated combination do not exist so far in a project of this scale. The local water authority could participate as well. The options of forming an operating authority (corporation) are studied at present.

Conclusions

The aim of the research and development component of this project is to demonstrate the functioning of a comprehensive approach under technical, socio-cultural, economical and legal aspects by integrating new technologies reflecting the state of art. The previously existing autark systems for energy and water supply as well as wastewater treatment will be reactivated and technically modernised. It is expected that the integral planning approach will create a synergy, which will result in the enhancement of both environmental and economic benefits.

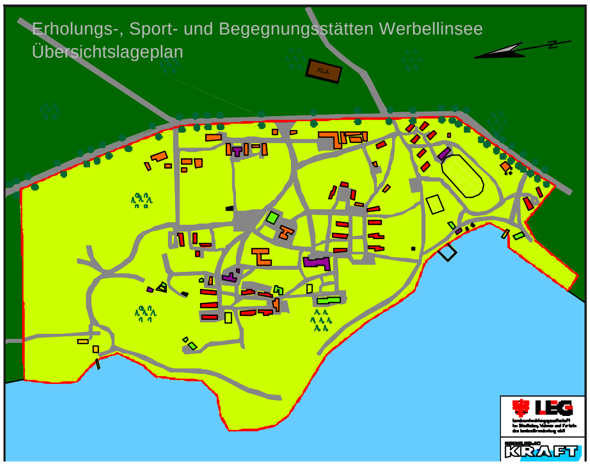

Figure 1: Layout of Werbellinsee Project

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SWAMP - Sustainable water management and wastewater purification in tourism facilities

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Keywords

Ecological sanitation, reclamation concepts, water saving, urine separation, irrigation, reed bed treatment systems

Abstract

A great number of tourism facilities of various types in different locations throughout Europe do not yet have an adequate sewage treatment system solving the related problems, e.g. high seasonal fluctuation of wastewater flow, lack of water, low maintenance capabilities of owners, and natural environment deserving special protection. "SWAMP", a project under the Energy, Environment and Sustainable Development Programme of the 5th Framework Programme of the European Community develops sustainable water management concepts and tests them on 13 concrete examples with partners in Austria, Italy, Latvia and Germany. SWAMP means an efficient water use, recycling of nutrients and a cost effective wastewater treatment by constructed wetlands.

Wastewater and sustainable water management in tourism facilities

Water management in tourism facilities is of particular concern throughout the world. In fact, tourism industry is more and more attracted by isolated virgin locations where neither water supply nor wastewater collection is available. A welcomed development beside these aspects is a growing tendency of tourists to consider the environment quality when choosing an accommodation facility. Sensitivity to environmental matters and relating requirements are increasing in all segments of the conventional tourism market. The main innovation of SWAMP is to consider wastewater as part of the entire water consumption process. Sustainable water and wastewater management means an efficient water use, avoidance of hazardous substances, cost-effective wastewater treatment and reclamation of nutrients by agricultural irrigation.

Objectives of the SWAMP-project

SWAMP aims at developing economically feasible and technically satisfying wastewater management systems for tourism facilities with high fluctuations of wastewater quantities. Sustainable water management concepts will be developed and tested. This will be achieved by the following work packages:

WP 1: Audit of each participating facility and development of sustainable wastewater concepts for 13 typical tourism sites with capacities from 50 to 1.200 p.e. in various climates of Europe

WP 2: Realisation of one practicable variant at each location

WP 3: Monitoring of pilot plants focusing on operation, social acceptance, economical advantages and of innovative sanitation appliances and treatment efficiency of constructed wetlands

WP 4: Contributions to common European guidelines and elaboration of national proposals focusing on technical rule, cost-effectiveness and ecological benefits

WP 5: Promotion and publication of the applied technology by marketing agencies in each partner country

SWAMP - Sustainable Water Management and Wastewater Purification in Touris Facilities		Save Water			Reclaim Nutrients				Reuse
		Water saving technologies	Waterless urinals	Vacuum toilets	Separate grey- and blackwater	Use of sludge in agriculture	Urine separation	Natural treatment plants	Irrigation
Austria	Klug-Veitl							X	
	Weissmann	X	X					X	
	Pleschwirt							X	
Italy	Fattoria Baggiolino	X						X	X
	Parco del gigante							X	
	La Cava	X			X			X	X
	Relais Certosa							X	X
Germany	Park Moränasee	X				X		X	X
	Burg Lenzen	X	X	X			X		
	Stranddorf Augustenhof	X					X		
	Kulturraum Sammatz	X				X		X	
Latvia	Art museum Pedvāle	X				X		X	
	Mazais Krogs	X				X		X	
	Mežezers	X				X		X	

Figure 1: Components of Sustainable Techniques in SWAMP -Projects

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Innovative approaches

The project will advance the state of the art of wastewater treatment in combination with constructed wetland technology by following three innovative approaches:

Least-Cost Planning: An audit of the water flow optimises the layout of a treatment facility. An integrated view of used and treated water will lead to technically adapted and cost-effective solutions. Less water consumption will reduce costs for water supply and wastewater treatment. A decrease of wastewater discharge will minimise pollution of wastewater effluents and expenditures for water protection.

Treating Wastewater as a Resource: Normally wastewater is considered as a substance to be disposed of as soon as possible. In this part this attitude has led to expensive and energy intensive treatment plants with a negligible reuse of nutrients. Separation of sewage into its components black water, urine and grey water offers new possibilities for treatment and reclamation of wastewater. Natural treatment plants, e.g. ponds, reed beds, constructed wetlands as an efficient method for wastewater purification have to be adapted to these new challenges. One innovative approach of SWAMP is to implement these techniques and to test them in routine operation.

Wastewater pond-reed bed treatment system at Park Moränasee – one of the German SWAMP - Projects

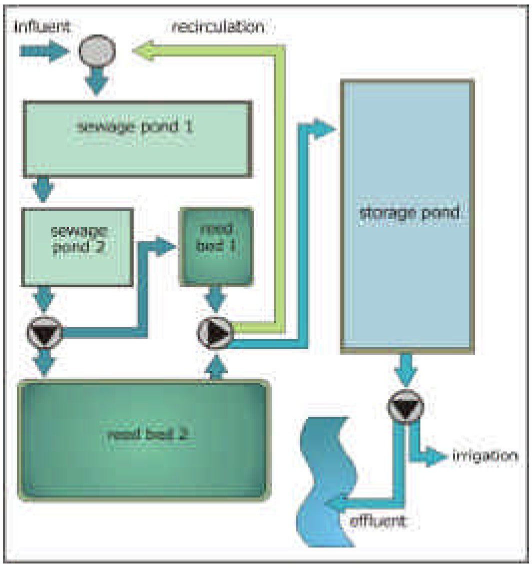
„Park Moränasee“ is a camping site mainly used in summer and at weekends. According to economic advantages instead of connecting the park to a public sewer system the sewage is purified in a private treatment plant on site. Rainwater was consequently separated from wastewater and percolated into the ground on the parks area. Depending on season wastewater quantities vary between 20 - 250 m^3/d. Due to these high fluctuations the treatment plant is designed as a combination of wastewater ponds and planted soil filters.

Wastewater pond-reed bed treatment
Park Moränasee, Dittmern, Germany

Construction year:	2002
Scale:	900 p.e.
Wastewater quantity:	20 - 250 m^3/d
Wastewater ponds:	2.800 m^2
Soil filter:	2.600 m^2
Storage pond:	5.000 m^3

Figure 2: Wastewater pond-reed bed treatment system “Park Moränasee”

The ponds serve for pre-treatment and storage of the sewage. The reed bed treatment system where aerobic treatment takes place is continuously fed with sewage. First desludging of pond 1 is scheduled after 20 years of operation. During the main season purified wastewater is stored in a detention pond for agricultural irrigation, the effluent is released into the receiving water by a discharge control. Purification requirements are very strict in order to protect the good river quality.



In sense of a sustainable wastewater management advantages of the natural treatment system at Park Moränasee are a simple structure with easy obtainable construction materials, construction by local firms, high hydraulic buffer capacity, high treatment efficiency, especially concerning hygienic parameters, low energy consumption and operation costs, long term desludging of ponds and agricultural utilisation of sludge and a good integration into natural environments.

Figure 3: Flow scheme of the wastewater pond–reed bed treatment system “Park Moränasee”

New Sanitation Appliances: Nowadays some special sanitation appliances are available on the market. Water saving and wastewater avoidance by water saving armatures, water flow-restriction, limitation devices for toilet flushing, waterless urinals, vacuum toilets and separation toilets decrease the drinking water consumption. Reduced wastewater quantities lower investment costs and increase the effectiveness of treatment plants. Vacuum systems in combination with no-mix toilets allow the separation of faeces (black water) and urine. Urine contains nutrients as N, P, K that can be utilised as fertiliser in agriculture. There is a need to gather experiences of a broader use of such appliances, with respect to cultural particularities, as water- and sanitation-related hygiene practices are very individual and related to education. A further innovative approach of the SWAMP-project will be to start cautiously but seriously a public discussion on sustainable wastewater management.

Guidelines and scientific objectives

Recommendations for European and national guidelines concerning sustainable water and wastewater management and reed bed treatment systems in tourism facilities in partner countries are prepared. The overall objective of preparing guidelines implies several other scientific and technological subordinate objectives, as the development of a cost-effective water management, reclamation concepts for treated wastewater, separation technologies in sanitation, reed bed treatment systems for wastewater treatment with respect to tourism facilities in remote areas. The work will be accompanied and completed by marketing agencies involved in the project promoting and disseminating the new technologies.

SWAMP-partners

AEE Intec
Gleisdorf, Austria

Ambiente Italia s.r.l.
Milano, Italy

Carl Bro Latvia
Riga, Latvia

Ingenieurbüro AWA
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IRIDRA Srl
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Ökologisches Projekt
Graz, Austria

Sia Aprite
Cesis, Latvia

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www.cordis.lu/fp5 Overview of the Fifth RTD Framework Programme

www.swamp-eu.org Web site of the SWAMP-project

www.baltic-soilfilters.de Information on constructed wetlands in rural areas of the Baltic States

Sanitary systems in Ouagadougou, Burkina Faso: Current practices and future potential

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Keywords

Domestic sanitation, sanitation providers, urban agriculture, pilot project

Abstract

This paper aims to establish the current sanitary situation within the formally settled quarters of Ouagadougou. The current sanitary trends will be presented and analysed and a very brief overview of some of the measures considered necessary for the introduction of a closed-loop oriented system of domestic wastewater management in this context will be given.

Introduction

Ouagadougou is the capital of the land-locked West African Sahel nation of Burkina Faso. The city currently has a population of 1.2 million, with an estimated growth rate of 9.8%. Average temperatures are around 30°C (max. 40° from May – June, min. 19°C from December – January). The city's water supply is reliant on surface water resources, with the major source being the reservoir at Loumbila (30km west of the city), supplemented by three drinking water reservoirs within the city limits. In recent years the national water supplier ONEA (l'Office National de l'Eau et de l'Assainissement) has been unable to ensure a continuous water supply in the dry months of May, June and July, and there is an urgent need for the new drinking water reservoir at Ziga (50km west of the city) to come into service (planned for 2007). Groundwater resources represent a relatively small percentage of the public water supply (10%), due to the hydrogeology of the region. This small percentage is however not unimportant as it represents a relatively reliable fresh water reserve in dry seasons.

At the start of the 1990's a quarter of all illnesses in Ouagadougou were attributable to poor sanitation. The poor sanitary situation was aggravated by the wide range of institutions implicated in the provision of sanitary services and their lack of coordination. Since 1992 a concerted effort has been made by ONEA to improve the city's sanitary situation with the development and implementation of a strategic plan for the "classical" sanitary disposal of wastewater (a central wastewater treatment lagoon for industrial and medical wastewater; VIP latrines and closed greywater soakaway pits for decentralised domestic sanitation; latrine blocks in schools). The original strategic plan for decentralised domestic sanitation was tested during a 3 year pilot phase in two sectors of Ouagadougou, eventually being expanded to the entire population living within the officially recognised city limits (i.e. the sanitation needs of informal settlements are not considered within the plan). Today there remains a huge demand on behalf of the population that sanitary facilities be improved.

During a three-month period, from August to November 2002, the sanitary installations in Ouagadougou were visited with sanitary extension agents of ONEA. These included new or rehabilitated domestic installations as well as older, more traditional means of sanitation. The latest reports on the sanitary situation were collected and analysed and compared to the

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findings of the field visits. In addition to establishing the local sanitary situation, the legislative, social and agricultural conditions were examined in order to assess the ease with which ecosan systems would fit into the local context.

Additionally, a very successful ecosan advocacy workshop was organised with decision makers from governmental and non-governmental agencies, and from the fields of sanitation, agriculture, education, research, population participation, women's groups etc. being invited. The aim of the workshop was both to provide information on the possibilities to implement ecological sanitation and to establish the level of interest and opinion of the participants.

Results

1. The domestic sanitary situation

In Ouagadougou, decentralised domestic sanitary installations dominate. The present construction of a sewage network and centralised wastewater treatment lagoon is planned only to serve the city centre, the hospital, the main hotels, and the industrial park. Each individual household is responsible for its own "waste"water management, which is chosen according to the household needs and financial means.

Greywater from domestic use is for the most part disposed of either by allowing it to flow freely across the ground surface, or channelled toward an open soakaway pit. These also serve as depositories for domestic waste and as breeding grounds for disease.

Figure 1: A "traditional" pit latrine

Traditional pit latrines (often doubling as showers) represent around 80% of all toilet facilities, compared to an estimated 70% in 1991 before the strategic plan was introduced. Improved Ventilated Pits, which have been extensively promoted over the last 10 years only represent around 5%. This is due in part to the high construction costs for such a latrine as prescribed by ONEA (approx. 450 Euro, excluding a subvention for the floor slabs, aeration pipe and doors). An estimated 7% of the urban population remain without access to any form of sanitary installation in their courtyards – unchanged from 1991, before the strategic sanitation plan was introduced – and defecate simply in the surrounding environment.

Most homes (around 75%), if choosing to construct a new sanitary installation, will simply engage a local mason who will charge much less than those trained by ONEA to dig an unlined single pit and build the superstructure. These installations, while all being similar, are not constructed according to a particular plan. Pits normally average 4m depth, with exceptions in the area of the drinking water reservoirs, where the high groundwater level has limited this depth to around 2m. Fig. 1 shows a well maintained latrine in a courtyard with 7 apartments. In this case the single pit also serves to collect shower water, and pit ventilation is provided by means of a PVC pipe.

The emptying of latrine pits is most often performed by hand when the pit is almost full, although several firms do also offer a vacuum service (cost around 22 Euros). The contents are either left in a public place to dry completely, after which they are used for gardening/agricultural purposes, or they are taken by the vacuum tankers to the outskirts of town where they are freely dumped or sold to farmers.

No particular anal cleansing method was found to be particularly dominant. Users were equally likely to use water as they were to use paper, pieces of wood, or other material. Along with

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receiving the blackwater, the pits are also used to dispose of greywater (from showering), and domestic solid waste, such as plastic bags, broken bottles, used batteries etc. This leads to a rapid filling of the pits with various materials and a highly heterogeneous content.

2. Organisational responsibility and legislation

Today, as in 1990, a wide range of both national and communal bodies have a responsibility for sanitation provision, however only ONEA, who charge around 1.5 Euro cent per m³ of drinking water sold for the collection and treatment of wastewater, appear to have any funds to intervene in the sector. However, while other organisations may not dispose of sufficient funds to finance sanitary measures, they do have responsibilities in this regard. The government ministries involved in sanitation include the Ministries of Water; Health and Social Action; the Environment and Tourism; Basic Education; Secondary and Superior Education and Scientific Research; etc. Added to this are communal authorities that are gaining increased responsibility due to the decentralisation process currently underway, as well as private enterprise and NGOs. No effective coordination between these actors is currently apparent.

This multitude of actors and responsible authorities has contributed to a high degree of uncertainty and intransparency in the provision of sanitation. Often the actors even within government bodies are not aware of the activities / responsibilities of other government bodies.

On a legislative level it is stated that for an individual to obtain a construction permit in Ouagadougou, evidence must be provided that a form of sanitation will be constructed. The type of installation must not be stated, nor are there any formal instructions laid down by the authorities, which could regulate the performance of the sanitary facilities.

3. Urban agriculture

Agricultural activity is widespread among the population of Ouagadougou, and can broadly be divided into four different forms:

a) Officially sanctioned urban agriculture – this is practised for the most part on the land surrounding the drinking water reservoirs within the city limits. 2 main types of cultivation are pursued: Individual gardeners, for the most part women, cultivate vegetables for sale and consumption within the city, while another mainly male group tend tree and ornamental plant nurseries. These groups currently use industrial and medical wastewater collected from the open storm sewers, to irrigate and fertilise their plants.

b) Inter-domiciliary agriculture – this is practised within neighbourhoods where empty plots of land, sometimes of only a few square metres are planted with a wide range of crops (maize, millet, gumbo, ground-nut etc.) by local people in order to supplement their income/diet. The town council formally forbids the practise.

c) Agriculture within the confines of a family compound – most families will plant a range of food-crops in their yard to supplement their diet. Crops include maize, possibly millet, peppers etc.

d) Agriculture on the outskirts of the city – here, agriculture is practiced on a large scale with much of the population having plots where they continue to cultivate, even if they are employed in other sectors.

Due to the scarcity of water resources in and around Ouagadougou, and the expense of mineral fertilisers, many cultivators, in particular those engaged in agriculture as their main source of income, currently use wastewater or the sludge from emptying pit latrines to fertilise their crops.

Possibilities to introduce closed-loop sanitation systems in the Ouagadougou context

The introduction of ecosan principles to the wastewater management in Ouagadougou could play an important role in helping the city's increasing population face the triple threat of poor sanitation, decreasing water quality, and an increasing demand for food. However there are also several factors that could prevent a successful implementation of the approach. Any intervention should start on a pilot level, identifying potential user who are in need of sanitary facilities and will be able to use the products of an ecosan system (either for their own activities or by identifying a potential market for them). Such groups have already been encountered who have expressed a great deal of interest in closed-loop systems. One proposed model to assist implementation would require action on both a legislative and executive level. Some of the proposed measures are:

Legislative level:

- Clearly establish one responsible body that is in a position to oversee sanitary measures and with the political responsibility to carry out its mandate. While not only relevant for the implementation of ecosan systems, this measure is of great importance in order to ensure efficiency of operations.
- Clarify legislation to obtain a construction permit. In order to better control the effects of sanitation on public health, the environment etc. basic guidelines should be given providing the framework of how sanitary systems should perform. Such a framework is envisaged to both regulate the impact of the sanitary system and provide an impetus to private enterprise (who currently provide the majority of installations).

Executive level:

- Identify the most suitable sanitary system to serve the needs of the users
- Awareness raising activities to propagate the full range of benefits of a closed-loop system
- Identify markets for the recyclates (whether it is the user or if it could be sold on)
- Investigate the logistical possibilities for transport / distribution of recyclates

Social acceptance for the agricultural use of the recyclates would appear not to pose too great a problem at present, and is in fact preferred by many to the current methods of crop fertilisation. While the environmental benefits of closed-loop systems were welcomed it was the income generating possibilities associated with ecosan systems that provoked a great deal of interest among those questioned (particularly women's groups), and should be considered as a strong motivating factor for participants.

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Conclusion

Due to an expressed need for improved sanitary facilities, an active agricultural sector requiring low-cost fertiliser, the need to protect surface water resources and the possibility of the creation of income generating activities, a great deal of interest exists in Ouagadougou regarding the implementation of closed-loop sanitation systems.

This interest however faces several problems, such as the costs of introducing new sanitation concepts and systems, unclear institutional responsibility, social practices of using toilets as receptacles for all kinds of waste and a certain resistance to new ideas among those currently promoting other forms of sanitation. A successfully implemented pilot project will help serve to overcome these difficulties.

Zero emission concept for water and wastewater management, project Rügen, Germany

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Keywords

Blackwater, case study, decentralized treatment, demonstration project, greywater, reed bed, rural area, source separation, sustainable sanitation, vacuum toilet, water saving, zero emission.

Abstract

A sustainable sanitation concept will be realized at a visitors centre in the national park JASMUND on the isle of Rügen, Germany. Main idea of the zero-emission concept is source separation of faeces. Blackwater will be collected by vacuum toilets and reused via a biogas plant and agriculture. Greywater will be treated on-site by reed bed technology and recycled for toilet flushing and watering. Rainwater will be throttled on-site and infiltrate in a nearby forest. In comparison to conventional wastewater management (3km duct to public sewer or decentralized treatment of unseparated wastewater) cost reduction of 25 percent are estimated.

Introduction

The environmental foundation World Wide Found for Nature (WWF) Germany and the city of Sassnitz are realizing the reconstruction of a former military base into a visitors centre. The project is located in the smallest German national park Jasmund on the isle of Rügen in the very north-east of Germany. The visitors centre will consist of ecological exhibition and restaurant. Up to 1.000.000 persons per year and up to 4.000 persons per day are expected to visit the location close to the famous chalk-cliff (figure 1).

Figure 1: Crowd puller chalk-cliff

Figure 2: Visitors centre

The planned shape of the building 120 m above sea level is shown in figure 2.

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Present situation

After feasibility studies in 1998 the centre is under construction at the moment and will open in 2004. During former use of the area wastewater from public restrooms and restaurant was partly discharged to the Baltic Sea after sedimentation and partly transported to municipal treatment plants by tanker. The public sewer is in a distance of 3km.

Freshwater is taken from a nearby spring. Due to the little flow especially during summer months and for ecological reasons the water consumption has to be reduced to a minimum.

Zero emission concept

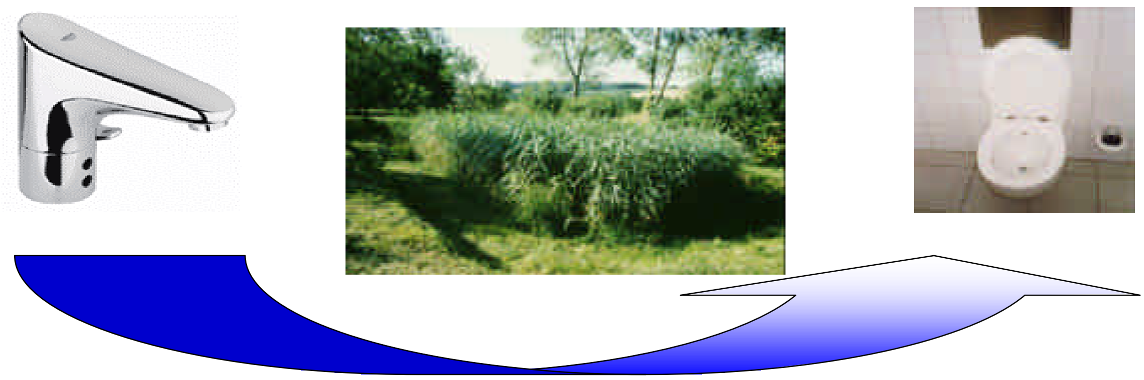
Water supply and wastewater management bases on the idea of source separation and recycling of substances and water. Another goal is to prevent any pollution in the surrounding ecosystems of the national park and the Baltic Sea. Furthermore the change of water balance of the area has to be reduced to a minimum.

Main idea of the concept is the separate drainage and treatment of

- rainwater
- greywater and
- blackwater.

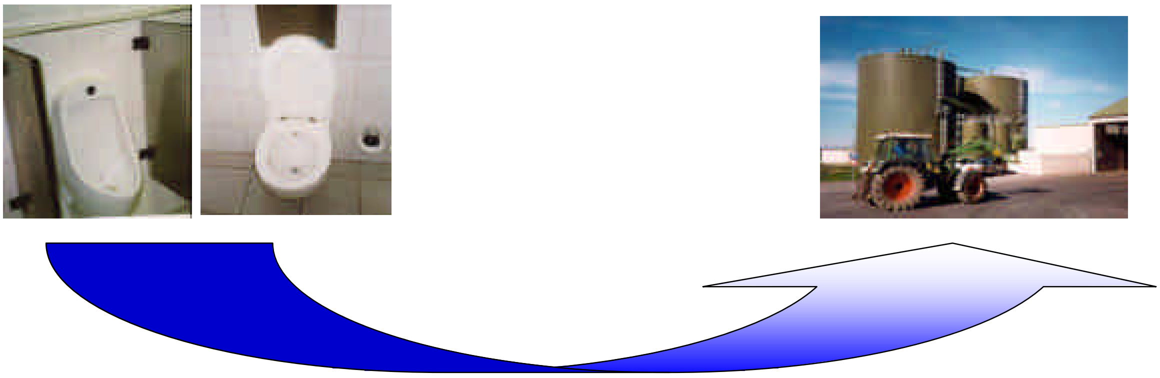
Rainwater will be collected in a pond on-site and throttled to the natural flow. It infiltrates in a nearby forest.

Greywater, mainly from washbasin, will be treated by reed bed technology on-site and recycled for toilet flushing and watering.



Blackwater will be collected by vacuum toilets and is stored on-site. Transportation takes place by tanker to a nearby existing biogas-plant. After fermentation the substrate will be used as fertilizer in agriculture.

Rainwater will be mainly drained in shallow trenches and collected on-site in a pond. To reduce erosion and to maintain the natural local water balance from this pond a throttled flow of rainwater will be discharged to infiltration in nearby forest.



Less polluted wastewater without faecal contamination (grey water) will be treated by a reed bed (vertical flow constructed wetland). The soil filter planted with reed was designed on the water and organic load on the basis of experiences gained with treatment of greywater in projects in Berlin and Hanover. The treated greywater is used for toilet-flushing and watering. Surplus water will be discharged together with the rainwater.

High polluted wastewater (dishwater, etc.) and wastewater from vacuum-toilets and urinals (blackwater) will be stored on-site. Transportation takes place by tanker to a nearby existing biogas-plant. After fermentation the substrate will be used as fertilizer in agriculture.

Conclusions and results

Based on a detailed analysis of the fluxes of water and nutrients, investment and running costs the effects of ecological sanitation compared to conventional solutions were quantified:

- Reduction of demand of drinking water of about 80%:
  - 5 percent by water saving fittings (2.5 litre per min at washing basins)
  - 12 percent by dry urinals
  - 43 percent by vacuum-toilets
  - 21 percent by greywater-recycling
- No emissions to the Baltic sea and the surrounding ecosystem
- Recycling (agricultural use) of 750kg nitrogen and 150 kg phosphorus each year
- Production of 1.900 m³ biogas each year
- Negligible change of local water balance
- 25 % reduction of costs (investment and running costs)

As shown in this example ecological sanitation is not only advantageous for environment but even cheaper than conventional (end-of-the-pipe) solutions.

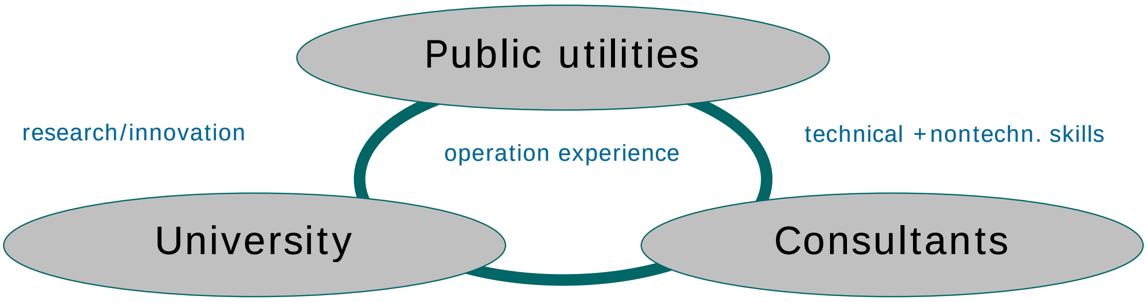
Other ongoing and future ecosan-projects of "*aqua*planer"

Apart the zero-emission-concept Sassnitz the following ecosan-projects of the *aqua*planer engineering office are in preparation. Depending on the local conditions different combinations of ecosan-techniques will be realized.

Ecological sanitation and water management for:

- Museum in Egypt (7.000 visitors daily)
- Housing estate in Darmstadt (400 inhab.)
- Housing estate in Hannover (750 inhab.)

Future projects will be offered in cooperation with the association „WATER HANNOVER - Centre for sustainable water management".



WATER HANOVER is a network of consultants (e.g. engineering offices), Public utilities of water supply and wastewater drainage and university.

The aim of WATER HANOVER is to offer independent integrated consulting services world wide. In comparison to conventional consulting offices social aspects, operation experience and education of local personal are included. By this holistic approach WATER HANOVER is the ideal partner for planning of sustainable projects.

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Possibility of sustainable sanitation in Japan

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Keywords

Sustainable sanitation, eutrophication, domestic wastewater, dry-toilet

Abstract

Sustainable sanitation is an approach from the actual sanitation to improve the environmental protection and resources. The flushing toilet, brought by modernization to make our life comfortable, is considered as sanitary by us.

However, nitrogen and phosphorus that are not removed through the conventional sewage disposal plant, pollute highly the water.

It is obvious that the sewage contaminates underground water, river, lakes, marshes. Furthermore, the current sewage disposal plant, which cannot remove those nitrogen and phosphorus, is causing a serious problem of eutrophication in lakes and marshes.

Many kinds of dry-toilets have been developed as reported in the last conference. In this paper, we understand how high and evident is the efficiency of the so-called dry-toilet in water saving and water quality.

Sustainable sanitation example (Nagasaki city, Japan)

There is a house situated in the city of Nagasaki using separation distributed processing system of domestic wastewater. Human excrement is treated by bio toilet, and gray water is treated by septic tank. This system has been in use now for one and half year. Just one technical problem occurred to the agitator in the bio toilet treatment tank. However, it is working smoothly. In this house, the garbage is also carried into the bio toilet to be treated. We can tell that this system is contributing highly to the reduction of the refuse. We are planning to carry out a quantitative investigation to reveal exactly the rate of nitrogen and phosphorus found through this system.

Figure 1: sustainable sanitation example

Figure 2: bio toilet treatment tank

Proportion of pollution coming from human excreta in domestic wastewater

According to an investigation conducted by the Tokyo Water Authority, the amount of the water used of a toilet is 24% of the whole domestic water use (see fig3). But, the proportion of pollution by human excrement in domestic wastewater is 75%. (see fig4) In regards to this high rate of pollution, it is urgent to introduce a system separating the human excrement from the domestic wastewater in order to save the quality of the water.

Through this process, the excreta can be carried out and used in an effective utilization. It will contribute greatly to load off the water area.

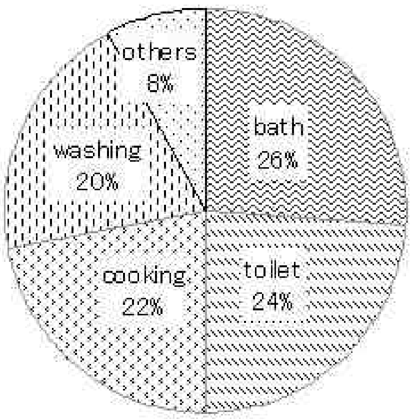

Figure 3: Proportion of quantity

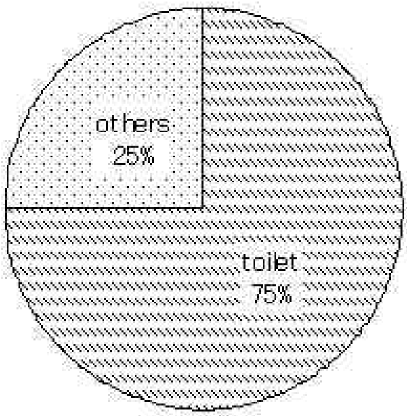

Figure 4: proportion of quality

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Comparison of the contaminant curtailment effect

The main processing method of human excreta in use in Japan are various: sewage disposal plant, human excreta treatment plant, combined septic tank, individual septic tank, sea dumping, etc.

Then, a comparison study on environmental pollution in public river basin has been conducted. For this study, an advanced wastewater treatment system that includes a bio-toilets has been used.

When considering the environmental load through this treatment-0ff-human excreta system, we should take into account all the environmental load items, from the design to the disposal system. However, we evaluated the BOD, T-N and T-P contained in wastewater. The result is shown on table 1.

We used the following fiducially points regarding the design of a human excreta septic tank in the calculation of human excreta and drainage from household.

a) and b) are widely used in the actual process which does not separate human excreta from the domestic wastewater.

c) Treat only human excreta.

An individual septic tank has a very loose effluent standard. (BOD90ppm) As the domestic wastewater is discharged without being treated. This is a very serious problem. Therefore, Private Sewerage System Law has been revised and the establishment of an individual septic tank is now forbidden. This law took effect on April 1st, 2001. However, all individual septic tanks have not been put yet out of use. In Nagasaki prefecture, 7.3 % of the whole processing methods of human excreta is an individual septic tank method.

d) The dipping-up system is used as well. In this case, human excreta is carried to the treatment plant. Like for the individual septic tank, domestic wastewater is discharged without being treated.

e) System based on the concept of sustainable sanitation.

Human excreta are treated in a merger dry-toilet, and domestic wastewater in a septic tank. By separating human excreta from domestic wastewater, the burden concerning the treatment equipment can be reduced greatly. We estimate that this system can replace the system described in c).

	BOD	T-N	T-P
a) sewage disposal plant	4.0	6.0	0.7
b) combined septic tank	4.0	6.0	0.7
c) Individual septic tank	31.5	10.0	1.0
d) human excreta treatment plant	27.5	2.5	0.4
e) sustainable sanitation	3.0	1.4	0.2
f) advanced process in the sewage disposal plant	2.0	2.0	0.2

(Unit:g/person·day)

Table 1: comparison of the contaminant curtailment effect

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f) We assumed performing advanced process in the sewage disposal plant. This system is carried out in about 13 disposal plants, such as Lake Biwa, Kasumigaura, etc which discharge drainage to a lake.

As mentioned above, according to the result of the comparison study, in the system using the bio-toilet we propose, it shows that discharged water quality is equivalent to the same than the quality from an advanced wastewater treatment institution, in regards to the BOD T-N, and T-P.

Conclusion

It cannot be said that in small and medium municipalities where density of houses is low, the cost of the investment will be reasonable. Though the sewerage is a suitable method in large cities with a high density of people, medium and small size cities should examine a method of treatment adapted to the needs of each area.

In the regions where sewage-treatment plant is used, as mentioned in this paper, the water pollution from human excreta is a major problem. It is necessary to consider a new toilet system.

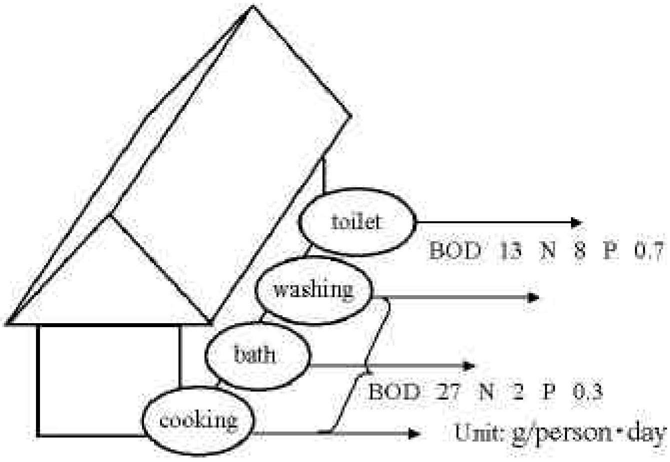

Figure 5: separated treatment for domestic wastewater

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Decision making tools

Chairpersons

Jes La Cour Jansen (Lund Institute of Technology, Sweden)

Ralf Otterpohl (Technical University Hamburg-Harburg, Germany)

Lectures

Ecological assessment of ecosan concepts and conventional waste water systems *
Ralf Mühleck, Andreas Grangler, Martin Jekel (Technical University Berlin, Gemany)

The phosphorus calculator: A planning tool for closing nutrient cycles in urban eco-systems*
Bekithemba Gumbo (University of Zimbabwe, Zimbabwe)*, Hubert Savenije, Peter Keldermann*

Assessment method for evaluating existing and alternative measures of urban water management*
Dongbin Huang, Roland Schertenleib, Hansruedi Siegrist, Tove A. Larsen, Willi Gujer (EAWAG, Switzerland)

Options for sustainable urban water infrastructure systems: Results of the AKWA 2100 project
Harald Hiessl, Dominik Toussaint (Fraunhofer Institute, Germany)

Comparison of resource efficiency of systems for the management of toilet waste and organic household waste*
Daniel Hellström, Andreas Baky, Ola Palm, Ulf Jeppson, Helena Palmquist (Stockholm Vatten, Sweden)

The Swedish Urban Water programme
Per-Arne Malmqvist (Chalmers University of Technology, Sweden)

Model city urban enclave in urban water - does ecosan improve sustainability of the sewage system?
Håkan Jönsson (Swedish University of Agricultural Sciences, Sweden)

Comparison of sanitation latrines used in China
Li Xianghong (Guangxi Medical University, China)*, Lin Jiang*

Overview on worldwide ecosan - concepts and strategies
Heinz-Peter Mang, Christine Werner, Susanne Kimmich (GTZ, Germany)

Data sheets on ecosan technologies and projects - an information management tool in process
Susanne Kimmich, Christine Werner, Heinz-Peter Mang (GTZ, Germany)

Oral poster presentations

Linking urban agriculture and environmental sanitation
Dionys Forster, Roland Schertenleib, Hasan Belevi (EAWAG/SANDEC, Switzerland)

Potentials for greywater treatment and reuse in rural areas
Elke Müllegger, Günter Langergraber, Helmut Jung, Markus Starkl, Johannes Laber (University of Natural Resources and Applied Life Sciences Vienna, Austria)

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This paper has been peer reviewed by the symposium scientific committee

Selection of DESAR system for unsewered settlement in almost completely sewered society *
Wendy Sanders, Katarzyna Kujawa-Roeleveld, Marianneke Wiegerinck, Maaike Poppema, Eligius Hendrix, Grietje Zeeman (Wageningen University, The Netherlands)

The decentralization of sewage purification from the perspective of open space and urban planning*
Gudrun Beneke, Hille v. Seggern (University of Hannover, Germany)

Sustainable treatment of waste(water) in rural-areas of Egypt*
Tarek Elmitwalli (Benha High Institute of Technology, Egypt), Harmed Elmashad, Adriaan Mels, Grietje Zeeman

Multi criteria decision aid in sustainable urban water management
Denis van Moeffaert (Scandiaconsult Sweden)

Poster presentations

Assessing the sustainability of domestic water systems, including water use and wastewater treatment
Annelies J. Balkema, Heinz A. Preisig, Ralf Otterpohl, Fred. J. D. Lambert (Eindhoven University of Technology, The Netherlands)

* This paper has been peer reviewed by the symposium scientific committee

Ecological assessment of ecosan concepts and conventional wastewater systems*

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Keywords

Decision support system, indicators, life cycle assessment, material flow analysis, source separation, wastewater systems

Abstract

In order to assess the environmental impacts of different water management options in urban areas, a decision support system (DSS) was developed. The DSS is based upon a Material Flow Analysis (MFA) of the technical system and a set of environmental indicators. With the help of this tool, two scenarios for the conventional wastewater treatment and two ecosan scenarios for the city of Berlin are assessed and discussed.

Introduction

Traditionally, wastewater systems had been designed and assessed according to their ability to fulfil specific, water-related tasks such as ensuring a reliable urban drainage system or the efficient protection of the receiving waters. However, for the development of sustainable wastewater concepts, the prediction of additional environmental impacts, of social and economic aspects must be integrated into the decision-making process. But even an integrated assessment of all the environmental impacts remains a complex task without the support of appropriate methods for the determination and a set of indicators for the quantification of those impacts.

Mostly, wastewater treatment plants (WWTPs) have been assessed using MFA (e.g. Dennison 1998, Jeppsson and Hellström, 2002). However, in only a few cases that method has been used for strategic planning or decision-making processes on a local or regional level. Most of the investigations were focused on the comparison of specific technologies and the determination of the best alternative for one single site, not necessarily being the optimal solution for the whole region. Therefore, a methodology for the assessment of water management strategies on a regional level was developed. From that perspective, all the benefits as well as the negative effects of water management strategies may be included in the comparative assessment of different alternatives.

To measure progress towards sustainability, various indicator concepts for the evaluation and comparison of water systems have been proposed (e.g. Lundin et al., 1999; Balkema et al., 2001; Raval et al., 2001). For the assessment of the ecological aspect of sustainability, the protection of natural resources and the minimization of environmental impacts (e.g. Daly 1990) are two important goals that are reflected in the indicator systems.

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*This paper has been peer reviewed by the symposium scientific committee

Methods

A generally applicable concept for a DSS was developed, consisting of MFA as a method for the simulation of environmental impacts caused by different water management strategies. Those local, regional and global impacts are quantified with a set of environmental indicators. The assessment of the current wastewater system in Berlin and three alternative scenarios was carried out to demonstrate the concept.

Material flow analysis

A material flow model for the technical constituents of the drinking water and wastewater system in Berlin was used. The model comprises the waterworks, the water distribution system, the sewerage system and the WWTPs (primary system, see fig.1) and is based on data supplied by the Berliner Wasser Betriebe (BWB, Berlin Water Company). In addition, the environmental impacts of relevant processes that are connected to water management systems (e.g. supply of raw and process materials, sewage sludge disposal) were integrated into the model (extended system, see fig.1). The material flow model was realized with the software UMBERTO®, a widely used tool for environmental management and Life Cycle Assessment (LCA) studies. The model is extended successively to different water treatment technologies (e.g. for drinking water production, wastewater treatment, sewage sludge treatment, storm water management, decentralized sanitation). The input flows and output flows of the system were calculated with that model and transformed into the values for the environmental indicators.

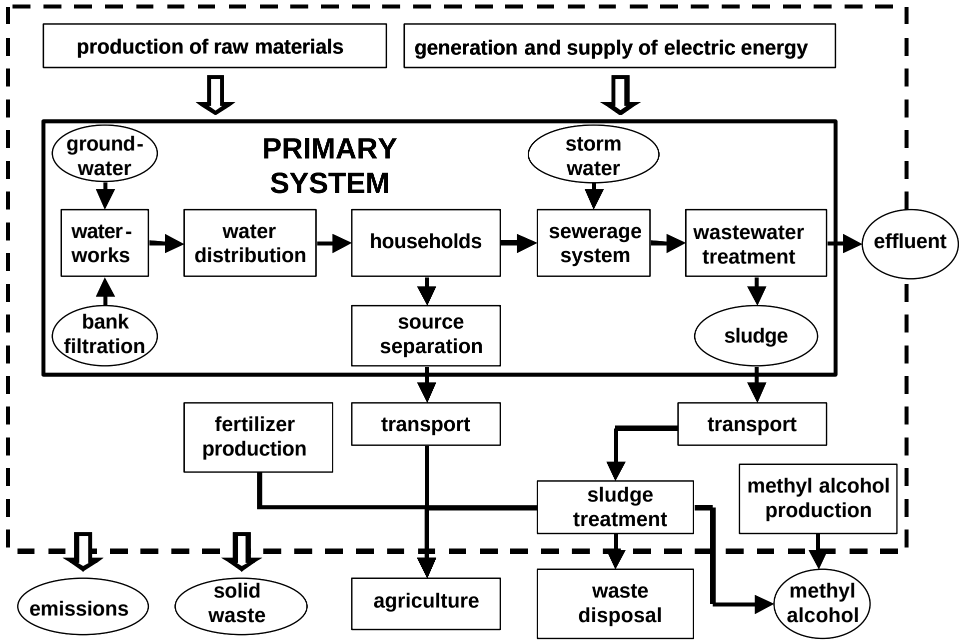

Figure 1: System boundaries

Indicators

Appropriate indicators for urban water supply and wastewater systems were to be a reflection of the current ecological problems related to water (OECD, 2000; Walz et al., 1997). In an interdisciplinary research group, the indicators for the assessment of the technical constituents of urban water management listed in tab.1 were developed together with indicators for groundwater, surface waters and land use (Weigert and Steinberg, 2002). Some of the indicators were adopted from the impact assessment of LCA (ISO 14040-43). In water management, suitable indicators must reflect specific local (e.g. emissions into surface waters and soil, consumption of local water resources etc.) and site-dependent environmental problems (Hügel 2000). Moreover, pragmatic reasons, above all the availability of data, influenced the choice of indicators. So the information from environmental management systems of water companies was used. The familiarity of decision-makers in water management with parameters that have legislative relevance was also taken into account. Thus, emissions into water were aggregated to the so-called "damage units" of the German Wastewater Charges Act for discharges into surface waters. In a similar way, the aggregation method for the indicator "emissions into soil" refers to the thresholds of the German regulation on sewage sludge recovery. Although those aggregation methods do not follow the ISO 14040 ff. guidelines, they were preferred for their higher practical relevance.

The results for the indicators may be expressed as absolute values with regard to the area under investigation, but the presentation as values per capita and year was preferred. That perspective draws the attention to the consumer as the beneficiary of water related services and the source of environmental impacts.

Specific water consumption per capita and year
Emissions into surface waters (nutrients, hazardous substances, oxygen-depleting substances)
Emissions to air
Emissions to soil
Recycling rate (e.g. nutrients, special waste fractions)
Consumption of finite resources
CO_2-Equivalents
Solid wastes

Table 1: Environmental indicators for water management systems

Scenarios

The DSS intended for application to urban areas in general was tested with scenarios for the specific situation in Berlin:

1. Current situation

Scenario 1 is based on the existing wastewater system in Berlin and reflects the predicted increase to 250.3 million m³/year of wastewater in 2010 (4.106 million inhabitants) that is treated in nine WWTPs with nitrogen and phosphorus removal. 34 % of the produced sewage sludge is incinerated, the rest is digested, treated in composting plants and spread on arable land.

2. Microfiltration of tertiary effluents

In scenario 2 further treatment of the effluent through microfiltration is introduced in all WWTPs, resulting in a reduction of phosphate (90%) and COD (15%) loads to surface waters. Sewage sludge is incinerated or dried and treated in a waste gasification plant where methyl alcohol is produced.

3. Source separation of urine and faeces with vacuum toilets

For this scenario, the introduction of a source separation system in 100% of the households in the urban area of Berlin is assumed. Through vacuum toilets, urine and faeces mixed with flush water are collected separately and treated together with biodegradable solid waste in biogas reactors. The residue is spread as fertilizer on arable land. As a result of the vacuum system and other water saving measures, wastewater flow decreases to 183.3 million m³/year and the

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number of WWTPs is reduced to five. As in scenario 2, the remaining sewage sludge is incinerated or used for methyl alcohol production.

4. Urine separation

Lowly diluted urine is collected separately, assuming the installation of urine separating toilets in 100% of the households. Urine separation efficiency is expected to be 70%. The remaining 30% are collected together with faecal matter in the rear bowl and mixed with other wastewater fractions in the sewerage system. Six WWTPs receive 204.6 million m³ wastewater annually. Sewage sludge is treated as in scenario 2 and 3, while the diluted urine is used as fertilizer.

Results

The design of the scenarios was influenced by the dominating environmental problem in Berlin connected to the wastewater system, the emission of nutrients into the surface waters. Moreover, recycling of nutrients and reducing the flow of contaminants into the soil were to be achieved at the same time. Therefore the lower emissions of P and N in all the progressive scenarios compared to the scenario based upon the current situation (see fig.2) could to some extend be predicted. Phosphorus emissions were reduced in the scenarios with the microfiltration stage at the WWTP and with the vacuum system for the separate collection by an order of magnitude, whereas the reduction in the urine separation scenario is less pronounced. Microfiltration has little effect on the emissions of nitrogen, as in contrast to phosphorus most of the nitrogen in the effluent cannot be separated in particulate form. Here source separation technologies show clear advantages over end-of-the-pipe technologies.

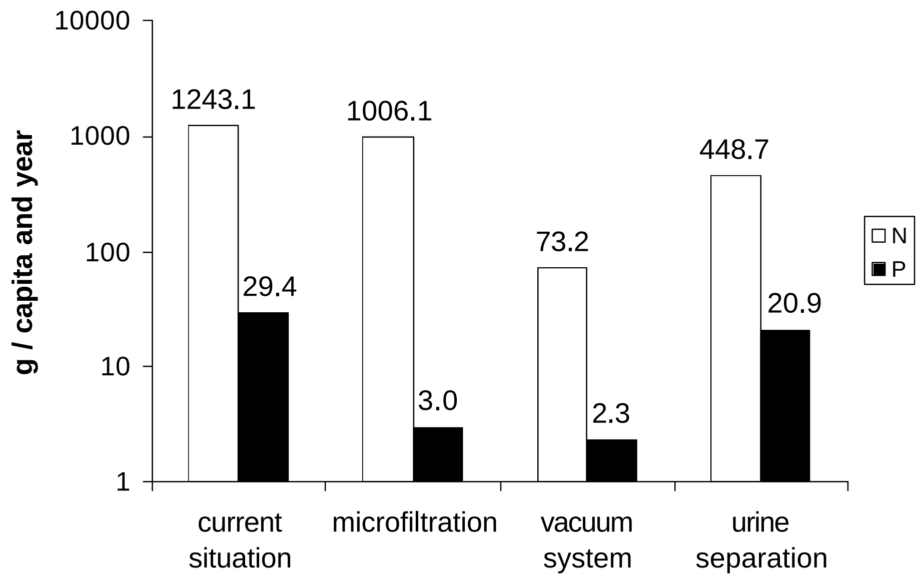

Figure 2: Emissions of P total and N total into surface waters

As a consequence, the proportion of phosphorus and nitrogen in wastewater that is spread on arable land and thus recycled is highest in the scenario with the vacuum toilets, since up to 100% of urine and faeces can be collected. Under the current practice, with a major part of sewage sludge from the WWTPs being composted and reused in agriculture, about half of the phosphorus input is recycled, but – because of the losses to the atmosphere in the denitrification tank and with the effluent - only 10% of nitrogen. More than 50% of nitrogen may be collected with the separated urine, but less phosphorus than in the existing system. Because of sewage sludge incineration, all nutrients are lost in the microfiltration scenario.

Even for the high nutrient recycling rates of source separation systems, the percentage of mineral fertilizer that may be substituted with nutrients from domestic wastewater in Germany is relatively small. It is estimated that the use of mineral fertilizer may be reduced by a maximum of 20% for nitrogen (ATV-DVWK, 2002) and 20% for phosphorus fertilizer (Grangler et al., 2002).

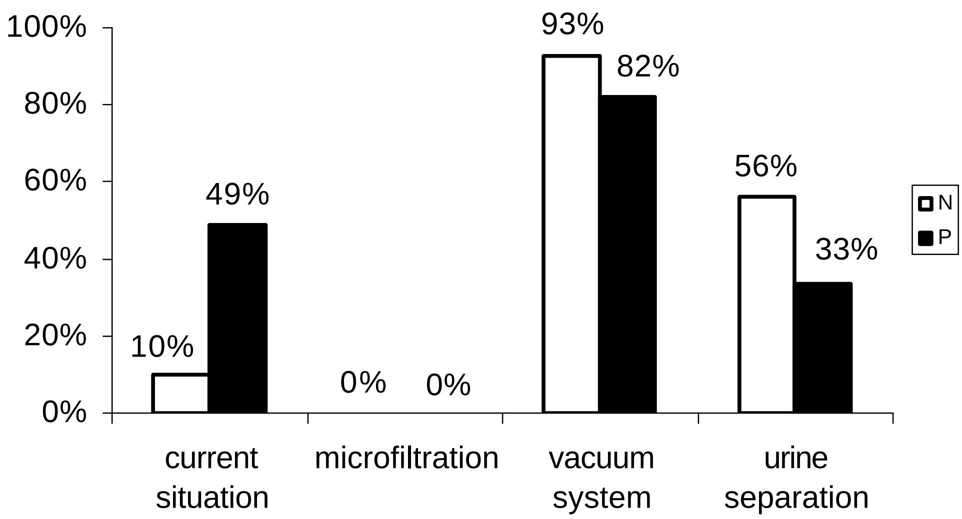

Figure 3: Flows of recycled N and P in relation to total input flows

Nutrient recycling rates in the conventional wastewater system are mainly influenced by the way sewage sludge is treated. A major disadvantage of the spreading of sewage sludge becomes visible in fig.4: together with the nutrients, contaminants like organic halogenated compounds (AOX) and heavy metals are brought back into the food chain. On the other hand, the incineration of sewage sludge (microfiltration scenario) makes nutrient recycling impossible. That dilemma of conventional wastewater systems is less severe in the source separation scenario with vacuum toilets, with emissions depending only from the pollutant load in human excretions, and almost negligible in the urine separation scenario.

In order to evaluate the possible risk for contamination of soil and groundwater by applying human excrements as fertilizer, a thorough investigation of the material flows of single substances is necessary (see tab.2). Whereas through the spreading of separated urine on cultivated land, only a small fraction of the current heavy metal flows is brought back into the food chain, the flow of AOX reaches almost 30% of the existing system. For the vacuum system scenario, the heavy metal flows into the soil, though clearly lower than in the existing system, may eventually cause problematic concentrations in the long perspective.

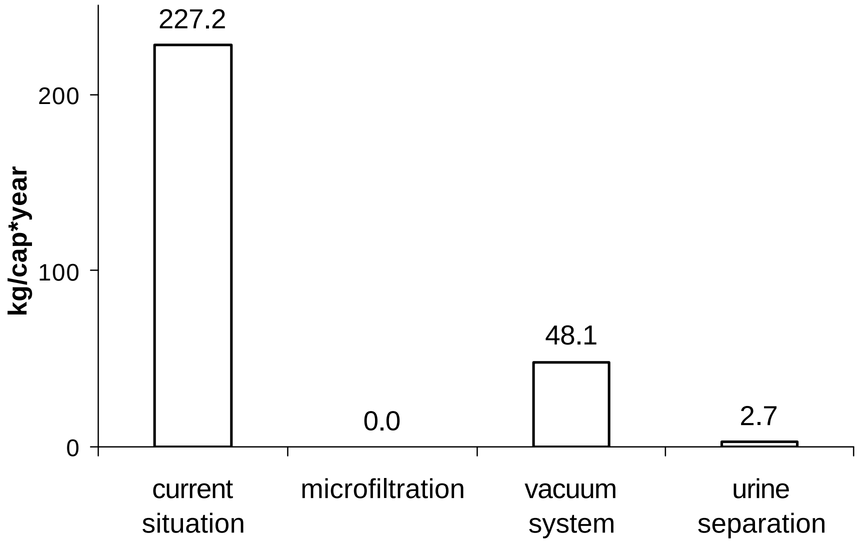

Figure 4: Critical amount of soil to which the emissions of contaminants would have to be applied for concentrations to fall below the limit values of the German sewage sludge regulation

	Vacuum system scenario	Urine separation scenario
AOX	41.8%	29.6%
Cd	21.3%	1.6%
Cr	26.6%	2.8%
Cu	13.6%	0.8%
Ni	13.4%	0.7%
Pb	1.9%	0.7%
Zn	42.1%	1.8%

Table 2: Contaminant flows into the soil for the source separation scenarios in relation to flows for the current wastewater system

The contributions of wastewater systems to the global environmental problems emission of greenhouse gas emissions (as CO_2 equivalents, see fig.5) were investigated. If only the emissions for the operation of the primary system (waterworks and WWTPs) and the transport of the residues are calculated, there are clear disadvantages for the vacuum system scenario. In this case, the vacuum toilet scenario is dominated by the high emissions caused by the transport of liquid fertilizer from digestion in the biogas plant to use in agriculture. The relatively high dilution of mixed urine and faeces with flush water in the vacuum toilets increases the transport volume compared to the relatively low diluted urine collected in the fourth scenario. The emissions of the remaining scenarios are in the same range, with slightly higher values for the microfiltration scenario.

If the credits for the production of methyl alcohol and – above all – for the substitution of commercial fertilizer are also considered, the resulting net emissions lead to a different ranking: greenhouse gas emissions are lowest for the urine separation system, the vacuum system shows only slightly higher emissions than the existing system, and emission are highest in the microfiltration scenario. Although the importance of the indicator “emission of CO_2 equivalents” for the assessment of wastewater systems is not to be overrated (in Berlin, the entire system of water supply and wastewater disposal accounts for less than 1% of total energy consumption per capita and year), the information about the impact of transports should not be overlooked. Apart from the negative effect of CO_2 emissions, this result points to the fact that the transport of the residue by truck might also be a problem from an economic point of view and contribute to the already high traffic volume in Berlin and similar urban areas. Optimisation potentials of source separation concepts clearly lie in the transport of human excrements to farmland. Possible approaches might be the investigation of the use of alternative transport systems, further reduction of flush water volume, the development of concentration techniques or the extraction of nutrients, e.g. through crystallization (Lind et al., 2000).

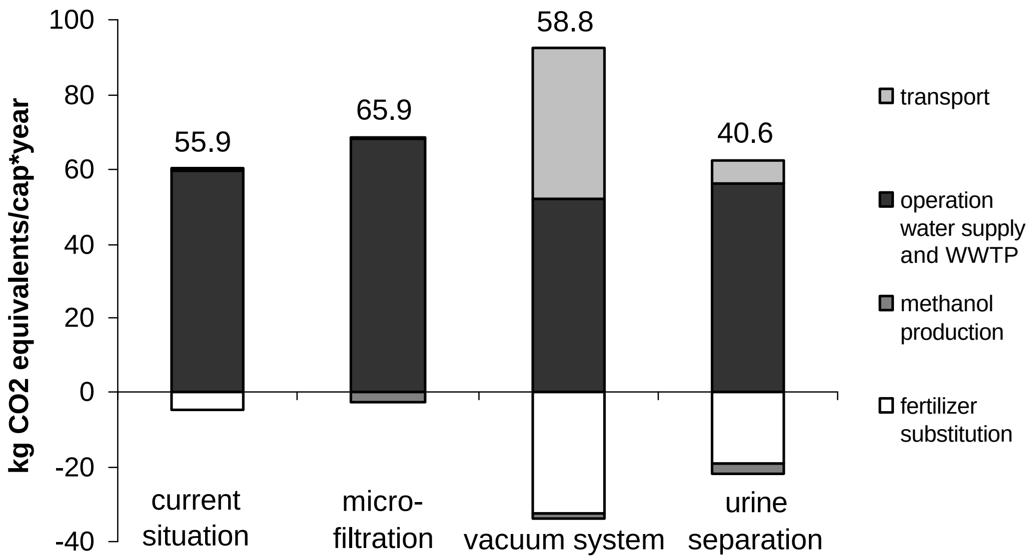

Figure 5: Emission of greenhouse gases (net values are given, taking into account the credits for fertilizer substitution and methyl alcohol production)

Conclusion

With source separation concepts it is possible to reduce emissions of nutrients to surface waters and recycle a significant percentage of those nutrients at the same time without the relatively high input of contaminants that is caused by agricultural use of sewage sludge from conventional systems. Taking into account the substitution of commercial fertilizer, even energy use and greenhouse gas emissions do not exceed those of conventional wastewater treatment, though the high transport volume of the separated and partly diluted human excretions may cause additional problems.

Regional MFAs contribute useful information to an integrated evaluation approach and may support decision-making in water management. Weaknesses of specific technologies may be identified and inspire the optimization of urban wastewater systems. The final decision on the optimal wastewater system for a specific region depends on the priorities of the decision-makers, on local conditions etc. To assess the relative importance of the indicators, reasonable weighting and normalisation is required as demonstrated in the case of the energy-consumption and greenhouse gas emissions. Less than 1% of the total energy-consumption and emissions of CO_2 equivalents per capita and year can be attributed to water supply and wastewater treatment, therefore the increased energy-demand in the progressive scenarios should not be attributed the same relevance as, for example, the impacts on the aquatic environment.

Acknowledgements

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The phosphorus calculator: A planning tool for closing nutrient cycles in urban eco-systems*

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Keywords

Ecological sanitation, material flow accounting, phosphorus, recycling, Stella, systems analysis

Abstract

The Bellagio principles underpin the basis for a new approach to sustainable sanitation where human excreta and other societal wastes (solid and liquid) are recycled and used as a resource. There are two main concepts emanating from the Bellagio principles, which make the basis of this paper. Firstly, the Household Centred Environmental Sanitation (HCES) which puts the household at the focal point of environmental sanitation planning and; secondly, the Circular System of Resource Management (CSRM) that emphasises conservation, local recycling and reuse of resources. Recycling of Phosphorus (P) (one the three macro-nutrients in plant growth) in urban or peri-urban ecological agriculture (without synthetic fertilisers) is used to assess the feasibility of these concepts. A phosphorus calculator is established, based on studies of monthly P-fluxes and stocks in a high-density suburb in Harare, Zimbabwe where agriculture is already a major activity. The P-calculator is a model based on Stella, a systems analysis software developed by High Performance Systems Inc. The calculator can be used as a planning and decision-making tool for closing the P-cycle within urban ecosystems. It also provides the means to simulate and evaluate different scenarios in linking household waste P-fluxes to agricultural P-requirements.

Introduction

Implementation of the Household Centred Environmental Sanitation (HCES) and Circular System of Resource Management (CSRM) approaches for environmental sanitation as proposed in the Bellagio (Italy) principles requires integration between excreta disposal, wastewater disposal, solid waste disposal, and storm water drainage (SANDEC and WSSCC, 2000). Firstly, the HCES makes the household the focal point of environmental sanitation planning, reversing the customary order of centralised top-down planning. The approach argues that only problems not manageable at the household level should be "exported" to the neighbourhood, town, and city and so on up to larger jurisdiction. Secondly, the CSRM, in contrast to the current linear system, emphasises conservation, recycling and reuse of resources (Schertenleib and Gujer, 2000). Many water supply and sanitation problems would be resolved by a new paradigm, which places all aspects of water and waste within one integrated service delivery framework (Gumbo, 2000; Larsen a. Gujer, '97; Niemcynowicz, '97).

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The principal nutrients (Phosphorus and Nitrogen) flow in a circular, closed loop system in nature, but human activities use and dispose nutrients in a linear, open-ended system. The danger is that once one closed loop system is opened, it may force open other closed loop systems elsewhere in the ecosystem. Short-cutting or closing P-cycles in the urban environment is closely related to closing of water cycles. New solutions in terms of ecological sanitation for sustainable cities (green or eco-cities) of the future are perceived to be source orientated, non-mixing, ecologically sound, closed loop systems, local and small scale (Otterpohl et al, 1997; Roelofs, 1996; Beck et al., 1994). Since cities need to close the open loop of limited resources such as P, urban agriculture seems to be an option in closing the open loop by reusing and transforming the by-products of human metabolism especially, which, usually are dumped as polluting waste into the bio-region (Smit and Nasr, 1992).

Closing the P-cycle in urban environments calls for holistic approach which is based on some form of computational framework. The P-calculator described here is one such tool that can be used to ensure that the ecological sanitation paradigm fits in the puzzle of the natural cycling of plant nutrients like P, so as to avoid creation of negative impacts on receiving media.

Methods

Using a systems thinking approach and material flow accounting the calculator is used to compute the P-fluxes and stocks between two subsystems the "household" (consumption and excretion) and "agriculture" (soil-plant interaction) (Figure 1). Systems analysis and material flow accounting present attractive tools in desegregating the complex web of cycles, stocks and flows. The tracking of the flow of materials and products through society and the environment is an activity of increasing prominence and consequence throughout the world. Material Flow Accounting (MFA) is the investigation of the physical flows of materials, typically on a geographic basis. MFA can help us understand how changes in land use, industrialisation, consumption and population affect the cycles of elements or chemicals of concern in a watershed. It provides a means of taking a comprehensive rather than an ad hoc view of the drivers and source of substances (Baccini and Brunner, 1991; Wackernagel and Rees, 1996; Ayres and Ayres 1998).

P-fluxes based on characterisation of input goods, processes, transformation, output fluxes and storage were established through measurement, field surveys and using literature values. The micro study catchment area of 6.5 $(km)^2$ has an estimated population of about 100 000. There are 9 400 residential stands which translates to an average occupancy per stand of 10.6 people. In total urban agriculture extends over an area of about 2.9 $(km)^2$ i.e. both on-plot and off-plot. P inflows into the "household" subsystem (mainly to do with the activities "to nourish and clean") was established through mapping of monthly diet and detergent and soap usage of the inhabitants based on a national nutrition survey and a local solid waste study. The dynamics of urban agriculture were also monitored for a period of two years documenting the amount of fertiliser and manure imported, the crop yields (as maize) and the quantity of phosphorus (both labile and non-labile) present in the soil after the harvest. Since the transport and transformation of P in a region is dependent on the water cycle, a water flux balance was also established for the study area.

Equations describing the various processes and transformations were developed from measured and collected data and then applied in Stella version 5, a software by High Performance Systems Inc (http://www.hps-inc.com). For simplicity the Stella model is desegregated into four compartments, namely the rainfall water balance, municipal water balance, household P-balance and agricultural P-balance. The list of principal equations used in the model is indicated in Box 1 to 4 together with the description of the various symbols in Box 5.

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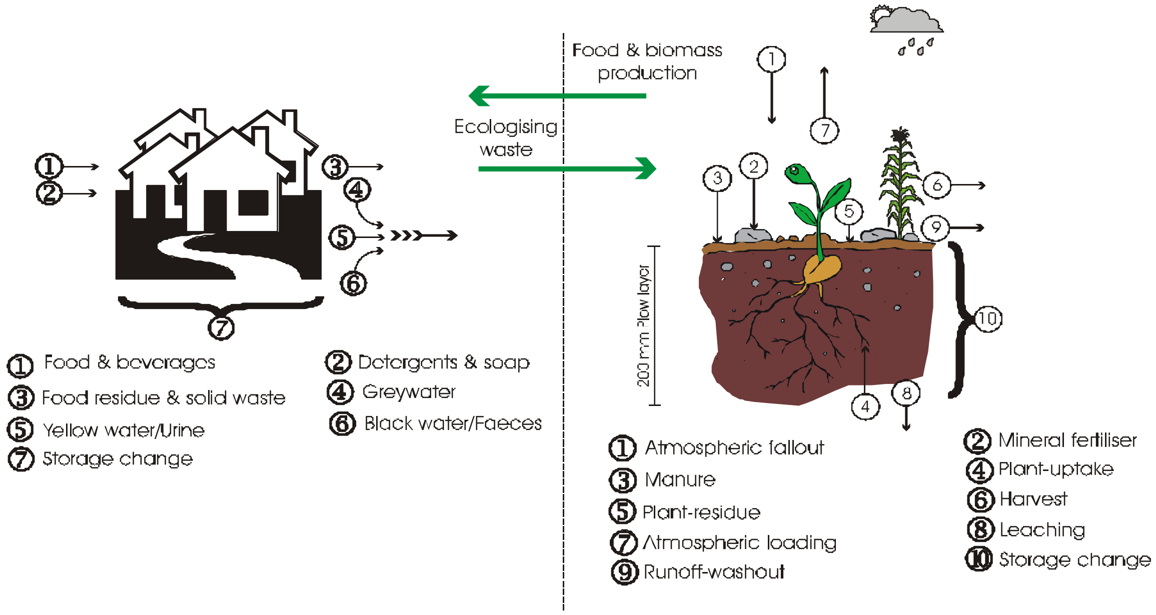

Figure 1: P-fluxes analysed in the household and agricultural subsystems

Box 1: Rainfall water balance (mm/month)		
Symbol	**Description**	**Equation**
R	rainfall	Input data
I	interception (de Groen, 2002)	$I_m = R_m\left(1 - \exp\left(\frac{-D}{ß}\right)\right)$
T	transpiration	$T_m = B(R_m - I_m)$
R_{eff}	effective rainfall	$R_{eff,m} = (R_m - I_m)$
Q_s	surface runoff	$Q_{s,m} = C_o \times R_{eff,m}$
Q_g	groundwater flow	$Q_{g,m} = S_{g,m}/?$
$\frac{dS_g}{dt}$	ground water stock variation	$\frac{dS_{g,m}}{dt} = (1 - C_0)R_{eff,m} - Q_{g,m}$

Box 2: Municipal water balance (mm/month)		
Symbol	**Description**	**Equation**
W	municipal water supply normalised to the catchment area	Input data
W_i	municipal water used for garden irrigation	$W_{i,m} = 0.2W_m$
W_g	grey water generated from the household activities related to nourishing and cleaning (kitchen, bathroom and laundry)	$W_{g,m} = (0.25_{bathing} + 0.1_{kitchen} + 0.15_{launrdy})W_m$
W_b	black water generated from household activity related to toilet flushing	$W_{b,m} = 0.3W_m$
W_y	yellow water or urine related to human waste excretion	$W_{y,m} = \frac{0.77H}{A}(30y_{day})$

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Box 2: Municipal water balance (mm/month)		
Symbol	**Description**	**Equation**
W_{ms}	municipal sewage water, a combination of yellow, black, and proportion of grey and storm water conveyed through a pipe to a sewage treatment plant (W_{yb} is the sum of black and yellow water)	$W_{ms,m} = W_{yb,m} + f\,W_{g,m} + j\,Q_{s,m}$

Box 3: P balance household subsystem (kg/month)		
Symbol	**Description**	**Equation**
P_{fb}	food and beverage P-flux reaching the household subsystem per month	$P_{fb,m} = H\sum_{n=1}^{n} F_{n,m} * s_{n}$
P_{sd}	soap and detergent P-flux used in the household subsystem per month	$P_{sd} = N[(M\sigma)_{soap} + [(M\sigma)_{detergent}]$
P_{g}	grey water P-flux emanating from the household activities related to nourishing and cleaning (kitchen, bathroom and laundry)	$P_{g,m} = W_{g,m} s_{g}$
P_{y}	yellow water P-flux derived from of urine excretion	$P_{y,m} = W_{y,m} s_{y}$
P_{ms}	municipal sewage P-flux arising from a combination of yellow, black, and proportion of grey and storm water conveyed through a pipe to a sewage treatment plant	$P_{ms,m} = W_{ms,m} s_{ms}$
P_{b}	black water P-flux emanating from toilet flushing of human faecal material	$P_{b,m} = P_{ms,m} - f\,P_{g,m} - P_{y,m} - (j\,Q_{m}) s_{s}$
P_{sw}	solid waste P-flux derived from household activities and local vegetation growth and die-off	$P_{sw,m} = ?_{m} H s_{sw}$

Box 4: P balance agricultural subsystem (kg/month)		
Symbol	**Description**	**Equation**
P_{mf}	mineral P-based fertiliser applied on land per month	$P_{mf,m} = ?M_{mf,m} s_{mf}$
P_{ma}	manure P-flux imported into the catchment per month	$P_{ma,m} = M_{ma,m} s_{ma}$
P_{csw}	composted solid waste P-flux applied on agricultural land per month	$P_{csw\,m} = 0.15?_{m} H s_{sw}$
P_{wdd}	wet and dry deposition P-flux due to atmospheric fallout per month	$P_{wdd,m} = ?_{m} A$
P_{gwi}	grey water P-flux arising from grey water irrigation on on-plot agricultural land	$P_{gwi,m} = (1 - f) P_{g,m}$
P_{sr}	surface runoff P-flux	$P_{sr,m} = s_{sr} Q_{s,m} A_{c}$
P_{sl}	soil loss P-flux arising from soil erosion	$P_{sl,m} = 0.005 Q_{s,m} \frac{A_{c}}{10000}$
P_{le}	leaching P-flux due to percolation and groundwater flow	$P_{le,m} = s_{le} Q_{g,m}$
P_{bm}	biomass P-flux uptake i.e. amount of P absorbed by the straw in a month relative depending on the amount of biomass produced during the growth of the crop	$P_{bm,m} = \frac{A_{c} Y_{bm}}{Y_{potential,bm}} X_{bm,m}$

Box 4: P balance agricultural subsystem (kg/month)		
Symbol	**Description**	**Equation**
P_{ha}	economic produce P-flux per month incorporated into the harvested portion of the crop during growth and finally transported from the agricultural subsystem to the household subsystem	$P_{ha,m} = \frac{A_c Y_Y}{Y_{potential,Y}} X_{Y,m}$
P_{nu}	plant uptake P-flux depending on the total biomass production for a particular economic produce yield	$P_{nu,m} = P_{ha,m} + P_{bm,m}$
P_{al}	atmospheric loading, P-flux arising from activities in the agricultural subsystem and other leading to atmospheric contamination	$P_{al,m} = ?_m A$
P_{ss}	soil storage, P calculated using either the total phosphorus or the available phosphorus concentration in the top 200mm soil layer (plow layer) for soil fraction with particles less than 2mm in size	$P_{ss} = s_{ss} ?_b V_{\langle 2mm}$

Box 5: Definition of symbols used		
Symbol	**Description**	**Unit**
β	Mean rainfall on a rain day and scale parameter of exponential distribution difference	mm/day
φ	fraction of storm water which enters the foul sewer system and is conveyed in a pipe as municipal sewage	-
ϕ	fraction of grey water which enters the foul sewer system and is conveyed in a pipe as municipal sewage	-
σ	phosphorus content in a material expressed as a ratio	kg/kg or m^3
λ	quantity of organic and biodegradable waste generated per capita per month	kg/month
κ	soil permeability parameter	month
χ	quantity of phosphorus delivered to the atmosphere normalised to the catchment	kg/m^2.month
ζ	quantity of phosphorus delivered from the atmosphere normalised to the catchment	kg/m^2.month
A	area of catchment	m^2
A_c	total area under cultivation	m^2
B	slope of relation between monthly effective rainfall and monthly transpiration	-
C_o	surface runoff coefficient based on land used and amount of effective rainfall	-
D	daily interception threshold	mm/day
F	quantity of food and beverage per food group consumed per capita per month	kg/cap.month
H	human population appropriately divided into two groupings	-
m	during month	1/month
N	number of households in the study micro-catchment	
θ	proportion of commercial fertiliser applied as compound D (8:14:7; Nitrogen, Phosphorus, Potassium) per month	-
S_g	groundwater storage	mm
ρ	density or (ρ_b) bulk density	m^3/kg
M	mass of P-bearing material per month	kg/month
V	volume	m^3
X	specific quantity of P absorbed per month for a particular crop and either stored in the straw or the economic produce i.e. $X_{Y,m}$ or $X_{bm,m}$	kg/month
Y	yield of economic produce or straw at harvest time i.e. Y_Y or Y_{bm} per unit area	kg/m^2
y	volume of yellow water excreted by an adult human being per day	m^3/day

Results

Monthly P-fluxes and stocks for the two subsystems including the water flux for the area are computed instantaneously by the P-calculator. Figures 2 depict the stocks, flows and converters of the agricultural P-balance compartment in Stella as an example. The output from the Stella model can easily be transferred to a spreadsheet for further statistical analysis. By summing the monthly P-fluxes and stocks the annual P-flux and stock diagrams can also be created for the two subsystems. Figure 3 summarises in graphical form the output from the P-calculator. Only the main fluxes are shown for each compartment. Table 1 provides a summary of the annual P-fluxes for the micro-study area.

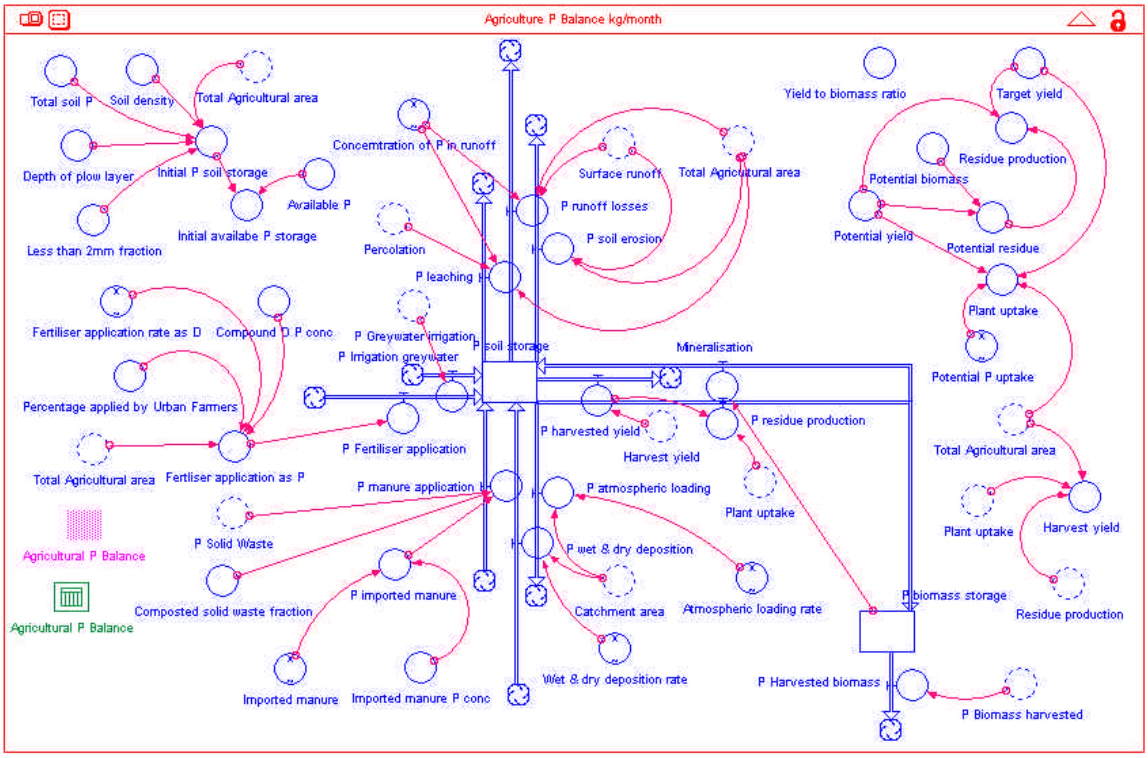

Figure 2: Stocks, flows and converters for the agricultural P-balance in Stella

Conclusions

The calculator indicates that total diversion of P in sewage onto the land under agriculture translates to an annual application rate of about 160 kg/ha.a compared to a recommended fertiliser application rate of 42 kg/ha.a as P, for maize production in Zimbabwe (Table 1). Whilst

partial diversion of the waste flux in the form of source separated human urine or yellow water (103 kg/ha.a) can also sustain agricultural activities in terms of P alone thereby enabling the closing of the P-cycle at household and neighbourhood scale through ecological agriculture.

However the recommended P-application rate for commercial farms in Zimbabwe is quite high compared to the maize crop requirement, which is about 14kg/ha as P. Excessive P applications are undesirable as P is quickly immobilised and accumulates in the soil and becomes a source of non-point pollution. The price for compound D fertiliser or “maizefert” in Zimbabwe is about US$0.50 per kg implying that in economic terms the urine so diverted and stored has an approximate economic value as P of US$104 000.00 per annum.

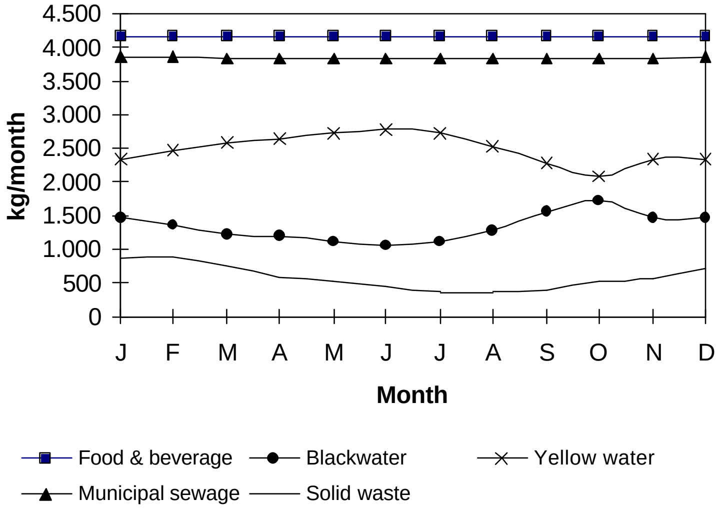

Figure 3a: Monthly variation of the household P-flux balance

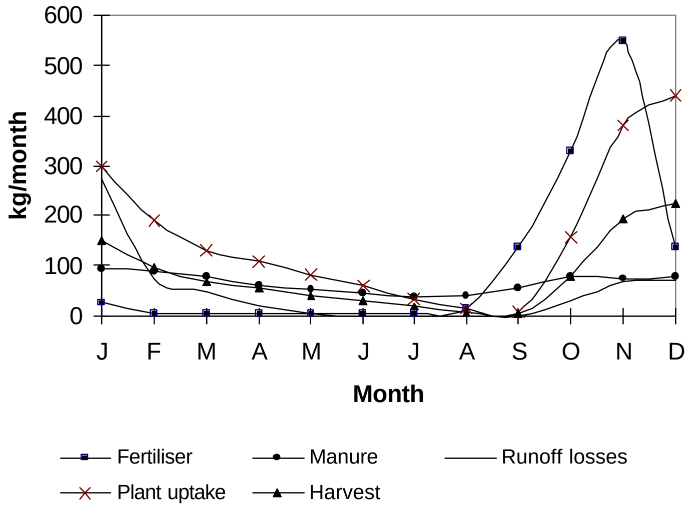

Figure 3b: Monthly variation of the agricultural P-flux balance

Soil fertility tests done after the harvesting period indicate a deficiency of available P in the plow layer for maize production. An average value of 10 mg/kg was obtained using the resin extraction method as compared to the recommended concentration of 30 mg/kg. From running multiple simulations of the model it is clear that there is net loss of P from the soil storage thereby necessitating the constant replenishment of P especially in the ionic form (labile P), which is readily taken up by the plants. A large part of the P is locked-up in the biomass storage and is not readily available for plant uptake. The phosphorus calculator is an indispensable tool in planning urban settlements, which incorporate ecological sanitation and urban agriculture. From the results it is clear that excess plant nutrient P is generated in the micro-study catchment and cannot be totally utilised for agriculture without creating negative impacts. Some functions of the calculator include sizing of urine storage tanks to match the P crop-uptake at either household or neighbourhood level for rain-fed or irrigated production.

Household subsystem			Agricultural subsystem		
Flow and stock	Symbol	Value	Flow and stock	Symbol	Value
1. Food and beverages	P_{fb}	49800	1. Atmospheric fall-out	P_{wdd}	30
2. Detergents and soap	P_{sd}	200	2. Mineral fertiliser	P_{mf}	1220
3. Solid waste	P_{sw}	7000	3. Manure	P_{ma}	780
4. Grey water	P_g	180	4. Plant nutrient uptake	P_{nu}	1900
5. Yellow water	P_y	29800	5. Plant residue	P_{bm}	1100
6. Black water	P_b	16000	6. Harvest	P_{ha}	800
7. Storage change	-	0	7. Atmospheric loading	P_{al}	70
			8. Leaching	Ple	100
			9. Runoff losses	$P_{sr\&l}$	580
			10. Soil storage change	P_{ss}	150

Table 1: The annual P-Flux for the micro study catchment (values are in kg/annum)

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Assessment method for evaluating existing and alternative measures of urban water management*

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Keywords

Pattern recognition, sewer infiltration, extraneous or parasite water (Fremdwasser in German), urine separation, wastewater

Abstract

Development of appropriate and sustainable sanitation options are required to face the problem of inadequate sewer systems in developing countries. High population densities and eutrophication problems of freshwater make source control a necessary alternative. To support decision-makers in assessing sewer system and source control, we developed a method to determine the origins of the wastewater and its property changes if source control measures are applied. The prototype of the method is based on a case study conducted in Zurich, which will later be adapted to a case study in Kunming, China. Analysis of uncertainty has been included in the method, as data quality will affect decision-making. Responses of wastewater amount, NH_4-N, TKN, and TP load, as well as concentration after urine separation, are simulated to study further treatment strategies of the new wastewater. The following methods were used: statistical pattern recognition, sensitivity analysis and system identification.

Introduction

Rapid urbanisation and a booming real estate in developing regions cause important changes in life style and pose a significant threat to freshwater resources. Although urban water management planning applying 'end of pipe' solutions still prevail, they repeatedly proved to be financially unfeasible to solve these problems in time. Poor information and data availability have considerably hindered efficient water pollution control practices.

In 1999, only 7% of the Chinese urban population were connected to wastewater treatment facilities. According to government plans, 45% of the urban wastewater should be treated by 2005. In the next five to ten years, investments in urban wastewater treatment facilities in China will amount to tens of billions of U.S. dollars (People's Daily, 30/11/2001). The wastewater load estimates are often based on drinking water consumption, which accounts for only about 30-60% of the total wastewater load, depending on the existing hydrological situation and drainage system. Extraneous water ("Fremdwasser" in German, sometimes the term for "parasite water" is also used to refer to "Fremdwasser") from groundwater infiltration, connected streams and rainwater runoff may add another 40 – 70% to the wastewater load if urban drainage is based on combined sewers. In extreme cases, it can amount to more than 70% and result in an insuf-

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ficient capacity of existing or planned sewers and wastewater treatment plants if extraneous water and rainwater are not correctly taken into consideration in the design phase.

Construction of separate sewer systems to gradually replace combined sewers is regarded as the solution to the problem of combined sewer overflow. However, this is not always the most appropriate option, as it involves financing difficulties and also the risk of untreated rainwater draining directly into receiving waters. This is especially the case in regions with high population densities. In less developed areas with poor solid waste management practices, rain runoff can greatly contribute to the pollution load of receiving waters.

An assessment method for evaluating urban water management in rapidly growing developing countries is required to assist decision-makers, scientists and engineers in improving urban water management and water pollution control practices. The aim is to conduct an impartial study on the current measures and other alternatives, as well as to assess their suitability in different areas and under different conditions. The reason for initiating the study in Zurich was to first develop a method on the basis of good data quality, and to supply a "modern" urban drainage model for further assessment of its suitability in developing countries.

The city of Kunming, at Yunnan China, numbers 2.4 million inhabitants and 6 operating WWTPs, with a total capacity of 555,000 m^3/d. How efficient are these WWTPs, and how much capacity is still required if that region continues to follow the 'end of pipe' solution? What happens if source control is implemented? The following describes:

- A method to quantify the origins of the wastewater using statistical pattern recognition;
- The simulation of wastewater load and concentration dynamics after applying the urine separation concept.

System comparison

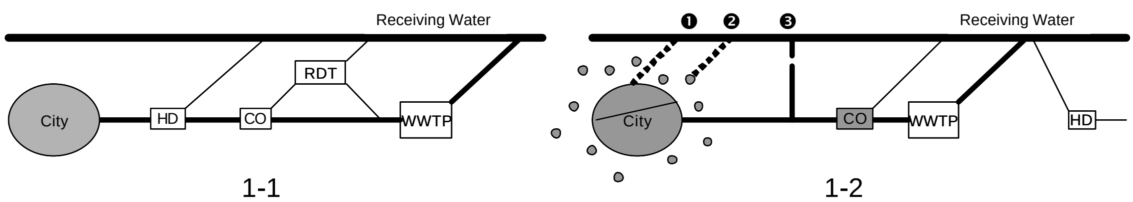

Figure 1: System comparison: on the left, the urban drainage system in Zurich, on the right, a system in a developing country. ❶ Illustrates city districts not connected to WWTP; ❷ Shows small villages scattered outside the city, mainly without water sanitation facilities;❸ Small streams inside the city of some developing countries used as open sewers and conveying wastewater to WWTP. These are likely to be replaced by sewers requiring important investments in pipe construction. HD: Flood discharge; CO: Canal overflow; RDT: Rainwater detention tank.

Gujer (1999) described the system in Zurich (Fig. 1-1) during different precipitation intensities. A typical system in developing countries is illustrated in Fig. 1-2, with sections of the city not connected to the WWTP, and villages, mainly without sanitation facilities, scattered outside the city. The load from these sections is directly conveyed to receiving waters. Streams or small rivers are sometimes also used as open wastewater canals, thereby greatly increasing the volume of extraneous water and reducing the efficiency of WWTP. Canal overflow occurs frequently during dry and raining days. Street flooding also takes place regularly after heavy and extreme precipitation; the floodwater discharge is not designed ahead of the canal overflow but sometimes at the end of the receiving water.

According to the 1989 Swiss annual statistics report, the wastewater discharged into the treatment plant originates from households (25%), industry (20%), precipitation (15%), and from extraneous water (40%). Extraneous water is currently decreasing due to sewer monitoring and maintenance. However, the volume of rainwater increases, since less untreated rainwater is allowed to be discharged directly into freshwater (Gujer, 1999).

Determination of wastewater origins using pattern recognition

The method applies two simple classification criteria to extract the dry weather flow from the mixed wastewater flow signals (Fig. 2).

$$Q_{in} = Q_{in,dry} + Q_R = (Q_{WW} + Q_F) + Q_R \qquad \text{(Equ. 1)}$$

$$Q_{WW} = (1 - r_{lost}) \cdot Q_{DW} \qquad \text{(Equ. 2)}$$

Consequently: $Q_F = Q_{in,dry} - (1 - r_{lost}) \cdot Q_{DW}$ (Equ. 3)

where: Q_{in} = total wastewater inflow; $Q_{in,dry}$ = dry weather flow; Q_R = rainwater flow. Q_F = extraneous water flow; Q_{DW} = water supply quantity into distribution system; r_{lost} = lost fraction of water supply. The water recorded as water consumption, which is not conveyed to the sewer, is regarded as "lost"; Q_{WW} = the wastewater conveyed to the sewer after consumption.

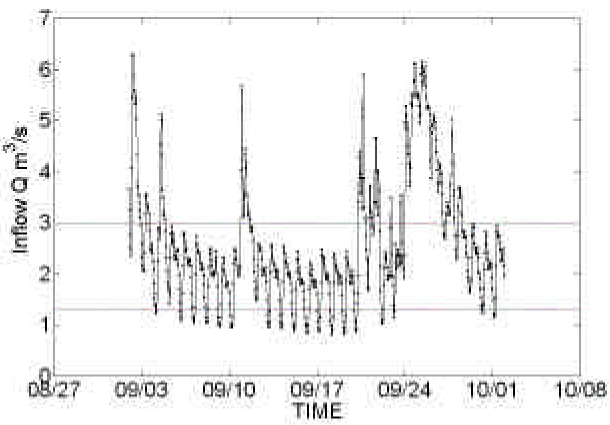

Figure. 2: Time series of wastewater inflow rate into WWTP Werdhölzli. Dry weather flow is classified according to the following criteria: (1) Q_{min}<1.3 m^3/s, and (2) Q_{max}<3 m^3/s. A full year dataset was used, however, only one month is illustrated here.

The dry weather flow $Q_{in,dry}$ can be determined on the basis of datasets of WWTP inflow and meteorological data records. However, this involves two difficulties: (1) if the region is quite large and if the rain gauges are not evenly distributed throughout the region, (2) water from the rainwater detention basin (RDT) is not always pumped to the WWTP on meteorologically rainy days. To counteract these difficulties, the method of statistical pattern recognition is applied.

We have established two straightforward criteria for determining dry weather flow derived from the signals in Fig. 2. If the maximum daily flow exceeds 3 m^3/s, or the minimum daily flow is greater than 1.3 m^3/s, these days are filtered out as days with rainwater runoff in the sewer. Since weekday flows behave differently from those of weekends, we automatically separate weekday, Saturday and Sunday flows and then generate a statistic week flow dynamics. Fig. 3 illustrates the distribution before and after filtering out the rainwater according to the aforementioned classifier. Classification method and its uncertainties can be estimated, but are not addressed in this paper.

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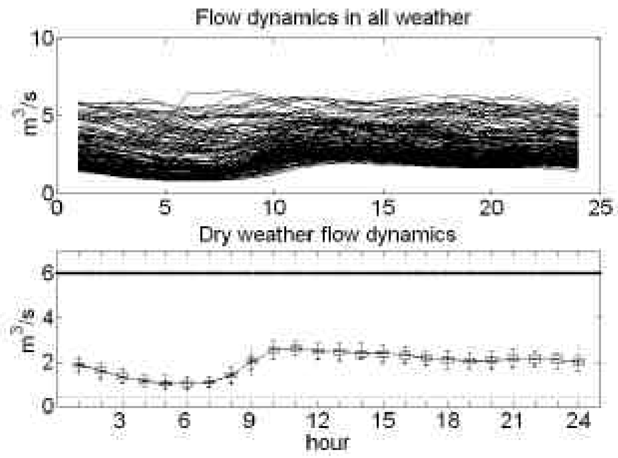

Figure 3: Flow dynamics before and after classification.

Distributions after classification reveal a similar to normal distribution. Median and average values fit almost exactly (Fig 3). Therefore, calculation of total annual dry weather wastewater quantity, based on the statistical average flow dynamics, is fairly accurate.

By combining the weekdays with Saturdays and Sundays, we have formulated a statistical time-variant-curve (Fig. 4). Note the flow rate difference between weekdays and weekend. By summarising the total weekly wastewater quantity, we obtain $Q_{dry,week}$ (weekly total dry weather flow). Consequently, we obtain $Q_{dry,year} = 5.98 \cdot 10^7$ m^3 / a, (total dry weather flow in 2002).

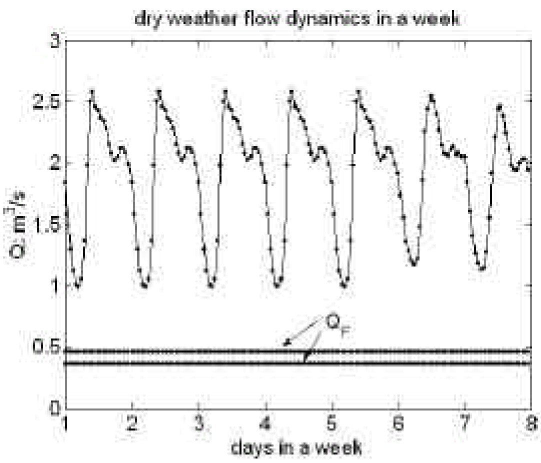

Figure 4: Statistical dry weather week flow dynamics in WWTP Werdhölzli and estimated extraneous water.

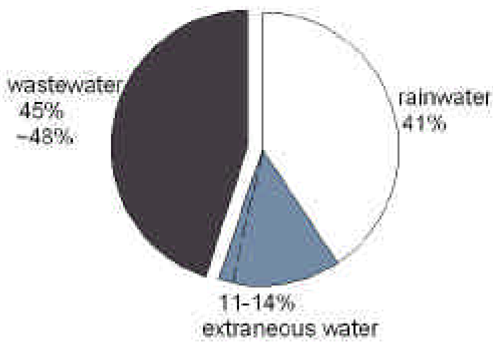

Figure. 5: Origins of wastewater to WWTP Werdhölzli.

We used the statistics on the total water consumption of different communities in the catchment area and statistics of inhabitants in every community connected to the WWTP Werdhölzli. The estimated water consumption in the catchment area amounts to $Q_{DW} = 5.33 \cdot 10^7$ m^3 / a, with 9% loss due to leakage (5%) and quenching water and possible measuring errors (4%) (Zurich Water Supply, 2001). Based on this information, the extraneous water flow into the WWTP Werdhölzli is estimated at 0.36 m^3/s (Fig. 4). We assume that gardening and other water consumption activities, which are not conveyed to the sewer after consumption, account for up to 6%. Therefore, the loss ranges between 9% and 15%. The extraneous water conveyed to the WWTP is then estimated at 0.36 – 0.46 m^3/s, which accounts for 11 – 14% of the total wastewater inflow (Fig. 5) and for 25 – 30% dry weather flow.

Extraneous water is not always constant, especially after precipitation, as revealed by the exponential recession after rainy periods illustrated in Fig. 2. Dynamic extraneous water flow can be simulated by the theory of linear reservoir (Gujer and Krebs, 1997).

The data obtained from the City of Zurich is of good quality. In order to render the methods developed here widely accessible, we conducted a sensitivity and uncertainty analysis. It reveals the importance of data quality for scientists and decision-makers. Sensitivity of Q_F in relation to the three model parameters is predicted as: 0.019 m^3/s for a 1% change of $Q_{in,dry}$, -0.015 m^3/s for a 1% change of Q_{DW} and 0.017 m^3/s for a 1% change of r_{lost}. These numbers indicate that a systematic measurement error of 1% of either $Q_{in,dry}$, Q_{DW} or r_{lost} would change the resulting Q_F by approximately 5%.

Since measurement errors for the three parameters are independent, we can use the Gaussian error propagation law in its simplest form:

$$s_y = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial y}{\partial p_i} \cdot s_{p_i} \right)^2} \qquad \text{(Equ. 4)}$$

with σ_y = standard error of prediction y, σ_{pi} = standard error of parameter p_i

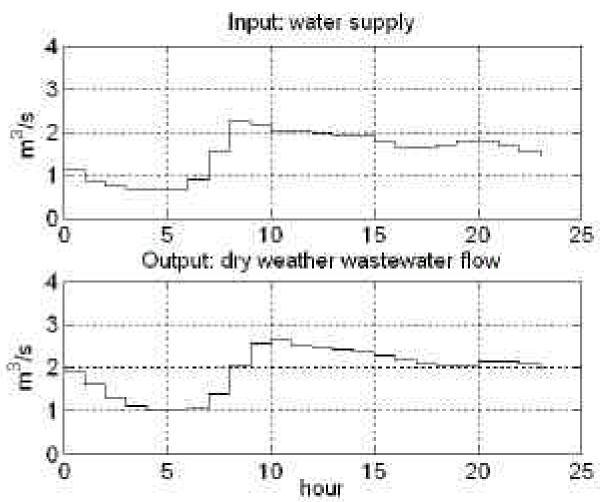

Figure 6: Daily variation curve of water consumption and dry weather wastewater flow of the catchment area.

For Zurich data, the standard errors for the three parameters are estimated at less than 5%, and result in a standard error of the predicted amount of parasite water of $\sigma_{QF} \leq 0.12$ m^3/s. The prediction method introduced here is obviously quite sensitive to data quality. In developing countries, where measurement errors can possibly be greater than 15%, this error will exceed 0.36 m^3/s, thereby rendering the results practically irrelevant, as the 95% confidence interval of Q_F becomes 0 – 1 m^3/s. Decisions based on poor data quality become highly questionable. Therefore, the methods to be developed must deal with possible data uncertainties. It is also important to enhance data management awareness in developing countries.

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Determination of extraneous water by system identification

$Q_{in,dry}$, obtained through the method of statistical pattern recognition, is now used as the output of the system, and the water supply signals as the input. We used the original water consumption signal of 2002 (hourly data record) for the entire city of Zurich (Bolli, M., 2003). Like with the method in the previous chapter, we also filtered out the weekends and extreme outliers and obtained a daily time-variant-curve distribution on weekdays. Based on this curve, we calculated the hourly factor f_h curve of water consumption. Since the city of Zurich has the highest population (90%, not including commuters) in the catchment area of WWTP Werdhölzli, the f_h curve can be approximated to that of the entire catchment area. The dynamic curve of water consumption is obtained by multiplying f_h with the average water consumption of the entire catchment area.

Extraneous water Q_F is regarded here as a system parameter. The following simple model neglected the fact that the extremes of the flow rate in the sewer are slightly dampened during residence time of the wastewater in the sewer system:

$$\frac{Q_{\max,DW} - Q_{leak}}{Q_{\min,DW} - Q_{leak}} = \frac{Q_{\max,WW} - Q_F}{Q_{\min,WW} - Q_F} \qquad \text{(Equ. 5)}$$

where $Q_{max,DW}$ and $Q_{min,DW}$ stand for maximum and minimum daily drinking water delivery to the distribution system; Q_{leak} for leaks from the water distribution system; $Q_{max,WW}$ and $Q_{min,WW}$ for maximum and minimum dry weather flow in the sewer system (Fig. 6).

If no leaks are assumed (Q_{leak} = 0), then Q_F = 0.33 m^3/s. By assuming a loss of 5% drinking water due to leaks, which is typical for Zurich, then Q_F = 0.4 m^3/s. This compares favourably with the previously estimated 0.36 to 0.46 m^3/s.

In developing countries, leaks from distribution systems are generally very high due to lower investments and poor maintenance. It is therefore crucial to consider this aspect if this method is applied in developing countries.

Response analysis for the complete urine separation scenario

How will the properties of urban wastewater change after source control measures, such as urine separation with No-Mix toilets, are implemented? After applying urine separation in the entire catchment area, the "response" is defined here as the change of the following variables: dry weather flow Q, NH_4-N, total Kjeldahl nitrogen (TKN) and total phosphorus (TP).

Since the city of Zurich is service-oriented (trade, financing, tourisms, and other services), the source of ammonium to the WWTP can actually be assumed to originate only from urine. According to an investigation conducted by the WWTP Werdhölzli (Antener, 2002), the living population in the catchment area of WWTP Werdhölzli totals 393,000, commuters to the area are estimated at 100,000 persons/day. By assuming that the commuters spend about 8 hours a day in the area, the specific daily ammonium load per person amounts to:

$$L_{NH4} = NH_{daily,tot} / (inhabitants + 1/3 \cdot commuters) = 7.4 \text{ gNH}_4\text{-N / PE / d}$$

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PE stands for population equivalent. The dry weather load of ammonium $NH_{daily,tot}$ = 3.15·10^6 g /d is based on analytical data of the first half of 2002. L_{NH4} values for urine higher than 7.4 g N/PE/d have been reported in medical literature. However, the population sample (age structure, sex, etc.) of a city the size of Zurich is entirely different from the typical sample in the medical literature (adult male), which explains the lower value obtained here.

Pöpel (1993) reports that 88% of TKN and $L_{TP,U}$ = 0.8 g P/PE/d in domestic wastewater originate from urine. With the observed ratio of TKN/NH_4-N = 1.6 in the wastewater of Zurich, the specific nutrient loads in urine become:

$L_{TKN,U}$ = 7.4·1.6·0.88 = 10.4 g N/PE/d; $L_{NH4,U}$ = 7.4 g N/PE/d; $L_{TP,U}$ = 0.8 g P/PE/d

These values will now be used to compare wastewater composition before and after separation of urine in no-mix toilets.

A complete urine separation in Zurich could remove annually 1.62·10^9 g of the TKN load and 1.25·10^8 g of the TP load. After urine separation, the TKN, NH4-N and TP loads will amount to 2.9·10^8 gN/a, 0 gN/a (excluding the load conveyed by rain), and 2.26·10^8 gP/a respectively. From a resource point of view, the nitrogen could meet the commercial fertiliser demand of

186,000 Swiss, and the phosphorus the demand of 83,000 Swiss citizens. The specific commercial fertiliser consumption of N in Switzerland amounts to 8.7 kg_N/PE/a, and of P to 1.5 kg_P/PE/a (Lienert, 2003).

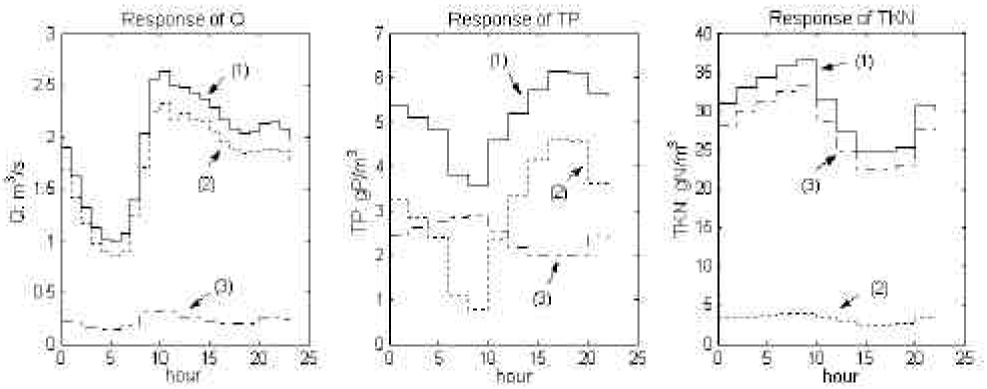

Figure 7: Variation of wastewater flow, pollution load before and after urine separation (dry weather).(1): without urine separation; (2): with complete urine separation; (3): urine flush load

Information on a 2-hour urine and urine flushing quantity is obtained from the NH_4-N time-variant-curve measurements after primary treatment in the WWTP Werdhölzli (with 2-hour time resolution and flow proportional sampling). The dynamic variation of TKN, TP and the inflow rate to the WWTP before and after applying urine separation are simulated (Fig. 7). How the wastewater treatment process should respond to this change can be studied on the basis of the information supplied. However, further measurements on load variation should be conducted. Qualitatively speaking, nitrification and denitrification may become unnecessary. Biological phosphorus removal would probably improve due to removal of substrate competition from the denitrification process. Use of chemicals for phosphorus precipitation and sludge production could also decrease significantly.

In existing conventional sanitation systems, urine separation measures can generally be implemented step by step and whenever feasible. Information on the number of inhabitants connected to conventional systems, and those linked to urine separation, will also allow to assess the wastewater properties after implementing the measures stepwise in some areas.

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Conclusions and discussions

The prototype of a method to assess the existing and alternative measures of urban water management has been developed and is ready to be adapted to further case studies in Kunming, China. This method will be refined and its function extended further depending on stakeholder requirements. Statistical pattern recognition and system identification are used to determine wastewater origin. The results obtained, including the uncertainty analysis in the case study of Zurich, reveal that the method is reliable and that the current volumetric composition of wastewater conveyed to the WWTP Werdhölzli in Zurich originates from: rainwater (41%), wastewater (45 – 48%) and extraneous water ("Fremdwasser") (11 – 14% accounting for 25 – 30% of dry weather flow). This shows that quite a large amount of extraneous water is still conveyed to the WWTP even in a well-maintained urban sewer system.

The water flow peak reduction in no-mix toilets in Zurich is estimated at around 0.32 m^3/s, which is a minor reduction in sewer runoff. However, urine separation can efficiently remove $1.62 \cdot 10^9$ g of the TKN load, $1.15 \cdot 10^9$ g of the NH_4-N load and $1.25 \cdot 10^8$ g of the TP load per year from the source within the catchment area of WWTP Werdhölzli, Zurich. The simulation results of dynamic variation of Q_{in}, TP, NH_4-N, and TKN, both as load and concentration, reveal how the urban wastewater will respond after urine separation measures are adopted. After urine separation in Zurich, the concentration of NH_4-N will be very small, the TKN concentration will vary between 2.6 and 4.4 gN/m^3, TP concentration will vary between 0.85 and 4.8 gP/m^3. Further studies will indicate how to deal with the "new" wastewater.

Acknowledgement

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Options for sustainable urban water infrastructure systems: Results of the AKWA 2100 project

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Introduction

The basic concept of today's conventional centralized water infrastructure systems (water supply and wastewater) for urban areas in Germany as in other industrialized countries dates back more than 100 years. Since then the systems have been continuously extended to spreading urban areas, adapted to changing needs of the population served, and to changing requirements with respect to public health and environmental concerns. In addition, these infrastructure systems are characterized by very long technical lifetime and high sunk costs resulting in a very high technological path dependency.

Due to insufficient maintenance in the past as well as other reasons the urban water infrastructure, especially the sewer system of most urban areas, is seriously deteriorated and requires rehabilitation or renewal. This requires large investments in a time when municipal budgets are tight. Estimates are that about 17 % (= 76.000 km) of Germany's public sewer system (446.000 km) require rehabilitation immediately or at least in medium term. This will require investments of 45 billion € over the next years. Before spending lots of money into the traditional centralized water infrastructure concept it is necessary to identify and assess other options. This is also demanded due to the availability of new technologies and new and more stringent environmental requirements.

The paper presents the results of the interdisciplinary AKWA 2100 project which undertook a scenario study of long-term alternatives to the conventional urban water infrastructure using two German municipalities (Dortmund-Asseln and Selm-Bork) as case studies.

Methods

The scenario approach was used to develop long-term visions of alternative urban water infrastructure systems. Using the year 2050 as time horizon, three scenarios were constructed. The scenarios differ with respect to the degree of 1. (de-) centralization of the (waste)water-treatment plants, 2. separation of various streams of (waste)water, 3. closing loops with respect to water and nutrients, and 4. (de-)regulation assumed.

The "Continuation"-scenario (reference scenario) retains the centralized concept of today's conventional systems. Major improvements of the eco-efficiency are gained through a more systematic separation of rainfall runoff and wastewater and through the use of innovative technologies such as membrane technology for wastewater treatment.

The "Municipal Water Reuse"-scenario takes a decentralized approach for rainwater management. It applies a water reuse scheme for treated wastewater on a municipal scale to provide non-potable water uses in industry, households, and municipal purposes. The urine fraction of the sanitary wastewater is separately collected for recycling of the nutrients. The second fraction (feces and gray-water) is collected together with organic wastes from the households using the gravity sewer system continuously flushed with non-potable water. The water is treated anaerobically and the bio-gas is used for energy production.

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The "Local Recycling"-scenario abandons the central water supply and wastewater systems altogether. Decentralized systems to provide potable water from rainwater and water for non-potable uses through recycling of various grades of wastewater are used single houses up to groups of houses. Feces and organic wastes are used as feedstock for decentralized bio-gas production. Since the need to operate large numbers of decentralized treatment plants, this scenario describes a highly liberalized situation with competition for the operation of the on-site plants.

To evaluate the scenarios, two case studies were performed. The technical components (pipes, pumps, fittings, installations, equipment etc.) necessary to implement the respective scenario were identified and quantified and the technical lifetime of the components was estimated. These data provided the basis for the economic evaluation of the investment and operation costs associated with the scenarios using the dynamic net present value (NPV) approach. To compare the scenarios with respect to their sustainability the Analytic Hierarchy Process (AHP) was applied to develop a system of 39 criteria (including the NPV evaluation) and as a multi-criteria evaluation procedure to rank the scenarios.

Results

The result of NPV-assessment showed, that in both case studies the “Continuation”-scenario is the most preferred one with respect to investment and operation costs. However, the “Local Recycling”-scenario is only slightly more expensive than “Continuation” (5 to 15 %, depending on the case study and the mode of implementation). The “Municipal Water Recycling”-scenario is consistently the most expensive one compared to “Continuation” (22 to 27 %). In contrast, the multi-criteria sustainability evaluation of the scenarios resulted in a different ranking: The “Local Recycling” scenario was highly preferred with respect to sustainability as compared to both, the “Municipal Water Recycling”- and ”Continuation”-scenario which are nearly equivalent.

Conclusions

The results of AKWA 2100 show that alternative concepts to conventional centralized urban water infrastructure systems are available, technologically and economically feasible (at least for the two case studies) and more sustainable than the conventional concept. One of the obstacles against a transformation of today’s conventional systems to more sustainable ones is the long time span required for such a transition. This strongly opposes the short time-frame imposed by the legislative periods of municipal decision making bodies. Other obstacles are the insufficient practical experience with the technologies required for these new concepts and the missing know-how regarding the organization and the management of such extended transformation phases. The only way to improve this situation is to learn by actually performing such system changes in pilot projects.

Comparison of resource efficiency of systems for management of toilet waste and organic household waste*

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Keywords

System analysis, simulation, blackwater, toilet wastewater, organic household waste, exergy, nutrient recovery, urine separation

Abstract

Using a system analysis approach compares different systems for handling and treatment of toilet waste and organic household waste. Design issues considered are source separation of urine, use of vacuum toilets and advanced nutrient recovery processes such as Reverse Osmosis (RO). All of the studied systems have low emissions of eutrophying compounds. Other environmental effects are mainly related to the amount of exergy used at each system. Source separating of urine is favourable if only a moderate (50 - 70 %) recycling potential for nutrients such as N and K is required. However, if higher recycling potential is required systems using nutrient recovery processes such as RO/evaporator are probably to prefer. For vacuum systems, the maximum amounts of flush water must be below 10 lit/p,d to make them reasonable efficient in terms of exergy consumption. The low-flush systems are less sensitive to the use of flush water in terms of exergy consumption.

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Introduction

To be able to meet the challenges of the concept "sustainable development" the resources in wastewater and organic waste must be more efficiently managed. The most important resources in wastewater and organic waste are plant nutrients and energy. Conventional wastewater treatment plants (WWTP) using biological nitrogen removal and chemical phosphorus removal only have potential to recycle phosphorus and a minor part of the nitrogen by using biosolids as a fertiliser. However, only a small fraction of the sludge produced at Swedish WWTP is used for agricultural purposes. Almost all of the organic household waste is deposited at land-

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fills or incinerated, although development is under way where source separation systems gradually are introduced. A more detailed description is given in Jeppsson et al. (2001).

A common problem for both sewage sludge and source separated organic household waste is the quality in terms of heavy metals and other hazardous substances (e.g. pharmaceutical residues). In order to improve the quality of the collected waste products different source separation systems are discussed and sometimes tested in pilot areas. This study concerns a blackwater (i.e. toilet waste) system, using vacuum toilets, in which the organic household waste is integrated. The study is a part of the Swedish research programme "Systems for efficient management of resources in wastewater and organic household waste" described in Jeppsson et al (2001).

The investigation is focused on the following questions:

- Should the urine be source separated, collected, and treated separately or mixed with other wastewater streams?
- What are the maximum amounts of water to be used in different system structures in order to make them efficient in terms of use of resources and energy?
- How should the residues from the anaerobic (or aerobic) treatment be managed to achieve an efficient utilisation of nutrients and organic matter?
- How should the blackwater be treated?

Method

Comparing different strategies for design of a blackwater treatment system approaches the above questions. The comparison includes utilisation of natural resources, environmental impact and potential to utilise available nutrients in agriculture (i.e. potential for recycling of N, P and K). A sensitivity study concerning water use and distance to arable land is included.

Blackwater systems for blockhouses have only been implemented in a few cases and systems where the organic household waste is integrated are rare. However, all parts of the investigated system are in use and the experiences from different areas have been used for collection of reliable data.

The different system structures under investigation are simulated using an extended version of ORWARE (ORganic WAste REsearch model) – a computer-based material-flow simulator using evaluation techniques from life-cycle assessment (Nybrant et al., 1995; Jeppsson *et al.*, 2002). ORWARE consists of a number of separate sub-models, which may be combined to design a waste management system for e.g. a city, a municipality or a company (Dalemo et al, 1997). ORWARE is a model primarily for material flows analysis (MFA). The material flows from different sources (wastes) through different methods for waste treatment (composting, anaerobic digestion etc) to different end uses (spreading of residues on agricultural soil or landfill). Emissions from transports, treatments etc are allocated as emissions to air, water and soil. Using methodology for impact analysis from life cycle assessment (LCA) different environmental impact categories are calculated (ISO 14042:2000). The ORWARE model has been complemented with exergy analysis. Exergy is energy of supreme quality, i.e. energy that is convertible into all other forms of energy. The quality of energy depends on how concentrated, ordered and structured the energy source is (Holmberg, 1995). Examples of quality factors for different energy sources are given in Table 1.

Form of Energy	Exergy/Energy (%)
Electrical energy	100
Hot steam (200 °C)	~70
District heating	~30
Heat of wastewater (15 °C)	< 5

Table 1: Example of quality factors for some energy sources. (Reference temperature 5 °C).

The studied systems include collection and transport of blackwater and organic household waste from households to treatment units, operation of treatment units, transport of recovered nutrients, and application of nutrients on farmland. The study considers only the operation of the systems, and not the building and maintenance of the system. Furthermore, the analysis does not include indirect use of resources such as resources needed for production of electricity.

Description of system alternatives

The blackwater system could either treat urine and faeces together or separately (i.e. two separate collection-, storage- and end-use systems). The organic household waste is collected by using kitchen waste disposer and mixed with wastewater from the toilets, i.e. blackwater. A low-pressure system is used for transport of the wastewater to the treatment plant. The greywater treatment has been excluded from the comparisons based on the assumption that it is handled in the same way for all cases, e.g. treated at a conventional treatment plant. All systems include hygienisation by heating of the biologically treated residues (70 °C, 1 h).

The studied systems are supposed to be large-scale systems (> 20 000 pe) and located in a city surrounded by a rural area. The sewage will be generated and treated within the urban area and residues such as urine and bio-solids will be transported by trucks and spread on available farmland within the rural area. The average distance to the farmers is 35 km.

The investigated systems are (Figure 1):

System 0: Reference system: The reference system is constructed of conventional collection and treatment of blackwater including biological nitrogen removal and chemical phosphorus removal. Organic household waste is collected separately and anaerobically digested.

System 1: Vacuum toilets and anaerobic treatment (VacAn): Blackwater system using vacuum toilets and anaerobic digestion.

System 2: Vacuum toilets and aerobic treatment (VacAer): Vacuum system and aerobic treatment without dewatering (VacAer, System 2): Blackwater system using vacuum toilets and aerobic digestion, i.e. wet-composting.

System 3: Vacuum toilets and nutrient removal (VacRem): Black water (toilet waste) and organic household waste is mixed and transported to a mesophilic anaerobic digestion unit by a combination of vacuum and low-pressure systems. Anaerobic residues are dewatered by centrifugation. The reject water from the dewatering is treated by biological nitrogen removal (BNR) and chemical phosphorus removal.

System 4: Vacuum toilets and nutrient recovery (VacRec): Similar to previous system (VacRem, system 3) but nutrients in reject water are recovered and concentrated by evaporation.

System 5: Vacuum system and urine separation (VacUS): VacRem, system 3, complemented with source separation of urine. Urine is transported in a separate pipe to a short-term storage facility located at the treatment plant.

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System 6: Advanced anaerobic treatment and nutrient removal (EGSB-Rem): "Conventional" low-flush toilets are used. The treatment plant consists of chemically enhanced sedimentation, two EGSB/UASB reactors operated in series (EGSB = Expanded Granular Sludge Bed Reactors). For removal of nutrients, biological nitrogen removal (BNR) and chemical phosphorus removal will be used. Sludge treatment consists of anaerobic digestion, dewatering and hygienisation before transportation to farmland by trucks. The reject water from the dewatering is treated together with the influent wastewater.

System 7: Advanced anaerobic treatment and nutrient recovery (EGSB-Rec): Blackwater system utilising ordinary low-flush toilets and advanced anaerobic treatment, e.g. EGSB—reactors (EGSB = Expanded Granular Sludge Bed Reactors).

"Conventional" low-flush toilets and kitchen waste disposers are used. Blackwater (toilet waste) and organic household waste is mixed and transported to a treatment plant by a low-pressure system. The treatment plant consists of chemically enhanced sedimentation, two EGSB/UASB reactors operated in series. For nutrient recovery, reverse osmosis (RO) and evaporation is used. Sludge treatment consists of anaerobic digestion, dewatering and hygienisation before transportation to farmland by trucks. The reject water from the dewatering is treated together with the influent wastewater.

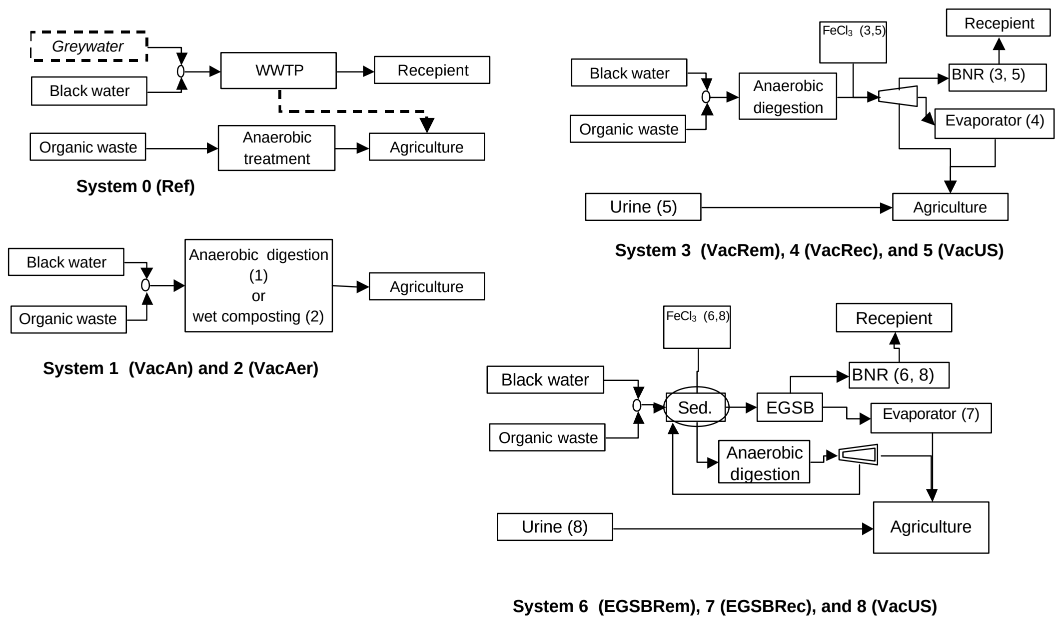

Figure 1: Conceptual model of systems for collection and treatment of blackwater and organic household waste. Used abbreviations: WWTP = Wastewater Treatment Plant, BNR = Biological Nitrogen Removal, EGSB = Expanded Granular Sludge Bed reactor, CSTR = Completely Stirred Reactor (Anaerobic).

System 8: Advanced anaerobic treatment and urine separation (EGSB-US): Advanced anaerobic treatment complemented with urine separation (EGSB-US, system 8). Urine is transported/pumped in a separate pipe to a short-term storage facility located at the treatment plant. Stored urine is then concentrated by evaporation or directly transported by trucks to long term storage at farms using urine as a fertiliser. Since most of the nitrogen is recycled by urine, the only nutrient recovery process in the treatment plant is chemical phosphorus precipitation. To meet stringent demand concerning nitrogen emissions the anaerobic process is complemented by biological nitrogen removal.

Results and discussion

Potential nutrient recycling for different systems is shown in Figure 2. As expected, systems with nutrient recovery processes such as RO and evaporation and systems where all of the collected waste is recycled will have the highest potential for nutrient recycling. Blackwater systems without urine separation or nutrient recovery processes will have a rather low recycling potential, except for phosphorus. Even if all systems will have a high potential for phosphorus recycling, it should be noted that the quality of the product from the different systems would differ, although the quality is very good due to exclusion of the greywater. The Cd/P-ratio (mg Cd/kg P-tot) are as follows: 4,5 (ref.syst.), 6,9 (syst. 1), 6,9 (syst. 2), 4,1 (syst. 3), 6,0 (syst.4), 4,4 (syst. 5), 4,2 (syst. 6), 6,0 (syst. 7), 7,9 (syst. 8). If greywater from the households is treated together with blackwater in the reference system the Cd/P-ratio would be 11.

Even if the reference treatment alternative has high phosphorus removal efficiency, i.e. above 95 %, and nitrogen removal efficiency above 70 %, the reference system still has the highest emissions of compounds contributing to eutrophication (Figure 3). However, the difference between the systems is mainly explained by different ambitions for nutrient removal (and not due to the design of the system). The removal efficiency for the reference system could be improved by adding external carbon source and using post-denitrification processes as is done in system 3, 5, 6 and 8 (VacRem, VacUS, EGSB-Rem, and EGSB-US). However, this would increase the exergy demand for that system (Hellström, 2002).

The emissions to air derive from transport and handling of the residues from the anaerobic and aerobic treatment. Since the volumes to handle are highest for system without dewatering, i.e. VacAn (1) and VacAer (2), these systems also have the largest emissions of NO_x from trucks and tractors

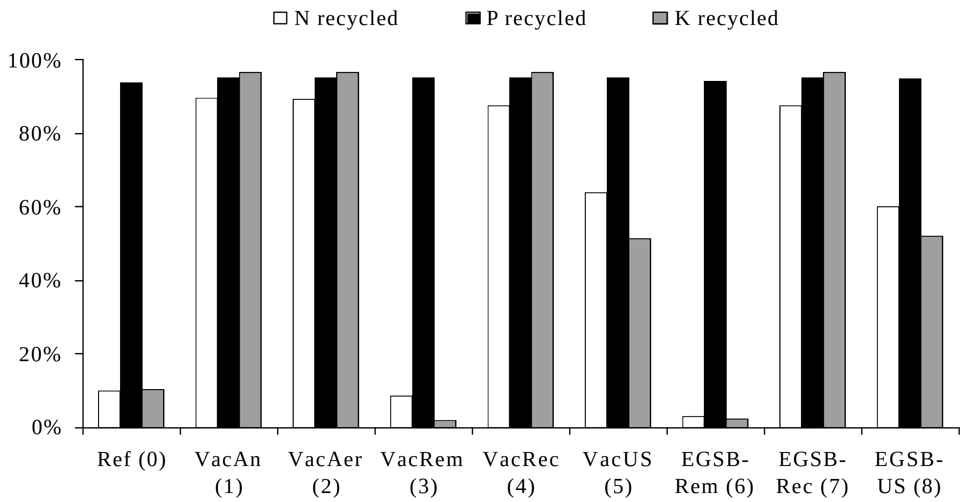

Figure 2: Part of nutrients that can be recycled to arable land.

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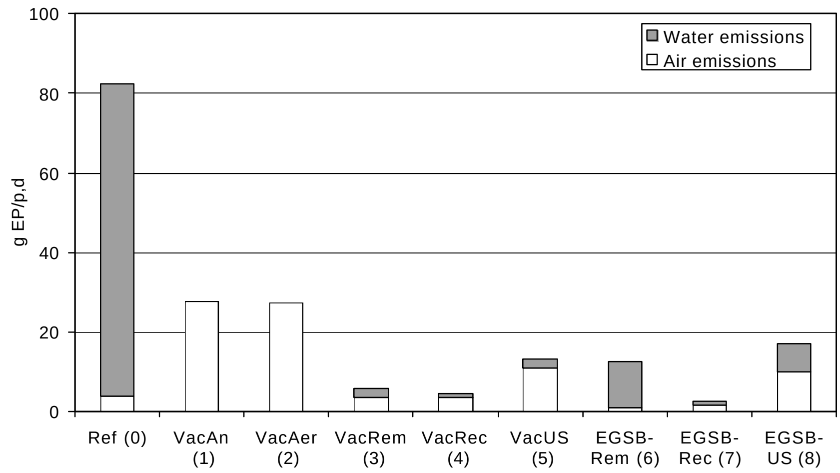

Figure 3: Eutrophication calculated as maximum eutrophication potential (g/p,d)

Hence, all of the studied systems have low emissions of compounds contributing to eutrophication. Other environmental effects are mainly related to the amount of exergy used at each system.

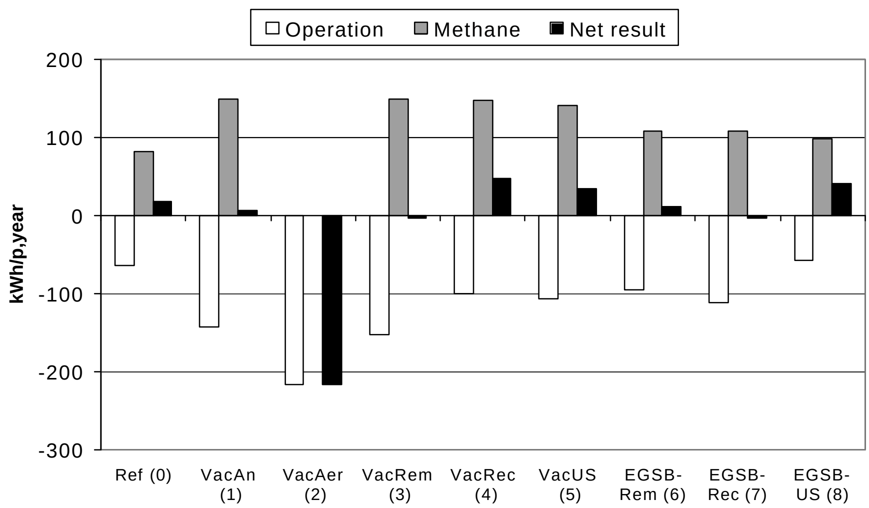

Figure 4: Exergy demand for operation and gas production as kWh/person, year. The difference between these is considered as a net result (positive result if production > consumption). It is assumed that the vacuum systems use about 7 lit flush-water/p,d (system 1-5) and the low-flush systems use about 32 lit/pe,d (system 0, 6-8).

The exergy demand for operation and exergy in produced methane is shown in Figure 4. The exergy demand for hygienisation for the vacuum systems (1 – 5) is relatively high (50 to 60 kWh/p, year). Systems without dewatering of treated residues (system 1 and 2) also requires much exergy for transport and spreading of nutrients (about 65 kWh/p, yr). The wet-composting process in system 2 requires about 140 kWh electricity/person, year. Carbon source contains exergy and a significant amount of carbon source is used in system using biological nitrogen removal (60-70 kWh/p, yr. in system 3 and 6 and about 20 kWh/p, yr. in system 5 and 8). In Figure 4 the reference system is complemented by post-denitrification to achieve the same removal efficiency as the other systems and carbon source corresponding to 15 kWh/p, d is used.

Reverse osmosis and evaporation requires exergy (in system 5 about 20 kWh/p, yr. and in system 7 - 80 kWh/p, yr.).

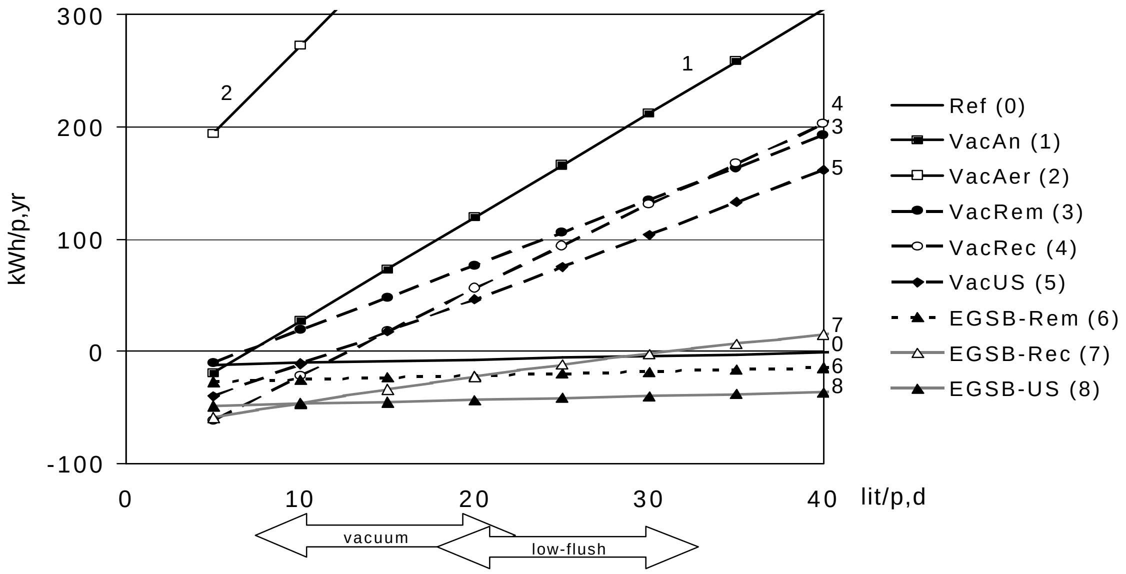

Figure 5: Exergy demand for each system versus amounts of flush water that is used (negative exergy value means that the exergy content of the methane is higher than the exergy needed for operation).

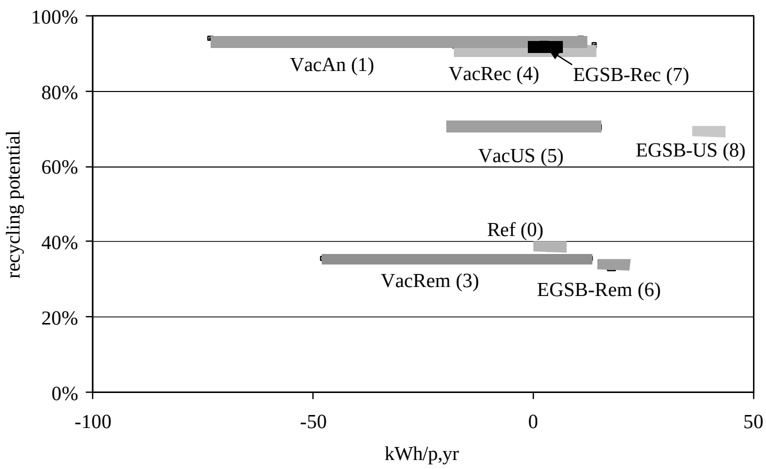

Figure 6: Average potential recycling of nutrients, $(N_{rec} + P_{rec} + K_{rec})/3$, versus net exergy production for each system indicated as an area (positive exergy value means that the exergy content of the methane is higher than the exergy needed for operation). It is assumed that the vacuum systems use 10 - 15 lit flush-water/p,d (1-5) and the low-flush systems use about 30 lit/pe,d (0, 6-8).

The exergy demand for operation depends on the amount of flush water used in the various systems (Figure 5). Especially all systems with hygienisation of all the collected wastewater (system 1 – 5) and system with RO/Evaporator (system 4 and 7) are sensitive to the amount of flush water. The normal amount of water for the different systems is also indicated in Figure 5. Since the main differences between the systems are the exergy demand and nutrient recycling potential, the results could be summarised by Figure 6.

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Conclusions

All of the studied systems have low emissions of eutrophication compounds. Other environmental effects are mainly related to the amount of exergy used at each system. Source separating of urine is favourable if only a moderate (50 - 70 %) recycling potential for nutrients such as N and K is required. However, if higher recycling potential is required systems using nutrient recovery processes such as RO/evaporator are probably to prefer. For vacuum systems, the maximum amounts of flush water must be below 10 lit/p, d to make them reasonable efficient in terms of exergy consumption. The low-flush system is less sensitive to the use of flush water in terms of exergy consumption.

Acknowledgement

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The Swedish Urban Water programme

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Keywords

Sustainability, urban water, interdisciplinary, toolbox, model cities.

Abstract

The Urban Water programme is a major Swedish transdisciplinary research programme, financed by MISTRA. The programme started in 1999 and will end in 2005. Eight Swedish universities take part in the programme. The Urban Water programme aims at developing support for strategic decisions on future water and wastewater systems. The main goal for Urban Water is to answer the questions: How should the urban water and wastewater systems be designed and operated in the future sustainable Sweden? Will the sustainable water and wastewater systems of the future be improved versions of what exist today, or will there be some radical changes? A conceptual framework has been developed, defining the three subsystems technology, users and organisation as equally important. Five aspects of sustainability are studied: health, environment, economy, socio-culture and technical function. A tool box is being developed for assessing these five aspects, and applied to five Swedish model cities.

The programme

The Urban Water programme is a major Swedish transdisciplinary research programme, financed by MISTRA (The Foundation for Strategic Environmental Research), other research councils and the participating municipalities. The total budget for the programme is about 12 MEuro. The programme started in 1999 and will end in 2005. Eight Swedish universities take part in the programme

Objectives

The Urban Water programme aims at developing support for strategic decisions on future water and wastewater systems. The main goal for Urban Water is to answer the question:

> *How should the urban water and wastewater systems be designed and operated in the future sustainable Sweden?*

Will the sustainable water and wastewater systems of the future be improved versions of what exist today, or will there be some radical changes?

The Urban Water approach

The Urban Water approach is simple and logical:

a) A framework describes the system that we study and the five sustainability aspects that we apply. Sustainability criteria are developed.

b) Tools are developed for assessing the five sustainability aspects.

c) The tools are applied to and partly developed in five model cities.

d) The criteria, the tools and the experiences from the applications are presented in a comprehensive "Guidebook" and integrated into the Urban Water syntheses.

e) Recommendations for the planning and decision-making process are developed, as well as recommendations for the choice of systems.

Each tool development and model city application is carried out as an individual project, held together in the Urban Water systems analysis.

Sixteen doctoral projects take active part in the systems analysis, delivering pertinent knowledge and data within their respective scientific discipline. The PhD students are all participating in the Urban Water research school.

Systems analysis

"Systems analysis" in the Urban Water programme refers to our interdisciplinary research approach for comprehensive analysis and assessments of sustainable urban water systems. Thereby the concept is more inclusive than the prevalent understandings. A conceptual framework guides the understanding of a system and the research strategy, Figure 1.

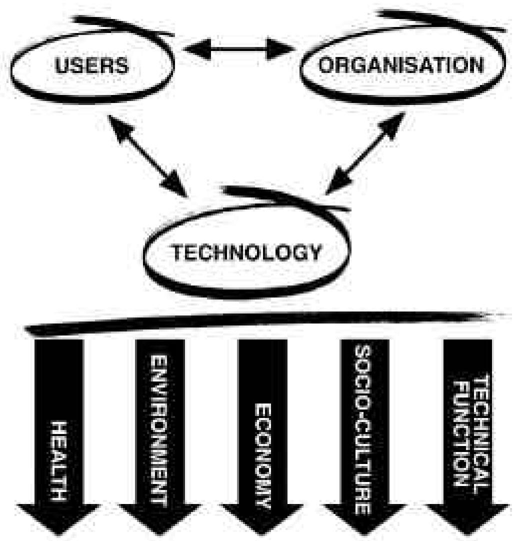

Figure 1: The Urban Water conceptual framework.

An important consequence of the conceptual framework is the definition of a system as including the technical structure, the organisation and the users of the system. Together these three subsystems constitute the urban water system, which is analysed from five main perspectives – representing the programme's five groups of criteria where physical criteria can be separated from immaterial criteria. Physical criteria are regarded as impacts on the environment (environmental criteria) and society (health & hygiene criteria). The immaterial criteria, which are socio-culture, economy and to some extent technical function, concern the interactions within the system as well as between the water system and the surrounding society.

The Urban Water model cities

The model cities are central in the systems analyses. Five model cities have been chosen, representing typical Swedish urban areas. The model cities are:

Model city Country town

Model city City centre

Model city Suburban area

Model city New area

Model city Urban enclave

The Urban Water toolbox

A crucial part of the Urban Water programme is devoted to developing a toolbox for the assessment of urban water and wastewater systems. The toolbox contains models and methods both for detailed assessments of the studied systems and methods for the decision-making process. The main tools are the following:

Substance flow analysis – URWARE and SEWSYS

The project aims at developing systems analytical tools for analysing environmental sustainability criteria of urban water systems and applying these tools to the model cities of the programme. The model URWARE, designed for annual averages, and SEWSYS, designed for shorter time periods, are both being constructed using the MATLAB framework. The graphical interfaces used are also being applied in several of the other tool projects.

Microbial Risk Assessment

The objectives of the MRA tool project are 1) to undertake microbiological monitoring/modelling in the model cities, and to collect data from the literature to estimate viral, parasitic protozoan, bacterial and helminth pathogen ranges in source materials and their removal by the key system units expected; 2) develop a model to undertake life-cycle pathogen flux analysis for index pathogens in the model cities.

The objective of the MRA tool is to identify critical control point(s) (CCP = barriers fundamental to controlling risk) for each system structure and describe the desired level of performance for each barrier. Thus the MRA and CRA tools will not only allow comparison of overall system risk, but also where and to what degree control is necessary for safe operation; hence linking to the social tool within the UW tool box.

Chemical Risk Assessment

The objectives of the CRA tool are 1/ to identify and describe relevant risks for the environment and health that are associated with the flows of chemicals in different wastewater systems; 2/ to quantify relevant risks that may be associated with discharges of wastewater to receiving waters and with use of products from the wastewater system on cultivated land. (Subproject Risk analysis); 3/ to identify and assess main sources to substances that imply high risks and to suggest risk-reducing measures at the sources and in the wastewater systems (Subproject Barriers) and 4/ to develop recommendations for how the assessment of risks can be a/ communicated; b/ assessed in relation to other characteristics of different wastewater systems; and c/ used as part of the integrated decision support.

Cost estimation tools

The objectives are to develop 1/ a method to assess economically sustainable urban water management systems and 2/ criteria and indicators to evaluate economic aspects of sustainable urban water management.

Capacity profiles and network analysis - graphical tools for systematic comparisons

The objectives of this project are to develop 1/ criteria related to organisational and institutional aspects on sustainable water management and 2/ graphical tools in order to enhance systematic comparisons between different system structures.

A comparative approach to developing and feeding knowledge about household's needs and prerequisites into urban water management

Households are currently identified as important actors in the process of restructuring society in the direction of ecological sustainability, so also in the field of urban water management. Although recognized as vital for sustainability, applied knowledge concerning critical household–

system relations as well as methodology for eliciting and feeding this type of knowledge into development and management processes are very much wanted.

The objective of this work is to perform and present a systematic compilation and analysis of knowledge about individual's and household's perceptions, preconditions and preferences in relation to the context and conditions provided in the different model cities and system structures. A conceptual framework will be outlined in order to analyse and discuss the results. Emphasis will be put on the transformation of findings into recommendations for policy and systems development in concordance with the needs and wishes of households.

Methodologies for integration of knowledge areas – MIKA

The aim of the Urban Water programme is to provide with a comprehensive toolbox to be used in strategic planning- and decision-making processes. One tool in the toolbox can be characterised as a process support tool through which integration of knowledge areas, in a trans-disciplinary sense, are made. The trans-disciplinary perspective comprises all kinds of knowledge including layman knowledge, professional knowledge, traditional knowledge as well as scientific knowledge.

A wide range of methodologies for integrating knowledge exists today, from product oriented, software-based multi-criteria methods to process oriented methodologies emphasising participation, learning and communication. The model *NAIADE* has in a comparative evaluation been selected for application in the programme. The model has been tested in the research school and will this autumn be applied in the model city Surahammar (the small town model city).

The Urban Water context projects

All water and wastewater systems exist in a context that to a high degree affects the systems and sets limits to what is possible. This project aims at defining and assessing the possibilities and limitations to the urban water systems.

Environmental context

This project focuses on the ecological or environmental dimension of sustainability. The objective is to examine different approaches to define ecological sustainability and what they imply for the assessment of urban water management. Proposed environmental criteria and indicators for urban water supply and wastewater management are discussed.

The following approaches to define ecological sustainability are examined:

- Ecological sustainability defined by using a Guiding principles approach
- Ecological sustainability defined as compliance with politically set environmental quality criteria
- Ecological sustainability defined by using scientifically derived critical loads and carrying capacities.

Legislative context

Legislation affects the urban water systems, in particular the Swedish legislation and the EU legislation. These legislations set certain limits to what is possible to do or not, at least in a short to medium-long sight. The project aims at identifying the current laws that affect the design and operation of urban water system. Further, laws-in-making will be studied and attempts will be made to forecast forthcoming laws that affect the water sector. Conflicts between Swedish and EU laws will be identified.

Sustainable water organisations: international experiences of organisational structures and driving forces in a water sector in development

The objective is to compare international experiences of different organisational structures. The driving forces for existing structures will be studied.

Three questions will be studied:

- Which principally different organisational structures exist for urban water management?
- What are the experiences regarding efficiency and sustainability?
- What can we learn?

The future city

The objective is to attempt to describe possible developments of future Swedish urban areas and to put the urban water systems into this context. Possibilities and limitations to different developments of the water systems will be identified and assessed.

Risks associated with future climate change

The project aims at assessing the impacts that future climate change will have on urban water systems. The Urban Water framework will be applied. The scenarios developed by the MISTRA programme SWECLIM will form the basis for the assessments. The project comprises both a systematic structuring of the problem and applications in the Urban Water model cities and/or other cities with different prerequisites. Experiences from the last year's flooding in Sweden and Europe, as well as drought situations, will be taken into consideration.

Effective communication? – perceived and measured impacts of environmental approaches

The objective is to assess the impacts of the information efforts by the recycling companies in Stockholm, including economic incitements, on the tenants´ environmental behaviour.

Sub-objectives are

- To assess the interest and preparedness of the recycling companies and the households to take responsibility for different aspects of a more sustainable urban living.
- To investigate the relevant actors´ anticipations and the communication between them regarding environmental measures in Hammarby Sjöstad.
- To compare the anticipations with measurements of physical parameters wherever possible.

Syntheses

"Will the sustainable water and wastewater systems of the future be improved versions of what exists today, or will there be some radical changes?"

The answer cannot possibly be a single clear answer covering all cities in Sweden. On the contrary, each city has to make strategic decisions depending on the local context. Urban Water aims at delivering decision support to the planners of future sustainable water and wastewater systems. This decision support has the following components:

Criteria for the main critical aspects, defined as hygiene and health, environment, economy and socio-cultural aspects. Each group of criteria contains a set of indicators or strategies for the assessment of sustainability. Some of these indicators will be based on thresholds where specific requirements have to be met. Some of the indicators will be relative and intended for comparisons between two or more systems.

Characteristics of a number of possible and realistic systems for drinking water, wastewater and stormwater. These characteristics are related to the three system components technical systems, organisation and users. The combined results from the PhD projects and the Systems Analyses will give recommendations concerning design and operation of the system or system components, as well as more generalised recommendations.

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Tools for the assessment of urban water systems will be crucial components guiding the syntheses. The planner of a local water system will have access to tools – models, methods and recommendations – for the assessment of possible systems for the area to be planned. These tools and methods will be delivered in a version that can be managed by a skilled and interested professional. Handbooks and guidelines will be developed.

Recommendations for the planning and decision-making process. Decisions concerning future urban water systems have a multi-dimensional character and must include a multi-criteria decision-making approach, whether explicit or not. Evaluations of a number of methods for knowledge integration in some of the model cities will generate recommendations regarding involvement of stakeholders, the process of planning and decision-making, information to the participants, and workable presentation of knowledge.

Experiences from the model city applications. Different water systems, real and hypothetical, will have been assessed in the model cities by using the Urban Water toolbox. Experiences from the model city assessments will guide the planner not only for the use of the tools but also for the process of applying the tools.

Recommendations for the choice of system. The Urban Water syntheses will be based on experiences gained in the PhD projects, the model cities and in several cases in other cities. General conclusions will be drawn regarding which kind of system that may be appropriate in a certain local context, and which kind of system that is inappropriate. The recommendations will have many dimensions, but will be structured along three main dimensions a/ physical scale (large-scale technical structures or small-scale structures?); b/ flows (combining the flows in one pipe or separating the flows in several pipes?) and c/ organisation (a centralised or a decentralised organisation?).

Conclusions for urban planning. The water systems are integrated parts of the city infrastructure. They affect and are affected by all other systems and activities in the city. The relations between the water systems and the city that they serve will be visualised.

Conclusions for regional and national spatial planning. Based on statistical data for Swedish built-up areas (population, surrounding environment, existing infrastructure etc.) conclusions will be drawn concerning the environmental effects of a change to alternative systems. Will alternative water systems contribute to a more sustainable Sweden? Will alternative systems contribute to achieve the Parliament's environmental goals? Will investments in the urban water sector be cost-effective compared to investments in other sectors?

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The doctoral projects

There are 16 PhD projects in the programme. For more information look at www.urbanwater.org

The Urban Water research school

The research school has been central for the interdisciplinary ambitions within the Urban Water-programme, giving the PhD students 20 academic points (corresponding to 20 weeks) of interdisciplinary courses, based on the PBL principles (Problem-based learning).

In 2002 and 2003 four study tours to international Mega-cities take place. Calcutta and Tokyo have been visited; Cairo and St. Petersburg to come.

References

Published papers, conference contributions and other publications can be found at www.urbanwater.org

Model city urban enclave in urban water - does ecosan improve sustainability of the sewage system?

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Keywords

Sewage system, source separation, urine, faeces, greywater, research.

Abstract

The aim of the research programme Urban Water, financed by MISTRA - the Foundation for Strategic Environmental Research, is to develop support for strategic decisions on future sustainable sewage systems in Sweden. About 20 researchers and 17 PhD-students are engaged in the programme.

The single most important question in the programme is whether the best way towards a sustainable sewage system would be by improving the present system or whether the shortcomings of this are so large that it would be better to change over to an alternative, source separating sewage system.

The research in Model City Urban Enclave concentrates upon investigations and studies of source separating sewage systems, i.e. systems where the greywater is not mixed with excreta. Excreta are either collected mixed with flushwater, as black water, or the urine is diverted and the faeces collected dry. The research within Model City Urban Enclave is well under way and several papers are being presented here in Lübeck.

Introduction

The Swedish parliament has decided on 15 environmental goals and the performance of the sewage system is of prime importance for reaching several of these. The most important goals for the sewage system are “no eutrophication” and “a good built environment”, which includes as sub-goals increased resource efficiency and increased recycling of the plant nutrients in sewage and organic waste. Thus, ideally the sewage system should not cause any eutrophication and it should be resource efficient and allow recycling of safe, i.e. hygienic and unpolluted, plant nutrients.

The aim of the research programme **Urban Water** is to develop support for strategic decisions on future sustainable sewage systems in Sweden. About 20 researchers and 17 PhD-students are engaged in the programme.

The single most important question in the research programme **Urban Water** is whether the best way towards a sustainable sewage system would be by improving the present system or whether the shortcomings of this are so large that it would be better to change over to an alternative, source separating sewage system.

More information on the whole **Urban Water** programme can be found in the paper “The Swedish Urban Water Programme” presented by Prof. Per-Arne Malmqvist at this symposium.

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Methods

To answer the question of whether the sewage system should be further developed in small steps or be changed to a source separating system, criteria are needed for evaluating different aspects of sustainability, i.e. hygiene, environment, economy, socio-culture and technical function. Several tools, e.g. Microbial Risk Assessment (MRA), Substance Flow Analysis (SFA) and Life Cycle Assessment (LCA) have been developed for assessing these aspects. These tools are being used to analyse different sewage systems (varieties of conventional systems and source separating ones) in different physical settings. In the Urban Water programme five different settings, called model cities, are thoroughly analysed, namely country town, city centre, suburban area, new area and urban enclave.

In three of these, country town, new area and urban enclave, source separating sewage systems are compared to conventional ones. In the country town and in the new area, different varieties of blackwater systems (systems separating between toilet waste – blackwater – and greywater) are being compared to conventional sewage systems.

In the Urban Enclave, the comparison is mainly between a conventional water-flushed system and a system based on urine separation and dry handling of the faecal matter. Aspects being compared are: health and hygiene, environment, economy and socio-culture. Furthermore, for the urine separating, dry faecal handling system, specific functions are also being studied, e.g. the technical function and different methods to sanitise the faecal matter.

The urban enclave activities and projects

Most of the research within the Urban Enclave is performed within different projects. Engaged in these are five senior researchers and nine PhD students. The senior researchers are: Ann Albihn, Head of Division, National Veterinary Institute; Nicholas Ashbolt, Assoc. Prof., University of New South Wales, Australia; Jan-Olof Drangert, Assoc. Prof., Linköping University; Håkan Jönsson, Assoc. Prof. and Dr. Björn Vinnerås, SLU - Swedish University of Agricultural Sciences.

The PhD students are: Mattias Hjerpe and Helena Krantz, Linköping University; Annika Holmqvist, Jakob Ottoson and Therese Westrell, Swedish Institute for Infectious Disease Control; Helena Palmquist, Luleå University of Technology; Pernilla Tidåker, SLU – Swedish University of Agricultural Sciences; Simon Fane and Susan Pettersson, University of New South Wales.

The projects within the urban enclave are:

Substance flows of chemical risk substances and nutrients in greywater, faecal matter, urine and biodegradable waste

In a conventional sewage system, all different wastewater fractions are mixed, forming conventional sewage. In source separating systems, however, the separate fractions are collected and treated separately. To analyse and compare these separating sewage systems with conventional ones, the flows and compositions of the different contributing wastewater fractions are needed. Data on these flows were lacking. Therefore, the objective of this project was to measure the flows and compositions of the fractions that can contribute to conventional household sewage, i.e. urine, faeces, greywater and solid organic household waste.

In the project, the flows and compositions of urine, faeces, greywater and solid organic waste emanating from the 32 apartments (80 residents) of the Gebers house in Stockholm were measured during three consecutive one-week periods. Both nutrients and hazardous organic and inorganic substances were measured.

The measurements showed that of the total flow, including solid organic waste, the largest contribution of nutrients came from urine (70% of the nitrogen, 30% of the phosphorous and 50% of the potassium), while greywater contributed only 10% of the nitrogen, almost 30% of the phosphorous and 20% of the potassium. For hazardous metals, it was quite the opposite. The contribution from urine was very small, less than 5%, while it was large for greywater, above approximately 40% except for mercury and zinc. For these two metals the faecal contribution was large, 70% for mercury and above 80% for zinc.

The results of this study are given in full detail in Andersson & Jensen (2002). Many of the results are also reported internationally in the paper “Urine, faeces, greywater and biodegradable solid waste as potential fertilisers” by Palmquist & Jönsson (2003), which is being presented at this symposium. The measurements have also been an important input to a proposal for new Swedish default values (Vinnerås et al., submitted).

Nutrient management and environmental evaluation of different sanitation methods for faecal matter

The objective of this project was to develop chemical methods to sanitise faeces. In the study the sanitising effect of two different chemicals, urea and peracetic acid, was investigated.

The dose of urea corresponded to 30 g of urea nitrogen per kg of faeces. At this dose, an efficient reduction of *E. coli*, *Enterococcus* spp and *Salmonella* spp was achieved within 3 weeks and of the virus indicator phage *Salmonella typhimurium 28B* and *Ascaris suum* eggs within 50 days. Spores of *Clostridia* were not reduced at all.

At a dose of 10 g of PAA per kg of faeces, all organisms investigated (*Ascaris suum* not investigated) were efficiently reduced within 12 hours.

From the aspects of resource efficiency and environmental friendliness, sanitation with urea was found to be promising. Urea is a common nitrogen fertiliser and its fertilising effect is not lost when it is used for sanitation. Its cost in terms of money, energy and environmental effects can be allocated to this fertilising effect. Thus, the sanitising effect is “free”, as it is achieved by “borrowing” the urea fertiliser before it is applied on the field. Results are published in Vinnerås et al. (2003).

Influence of sewage fertiliser products on sustainability of farming

The objectives of this study were:

- to assess the influence on environmental impact and resource management in a systems perspective when sewage fertiliser products, e.g. source separated urine and blackwater, replace mineral fertiliser in arable farming and
- to develop sustainability criteria for classification of sewage fertiliser products used in agriculture.

So far one product, source separated human urine, has been compared to mineral fertiliser. The method used in the project was LCA and the production of the urine, i.e. the sewage system, was included in the study. This is the reason why the eutrophication proved to be much less when urine instead of mineral fertiliser was used as fertiliser. Using urine also saved energy, but the amount of energy saved proved very dependent on the payback time and type of the additional capital goods, e.g. storage tanks, needed when the urine is source separated. The full results of this study are published in the report “Life Cycle Assessment of Grain Production Using Source Separated Human Urine and Mineral Fertiliser” (Tidåker, 2003).

The interests and preferences of farmers have also been studied and are being presented here in Lübeck (Tidåker et al., 2003).

Systems evaluation of source separating sewage systems in a small urban enclave, a large urban enclave and a small country town

One objective of this project is to test the potential of source separating sewage systems in enclaves of different sizes. Another objective is to compare different source separating sewage systems with each other. The source separating sewage systems which we intend to test are: a) urine separation and dry faecal handling, b) urine separation and vacuum collection of wet faeces, c) urine separation and collection of wet faeces via separation from flushwater using Aquatron separators, d) blackwater collected with a vacuum system and e) blackwater created by mixing urine and faeces collected via system c).

The evaluations carried out in this project will be based on systems simulations performed with the software tool URWARE (URban WAter REsearch simulation model). This is a further development of ORWARE (ORganic WAster REsearch simulation model) (Dalemo et al., 1997; Sonesson et al., 1997). URWARE is based on Substance Flow Analysis (SFA), but also incorporates important aspects from Life Cycle Assessment.

This project is planned to start in May 2003, when URWARE should be fully functional.

Greywater, separated urine and dry faeces – hygiene and microbial risk assessment (MRA)

The objectives of this project are:

- to evaluate whether composted faeces will be hygienic enough to allow reuse as fertiliser on crops grown by the source household or by nearby farmers,
- to measure the faecal contamination of different greywater flows (kitchen, other) and to examine the growth/reduction potential of microorganisms in greywater sediments,
- to undertake modelling of likely infections per pathogen group within the community over the expected lifetime of the system, utilising the MRA tool from the SA-project and
- to combine all the data in order to assess the health risks that this system poses in daily life, to whom and how often, with the purpose of estimating the sustainability of the system, i.e. to perform a MRA (Microbial Risk Assessment) of the system.

So far, the faecal contamination of different greywater flows has been measured and the associated microbial risk estimated (Ottoson & Stenström, 2003). The growth/reduction of microorganisms in greywater sediments has also been studied and reported (Ottoson & Stenström, 2002) and a MRA of greywater in a source separating wastewater system is being reported here in Lübeck (Ottosson, 2003).

Why some take on the responsibility of sustainability

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The overall aim of the project is to enhance understanding of the willingness and ability of households to take on new responsibilities for improved sustainability. A study carried out in the Gebers house in Stockholm also aims at analysing water and sanitation arrangements as culturally and socially embedded. The residents have chosen a technical structure, with urine diversion and dry handling of faeces, that entails some "own-key" arrangements. The study of how residents/users view and perform their roles as guardians of nature is important for the proper design of water and sanitation systems.

The methods used in this project include in-depth interviews and writing of diaries. The study is well underway and initial results are being reported by Helena Krantz (2003) at this seminar.

Urine separation and dry handling of faeces – technical function

The objectives of this project are

- to document the frequency and severity of the different functional problems encountered in sewage systems with source separation of urine and dry handling of faeces,
- to analyse between one and three of the most frequent or severe problems in depth, with the goal of eliminating these problems in the future and
- to analyse the other problems to some extent.

This project is planned to start May 2003.

Interested – want to know more?

Visit www.urbanwater.org! Contact Håkan Jönsson, Hakan.Jonsson@lt.slu.se

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Comparison of sanitation latrines used in China

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Keyword

Comparison, rural, sanitation latrine

Abstract

The rural latrines in China exists two issues, one is low coverage rate, and the other is that the latrines is too simple and the excreta is unable to achieve harmlessness. 5 kinds of sanitation latrines to the country of China have been recommended. These 5 kinds are: Three-Compartment Septic Tank latrine; Triplex Biogas latrine; Double Urn Funnel-pan latrine; VIP latrine and Urine-Diversion Eco-san latrine. In order to know which kind of latrine is more suitable in which areas,and make the latrines improvement is more effective and more economic, some comparison was made on above kinds of latrines used in China. These kinds of latrines have some different characteristics and that can be fitted different areas in China.

General information of the water environmental situation in China

China is a developing country with the most population. According to the Fifth National Census, the total population of the country is 1.29533 billion. Near 80 percent of the people live in rural.

The volume of China's water resource amounts to 280 million m^3 with over 7 percent of the world's water resource, which is the forth in the world and less than Canada? Brazil and Russia as well as more than U.S.A and Indonesia. Although large quantity of water resource, too many population make the volume of water resource per capita lower. The volume per capita reached from 2251m^3 in 1998 to 2220m^3 in 2000, with only over 25 percent of the world. So United Nations considers China as one of 13 water shortage countries. The distribution of China's water resource is also irregular. The volume in the northern of China is only 995.4m^3 which does not reach the international standard (1000m^3).

Water environment of China has deteriorated increasingly. In the past decade, the volume of sewage discharge in enterprises on an average annually amounts to 60 billion m^3 out of which 50 percent comes from industry. But the rate of sewage treatment is under 70 percent. And in 1999, the volume of sewage discharge of daily life in urban is above 50 percent of volume of industries. Water pollution is mainly caused by these following reasons:

a) Sewage of industry;

b) The rising of sewage discharge in urban;

c) The rising of sewage discharge in rural.

Present situation of latrines in urban areas of China

In the light of WHO Global Water and Sanitation Assessment 2000 Report, the coverage rate of sanitation latrines was 38% in China which 68% belonged to urban areas and only 24% laid down in rural areas. The report indicated that more than half of Chinese were difficult in enjoying necessary sanitation facilities.

In China city where with sewage system flushing latrine hold a dominating position, accordingly there are 80 million flushing latrine in China. The volume for water flushing adds to 14 million liters each day, which corresponds to the volume of 140 medium water works (100,000 ton per day). Investigations concerned show that the water consuming in flushing system amount to 50% of the total family water consumption. We call the waste water which come from latrine as black water, that means these part of water are polluted seriously. Black water contain a lot of pathogen, parasite spawn, furthermore its COD as well as BOD, SS are much higher in black water than in grey water. Survey also manifests that total bacterial in black water reach as high as 10^4---10^5/ml, coliform could be more than 10^5/l, parasite eggs more than 100,000/100ml. BOD could be high to several thousand ppm, COD even reach more than 10,000 ppm. Compare to mixed sewage, its BOD is about 200 ppm, COD is a little higher but not more than 400 ppm before its treatment. From what are mentioned above, we can safely arrive at a conclusion that both quantity and quality of black water take up the most proportions in city domestic sewage.

In small towns, quite lot of residents use three-compartment septic tank toilet, but they are no way to treat the excreta since no land for garden, the tank always take black water as well as grey water, furthermore sewage system is not so good in these towns, waste water discharge without order, so water pollution is more serious in small town general speaking.

Owing to lower treatment rate for urban domestic sewage in China, what sewage discharges outcome directly results in contamination of rivers and lakes. Nowadays the trend of water pollution is worsening and affecting the sea basin nearby. Frequence of red tide in close sea increasing every year has been alerting us to the crisis facing water pollution deterioration. With economic rapid development and the fast pace of urbanization in China, new adding city population attains to more than 10 million each year and floating population exceeds 100 million, all these factors make the increase of city sewage discharge and water pollution control will become more and more challenging assignment.

Present condition of latrines in rural areas

Different from city, in history peasants in China have been used to manufacturing organic fertilizer by means of human and animal manure. They keep this tradition although demand of chemical fertilizer has been raising since 1960s all the long, dung application remains in quite a few village regions. As a result, most latrines in rural areas are built independently and the peasants dispose the manure individually by themselves.

On account of backward economy and education, rural latrines exists two issues in China, one is low coverage rate and the other is that the latrines is too simple and the excreta is unable to achieve harmlessness. This is the key reason that the incidence of intestinal infectious disease and parasite sickness in rural areas is still so high.

With respect to coverage rate of rural latrines in China, the data between WHO and China authorities—National Patriotic Health Campaign Committee (NPHCCO) have a great difference. By the end of 2000,WHO statistic data was 24% but the data of NPHCCO reaches 44.8%(Fig1 showed 39.8% in 1999). In terms of proportion of all kinds of latrines declared by NPHCCO maybe we can find out the answer. NPHCCO who serve as authorities, takes in charge of latrine construction and improvement in rural areas in China. At present stage, it recommends 5 kinds of sanitation latrines to the country of China. The kinds are: Three-Compartment Septic Tank latrine; Triplex Biogas latrine; Double Urn Funnel-pan latrine; VIP latrine and Urine-Diversion Eco-san latrine. The first four have applied for a long term in China. Urine-Diversion Eco-san latrine was only introduced from Sweden in 1997,which was listed as recommendation latrine in 1998 by NPHCCO. Up to now its quantity is still little so proportion graph only provide the first four kinds of toilet amount for percent in whole country, even in Guangxi province (one of the eco-san latrine pilot project province by Sida and NPHCCO), this kind of latrine did not put into graph. Figure 2 show proportion of different kinds of latrines in China. From the graph we can see, beside four kinds of latrines which are recommended by NPHCCO, the "other'' take almost 50% of the constructional graph, most of this part was shallow pit dry latrine and some of them even took the public latrine instead of household latrine. Shallow pit dry latrine is so simple in structure and that it can't meet the sanitation standard, it is not only smells foully but offer a reproduction area for fly and mosquito, even more this kind of latrine gives rise to the pollution of surface and ground water so which is the objective of rural latrine reform.

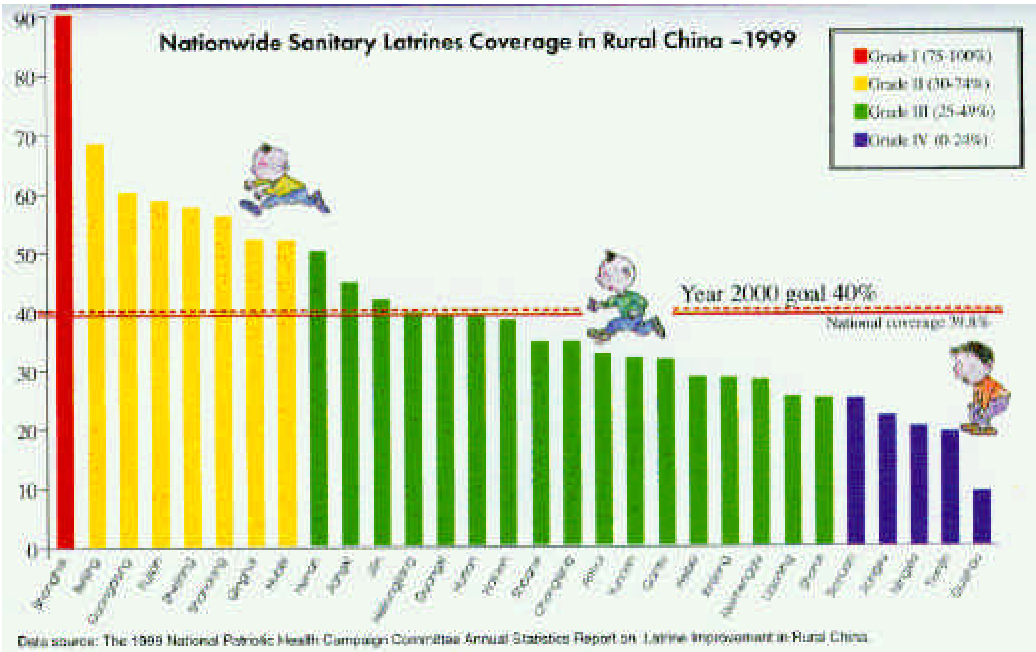

Figure 1: Nationwide sanitary latrine coverage in rural China-1999

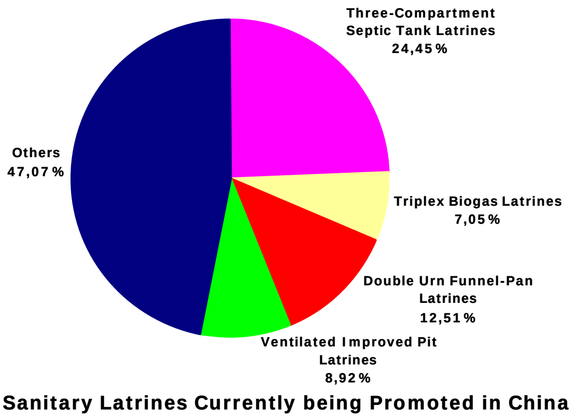

Figure 2: Type of sanitary latrine currently being promoted in China

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In order to know which kind of latrine is more suitable in which areas, and make the latrines improvement is more effective and more economic, we made some comparisions among these latrines used in China rural as below.

Comparison of sanitation latrines in rural in China

Water- flush latrine

This kind of latrine is introduced from the west, which requires water supply ,water outlet facilities and sewage treatment system. All these need strong financial support and it is too expensive for most developing countries. Owe to dear costs, it is hard to put into large scale practice in many developing countries. Another deadly shortcomings are not be neglected, One is it consume a lot of clean water, another is it could cause serious water pollution.

Three-Compartment Septic Tank latrine

This kind of latrine is quite popular in China rural areas. It costs about 1000 RMB to build and it is possible to put the latrine inside the house and put the tank outside.

The faeces are keep in the tank and it will take about 50 days to go to the third compartment, pathogens and parasite eggs are killed in anaerobic environment. In case of correct operation and following rigid construction requirement, this kind of toilet sanitation is also quite well. The date from different places is certificated compared with the first compartment, parasite spawn reduce by 95.5% and its mortality rate attains 80 % or so. Coliform bacteria decreases by 99%.NN increases three times. But the price of this kind of latrine is rather expensive for a large farmers in rural of China now.

Triplex biogas latrine

On the basis of three-compartment septic latrine, marsh gas tank latrine is mapped out as a sustainable energy latrine. Marsh gas is produced by seal fermentation and then passed through a pipe into family house. Which can be used in cooking ,boiling as well as lighting . The fermentation tank treat not only the human faeces but the excreta from the animals as well.

The system costs about 2000---3000RMB,compare to farmers' income it is quite expensive, but the family could get money back from energy consumption and organic fertilizer, general speaking the family could get the investment back in one or two years by this way. Since the family use the gas as energy instead of wood so it is good for forest preservation.

Beside the high investment the biogas system has its another problem, that is sanitization. Since fresh faeces is mixed with old one and it is no enough time to kill the pathogens, so the ending from the tank need to be treated secondly before using as fertilizer but it is not so easy when practice in large scale.

Double Urn Funnel-pan latrine

Double Urn Funnel-pan latrine was invented by Henan Province. Compare with three –compartment latrine ,this kind of latrine use two urn instead of the tank, by this way, it only costs about 1/2 of the three compartment latrine. The principle of sanitization is same in both kinds of latrine. Quite lot of study indicate, if use and manage carefully, it could be meet sanitation standard.

Since its urns are not so big, so the most important thing is to control the flush water after each visit and never put the grey water into the urn.

Ventilated Improved Pit latrine

According to own special climate characteristic, deep pit latrine, a uncomplicated latrine, it invented by Jilin Province .the pit is deep as 1.5 m over the frozen soil. Apart from a moving cement plate(10 mm thick, served as seal material),manure store in pit naturally from two to three months, which can reach fundamentally harmlessness. Adding a vent piper on the pit, it become a quite famous VIP latrine .

The price of this kind of latrine is almost same as Double Urn Funnel-pan latrine and it is common in the north of China.

Urine-Diversion Eco-san latrine

Urine-Diversion Eco-san latrine is a creation newly out of traditional pattern and has different kinds of model. China introduced this kind of toilet from Sweden in 1997. Guangxi as one of pilot project side began its construction in 1998. Since the pilot project was so successful, Guangxi PHCCO promoted it in Yongning, a county belong to its capital city Nanning (the capital of Guangxi) at large scale.

There are some obvious features of this kind of latrine but the most obvious is its flexibility, it could be build by no more than 200 RMB but it still works well, it also could be built more luxurious combined with bathroom and become permanent sanitation facility just like their house, in this case it only take about 500—800 RMB. Another obvious feature is this kind of latrine could be built inside the house easily, so the user enjoy it very conveniently and easy to manage it as well.

In Yongning county, eco-san latrine has been developed with biogas digester and physical environment comprehensive improvement at same time, by these ways, forming the ecosan village a new model for sustainable human settlements in rural areas. Ecosan village is welcomed by local people from its beginning and there are more than 200 ecosan villages now in Guangxi more than 10,000 households and about 50,000 population have benefited from this system.

By the end of 2002, Guangxi will complete 100,000 units of ecosan dry latrine , the latrines has been increased at least double each year in Guangxi since its introduction in 1998.

Because of its outstanding achievement in developing eco-san, the first international ecological sanitation conference was held in Nanning, Guangxi in 2001. More than 300 participants from domestic and abroad visited ecosan villages in Yongning. In the Conference Report which published latter, Guangxi was praised as jewel in the ecosan crown of the world. Guangxi is going to introduce ecosan system into urban areas, the pilot project will be started next year.

Conclusion

Because the population of China are distributed irregularly across vast areas, the condition of the water source, climate, economy and others are rather different. Sanitation latrine should conform with the standards and fulfill the requirements of safety, hygiene, affordable cost and service ability. These kinds of latrines above have some different characteristics in China, so that can be fitted different area in China:

1. There-Compart Tank Septic latrine is good for most part of China, but mainly used in the south because it needs enough water and the price is not so cheap;
2. Double Ure Funnel-pan latrine is more suitable for temperate zone where soil layer is thick and rainfall moderate;
3. Triplex Biogas latrine is suitable for rural areas in the valleys of the Yellow River and the Huai He river ,and to the south of Qin Ling ,and the price is also not cheap;
4. Ventilated Improved Pit latrine is suitable for areas with little rainfall or arid and areas where the level of underground water is low;
5. Urine-Diversion Eco- latrine ,faeces and urine do not mix, ash are used to cover faces and no water needed for flushing, and the price is rather cheap, it is good for almost everywhere, especially for areas is scarce of water and the climate is cold.

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Overview on worldwide ecosan – concepts and strategies

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Keywords

Ecosan technology components, introduction strategies, pilot projects

Abstract

This paper aims to describe some of the current ecosan concepts and strategies spread world-wide in different developing countries. Based on field visits and working experiences in Afghanistan, Belgium, Burkina Faso, Bolivia, Botswana, Burundi, China, Cuba, Germany, Lesotho, Mali, South Africa, Turkey, Tunisia and the United Arab Emirates the currently applied technology components suitable for ecosan will be presented as a slide show, and some closed loop concepts operating under different framework conditions will be briefly explained.

Introduction

Generally speaking, there are two types of closed loop nutrient, material and energy recovering ecological sanitation concepts: (A) dry sanitation and (B) waterborne sanitation. As all human life requires water, even the so-called dry sanitation of households has to integrate the greywater stream produced by humans, an often neglected fact in strategic ecosan discussions. Often households served by dry sanitation systems need additional investments to solve their greywater problems.

The first step for the introduction of waterborne ecological sanitation would be a fully mixed wastewater stream (including organic waste, but without rainwater), with strict water saving and recycling measures being introduced. As a second step, in-house-stream-separation could be achieved, with low charged greywater bypassing the treatment system, then urine diversion or liquid/solid separation could be installed.

Analysing some of the ecosan approaches used world wide , the introduction of ecosan concepts can be divided into three groups: (1) individual household solutions (on site solution), (2) neighbourhood solutions (decentralised systems), (3) communal solutions (centralised systems) with combinations of the above mentioned two areas and three group often being found.

Dozens of technology components are already well known and will be presented in the slide show during the presentation of this paper in the symposium. They could be classified in A1 (dry sanitation as on site solution), A2 (dry sanitation as decentralised solution), A3 (dry sanitation as communal solution), B1 (waterborne sanitation as on site solution), B2 (waterborne sanitation as decentralised solution), and B3 (waterborne sanitation as communal solution).

Examples "on the way"

Vacuum sewer as a key technology in a waterborne ecosan concept in Botswana

In Botswana, the first vacuum sewer system in Shaoshong (10.000 hab.) is under construction, with complete local financing. The vacuum system will be the first on the African continent. The idea is to compare a conventional gravity sewer system with a vacuum sewer in the same town in a flat area, gradually introducing household water saving measures later , along with simple treatment procedures, and to develop community based and household centred nutrient reuse concepts for both types of sewer system (central sludge treatment and reuse, individual greywater separation and gardening, household water saving measures, household based rainwater harvesting, urine separation and use etc.). The final decision to compare both systems was supported by a Ghanaian consultant (working for a local consulting firm), who prepared the bidding procedure and supervises the construction work on behalf of the Government of Botswana. The contract for both systems was won by the Chinese Civil Construction Company, which is working with experienced workers from Botswana, Zimbabwe, Zambia and Chinese engineers. The material for the gravity system (uPVC pipes and concrete manholes) is locally manufactured, the vacuum sewer pipes (uPVC) are also locally manufactured in Botswana, and some special equipment (vacuum pumps, household connection chambers) for the vacuum system comes from Germany.

First evaluations show that the investment for the vacuum system is 23% lower than for conventional gravity sewers, due to less excavation, a smaller pipe diameter, much less working time, fewer pumping stations (flat area), and there being no need for large machinery for the excavation work. Local, unqualified workers could manually carry out the excavation work manually. As the vacuum system investment is cheaper than the conventional sewer, the consultant charged a higher planning and commission fee, as did the contractor. They therefore had a lower profit margin when installing the conventional sewer.

It is expected; that there are even lower operational costs, with only one central vacuum station planned for one half of the (village) town, rather than between 4 and 6 pumping stations being needed. Moreover, there is no need for the central water works to flush a vacuum sewer during the night, as the recently installed gravity systems in neighbour towns require. There, the town population is not consuming the amount of water planned for standard household water connections, due to the steadily increasing water price, the high connection fees, separation and recycling of greywater for gardening, low flush systems instead of conventional one gallon flushes etc. and therefore a flushing of the system at night time is necessary.

Dry ecological sanitation in Botswana

The "CBNRM - Missing Link" project endeavours to introduce a new approach to Community Based Natural Resource Management (CBNRM), which consists of starting at a household level (Household-centred Approach HCA)[1] and, at a later stage, to transfer the knowledge to the wider community. It aims at first understanding the interactions between people and their environment, and secondly to pilot the integrated management of all natural resources at household level with a long term vision of expanding results to a community level. It defines the concept of environmental management as "the implementation of a set of activities / measures which pursue sustainable natural resource utilisation and safe environmental sanitation at household and community level".

[1] The HCA supports a process whereby the "thinking starts at the household level. The solution to the problem might be at any level" and where the conventional model of the past whereby decisions would flow from a national level down to household level by passing through all other intermediary levels is turned into a circle in which "the flow of decision-making is in both directions not only out from the centre, but also in towards the centre". One of HCA main aims is to encourage first Households, then communities to look at environmental issues in an integrated way (including water, waste, sanitation, backyard and natural resources generally). ***HCES-The Household-centred Environmental Sanitation Approach, a new way to increase the sustainability of water and sanitation projects***, Report on the 16th AGUASAN Workshop, June 26 to 30, 2000, Adrian Coad, SKAT.

The project is being implemented by IUCN (The World Conservation Union), an international NGO, in partnership with the Permaculture Trust of Botswana (local NGO) and with the financial support of the German Government.

It focuses on household practices around:

- Ecological Sanitation and use of by-products as fertiliser (urine) and soil conditioner (dry faecal matter)
- Water conservation, rainwater harvesting, grey-water reuse
- Use of organic and non-organic waste (reuse and recycling)
- Gardening and agricultural product marketing

All these aspects are combined with the aim of improving rural livelihood, including imporved hygiene, and thus improved economic and social conditions. One of the most innovative aspects implemented by the 20 families identified in three villages of Western (Kalahari area) and Eastern Botswana is the concept of ecological sanitation. Families have chosen the urine diversion system (dry sanitation), whereby urine is diverted into a container for collection, and faecal matter is kept dry and collected in a bucket or hole. This project is one of the first that is includes children under five as users of separation toilets and introducing urine diversion toilet pedestals with additional kiddie seats, produced in South Africa. The use of the by-products from the urine diverting toilets as fertiliser and soil conditioner for gardening, is combined with composting of organic waste, rainwater harvesting, grey-water re-use and non-organic waste recycling as building material, towards improving rural livelihoods in a sustainable manner.

The ecological sanitation part of the project is facing two main problems: (1) a highly subsidised sanitation system in Botswana, whereby pit latrines are provided by the government with only a symbolic contribution by each household, and (2) the seasonal migration of households to their fields and livestock areas, far away from their home villages. The project addressed these problems respectively through an intensive awareness raising on the added values of ecological sanitation systems and by suggesting the use of removable / transportable pedestals that can be transferred to the fields during the rainy season and be used in the village home during the rest of the year.

People, once adequately informed, are open to new technologies. Households voluntarily accepted to invest in the construction of the superstructure of the toilets and thus move from a highly subsidised system to a self-help system.

Different ecological sanitation concepts in China

Chinese eco-sanitation experience is thousands of years old. Ecological sanitation in China is defined as 'sanitation systems based on preventing pollution, destroying pathogenic organisms, recycling human (and animal) excreta, greywater, and organic household (and farm) waste'. This ecosan concept was tested with strong support from Sweden in relatively small-scale projects in rural areas in Southern China, and it was even introduced more than 50 years ago through integrated rural biogas programmes for small pig farmer families all over China. Now it is ready for urban applications. It is in urban areas where there is an urgent need for alternatives to conventional sanitation. All around China, there are fast growing small and medium-sized towns where most households have no access to a hygienic sanitation system. There are 47,000 such townships with a total population of more than 200 million. Often, the municipal economy does not allow large investments in pipe networks, pumping stations and treatment plants and many towns are critically short of water. However, not only for such townships, ecological sanitation systems based upon decentralized management of human excreta, greywater and (organic) household refuse could be an immediate solution.

Eco-sanitation with urine diversion

The use of night soil as fertilizer is far from new in China. Around 93% of agricultural households utilize human excreta in this way. However, what is new is the introduction of a sanitation facility, which allows for the diversion of urine and the treatment of faeces so that the practice can be safe and the facility pleasant to use. Modern-style waste and wastewater stream separation, i.e. 'ecosan', began in 1999 in three provinces under a pilot project supported by Sida and UNICEF. In Guangxi, ecosan is promoted as a comprehensive drive for a better village environment, including paved lanes, improved kitchens, biogas digesters, and other amenities. There are now 100 'ecosan villages' in Guangxi; around 30.000 private tiled toilets have been built. Ecosan facilities have also been constructed in schools. The programme is so successful that rapid expansion, in Guangxi and elsewhere, is ongoing.

„Decentralised Wastewater Treatment Systems“ - DEWATS

The project had been co-financed by the Commission of the European Union, with a substantial contribution from the State Office for Development Co-operation of the Free Hanseatic City of Bremen from October 1994 to April 1998. The following organisations participated in the project: CEEIC (Chengdu) and HRIEE (Hangzhou) from China; SIITRAT (New Delhi), MDS (Kanjirapally) and CSR (Auroville) from India, and GERES (Marseilles) from France. BORDA from Germany co-ordinated the project. Up to date, even after closing the development project, more than 200 such systems have been installed in densely populated urban areas of Western China. DEWATS is based on four treatment systems:

- Sedimentation and primary treatment in sedimentation ponds, (biogas-)septic tanks or Imhoff tanks
- Secondary anaerobic treatment in fixed bed filters or baffled septic tanks (baffled bioreactors)
- Secondary and tertiary aerobic / anaerobic treatment in constructed wetlands (subsurface flow filters)
- Secondary and tertiary aerobic / anaerobic treatment in ponds.

The above four systems are combined in accordance with the wastewater influent and the required effluent quality. Hybrid systems or a combination of secondary on-site treatment and tertiary co-operative treatment is also possible. Three material loops of mixed household wastewater are generally designed: water, sludge and energy. In addition, urine diversion toilets could be integrated into the concept.

Reuse of wastewater: Irrigation directly from anaerobic systems overflow in urban garden areas is best performed with an underground network of irrigation pipes. Effluent from aerobic ponds or constructed wetlands is suitable for surface irrigation, even in domestic gardens. However, the better the treatment effect of the system, the lower is the fertilising value of the effluent. Irrigation of crops should therefore stop 2 weeks before harvesting in order to protect the public health. Treated wastewater can be used for fish farming when diluted with fresh river water or after extensive treatment in pond systems. Integrated fish and crop farming is possible.

Reuse of Sludge: Each treatment system produces sludge, which must be removed in regular intervals, ranging from several from some days to several weeks (Imhoff tanks) or to several years (treatment ponds). Aerobic systems produce more sludge than anaerobic systems. Desludging should comply with agricultural requirements because sludge although contaminated by pathogens is a valuable fertiliser. Consequently, sludge requires careful handling. The process of composting kills most helminths, bacteria and viruses due to the high temperature that it generates.

Use of biogas: The use of biogas may reduce the cost of treatment. Biogas utilisation makes economic sense in the case of heavily charged wastewater, and especially when biogas can be regularly and purposefully used on-site. Approximately 200 litres of biogas can be recovered from 1 kg of COD removed. A Western Chinese household normally requires 2 to 3 m³ of biogas per day for cooking. Thus, biogas from 20 m³ of wastewater with a COD concentration of not less than 1000 mg/l would be needed to serve the requirements of one household kitchen.

"4 in 1 peri-urban agricultural ecosan-model"

Pig – Toilet – Biogas – Vegetable, combined with greenhouse production: The so called "4 in 1 Model": The model, already constructed more than 160.000 times in peri urban areas of mega-cities in Northern China, takes the ecological principles as its base, makes full use of solar energy, takes biogas as a key linkage, combines intensive peri-urban vegetable farming, sanitation and animal breeding, forms a courtyard energy ecological comprehensive application by linking biogas digester, pig-sty, toilet and vegetable plastic-membrane-roofed greenhouse under fully-closed conditions on the courtyard land through bio-energy conversion technique. It enables biogas digesters to be used all year round even in cold climates. The system promotes pig growth, shortens the breeding cycle, saves feed and increases the efficiency of livestock breeding. It is on the same plot of land, to realize biogas production with organic fertiliser collection and human faeces treatment, enriched with nutrient rich urine, to conduct at the same time farming and breeding. The greenhouses guarantee the temperature that is necessary for the biogas plants to produce biogas in winter and pre-hygenize the substrates, the produced biogas is used to raise the temperature of greenhouses and for cooking purpose. CO2 produced by burning biogas inside of the greenhouse promote vegetables photosynthesis. In addition, the digested slurry and sludge is applied as fertilise to the vegetables. The seedlings will be even and strong and the survival rate will be high after transplanting, so long as biogas fertiliser is used to raise them. Applying biogas fertilizer saves a lot of chemical fertiliser and agricultural chemical; the economic benefit is promoted naturally. In short, this technology can promote the utilisation ratio of biomass and produce vegetables without pollution, plant diseases and insect pests.

Biogas septic tanks as a key technology for a water borne closed loop concept in Lesotho

Lesotho is selling drinking water to South Africa, but in the capital Maseru, high quality drinking water is rare. Groundwater and lake water pollution in the city area was measured and Pit latrines and Septic tank overflow identified as contaminating source. The rocky underground is impermeable. At the other side, the large urban housing plots could be more efficient used for urban agriculture and gardening, a need in a land where the arable space is under pressure. The central sewer treatment system is under loaded, because only a small part of Maseru city is connected and even half part of this sewer-connected area could not reach the treatment plant, because since years the pumping station is out of order. Reason: high operation cost and technical difficulties, resulting in an untreated shortcut to the border river.

Supported by the German Embassy, the German Service for Development (DED) is realising some training and demonstration measures for household centred and community based closed loop on plot reuse of all wastewater and nutrients, driven by a market oriented sanitation approach.

The first system, a small bore sewer grid for eight houses (40 persons), a biogas-septic tank unit, and an upflow filter based on recycled plastic bottles, a wetland, and 800 sqm. Vegetable and fruit garden, and two household connections for the biogas as full cooking energy source (for two families), has been installed and is now one year under full service conditions. Moreover, organic waste of the whole neighbourhood is composted in the garden area. The demonstration effect shows, that there is a all year around gardening possible, with higher yields and quality than only rainwater depending agriculture and much cheaper than use of piped fresh water fro irrigation with additional fertilizer use. Driven by private demand and investment, an extension of similar systems for individual households and neighbourhood (3-10 houses) is on-

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going. Due to the German support, actually, each site is used for training of private constructors and engineers, even from South Africa.

As the non-separation of streams results in a potential over-fertilisation of the garden area, and as first results of the pilot unit shows, that the biogas-septic tank unit could be smaller with the same energetic efficiency if the hydraulic charge is lowered, the next steps planned are the stream separation of greywater and blackwater, than later one the introduction of urine diversion. However, this last step than, when the gardening and urban agricultural demand is established and a liquid fertiliser demand are stabilised.

Greywater gardening through ecosan in Mali

Koulikoro, Mali, has a central potable water supply system dating from the 1970s, but yet no sewage system. In an arid sub-Saharan country like Mali, where financial and water resources are scarce, a water-carrier sewage system resembling those used in Europe would be inappropriate and too expensive. Mali is also faced with the steadily worsening problem of soil degradation, up to and including desertification, chiefly because of agricultural overuse and insufficient return of nutrients.

An affordable means of proper wastewater disposal is needed. Therefore, GTZ and DED developed on-plot household ecosan systems in which faeces, urine and greywater could be separately collected and treated. This offers major advantages over conventional latrine based systems, as it enables the hygienic recovery of soil amending substances from faeces and of nutrients from urine and purified greywater. These ecosan systems are also in harmony with local traditions.

In 2002, the National Sewage and Solid Waste Department at the Malian Ministry of the Environment incorporated the greywater gardens and separating toilets developed by the ecosan initiative into its program. Together with GTZ, the department is now examining their suitability for widespread introduction. Ultimately, however, the success of greywater gardens depends solely on the degree to which women for growing vegetables accept them, bananas and papayas.

Some ecosan technology components showed in pictures

- Urine diversion with dry sanitation (seat toilet, squatting toilet, water saving urinals)
- Urine diversion with flush systems (seat toilet)
- Liquid/solid separation in dry toilets (on site)
- Liquid/solid separation in flush systems (on site)
- Rainwater collection and separation (on site)
- Rainwater reuse devices
- Compost toilets combined with urine (on site)
- Bucket and bag toilets (on site)
- Vacuum sanitary equipment (on site)
- DEWATS
- Biogas technology (for wet and dry systems)
- Filter technology (many kinds)
- Vermiculture
- Constructed Wetlands
- Rotational disks
- Drying techniques
- …

Lessons learnt

Often, the introduction of ecosan concepts faces several problems, such as the initial costs of introducing new sanitation concepts and systems, unclear institutional responsibility, social habits to use toilets as receptacles for all kinds of waste and a certain resistance to new ideas among those currently promoting other forms of conventional sanitation. A successfully implemented pilot project in each country or region will serve to help overcome these difficulties.

Afghanistan

Urine and washing water diversion systems have been used for hundreds of years. It can be used for a maximum of 5-8 users per day/toilet room. The liquids are piped out of the building and dried in the open air. The faeces have been collected the whole year around in a half open chamber. When it was frozen in wintertime, the faecal matter can easily transported to the fields, stored in heaps and was used in summer time as dry material as agricultural soil improvement. The ground water table in Kabul is high and the sandy soil has almost no biodegrading capacity, so the separation of urine, water and faeces is/was the best environmental solution to prevent water pollution. Unfortunately, due to a much higher density of the actual population, these diversion toilets are currently overcharged.

South Africa

One part of the idea for urine diversion was introduced in South Africa as a result of a workshop in Mexico. First, Mvula Trust brought the mould from Mexico for cement toilet seats. In different rural areas, the seats with the original Mexican dimensions have been introduced with and without urine diversion. Due to the different quality of the seats caused either by the manufacturers, the material used, or simply because of the way they were used, many of the toilet seats have broken. Based on this experience, a stronger cement mixture and a bigger “bowl wall thickness” were introduced and new moulds have been developed. For this reason in some “ecosan project” villages, we will find other uses for former broken Mexican dimensioned cement toilet bowls.

A famous urban household in South Africa is used as demonstration site. The sanitation system of an old townhouse were converted from flush toilets to a dry bucket toilet with urine diversion and collection. The cleaning management shown to visitors is not so promoting, due to less working space under ground and difficulties to get the bucket in a clean way in and out the toilet hole.

Urine diversion seats: Especially when children are not included in trainings how to use urine diversion seats, the misuse of the different sections leads to blockages, urine contamination, dirt etc.

China

In some dry sanitation rural ecosan projects, dry toilets with urine diversion have been installed. Due to the fact, that the farmers are pig raisers, the have already a biogas plant to treat pig manure (where sometimes - as designed - even a toilet has already been connected) before applying it to their agriculture. As these biogas households are cooking on biogas, no ash will be available from their kitchen for the dry toilet system. Therefore, they have to burn straw to prepare “toilet ash”.

Introducing flush toilets in some suburban areas led to the use of four toilet systems in some farmer households: (1) in house flush toilet for visitor and for during night, (2) transportable pot latrines for in-house use at night time, (3) out-house toilet with collection chamber for the pot collected “night-soil” and the “day-soil”, (4) urine pots for collecting urine as intensive vegetable fertilizer

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Some applied ecosan introduction strategies and tools, found in different countries

Introduction strategy step	tool
Political support available or can be created	Advocacy and information workshop
Build on what is already on-going	Baseline study
Appropriate knowledge available or accepted	Study tour with decision makers
Social, scientific and economic acceptance	Feasibility study
Spreading know-how	Training workshop, health campaign, fertilizer demonstration, lecturer in vocal training centres and universities
Working with clear objectives	Project Cycle Management, Logical Framework
Gender Impact Monitoring	Gender Impact Matrix
Optimise dissemination factors	Regional networking, demonstration unit, demonstration field
Right people on place	Championship, Bellagio Principals
Strength local ownership available	Public Private Partnership, BOT

Minimum frame conditions for successful ecosan introductions are:

1. existing (organic) (urban) agriculture with reuse of wastewater, urine and/or faeces,
2. existing ecological movements, awareness, and awards,
3. comparable high costs for centralized gravity sewage piping connection,
4. water related problems (high groundwater table, scarcity of water, pollution).

Data sheets on ecosan technologies and projects - an information management tool in process

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Keywords

Ecosan - reference projects, project data sheets, technical data sheets

Introduction

Ecosan ideas are currently spreading with a tremendous speed, with more and more projects throughout the world having been started over the last few years. This fact is to be warmly welcomed, however it also renders it extremely difficult to follow developments and to obtain an overview of current trends and practices. The available published overviews of ecosan-projects and technologies are incomplete and become outdated very quickly. To address this problem, the ecosan-project team of the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit GmbH) in cooperation with the SIDA (Swedish International Development Cooperation Agency) founded EcoSanRes-Programme of the SEI (Stockholm Environment Institute) are working on an overview list of the existing pilot and research projects. Additionally, information on interesting and exemplary projects will be realised in the form of data sheets.

Project overviews and data sheets

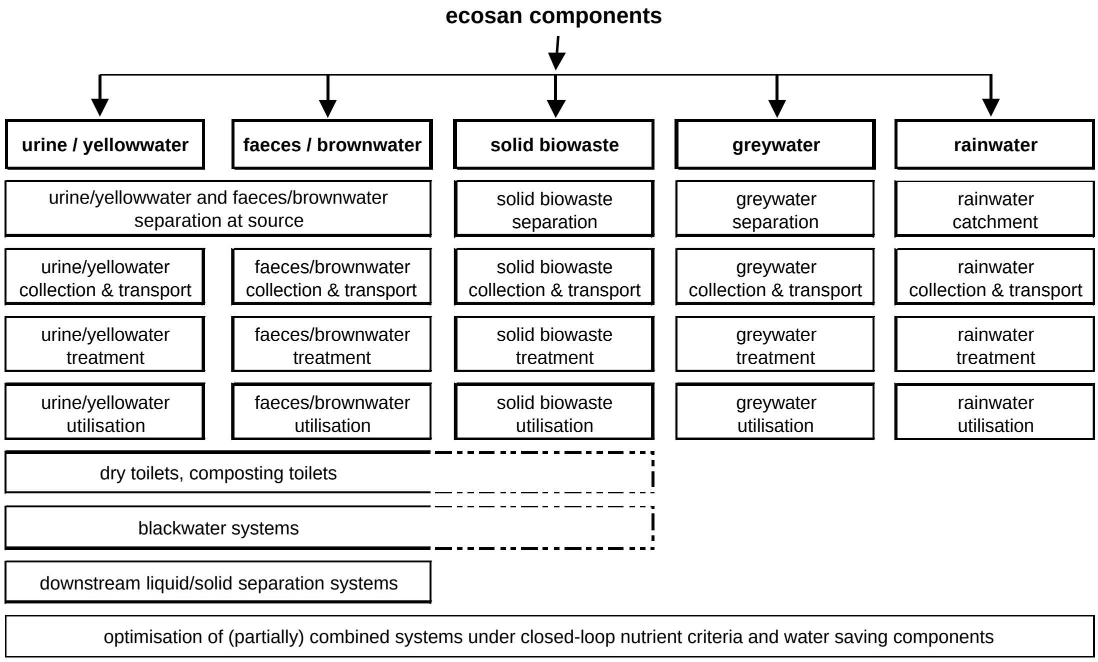
The following information will be included when compiling both the project overviews and the data sheets:

- country and project title
- project type (e.g. study, pilot project, research project, dissemination project)
- project scale (type of settlement, size (habitants, area …))
- current phase (advocacy; baseline study; pilot -, implementation -, or going to scale phase)
- planning institution
- supporting agency, executing agency, executing institution
- basic and general conditions (e.g. climate, users habits, availability of water)
- technologies applied and type of reuse, use, recycling
- costs (in Euro with basic year, e.g. investment and operations costs per inhabitant)
- design and technical specifications
- practical experience
- available documentation and publications (e.g. studies, reports, photos, films)
- website and contact persons

In addition to the research and pilot project data sheets, information sheets on the currently available ecosan technical modules will also be developed. These will provide information on the best available technologies and the different firms providing them. This task will be performed in co-operation with the technical working group of the ecosan project.

Technical data sheets

The technical data sheets will be developed using the following structural framework to categorise the technologies:



For the compilation of the technical data sheets the following information is to be included:

- process description
- basic and general conditions (e.g. application area, limits, restrictions)
- range of application
- design and concept (e.g. technical details, varied designs, state of dissemination)
- function (functional characteristics, manuals, operation instructions etc.)
- evaluation under ecosan-principles (pros and cons)
- economical data
- conclusions and further development
- producer / manufacturer
- references and further information

The project and technical data sheets will be made available through the internet by GTZ-ecosan and EcoSanRes. They will be published as pdf-files to keep download times to a minimum and to ensure that the online view matches the printed version.

Linking urban agriculture and environmental sanitation

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Keywords

Environmental sanitation, Ghana, Kumasi, material flux analysis, urban agriculture, West Africa

Abstract

In developing countries, demographic and urban growth often results in severe environmental and social problems, including the lack of adequate water supply, environmental sanitation services and food security. Reusing waste products in peri-urban and urban agriculture can contribute to food security and reduce environmental pollution and waste management costs. A comprehensive method is required to assess the potential and limitations of channelling urban waste products to peri-urban and urban agriculture. Material Flux Analysis is a helpful tool to assess material fluxes in a given system. It allows to identify problems and to quantify the impact of potential measures on resource recovery and environmental pollution. The present study analyses the material/nutrient fluxes of the city of Kumasi, Ghana. Import and export of products into or from the given system are recorded. Processes are identified and material fluxes between these processes are determined. The analysis revealed that households are the key process for material and nutrient fluxes. The groundwater and surface waters receive large amounts of waste products from the households. Reusing organic waste products in peri-urban and urban agriculture could significantly improve the organic matter and nutrient situation of agricultural soils and also protect the environment. However, a treatment process (e.g. co-composting) is required to reduce the health hazards related to the use of waste products.

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Introduction

Demographic and urban growth is one of the major challenges of the next decade. In 1994, 45% of the world's population lived in cities; by 2025 this figure will have risen to 65% (Nugent, 1997). The most rapid change is occurring in the developing world, where urban populations are growing at 3.5% annually. Historically, cities have been the driving force in the field of economic and social development. However, urbanisation not only provides benefits, but also creates environmental and social problems. These include a lack of adequate water supply, environmental sanitation services and food security.

This challenge should be faced by a holistic approach to environmental sanitation and urban agriculture. Human and municipal solid waste is a cheap fertiliser as it contains significant amounts of nutrients for food and non-food crop production. Reuse of municipal wastewater and solid waste in urban agriculture is usually the most effective way to reduce waste treatment and disposal, provided public health is not impaired. However, it is often difficult to quantify and assess the potential and limitations of nutrient recycling in environmental sanitation systems.

A helpful tool for linking environmental sanitation with urban agricultural production is the "Material Flux Analysis" (MFA). The method studies the fluxes of resources used and transformed as they flow through a region, through a single process or via a combination of various processes.

It allows planners and decision-makers to identify key processes, and to suggest appropriate environmental protection and resource recovery measures in a given system. In industrialised countries, material flux analysis proved to be a suitable instrument for early detection and solution of environmental problems. Data from market research can be combined with those from urban waste management to analyse the metabolism of urban regions (Baccini and Brunner, 1991).

In this study, fluxes of organic material are used to describe the present system in Kumasi, Ghana with 982,000 inhabitants spread over 254 km^2, of which 38% is open land (Kumasi Metropolitan Assembly, 1996). The peri-urban districts cover an area with a radius of about 40 km from the city centre beyond the administrative boundaries of the city and with about 740,000 inhabitants (Blake and Kasanga, 1997). Breweries, sawmills and poultry farms are important industries regarding organic material fluxes. Existing sanitation systems such as unsewered public toilets, pit latrines or septic tank systems are recorded. Production and supply of organic material (e.g. agriculture, industries), including production, collection and treatment of urban waste, like human excreta and municipal solid waste, are quantified.

Method

According to Baccini and Brunner (1991), development of a regional material flux analysis starts with an analysis of the overall system: Goods, processes, system borders and time period have to be defined. The term ”materials or material mixtures” is used for chemical elements and their compounds such as nitrogen, nitrate, phosphorus, and phosphate. Materials and material mixtures with functions valued by man are defined as “goods”. Transport, transformation or storage of materials and goods are called “processes”. While in most cases transport does not change the chemical composition of goods, it requires energy and involves other goods and materials. The same applies to storage. Through transformation, goods are converted into new products with new qualities and usually different chemical composition. In system analysis, goods and processes are linked. Each good has one origin and one destination process. Consequently, each process is linked to other processes by means of goods. A particular good, which flows from process A to process B is called an output good for process A, and an input good for process B. An import good is defined as a good entering the system, and an export good a good leaving the system. The same terminology applies to material fluxes. A flux analysis of selected materials comprises:

- Identification of goods and processes.
- Determination of the mass fluxes of all the goods per unit of time.
- Determination of the concentrations of the selected materials (elements) in these goods.
- Calculation of the material fluxes from the mass fluxes of goods and element concentrations in these goods (these fluxes can either be assessed by literature data, determined by field measurements, calculated by mass balances over a process or process chains or through a combination of all these methods).
- Interpretation and presentation of the results.

The system of organic material fluxes in the city of Kumasi, Ghana, is characterised by 7 processes within the system border, by the fluxes between these processes and by the import and export fluxes to and from the system. The administrative boundary of the city of Kumasi is chosen as the system border. Since peri-urban and urban agriculture have different characteristics, they are regarded as separate processes in the system. The environmental compartments “atmosphere”, “groundwater and surface waters”, and “soil” are sinks for the residual fluxes. They are placed outside the system border and have not been investigated here. The processes themselves are viewed as black boxes. In the case of Kumasi, material fluxes were assessed through a combination of field measurements, calculations of mass balances and literature data.

Results and discussion

According to Leitzinger (2000), an average person in the city of Kumasi consumes about 770 kg of food per year. This value is estimated with an error margin of about 20% and does not include food consumed from own production. While peri-urban agriculture covers about 66% of the household food requirements in Kumasi, urban agriculture contributes to only 14%. About 20% of the household food demand is met by import into the system. The local industry has a high turnover of organic material; i.e., sawmills, breweries and poultry farms. The raw material is imported into the system and an important part of the products is re-exported. Industry is responsible for a major nitrogen flux import of 3.2 kg · capita^{-1} · year^{-1} (Figure 1). About 54% of the nitrogen is exported and only 9% is transported to the households from industry. The remaining nitrogen is either landfilled or transferred to the air, water or soil. The industrial contribution to the phosphorus flux is low.

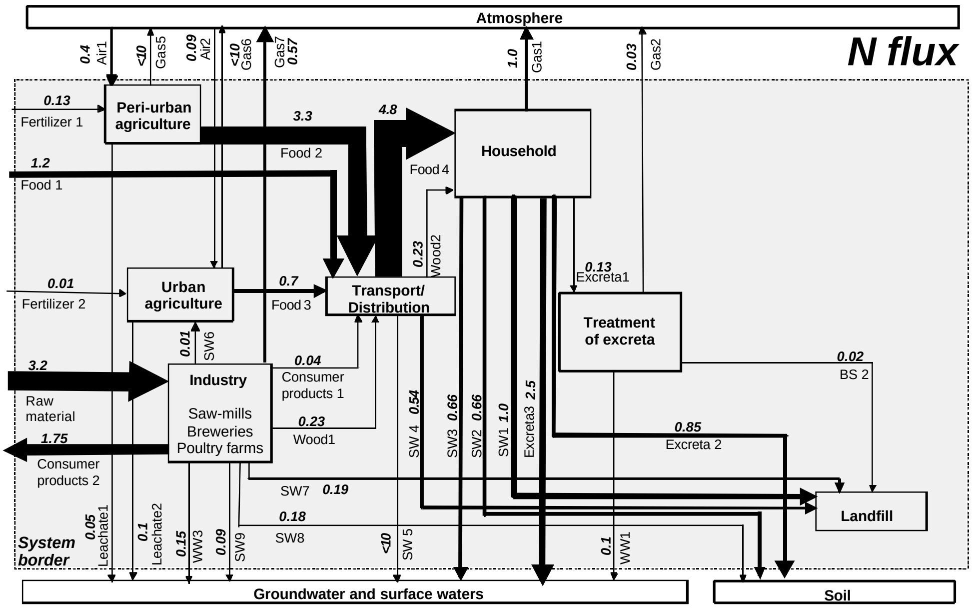

Figure 1: Estimated annual nitrogen fluxes (error margin 20-50%) of Kumasi, Ghana in kg capita^{-1} year^{-1}.

Households are the most significant transformation process with regard to nitrogen and phosphorus. In the analysed system, about 80% of total nitrogen and about 90% of total phosphorus, which is transferred to air, water, soil, and landfill, flow through the households. Households are responsible for 87% of the nitrogen and 82% of the phosphorus emissions to groundwater and surface waters, as well as for 90% of the nitrogen and 97% of the phosphorus emissions to the soil. About 58% of the nitrogen and 34% of the phosphorus fluxes to the landfill also originate from the households (Leitzinger, 2000). Consequently, households can be regarded as the key process. Measures should be implemented at household level, as they would contribute to saving resources and to protect the environment.

Groundwater and surface waters receive 47% of the total nitrogen and 54% of the total phosphorus from the households (Leitzinger, 2000). About 22% of the nitrogen and 29% of the phosphorus from the households reach the soil. About 15% of the nitrogen and 16% of the phosphorus from the households are landfilled. The faecal sludge treatment plant receives less than 2% of the nitrogen and phosphorus. The nitrogen transferred to the atmosphere is estimated at 15%.

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The total system fluxes can be calculated by multiplying the fluxes per capita and year with the number of inhabitants of Kumasi. Hence, the nutrient deficiencies in agriculture are obtained by calculating the differences between output and input fluxes. According to Leitzinger (2000), the annual nitrogen and phosphorus deficiencies in urban agriculture are estimated at 690 t and 160 t, respectively. In peri-urban agriculture, the soil lacks 2700 t of nitrogen and 720 t of phosphorus every year.

About 1700 t of nitrogen and 500 t of phosphorus originating from different types of waste are disposed of annually in landfills. Additionally, about 3600 t of nitrogen and 690 t of phosphorus are discharged into surface waters, and about 1700 t of nitrogen and 310 t of phosphorus reach the soil (Leitzinger, 2000). From a nutrient balance perspective, part of these nitrogen and phosphorus fluxes could be recycled for instance by co-composting faecal sludge and municipal solid waste, and by using the finished compost as fertiliser and soil conditioner. This could also reduce soil, groundwater and surface waters pollution and save landfill space. However, technical and socio-economic aspects must be taken into consideration in order to determine the feasibility of this recycling option.

Conclusions

Material flux analysis allows to quantify material (nutrient) fluxes moving through a defined system. It is a suitable tool to assess the emissions to air, water and soil and, thus, appropriate for early detection of possible hazards. Since it can be used to determine the impact of different waste management options on nutrient recycling and environmental pollution, it can assist in the choice of effective measures and strategies towards an integrated management of resources. Mass fluxes from and towards peri-urban and urban agriculture can thus be optimised.

In the city of Kumasi, private households are the key process for nutrient fluxes. Groundwater and surface water receive large amounts of waste products mainly in the form of faecal sludge from households. Channelling these material/nutrient fluxes towards peri-urban and urban agriculture could significantly improve the organic matter and nutrient situation of agricultural soils and also protect the environment. However, a treatment process (e.g. co-composting) is necessary to reduce the health hazards related to the use of waste products.

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Potentials for greywater treatment and reuse in rural areas

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Keywords

Cost comparison, greywater treatment, reuse, single houshold solutions

Abstract

This paper compares various ways to deal with greywater (wastewater from sources others than the toilet: e.g. kitchens, bathrooms and laundry) especially for small-scale solutions – single households and small settlements. General considerations on the treatment of greywater will be discussed as well as the advantages and disadvantaged of various treatment technologies. Finally possibilities and limitations for discharge and reuse of the end-product – treated greywater – will be discussed including health hazards. The investment and operational costs calculated for different scenarios of wastewater treatment for a single household with and without greywater separation and/or treatment show a clear economic advantage of the scenarios with greywater separation compared to the collection and treatment of the total wastewater.

Introduction

The sustainability of conventional sanitation concepts (which consist of a sewerage system and a wastewater treatment plant – technical or natural treatment systems), compared to alternative solutions based on source control and separation of the wastewater's constituent parts, have been heavily discussed throughout the world in recent years. Major projects dealing with that question are e.g. Swedish Urban Water, Swiss Novaquartis, German Lambertsmühle and the Austrian project "Applied strategies towards sustainable sanitation" (Starkl & Haberl, 2003).

It is commonly known that the main fraction of the volume of domestic wastewater comes from sources others than the toilet (e.g. kitchens, bathrooms and laundry). The water quality of this so called greywater is very site-specific, varying in strength and composition. Generally it can be said that greywater contains only low fractions of organic matter, nutrients and additionally has a low microbial contamination (Laber & Haberl, 1999).

By thinking about concepts for the future a separate collection of blackwater (wastewater from toilets) and greywater is a logical consequence. Separation of urine and faeces leads up to a reduction of 90 % nitrogen as well as 80 % phosphorus in the remaining wastewater (Laber & Haberl, 1999). The remaining relative harmless greywater can be reused after an adequate treatment to safe valuable fresh water resources as well as to safe costs. Sustainable concepts and a change of the personal behaviour of the users can therefore lead to a more ecological sanitation.

Both the quantity and the quality of greywater can be controlled at the household level. Any strategy for managing greywater can be made easier by water conservation measures and attention to the soaps, cleansers and other household chemicals used. The amount of greywater generated can be significantly reduced through behavioural changes, good maintenance of pipe and water taps, and the use of water-saving devices. About 2/3 of the total wastewater volume can be assumed to be greywater (Laber & Haberl, 1999; Jefferson *et al*., 2001).

Compared to municipal wastewater greywater contains less nutrients. The BOD_5 : N : P ratio is about 100 : 20 : 5 for typical municipal wastewater and about 100 : 4 : 1 for greywater (Laber & Haberl, 1999). The optimal ratio for heterotrophic growth is 100 : 5 : 1. Therefore a biological treatment of greywater without addition of nutrients is possible. The microbiological contamination of greywater is typically about a factor 10 lower compared to municipal wastewater. However the concentrations for phosphorus, heavy metals, and xenobiotic organic pollutants are around the same level (Ledin *et al*., 2001).

Greywater treatment and reuse

A number of technologies have been applied for greywater treatment worldwide varying in both complexity and performance (Jefferson *et al*., 2001). These technologies range from systems for single households (e.g. using disinfected untreated greywater for toilet flushing), to physical treatment systems (e.g. sand filters or membranes), biological treatment options (e.g. rotating biological contactors and membrane bioreactors), and natural treatment systems (e.g. constructed wetlands and infiltration systems). The experience has shown that especially rotating biological contactors and constructed wetlands are suitable for greywater treatment including disinfection of the treated greywater when reuse is considered (Lange & Otterpohl, 2000).

A mechanical pre-treatment is required when constructed wetlands are used as a main treatment stage. Using horizontal subsurface flow constructed wetlands a good removal efficiency for organic matter (> 90 %) and pathogens (up to a factor of 100) can be achieved. If nitrification is required only subsurface flow constructed wetlands with vertical flow and intermittent loading can be used. Compared to technical solutions (e.g. rotating biological contactor) constructed wetlands are relatively easy to maintain and operate resulting in low operating costs (however, low maintenance requirements does not mean no maintenance). In general natural treatment systems provide a more stable and robust than small-size technical systems. Disadvantages of natural treatment systems are that they require a larger area compared to technical systems and they can not be applied inside a house. For greywater treatment the specific area demand for constructed wetland is still a matter of discussion as well as the optimal design of the mechanical pre-treatment (Langergraber & Haberl, 2001).

If the treated greywater is discharged the same standards are applied as for treated municipal wastewater. In rural areas in Austria one major problem is that some receivers can fall dry temporarily. This fact has to be considered carefully when discharging effluents (Laber & Haberl, 1999).

The main risks when using greywater for groundwater recharge is contamination of the soil and the receiving groundwater body (Ledin *et al*., 2001). Using only treated greywater for recharge can reduce this risks.

Often the easiest way to recycle greywater is for plant irrigation. In many parts of the world where water is scarce, this is done as a matter of course. Greywater irrigation can be as simple as pouring it on garden areas by hand. Even where there are few gardens, greywater can be put to use, such as in the peri-urban areas in cities, where households routinely apply it on the road in front of their houses to keep dust down. However, recent studies confirm that there is a considerable amount of gardening practised in urban and peri-urban areas, so greywater irrigation is often feasible (Ersey *et al*., 1998).

For the use of treated greywater for toilet flushing only disinfected treated greywater can be used from a technical point of view (microbial growth in pipes and tanks) (Laber & Haberl, 1999).

Cost comparison of sanitation systems for a single household

Different systems of sanitation for a single household with and without greywater separation are discussed and their costs are compared (BMLFUW, 2003). The costs for wastewater treatment can be subdivided into investment and operational costs. To include the pay-back of the investments the investment costs are transformed into yearly costs (using an economical interest rate; 3.5 % are used in the examples given below). In the presented examples the assumed life-time of the treatment system (technical system, SBR (Sequencing batch reactor) in this case, and constructed wetland) is 20 years, for the sewer system a life-time of 40 years is assumed.

Table 2 compares the investment, operational, and yearly costs for different treatment scenarios. The costs were calculated using data typical for Austria. Operational costs include costs for energy, maintenance, sludge disposal, and analysis. However, costs depend on local circumstances and several, partly unquantifiable factors, thus the below given costs are different for different projects (c.f. Starkl *et al.,* 2002 and Ertl *et al.,* 2002).

Scenario		**1**	**2**	**3**	**4**	**5**	**6**	**7**
System		SBR	CW	CP	CP(BW)	CP(BW)	CP	US
Disposal of cesspit waste		-	-	WWTP	AU	WWTP	AU	AU
Separation Black-/Greywater		no	no	no	no	yes	yes	yes + US
Greywater treatment		-	-	-	-	CW	CW	CW
Investment costs								
Treatment unit	$EUR.PE^{-1}$	1'450	1'450	1'780	1'780	1'120	1'120	1'160
Sewer	$EUR.PE^{-1}$	350	350	230	230	410	410	290
Operational costs								
Treatment unit	$EUR.PE^{-1}.yr^{-1}$	240	170	370	230	160	130	90
Sewer	$EUR.PE^{-1}.yr^{-1}$	5	5	5	5	5	5	5
Yearly costs	$EUR.PE^{-1}.yr^{-1}$	**362**	**292**	**468**	**336**	**246**	**208**	**192**

Legend: SBR … Sequencing batch reactor; CW … Constructed wetland; CP(BW) … Cesspit (only for blackwater); WWTP … Wastewater treatment plant; AU … Agricultural use; US … Urine separation

Table 2: Comparison of investment, operational, and yearly costs for treatment alternatives for a single household with 5 PE (BMLFUW, 2003, modified).

Using a constructed wetland for treatment of the total wastewater (2) shows lower yearly costs compared to the conventional technical treatment system (1). When all the wastewater is collected in a cesspit the yearly costs of the scenario with agricultural use of the cesspit waste (4) are only about 75 % of the yearly costs when disposing the waste to a wastewater treatment plant (3). However, all scenarios with source separation (5-7) show the lowest operational and yearly costs. Separating toilet water from greywater leads to a tremendous reduction of the volume that has to be collected and therefore the operational and therefore also the yearly costs drop drastically. Urine separation (7) shows the lowest costs and additionally closes water and nutrient cycles on a local scale and is therefore a promising system towards a more ecological sound sanitation. The costs show a clear economic advantage of the scenarios with greywater separation compared to the collection and treatment of the total wastewater.

Conclusions

Greywater comprises about 70 % of the volume but only 40 % of the BOD_5 and less than 10 % of the nitrogen load of municipal wastewater. The BOD_5 : N : P ratio of about 100 : 4 : 1 enables a biological treatment of greywater without addition of nutrients. Rotating biological contactor and constructed wetlands are best suited for greywater treatment. When greywater is reused the hygienic aspects have to be considered.

For small wastewater treatment plants especially the operational costs are essential. For the given assumptions it was shown that for single households source control solutions with separation of at least blackwater and greywater have lower costs compared to solutions where the different types of wastewater are mixed and therefore a large volume has to be treated. Besides the cost advantages these systems also close water and nutrient cycles on a local sale and are therefore a more ecological sound way for sanitation

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Selection of DESAR system for unsewered settlement in almost completely sewered society*

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Keywords

Decentralised sanitation, multicriteria, selection method

Abstract

This study, focuses on application of DeSaR concepts a rural. Three of the technological schemes of sanitation are compared to each other using the priority theory of Saaty (Lootsma, 1980).

Introduction

The 97% of the total Dutch population is connected to sewerage bringing total wastewater stream to centralised treatment plant. From the total Dutch population of about 16 million people, 88% live in urban areas, while 12% have their residents in the rural parts of the country. As in urban areas 100% of the total inhabitants are connected to a sewer system, this is only 30% in rural areas. This remaining part has mainly decentralised sanitation systems in the form of a “conventional“ 1.5 m^3 septic tank. Due to new legislation (being currently revised) all these rural areas must have an "improved" 6 m^3 septic tank or a comparable decentralised sanitation system while connection to the centralised sewer network is often not cost-efficient.

This study performed within Dutch governmental EET project led by Dept. of Environmental Technology of Wageningen University, The Netherlands on application of DeSaR concepts focuses on the rural village situated in Province of Friesland in the Netherlands as a kind of prototype for a comparable existing (rural) settlements. The considered area consists mainly of dairy farms surrounded by grassland. There are no nature parks in the surroundings and no drinking water is gained in this area. There are 10 houses, 6 farms and a church, in total presently inhabited by 61 people. The village can be divided in two parts: a central area with clustered houses and disperse farms along the boundaries of the village.

Method

The current sanitation infrastructure of considered village was characterised. Prerequisite constraints such as current treatment system, quality and quantity of waste(water) streams, specific organisational, economical and institutional aspects as well as social aspects were formulated and formed starting point for selection of different scenarios. The quantity and quality of the

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produced waste(water) was assessed. Because the distribution of the inhabitants over the village house on-site (h.o.s.) as well as community on-site (c.o.s.) treatment are optional. The null scenario is defined as the current system used for sanitation in Swichum. It consists of a conventional flushing toilet, after which the blackwater is transported to a 1.5 m^3 house on-site septic tank. The transportation takes place in a gravitational sewer system. The effluent of the septic tank is discharged into the ditches around the houses, as is the untreated greywater. Swill is collected separately by the municipal refuse-service.

In scenario 1 the greywater and the blackwater are treated separately. The greywater coming from the kitchen is pre-treated in a house on-site grease remover. Together with the rest of the greywater it is then transported by gravity in small bore sewer system to a community on-site sandfilter after which the effluent can be discharged. The blackwater is collected in a water-saving toilet and is pre-treated house on-site in a UASB (Upflow Anaerobic Sludge Blanket) septic tank. The effluent can then be transported in a small bore sewer system, to the community on-site sand filter for post-treatment.

In scenario 2, the greywater is treated in the same manner as in scenario 1. The black water is collected in a vacuum toilet system, and transported together with swill by a vacuum sewer system to a community on-site pre-treatment step in an accumulation reactor (AC) and post-treatment step for hygienisation in order to produce a safe reuse product. The product could be used as a fertiliser in agriculture, for example

The evaluation of the scenarios was performed based on a methodology developed to create ranking between DESAR alternatives. This is an example of a multicriteria problem, an optimisation problem with more than one objective to achieve. There are many mathematical methods developed to solve multicriteria problems. The priority theory of Saaty has been developed in the seventies to weigh the significant factors in a decision problem via pairwise comparison (Lootsma, 1980). The first step, according to this theory, is to identify the p factors (criteria) that are relevant for the choice between several (m) alternatives. The criteria that were chosen to be relevant for DeSaR cases were effluent quality, energy consumption, noise nuisance, odour nuisance, investment costs, operational costs, water consumption, space requirements, demands for maintenance, flexibility, reuse potential and convenience for the user.

Next relative weights were ascribed to those criteria (w_i, i = 1..p) via pairwise-comparison of the criteria by the decision makers in the DeSaR case. The pairwise-comparison matrix has 12 rows and 12 columns, and $(12^2-12)/2 = 66$ comparisons have to be made. For one person as the decision-maker, it is very hard to fill in such a matrix. Moreover, the contents of the matrix will depend very much on who the decision-maker is. People working in the field of environmental technology may fill in the matrix completely different from the inhabitants of the houses where the DESAR concepts will be implemented. In this case the matrix was filled in by the authors. The ranking and relative weights (w_i , between brackets) for the different criteria that were calculated from the matrix of the pair-wise comparison are effluent quality (0.132), noise (0.132), odour (0.132), flexibility (0.132), investment costs (0.089), operational costs (0.089), maintenance (0.083), energy consumption (0.061), water consumption (0.059), reuse potential (0.043), convenience (0.043), space requirement (0.017). Parallel to the calculation of the relative weights, the score of each alternative for every criterion (s_{ki}, k = 1..m) was determined through a literature research (Table 2). The final ranking of the DeSaR alternatives were made by, comparing the total score for each alternative ($\sum s_{ki} \cdot w_i$).

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	A	B	C	D	E	F	G	H	I	J	K	L
A	**1**	3	1	1	2	2	3	6	2	1	3	6
B	0.33	**1**	0.33	0.33	0.5	0.5	1	4	2	0.33	1	3
C	1	3	**1**	1	2	2	3	6	2	1	3	6
D	1	3	1	**1**	2	2	3	6	2	1	3	6
E	0.5	2	0.5	0.5	**1**	1	2	5	1	0.5	2	5
F	0.5	2	0.5	0.5	1	**1**	2	5	1	0.5	2	5
G	0.33	1	0.33	0.33	0.5	0.5	**1**	4	0.5	0.33	1	4
H	0.17	0.25	0.17	0.17	0.2	0.2	0.25	**1**	0.2	0.17	0.25	1
I	0.5	0.5	0.5	0.5	1	1	2	5	**1**	0.5	2	5
J	1	3	1	1	2	2	3	6	2	**1**	3	6
K	0.33	1	0.33	0.33	0.5	0.5	1	4	0.5	0.33	**1**	0.25
L	0.17	0.33	0.17	0.17	0.2	0.2	0.25	1	0.2	0.17	4	**1**

With:
A- Effluent quality
B- Energy consumption
C- Noise nuisance
D- Odour nuisance
E- Investment costs
F- Operational costs
G- Water consumption
H- Space requirements
I- Demands for maintenance
J- Flexibility
K- Reuse potential
L- Convenience

Table 1: Matrix from the pair-wise comparison of the criteria

Results and discussion

In this paper a methodology is developed to create ranking between DESAR alternatives. The final ranking of the DeSaR alternatives were made by, comparing the total score for each alternative ($\sum s_{ki} \cdot w_i$). The final scores for scenario 0, scenario 1 and scenario 2 are 2.38, 2.64 and 1.98. Scenario 1 seems to be the best option, although the scores are relatively close to each other. On basis of these values it is hard to give an exact conclusion. To be able to give a more exact ranking the scores, per criteria, have to be sorted out into more detail. Then the ranking between these three alternatives will be better distinguished.

Another point of discussion is the choice for the priority theory of Saaty. With this theory it is necessary to give a clear overview of what you want. It must be clear what the alternatives are, between which a choice has to be made. The criteria, that are important for the decision, have to be described into detail. Furthermore, the method takes into account the importance of a criterion. Choices can be made about how much detail is required for the scores. Sometimes a general ranking will be enough, but other times it is necessary to sort things out to the last detail.

There are also disadvantages of the theory. It is possible to subdivide a criterion into a few other criteria. The criterion investment costs can, for instance, be subdivided into the criteria; costs for sanitary facilities and costs for treatment steps. If an alternative scores well on these criteria, this alternative gets extra points for this subdivision. Moreover a discussed before it is very difficult to make a consistent pair-wise comparison matrix for calculation of the weight factors.

	Literature values			Score of scenario (s_{ki})		
Criteria	Scenario 0	Scenario 1	Scenario 2	0	1	2
Effluent quality (Wiegerinck, 2002)	96 g COD. $p^{-1}.d^{-1}$ 12 g N. $p^{-1}.d^{-1}$ 1.7 g P. $p^{-1}.d^{-1}$	[2]11 g COD. $p^{-1}.d^{-1}$ 3.5 g N. $p^{-1}.d^{-1}$ 1.7 g P. $p^{-1}.d^{-1}$	[1]5.7 g COD. $p^{-1}.d^{-1}$ 0.1 g N. $p^{-1}.d^{-1}$ 0.3 g P. $p^{-1}.d^{-1}$	1	2	3
Noise	nrd	nrd	nrd	-	-	-
Odour	nrd	nrd	nrd	-	-	-
Flexibility	No shock loads can be applied	-	No 24 hr power failure possible	1	3	1
Investment costs	0	€ 400,- per house (water saving toilet)	> € 4162,- per house (vacuum + AC system)	3	2	1
Operational costs	nrd	nrd	nrd	-	-	-
Maintenance	desludging every 2 years	desludging every 2 years	desludging every 100 days + maintenance of vacuum system	2	2	1
Energy consumption	no energy consumption	no energy consumption	27 kWh $p^{-1}.y^{-1}$ (Vacuum system)	3	3	1
Water consumption	42 l. $p^{-1}.d^{-1}$	24 l. $p^{-1}.d^{-1}$	7 l. $p^{-1}.d^{-1}$	1	2	3
Reuse potential	no reuse potential	no reuse potential	All nutrients in black water and swill	1	1	3
Convenience	-	-	more cleaning (vacuum toilets)	3	3	1
Space requirement	1.5 m^3 per house	1.5 m^3 per house (UASB) + 4.8 m^3 (Filter) per house	22.4 m^3 (AC) +4.8 m^3 (Filter) per house	3	2	1
Comments	[1] Only effluent from treated grey water, treated black water is reused in agriculture [2] combined UASB + sandfilter					

Table 2: Data with respect to criteria obtained from literature and scores (s_{ki}) of the respective scenarios

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Conclusions

In this paper the priority theory of Saaty (Lootsma, 1980) is used to create a ranking between DESAR alternatives. From the results presented in this paper it can be concluded that the priority theory of Saaty is suitable either a quick or a more precise ranking between DeSaR alternatives depending on the amount of information available on the criteria involved. In this paper only a quick ranking was made between three DeSaR alternatives as the amount of information on the scenarios was limited. This quick ranking indicated that for the village of Swichum in the Netherlands the scenario in which the black water is pre-treated in a UASB-septic tank system is favoured.

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The decentralization of sewage purification from the perspective of open space and urban planning*

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Keywords

Decentralized sewage purification, decision making tool, feasibility study, open space and urban planning, planted soil filter beds, urban landscapes

Abstract

The paper sets out to discuss the possibilities for decentralizing wastewater disposal and wastewater treatment from the perspective of open space and urban planning. It demonstrates that wastewater treatment facilities using planted soil filter beds can also be located in urbanized settlement areas and that such facilities can be used to stimulate design and development measures for rebuilding urban landscapes.

Initial situation and object of the study

In Germany, the scientific debate on wastewater disposal and wastewater treatment is shaped largely by the widespread use of combined sewerage systems, the deployment of large-scale technology and its centralization (Korrespondenz Abwasser 1998, 1999). Given this situation, the opportunities for implementing decentralized wastewater treatment concepts that allow a much more careful handling of water as a resource are extremely limited.

In both water quality management and regional, urban and open space planning, the view is commonly held that decentralized wastewater solutions can – for reasons of space, among other things – only be implemented in rural areas. The research project "Wastewater as a Feature of Urban Landscape", which was funded by the Lower Saxony Research Association for Women's/Gender Studies in Science, Engineering and Medicine, addressed the issue of the extent to which decentralized wastewater solutions are also implementable in urban settlement areas (Beneke et al. 2001). Partners in the research project were the Institute for Open Space Development and Planning-Related Sociology (Dipl.-Ing. M.A. Gudrun Beneke, Prof. Dr.-Ing. Hille v. Seggern, Dipl.-Ing. Antje Stokman), the Institute for Water Quality and Waste Management (Prof. Dr. Dr. Sabine Kunst, Dipl.-Biol. Ulrike Brüdern) and the Institute of Landscape Planning and Nature Conservation (Prof. Dr. Eva Hacker, Dipl.-Ing. Barbara v. Kügelgen), all at the University of Hanover/Germany. The project set out to explore, on a conceptual level, the potential for comprehensive decentralization of wastewater disposal and wastewater treatment in a city with a population of 100,000, and to develop a suitable design for this concept.

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Methods

The city used for the study was Salzgitter. Salzgitter is located on the boundary between the mountainous region of Central Germany and the North German plains. It covers an area of 224 sq km and has a population of 120,000. This settlement area is characterized by both farming and industrial activity. It comprises 31 municipal areas, Salzgitter-Lebenstedt (population: 48,000) and Salzgitter-Bad (population: 25,000) constituting the core settlement areas.

Salzgitter is a typical example of urban sprawl with areas of varying quality, some of them growing, others shrinking. Nearly all the properties in the urban area are connected to centralized wastewater treatment facilities.

To give a proper impression of the development potential for environmentally friendlier wastewater solutions, our conceptual model largely abstracts from the existing drainage infrastructure. The model assumes a separation of material streams and the treatment of wastewater where possible at the point of generation. This means that stormwater is infiltrated or decentrally retained and subsequently discharged into surface waters. In the case of domestic wastewater, faecal matter is collected separately and the greywater is treated in planted soil filter beds. Single-family dwellings are equipped with composting or vacuum toilets, multiple-family dwellings with vacuum sewer systems; the manure obtained from the decomposed faecal matter is used for agricultural purposes. Industrial wastewater is treated in specially designed facilities.

The location of planted soil filter beds in urban areas

From the point of view of urban and open space planning, the challenge posed by decentralized wastewater treatment is integrating the required space-consuming planted soil filter beds in settlement areas. To keep the organization of wastewater treatment manageable, the catchment areas for the planted soil filter beds were modelled on those of the largest facilities already in operation in Germany, which are designed to serve 3,000 inhabitants. As the wastewater treated in the planted soil filter beds does not contain faecal matter, the required filter area is estimated at 1 sq m per inhabitant (Bahlo 1997, Wissing and Hofmann 2002).

What the study showed, among other things, was that the decentralization of wastewater treatment using planted soil filter beds should go hand in hand with the decentralization of stormwater management. To enable stormwater to kept out of the sewerage system as far as possible, piped streams were exposed, dried-up valleys and ditches were reactivated and new brooks were built. Extending surface waters in this way provides sufficient receiving streams to take up the outlet from the planted soil filter beds.

It also became apparent that sections of the existing sewerage system could continue to be used. Depending on the terrain, it is divided up into small subsystems to enable the greywater from private households to be discharged into the planted soil filter beds, making use of the existing slope.

Availability of land for water treatment facilities

Salzgitter needs 64 planted soil filter beds to treat the greywater generated throughout the municipal area. It is possible to integrate the facilities in existing open space.

Whereas in the small municipal areas one or two plants located on the outskirts are sufficient to treat the greywater produced, in Salzgitter-Lebenstedt, for example, 15 plants have to be integrated into the urban settlement structure. They are to be situated alongside either the existing flowing waters or two ditches that are to be newly constructed. In most cases, green areas bordering roads or the peripheries of public green spaces will be used for this purpose. Occasionally, use will be made of the peripheral areas of sports facilities or farmland. But suitable locations can also be found in the midst of residential areas. Housing developments built in the 1950s and '60s, for example, usually have enough suitable spaces for this purpose.

Wastewater as a feature of the urban landscape

Planted soil filter beds are, however, capable of being integrated in urbanized settlement areas not only in terms of space requirements. They are also of relevance in terms of open space planning. Unlike conventional technical sewage plants, planted soil filter beds do not cause odour problems or present any sort of risk; the adjoining areas can be used by the public. Planted soil filter beds are also flexible in terms of their form and constitute a versatile green planning element that, depending on the way they are planted, bordered and integrated into the surrounding area, can be used to different effect.

A water planning concept coordinating the location of the planted soil filter beds and the facilities for decentralized stormwater management can integrate wastewater treatment into existing open space and green systems or promote their establishment. Such green spaces are of great interest for recreational and conservation purposes and in terms of settlement design.

The use of planted soil filter beds in conjunction with the surface-water extensions needed for decentralized stormwater management offers great opportunities for the future development of settlement areas. As each location or settlement has different natural conditions, i.e. a unique terrain and hydrological structure, its respective water planning concept could be used to show to advantage its own specific identity.

Conclusion

The overall conclusion reached was that in the case of settlement structures like those in Salzgitter decentralizing wastewater treatment is not an insurmountable problem in terms of space. Locating planted soil filter beds at the functionally correct places is in most cases quite feasible.

Naturally, this applies to implementation of the concept in the context of new developments – here space requirements can be taken into consideration from the start. And it also applies to the subsequent integration of such facilities into already developed areas. When properly designed, decentralized wastewater solutions can constitute an aesthetic enrichment of an area and a substantial contribution to sustainable settlement development and the safeguarding of water as a resource. Strategically, this form of wastewater treatment can stimulate a comprehensive improvement of the urban landscape. Assuming, too, that cities are shrinking (DASL 2002), it also offers potential for a variety of reconstruction strategies.

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Sustainable treatment of waste(water) in rural-areas of Egypt*

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Keywords

Anaerobic digestion, decentralised treatment, domestic sewage, cow manure, modelling, rural areas

Abstract

In this paper, a sustainable concept was proposed for decentralised treatment and reuse of sewage and cow manure in rural-areas of Egypt. Moreover, a mathematical model was developed for anaerobic digestion of the domestic sewage and cow manure in UASB-septic tank and accumulation (AC) system, respectively. For the treatment of sewage (600 mgCOD/l) in a UASB-septic tank at 20°C, an HRT of 2 days is needed, which will lead to COD removal, biogas production rate and sludge wastage period of 65%, 14 litres CH_4/capita/day and 6 years, respectively. For the treatment of cow manure in an AC system at 20°C, the required filling period is 6 months, which will result in conversion of 41% of the COD to methane at a rate of 0.2-1.2 m^3CH_4/cow/day. For a house having 7 capita and a cow, the annual volume of treated wastewater, sludge production and energy production, are, respectively, 307 m^3, 18.5 m^3 and 3428 kW.h, which can be utilised as irrigation water, fertiliser and cooking energy, respectively.

Nomenclature

AC:	Accumulation system	S_b:	Biodegradable soluble-substrate concentration (mg COD/l)
COD:	chemical oxygen demand (mg/l)	S_i:	soluble-inert concentration (mg COD/l)
HFRF:	horizontal-flow-roughing filter	UASB:	upflow anaerobic sludge blanket
HRT:	hydraulic retention time (h)	μ_{max}:	maximum specific growth rate (1/d)
K_d:	decay of biomass (1/d)	X_b:	Biodegradable-particulate concentration (mg COD/l)
K_{hyd}:	first-order hydrolysis constant (1/d)	X_i:	inert-particulate concentration (mg COD/l)
K_s:	half saturation concentration (mg COD/l)	X_m:	biomass concentration (mg COD/l)
SBS:	small bore-sewer system	Y:	yield of biomass on substrate (mg COD_S/mg COD_X)

Introduction

In Egypt, more than 95% of the Egyptian rural-areas are not provided with wastewater collection and treatment facilities. There are about 4000 Egyptian rural-areas with a population ranging from 1000 to 20000 capita. The wastewater produced from houses in these rural areas is mainly

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treated in septic tanks. To meet the demands for water and wastewater services in the next decade, Egypt will have to invest 5-7 billion US$, which is well above the available national resources (USAID, 2002). Providing rural areas in Egypt with water supply (more than 98% of rural areas in Egypt have water supply) has resulted in an increase of wastewater production, which increases the urgent need for proper facilities for wastewater collection and treatment. Elmitwalli *et al.* (2002) showed that the domestic wastewater of the Egyptian rural-areas is relatively concentrated with a COD as high as 1100 mg/l, mainly due to the discharge of cow manure in the served areas with gravity sewers. This results in frequent clogging of the sewers and overloading of the existing wastewater treatment plant.

Separation between grey water and black water in rural areas of Egypt (for more sustainable collection, treatment and reuse) on the short term is very difficult, due to need for investment cost, existing infrastructures and poor education of Egyptian people in the rural areas. The aim of this paper is to develop an appropriate and sustainable concept for collection, treatment and reuse of domestic sewage and cow manure in rural areas of Egypt. Three concepts will be presented, depending on the local situation, like the population density and the existing infrastructures. Anaerobic digestion was chosen as the main process in this concept. Moreover, a simple mathematical model based on anaerobic digestion model no. 1 (IWA, 2002), is developed for determination the most suitable design of the proposed anaerobic systems.

Concept description

The concept is firstly based on separation of domestic sewage and cow manure. The separation of the cow manure from the wastewater will potentially reduce the pollution of the surface water, which represents the main source of drinking water in Egypt. The produced manure by 120 cows is equivalent to a total COD produced by about 10000 capita, based on the assumptions in Table1. In the concept, a UASB-septic tank and an accumulation (AC) system will be applied for treatment of, respectively, domestic sewage and cow manure. The UASB-septic tank differs from the conventional septic tank system by upflow mode, in which the system is operated resulting in both improved physical removal of suspended solids and improved biological conversion of dissolved components. In the AC system, anaerobic-digestion and storage of waste are com-

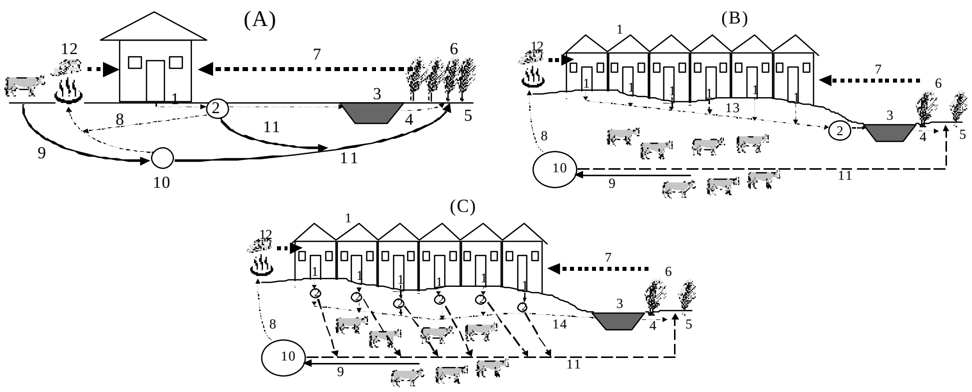


Figure 1: Schematic diagrams of the concept. (A) for a remote house, (B) for a densely-populated area, (C) for a densely-populated area with existing septic tanks. 1, domestic sewage; 2, UASB-septic tank; 3, HFRF; 4, treated sewage; 5, agricultural area; 6, plants; 7, food; 8, biogas; 9, cow manure; 10, AC system; 11, digested sludge; 12, cooking by biogas; 13, shallow gravity-sewers; 14, SBS system.

bined in one reactor (Zeeman, 1991). For remote houses in Egyptian rural-areas, each house will have its own AC system and UASB-septic tank (Fig. 1.A), while for densely populated areas, several AC systems and UASB-septic tanks will be installed. An AC system and a UASB-septic tank will serve a small community in the densely-populated areas, like an AC system and a UASB-septic tank for each street. Shallow gravity sewers will collect the sewage from the houses to the UASB-septic tank (Fig.1.B). Also, in the densely populated areas, existing septic tanks can be easily modified to UASB-septic tanks. The tanks effluent, which contain low SS concentrations, will be collected by a small bore-sewer (SBS) system (low-cost technology for wastewater collection) to the nearby agricultural area (Fig. 1.C). Accordingly, the anaerobic effluent can be reused for irrigation after a polishing step, like a horizontal-flow-roughing filter (HFRF). The excess digested-sludge from the UASB-septic tanks and AC system, will be used as a fertiliser and the produced biogas will be utilised as a source of energy for food cooking, mainly making bread, like in the past, when the Egyptian people were burning dry cow manure for making bread.

Mathematical modelling

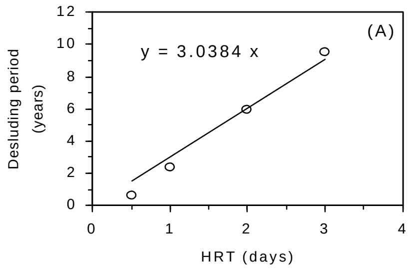
The model is mainly based on first-order and Monod kinetics for, respectively, hydrolysis of biodegradable particulate and conversion of dissolved organic matter (Elmitwalli *et al*., 2002). Table 1 presents the values of model constants and variables. The model was carried out using the QBASIC programme and applying numerical integration at small time interval of 7.2 and 1 minutes for UASB septic tank and AC system, respectively.

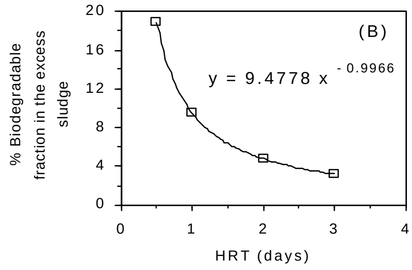
Parameter						References
Concentration:-	X_b	X_i	X_m	S_b	S_i	
Domestic sewage, mg/l, (COD=600 mg/l, 120 l/capita/day)	365	18	37	117	63	Elmitwalli *et al.* (2002)
Cow manure, g/l, (COD=120 g/l, 50 l/cow/day)	23.6	47.8	23.6	14.4	3.6	Zeeman (1991)
Kinetic parameters:-	Y	K_d	K_s	μ_{max}	K_{hyd}	IWA (2002)
Sewage (20°C)	0.1	0.02	400	0.15	0.15	
Cow manure (20°C)	0.1	0.02	400	0.15	0.03	
UASB-septic tank:- HRT = 0.5, 1, 2, 3 days, Sludge concentration = 35 g/l; Seed sludge = 25% of the volume, SS removal = 75%; Max. sludge volume = 70% of the reactor						Elmitwalli *et al.* (2002)

Table 1: Values of parameters and variables applied in the model.

Results and discussion

The model results show that increasing the HRT of the UASB septic tank from 0.5 to 3 days does not significantly affect the effluent COD and methane production, which were about 205 mg/l and 63% respectively. Such high performance is mainly due to long sludge residence time, which guarantees a sufficient biological activity and a stable physical performance. However,, increasing the HRT of the UASB-septic tank increases operational period of the reactor without sludge wastage (Fig. 2.A) and significantly decreases the biodegradable fraction in the excess sludge (Fig. 2.B). At HRT of 2 days, the reactor needs to be desludged every 6 years. Accordingly, the HRT of 2 days can be considered sufficient for the treatment of domestic sewage in the UASB-septic tank. The model results for an AC system treating manure of a cow show that the performance of the system is significantly affected by the filling period, Fig. 3. Addition of





inoculum in the start-up of the system slightly improves the performance (Fig. 3.B), as the influent has a sufficient amount of methanogenesis. Zeeman (1991) found that the cow manure could be treated in the AC system at 20°C without inoculation. The results show that the suitable filling period for the system should be higher than 5 months. Therefore, the AC system can be operated for a period of 6 months, i.e. will be emptied twice a year. The results demonstrate that anaerobic digestion of cow manure in an AC system and treatment of sewage in a UASB-septic tank will produce, respectively, 0.2-1.2 m^3CH_4/cow/day and 0.014 m^3CH_4/person/day. Therefore, for treatment of cow manure and sewage of an Egyptian house in the rural areas (7 persons and a cow), the annual biogas production will be 370 m^3CH_4, which can produce theoretical energy of 3428 kW.h/year (can be used for cooking). Moreover, each house will produce about 307 m^3 of treated wastewater (can be reused for irrigation) and 18.5 m^3 of sludge (can utilised as a fertiliser).

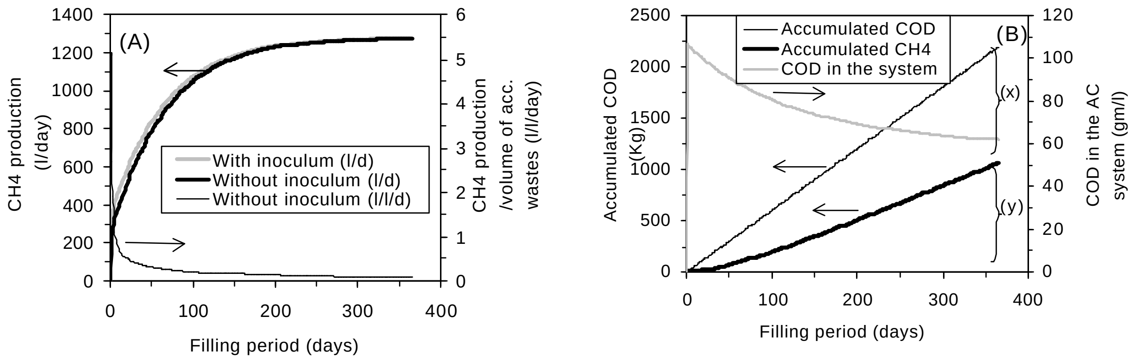


Figure 3: Daily CH_4 production (A) and accumulated total-COD and CH_4 production (B) in the digestion of manure of a cow in an AC system at 20°C. (x): non-degraded total-COD, (y): degraded total-COD. The inoculum = 10% of the AC system volume after a year.

Conclusions

- A sustainable concept was proposed in this paper for decentralised treatment and reuse of sewage and cow manure in the rural-areas of Egypt. Moreover, a mathematical model was developed for anaerobic digestion of the domestic sewage and cow manure in UASB-septic tank and accumulation (AC) system, respectively.
- The model results show that the suitable HRT and filling period for, respectively, the UASB-septic tank and AC system are 2 days and 6 months, respectively. At these conditions, 65% of COD in the sewage is removed with production of 14 litres of CH_4/capita/day and the excess sludge from the tank needs to be wasted every 6 years. In the AC system, 41 % of the COD in cow manure will be converted to methane at a rate of 0.2-1.2 m^3CH_4/cow/day.

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Multi criteria decision aid in sustainable urban water management[1]

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Keywords

Decision-making, Multi Criteria Decision Aid, NAIADE, public participation.

Abstract

The Sustainable Urban Water Programme has been developed to decide the course of action of the urban water and wastewater systems in future 'sustainable' Sweden. As part of the programme, research on decision-making tools to integrate knowledge from different areas is conducted. This paper uses Multi Criteria Decision Aid (MCDA) in order to help structuring scientific as well as economical information as a base for decision-making. Because of the great amount of MCDA methods, it is important to choose an appropriate method for a given situation. Therefore, a framework is presented to select an appropriate MCDA method. The decision-making process in Surahammar, Sweden, is simulated to test the selected MCDA method NAIADE. This simulation shows that MCDA is a useful tool in a decision-making process and might lead to more sustainable decisions. MCDA structures the problem over different criteria and allows public participation to take place. However, trust and transparancy are vital aspects in a MCDA process. All interest groups must trust the method being used and understandable information must be provided. Complexity and confusion can lead to mistrust or excessive faith in the results.

Introduction

Environmental decision-making problems are often characterised by a high degree of uncertainty. Estimations on environmental change caused by an intervention in an ecological system can only be incomplete and speculative. Possible benefits or harmful impacts are difficult to predict and therefore it is often impossible to link these impacts with clear measurements. Another problem is that people may value the same environmental features totally differently. For these reasons could monetary valuation, such as the Cost Benefit Analysis (CBA), be considered as inappropriate for use in environmental problems. This suggests that there is an important role to play for Multi Criteria Decision Analysis in environmental evaluation.

A wide variety of MCDA methods have been developed over the last years. These methods do not provide a unique solution, but rather help the decision-maker to arrive at a political compromise. The methods investigate different alternatives and judge them on the basis of economic, social and environmental criteria, and by their importance to different interest groups. The aim of MCDA is 'to enable us to enhance the degree of conformity and coherence between the evolution of a decision-making process and the value systems and objectives of those involved in this process' (Roy, 1990).

[1] This paper is mainly an abstract of Van Moeffaert, 2003, *Multi-criteria decision aid in sustainable urban water management*, Department of Industrial Ecology, MSc-uppsats, TRITA-KET-IM 2002:26, Royal Technical Institute, Stockholm, Sweden.

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Despite functioning well the water and wastewater systems in Sweden have been questioned on the point of view of sustainability (Urban Water, 2001). In the city of Surahammar, which represents a typical country town in Sweden, three different wastewater treatment systems are compared and a decision has to be made which system fulfils best the objectives.

To varify the usefulness of MCDA in environmental evaluation, a simulation of the decision-making process in Surahammar is conducted using an appropriate MCDA method.

Multi Criteria Decision Aid (MCDA)

The main goal of MCDA is not to discover a solution, but to construct or create something which is viewed as liable to help 'an actor taking part in a decision process either to shape, and or transform his preferences or to make a decision in conformity with his goals (Roy; 1990). In the field of environmental management, the Multi Criteria Decision Aid approach can reduce complexity, help the various actors to understand their preferences and establish an open dialogue between them.

There are a great number of MCDA methods, a situation that may be seen either as a strength or as a weakness (Bouyssou et al, 1993). The great variety of multicriteria methods makes it possible for the decision-maker to choose the appropriate method for a certain decision-making situation. The weakness however, lays in the fact that not one model is strong enough for all different kinds of decision-making situations.

In practice, it is experienced to be very difficult to choose one MCDA method for a certain problem. Many analysts and researchers are not able to clearly justify their choice for one MCDA method rather than another one. Very often, the choice is motivated by a sort of familiarity and affinity with a specific method. The result of this behaviour is that the decision-making situation is adapted to the MCDA method and not the opposite. This is not a productive attitude. It is important to know how a method works, and get through experience familiar with it, but one can not expect to solve all decision-making situations with the same method.

Multicriteria methods differ in the way the idea of multiple criteria is operationalised. In particular each method shows its own properties with respect to the way of assessing criteria, the application and computation of weights, the mathematical algorithm utilised, the model to describe the system of preferences of the individual facing decision-making, the level of uncertainty embedded in the data set and the ability for stakeholders to participate in the process (Johnson et al, 2002). By considering all the different characteristics the user has to decide about the most suitable method for the problem to be tackled.

Van Moeffaert, (2003), suggests three parallel paths to choose an appropriate MCDA method (figure 1). The first path consists of making a comparative study of different methods, to analyse some typical characteristics of every method. The second path tries to find out what the application domains are of the different methods, according to experiences in the past. In the third path, some general tentative guidelines on choosing a MCDA method are reviewed based on Guitouni, et al, (1998). By confrontating the results of those three paths, a motivation for the choice of MCDA method is conducted.

Van Moeffaert, (2003), compares the MCDA methods Promethee I and II, Electre III, Regime and NAIADE according to this framework. Also, the Multi Criteria Decision Making (MCDM) methods MAUT and SMART are evaluated, due to the high amount of applications by analysts. After evaluation, the MCDA method NAIADE is recommended for the decision-making process in Surahammar.

The motivation is based on some special features of the NAIADE method. Firtly, the NAIADE method does not make use of direct weighting to attach weights is a comman procedure in different MCDA methods. By attaching weights, one can assess personal preferences to each criterion. However, the attachment of weights to criteria is practically experienced as a weak point in the decision-making process. It is experienced to be difficult to give real value weights in environmental situations (Hokkanen and Salminen, 1995). Particular attention has been given in the NAIADE method to the different values of groups in society through conflict analysis procedures.

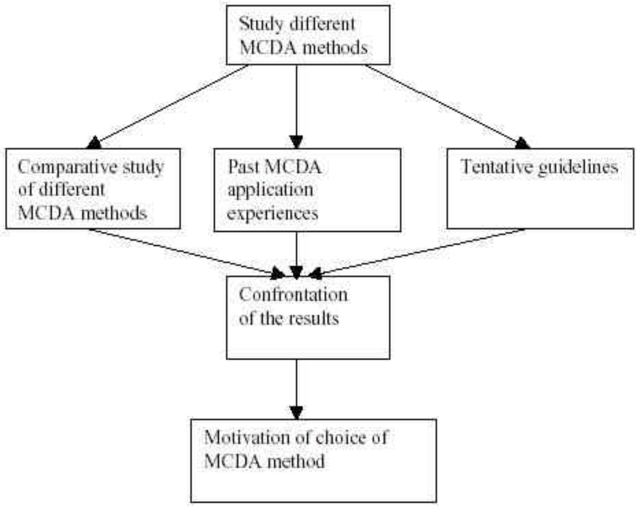

Figure 1: A framework to choose an appropriate MCDA method

The NAIADE method integrates conflict analysis procedures to seek for defensible solutions to reduce the degree of conflict between decision-makers. This conflict analysis conducts the relative importance each decision-maker assesses to a certain criterion, and can be used as a base for further negotiation. Another special feature of the NAIADE method is that it makes use of fuzzy set theory. While for example PROMETHEE and ELECTRE make use of sharply defined borders of different preferences, NAIADE allows these zones to overlap. This means that the NAIADE method goes a step further in the theoretical background than the other methods. At last, NAIADE is the only investigated method, which can assess fuzzy information. It is necessary to make use of fuzzy inputs when evaluating different environmental alternatives because it is possible that some alternatives do not have a real life application. In this situation it is difficult to make predictions with clear numbers.

The simulation of the decision-making process in Surahammar

Surahammar is a typical medium-sized country town in Sweden. The decision-making process is centralised as the responsibility of taking decisions lies with the board of politicians. There is little place for public participation in the current decision-making process of Surahammar. Involving different interest groups in the environmental decision-making process would drastically increase the level of public participation. Therefore, the simulation of the decision-making process in Surahammar is conducted with the participation of different interest groups.

The decision-making process of Surahammar was simulated during a two-day workshop with the help of nine Ph.D.-students working in the Urban Water Programme. Each Ph.D.-student acted through a role-play as one of the interest groups of the Surahammar community. The interest groups invited to participate in the decision-making process in Surahammar were: the farmers, the households, the Environmental Group, the Agency for Fish Protection, the Municipal Company, the Urban Planner, the Environment and Health Inspector and a representative for the future generations.

The first step in the NAIADE method is to construct the performance matrix. The performance matrix presents the scores of each alternative over each criterion. All interest groups received in forehand a report, which contained a preliminary performance matrix as well as the motivation behind the scores. During the first step, the interest groups could ask for additional information

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or even discuss the scores. This report would also help to assess the preference articulations by the different interest groups. During the preference articulations, the interest groups need to agree on the relative importance of the differences between the scores of the alternatives.

A second step in the NAIADE method is to construct the equity matrix. This matrix presents the evaluation of each interest group for each alternative. Equity and conflicting values in the NAIADE model are not introduced by weighting of the different criteria. Instead, the use of conflict analysis allows the decision-maker to seek for 'defendable' solutions. The authority in charge of the decision in Surahammar, the politicians, has the possibility to view the behaviour of interest groups, so that decisions, which have a higher probability of being accepted by certain groups, may be identified.

Conclusions and recommendations

Van Moeffaert, 2003, has shown that, in general, MCDA can be a useful tool in an environmental decision-making situation. MCDA allows the involvement of interest groups in the decision-making process. Increasing public participation might lead to more sustainable decisions. During the decision-making process, all interest groups learn more about the different aspects of planning waste and wastewater systems. By structuring the problem over different criteria, the transparency of the situation is increased, leading to a better consideration of all aspects when deciding for an alternative. On the other hand, the large amount of MCDA method, without a clearly superior one, makes it difficult to choose the appropriate method for a certain situation. Moreover, the complexity of analysis process can lead to mistrust or excessive faith in the results (Edwarts-Jones et al, 2000).

The simulation of the decision-making situation in Surahammar has shown that the MCDA model NAIADE is useful on certain conditions. First of all, all interest groups have to trust the method used in the decision-making process. A certain disbelief by participants in the method could lead to incompletion of the decision-making process. To make the interest groups trust the method, the whole decision-making process should be outlined in forehand to the interest groups during information sessions. The interest groups have to come fully prepared to the actual decision-making process. However, it is not the meaning to create confusion or disbelief with the interest groups by going too much in detail in the theoretical background of the MCDA method. The analyst should provide the necessary information, avoiding overwhelming the participants. The preparation of the decision-making process is crucial as it influences the quality of the further process.

The information about the different alternatives distributed to the interest groups is another important aspect for the quality of the decision-making process. Different interest groups have different backgrounds and thus different areas of knowledge. It is very important that all interest groups receive 'understandable' information to be able to defend their position. Too technical information could demoralise some groups and give advantage to the technically skilled professionals attending the decision-making process

The usefulness of MCDA in the decision-making situation of Surahammar is shown in figure 2. MCDA has the capacity to close the gap between the technical results of the system analysis and the actual decision-makers, namely the politicians. It also allows public participation to take place. As shown in figure 2, it is recommendable to collect the results of the MCDA process in a report, structuring the whole decision-making situation. The actual decision-makers, the politicians, will be able to take a more sustainable decision based on this report.

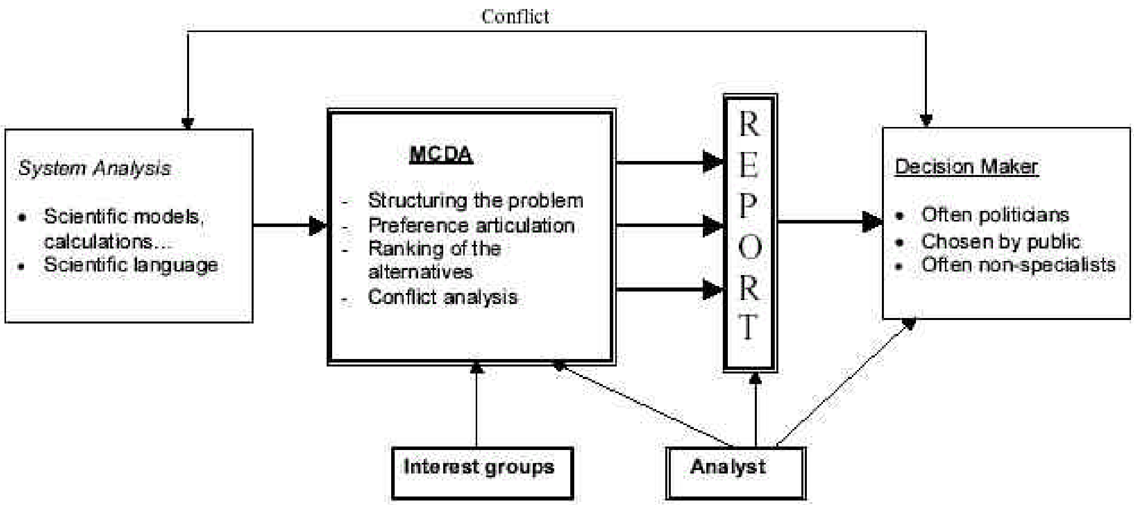

Figure 2: The role of MCDA in the decision-making process of Surahammar

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Assessing the sustainability of domestic water systems, including water use and wastewater treatment

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Introduction

The hippos in the Noorderdierenpark, a ZOO in the Netherlands, live in water that is recycled after treatment with membrane filtration and a living machine (Figure 1). In the Netherlands, this high-tech hippo sanitation system is considered sustainable. Naturally, here sustainability has a different content than if one talks about sustainability of hippos living in the wilderness. The Noorderdierenpark uses advanced technology at high costs to make up for the fact that the hippos live in an unnaturally small habitat and thereby importing food and exporting waste.

Similarly we find, that depending the availability of resources such as money, space, technology, energy, water, fertiliser, etc., people developed a wide variety of domestic water systems. Some people use simple on-site sanitation systems, while others use water flush toilets connected to a complex system with sewers and a centralised wastewater treatment. The enormous differences between those systems give raise to the questions: What determines the sustainability of domestic water systems? How do we compare such a wide variety of systems? And since there is world-wide a need for hygienic low cost water supply and sanitation, and an increasing demand for systems that conserve water, recycle nutrients, and upgrade living conditions in urban areas – an important question is: can we select solutions that meet these challenges?

Figure 1: The "living machine" in Noorderdierenpark, treating the wastewater produced by human activities as well as the sludge produced by the membrane treatment of the hippo, sea turtle and penguin wastewater.

Defining sustainability

There is no unambiguous definition of sustainability. Still, if one reviews the different indicators used in sustainability assessments of sanitation systems one finds that some indicators are almost always used, for instance: water use, energy use, nutrients, BOD, sludge, and heavy metals. Naturally, the choice of indicators depends on the goal and the scope of the research. For instance, social-cultural indicators are important when studying small-scale systems that are

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used in or near the household. The relative importance of the indicators depends on the local situation and the preferences of the decision makers.

Comparing domestic water systems

For the comparison of a wide variety of domestic water systems we developed a model based decision support tool of which the outlines are shown in Figure 2.

The wide systems boundaries and the complete set of sustainability indicators are two important characteristics of this tool, as we want to be able to compare small-scale with large-scale systems. For instance, certain treatment technologies ask for keeping waste streams separated and different systems have different advantage with respect to sustainability. Therefore, excluding the household and certain sustainability criteria means excluding possibly interesting systems a priori. Our tool thus uses a large set of sustainability indicators including technical, economical, environmental, and social-cultural measures and supports a wide range of options for domestic water systems including: different water sources (3), different toilets (10), separate transport of grey, black and yellowwater, on-site treatment, and 4 steps for blackwater treatment including 12 different technologies. The model requires three types of inputs, (1) characteristics of household and treatment, (2) the normalisation and weighting factors for the sustainability indicators, and (3) the choices contained in 32 decision variables. As output the tool quantifies all the sustainability indicators.

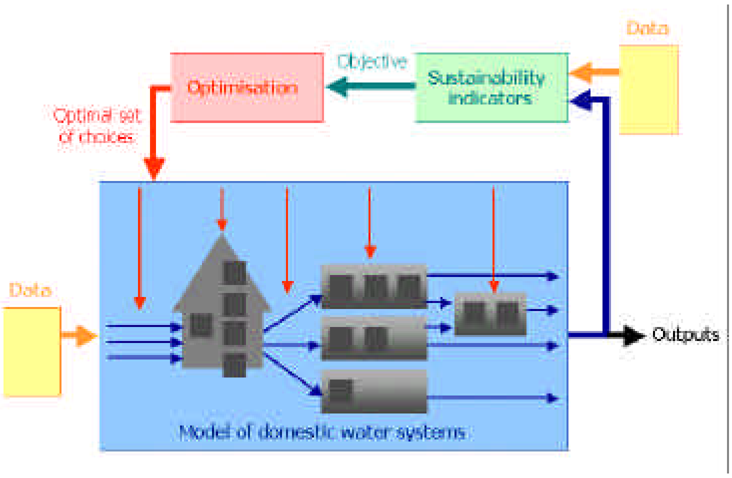

Figure 2: Multi-objective optimisation to design sustainable domestic water systems.

Selecting promising domestic water systems

The user of the tool specifies the scenario (characteristics and weighting factors) and the tool computes the solutions that give the highest scores on the sustainability indicators. For such-defined quite sizeable mixed integer nonlinear optimisation problems, we are presently evaluation different solvers. Thereafter, we shall use the tool to select promising systems that meet the current challenges of the water sector such as hygienic low costs systems to implement water for all by 2025, and systems to meet future challenges such as improving the living conditions in urban areas, and closing water and nutrient cycles.

Session I

Urban case studies

Chairpersons

Darren Saywell (WSSCC, Switzerland)

Uwe Stoll (KfW, Germany)

Ron Sawyer (Sarar Transformación SC, Mexico)

Heinz-Peter Mang (GTZ, Germany)

Lectures

Operation experiences with a source separating project*
Claudia Wendland (Technical University Hamburg-Harburg, Germany), *Martin Oldenburg*

Urine harvesting through institutional participation: a Nigerian experiment
M.K.C. Sridhar, O. Odusan (University of Ibadan, Nigeria), *A. O. Coker, I.O. Akinjogbin, G.O. Adeoye*

Further development of urban wastewater disposal systems in conurbation
Ulf Volker Rakelmann (Hamburger Stadtentwässerung, Germany)

Implementation of a closed-loop sanitation concept in Yang Song township, China
Ina Jurga, Bianca Gallinat, Heinz-Peter Mang (GTZ, Germany)

Implementing large-scale and urban dry sanitation: an agenda for action*
Ana Cordova, Barbara A. Knuth (Cornell University, USA)

Innovative sanitation concept shows way towards sustainable urban development. Experiences from the model project "Wohnen & Arbeiten" in Freiburg, Germany
Arne Panesar, Jörg Lange (Wohnen & Arbeiten, Germany)

Wet or dry ecological sanitation in periurban areas
Bjorn Brandberg (SBI Consulting & Supplies (PTY) Ltd, Swaziland)

Subterra – constructed wetlands for wastewater treatment (examples and experiences)
Joachim Krüger (Pflanzenkläranlagen GmbH, Germany)

Greywater treatment in combined biofilter/ constructed wetlands in cold climate
Petter D. Jenssen, Lasse Vråle (Agricultural University of Norway, Norway)

Community based sanitation program in Tangerang and Surabaya, Indonesia
Stefan Reuter, Andreas Ulrich (Bremen Overseas Research and Development Association, BORDA, Germany)

Introducing urine separation in Switzerland: Novaquatis, an interdisciplinary research project*
Judit Lienert, Tove A. Larsen (EAWAG, Switzerland)

Oral poster presentations

Practical examples of DESAR concepts in urban areas in the Netherlands
Adriaan R. Mels (Lettinga Associates Foundation, The Netherlands), *Grietje Zeeman*

This paper has been peer reviewed by the symposium scientific committee

The Skogaberg Project - a blackwater system with waste disposers under development in Göteborg, Sweden
Kristina Fermskog (City of Göteborg, Sweden)

Poster presentations

Low flush toilet systems for water saving, nutrient recovery and soil improvement in Hamburg and Berlin
Wolfgang Berger (Berger Biotechnik GmbH, Germany)

Local recycling of wastewater and organic waste - a step towards the zero emission community
Petter D. Jenssen, Petter H. Heyerdahl, William W. Warner (Agricultural University of Norway, Norway)

Ecosan-options for single households
Markus Lechner (TBL / EcoSan Club, Austria)

Decentralised water sanitation loop - a case study from Bangalore, India
S. Vishwanath (Rainwater Club, India)

Operation experiences with a source-separating project*

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Keywords

Anaerobic digestion, biogas, blackwater, source separation, vacuum toilet, water consumption

Abstract

In Lübeck-Flintenbreite, a source separation is realized in a housing estate firstly in Germany. The project demonstrates the feasibility of the source control system combined with water saving technology as well as fertiliser and energy production.

The water consumption decreases significantly due to the installation of vacuum toilets. The source separation is very effective by a strict separation of black-, grey- and stormwater: The blackwater with a very low volume is containing the main load of nutrients which can be recycled very efficiently. Anaerobic treatment together with organic waste leads to a production of biogas which is used for energy and heat production. The treatment of storm- and greywater is very easy because of the lack of nutrients and takes place in swales respectively in constructed wetlands.

Despite of the high technical approach the operation costs can be much lower than for conventional sanitation systems.

Description of the project Lübeck-Flintenbreite

The described sanitation system is installed in a housing estate for 350 inhabitants named Lübeck-Flintenbreite and is an example for a densely populated rural area. This semicentral system is capable to realise resources and energy recovery in more densely populated housing areas up to 5000 people. The area of the housing estate is not connected to the central sewerage system. All components of the sanitation concept are in use in different fields of application since many years and therefore well developed (Otterpohl et al 1999).

The sanitation system consists mainly of the following components (Figure 1):

- vacuum toilets with vacuum-sewer system and anaerobic digestion with co-treatment of organic waste in a semi-centralised biogas-plant, recycling of digested anaerobic sludge to agriculture with further storage for growth periods. Utilisation of biogas in combined power and heat generator (heating for houses/digester and production of electricity) in addition to natural gas.
- decentralised treatment of grey water in vertical flown constructed wetlands (reed-bed filters) with in interval feeding.
- storm water retention and infiltration in a swale system.

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*This paper has been peer reviewed by the symposium scientific committee

On the 3.5 ha area there are situated terraced, twin houses and flats. The houses are realised

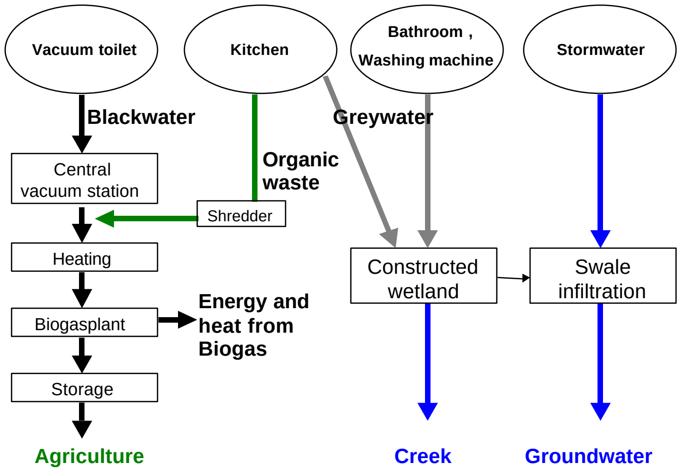

Figure 1: Scheme of sanitation system in Lübeck-Flintenbreite

as low energy houses to reduce the consumption of heating and energy. The construction of the technical equipment and the houses began in February 1999. Until now 28 houses are realised with 95 inhabitants. The central technical equipment is installed in a central community building which is regarded as the heart of the housing estate. First it contains the units for the production of heating and electricity, the vacuum station, the anaerobic digester and all distribution facilities. Secondly the residents can use the central convention room for meetings, parties and other events.

Operation experiences with the vacuum toilet system

The vacuum toilet system has been running for two years without any technical problems. The flushing system which has been optimised during operation needs only about 0.7 l per flush.

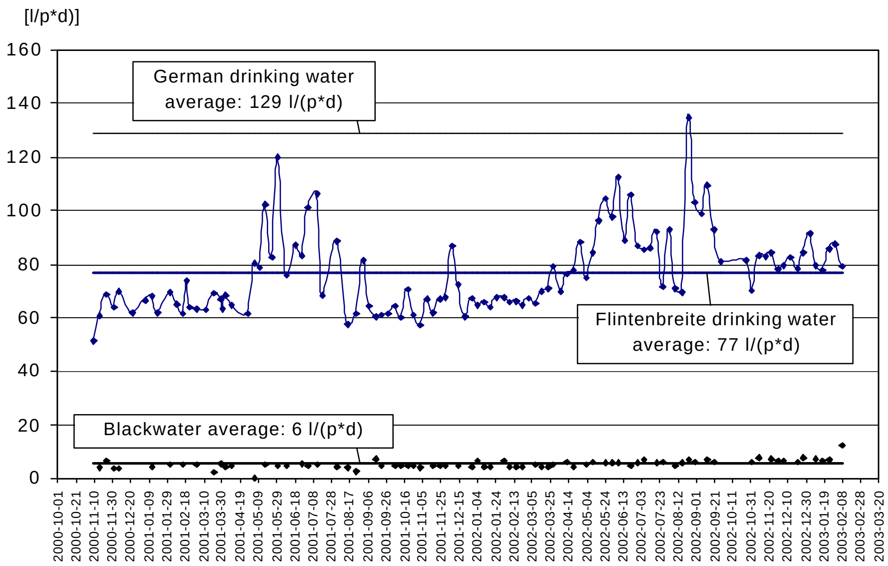

Figure 2: Drinking water consumption in Germany and in Lübeck-Flintenbreite and blackwater amount

Therefore the drinking water consumption is significantly low compared to the German average . (fig 2). The long time drinking water consumption in Lübeck-Flintenbreite is carried out to be only 77 l/(p*d). The peaks in spring and summer time are caused by garden irrigation.

The average amount of blackwater is found to be approximately 6 l/(p*d). The average amount of greywater is about ten times higher.

Regarding the nutrients in these two water flows, the source separation is very effective. Almost 90% of the nitrogen load is found in the blackwater (Oldenburg et al 2002). The blackwater composition shows the high concentration of organic substances and nutrients compared to conventional domestic wastewater (Table 1).

Parameter	Unit	Minimum	Average	Maximum
Total solids	g/l	7	12	23
Volatile solids	%	65	73	83
TOC	mg/l	3340	5511	10650
Total N	mg/l	1050	1364	1910
Total P	mg/l		131*	

* only one sample

Table 1: Characterization of blackwater

To find out the acceptance of the vacuum system by the users, a questionnaire for the inhabitants was carried out. The evaluation showed that the vacuum toilets are as accepted as the conventional system. Some residents even said that they are more hygienic. Noise might be a concern with vacuum toilets but the modern units which are installed in Flintenbreite give a shorter and a different but not a louder noise than conventional toilets. As an overall result of the questionnaire it can be emphasized that the residents are very satisfied with the vacuum toilet system.

Lab-scale studies with the anaerobic digestion of blackwater

In Lübeck-Flintenbreite, the anaerobic digestion of the blackwater is assigned with further agriculture usage of the digested liquid product. To kill the pathogens, the blackwater which is mixed with shreddered organic kitchen waste is heated previously to 55 C for 10 hours. But since there is only the fourth part of the calculated inhabitant number living there until now the installed digestion plant has not run yet.

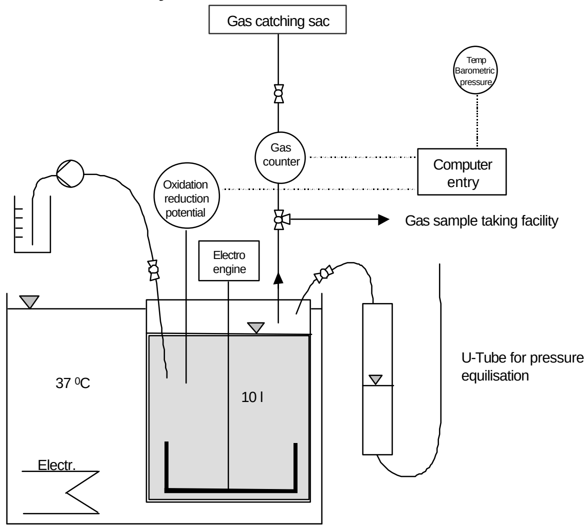

Figure 3: Scheme of the Lab scale digestion plant for blackwater and organic waste

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For the determination of optimal process conditions for anaerobic digestion in Lübeck-Flintenbreite preliminary experiments in laboratory scale have been started in December 2002.

The lab-scale pilot plant consists of three parallel reactors (10 l each), which are made of PVC and arranged in a heated water tub to keep constant reactor temperatures. Three times a week the reactor is fed with new pre-heated substrate. Until now no kitchen waste is added to the reactor? The retention time is chosen to be 20 days. Weekly samples are taken from the feed and the reactor, which are analysed regarding the parameters pH, TS, VS, TOC, TC, TN and TP. The produced quantity of biogas is registered and standardised in Norm-l online. The process is controlled by oxidation reduction potential, which is also measured online. Gas samples are taken and analysed regularly.

The first results show that the digestion process and the biogas production are very stable. However the starting phase is very sensitive (Wolff 2000). The produced biogas amount is about 500 Norm-l/kg VS_{feed}, thus comparable to production rates of organic waste (Gosch 1997) or sewage sludge digestion (ATV 1996). Even with pure blackwater no process inhibition takes place due to the high concentration of ammonia. Further studies with different kinds of organic waste are going to carried out. Different combinations of blackwater and organic waste, retention times e.g. will then be investigated in order to optimise the digestion.

Results

The results of the first three years of operation with the source separation can be named as:

- A low water consumption is achieved due to the installation of water saving technologies.
- A very effective source separation is realised. Nearly 90 % of nitrogen is found in the blackwater.
- The rate of operational problems/disturbances caused by misuse of the system is very low. Problems and their reasons can be identified very easily.
- The vacuum toilet technology is accepted by the inhabitants. After a time of accustomi ng the vacuum toilets are accepted and are seen more hygienic than conventional flushing toilets.
- The first results from the anaerobic digestion of blackwater in laboratory scale are confirming common design parameters like the gas production.

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Urine harvesting through institutional participation: a Nigerian experiment

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Keywords

Urine harvesting, institutional participation, stakeholders, fertilizer, vegetable crops

Abstract

A urine harvesting system was designed and developed at Federal Polytechnic, Ede, in southwest Nigeria. The stakeholders involved were staff and students. Two urinals, one for male and the other for female teachers were built using local materials. These were connected to a storage tank, which was linked to an experimental farm. The urine after dilution with water 1:4 ratio was used to grow common vegetables, viz. 'okra', maize, 'tete' (green amaranth), and tomato in a greenhouse. The nutritional composition of urine used was also compared with organo-mineral fertilizer and NPK chemical fertilizer, which are commonly used by farmers in the area. The growth characteristics of the test crops were followed for 12 weeks and monitored their height, number of leaves and the girth of the stems. The results indicated that the urine could be a good source of manure as well as irrigation water. Based on these results plots were made and the same crops were planted. The acceptability of the urine harvesting practice and the crops grown for consumption were assessed using volunteers from the school. The results indicated that urine-harvesting system is acceptable and found to be viable at institutional level if stakeholders are involved.

Introduction

Indiscriminate urination is a common practice in Nigeria whether it is a taxi park, market or an institution. In the absence of proper disposal facilities such as public urinals, people have no option but to use any convenient place such as a drain, bush, garbage dump or a stream where there is certain amount of privacy. Nigeria, with a population of about 120 million, urine constitutes a valuable wasted resource. Globally, urine harvesting is catching momentum in view of its manurial value as well as its nuisance potential when indiscriminately disposed. However, its hygienic value, odour problems, culture and attitude of the people who are the end users are yet to be ascertained in many countries (Danish EPA, 2001).

There have been no known reports of direct urine harvesting or utilization in this vast country with 120 million populations except that people use sullage or greywater (which is often mixed with human faeces and urine) for agriculture in major urban centres (Sridhar, 1995; Sridhar, 2000). Only one example is known in Kaduna in Northern Nigeria, where an equipment fabricator routinely uses urine as a source of ammonia to clean the steel in the thermal processing. This paper describes our experience in mobilizing various stakeholders for urine harvesting in a tertiary institution, Federal Polytechnic, Ede, in southwestern Nigeria and subsequent utilization for farming purposes on the campus. The specific objectives included mobilization of stakeholders, design and construction of acceptable urinals for both male and female participants, a urine storage tank, a mixing tank for urine and water with drainage, and a designated farming area for the cultivation of selected test crops after greenhouse experiments.

Study site and methodology

Study site

The Federal Polytechnic is located at Ede, a small town in Osun State. The Polytechnic was established in 1992 and has staff strength of 3,000 with a student population of 8,000, which can increase up to 12,000 in some sessions. The institution has 14 Departments under five schools, viz. Engineering, Environmental Studies, Applied Sciences, Business Administration and Management and General Studies. Some of the students reside on campus while staff and some students reside off the campus. There is a canteen, which caters to the students. The School has a large parcel of undeveloped land, which is currently being allotted to staff for farming purposes pending the time it would be utilized for Institutional purposes. The major stakeholders in the Institution are: The Rector, The Deans, Academic Board (the highest decision making body), Heads of Departments, Teaching and non-teaching staff, Principal Officers, and students.

Methodology

The experiments were conducted in 2 phases. Phase I comprised of sensitising the stakeholders, identification of the site, designing of the Urine Harvesting System (UHS), construction of the UHS, characterization of urine, greenhouse experiments using urine, organo-mineral fertilizer and NPK chemical fertilizers as sources of manures for growth of okra (*Hibiscus esculentus*), maize (*Zea mays*), 'tete (*Amaranthus chlorostachys,* popularly known as green amaranth), and tomato (*Lycopersicum sp.*) as test crops, and assessment of acceptability by the stakeholders. In phase 2 a small portion of land closer to the UHS was prepared into plots and test crops were planted for growth monitoring studies.

Sensitisation of stakeholders

The concept of starting a 'Urine Harvesting System' (UHS) was mooted through a formal application to the Academic Board through the Dean of Environmental Studies. After a long debate the Board has approved the novel idea with certain amount of scepticism. They further approved a take off seed funding and a parcel of land for the project. A 'Sanitation Club' was started with the student participation. Two casual labourers were also employed by the school to complement the efforts of the students in the day-to-day management of the project such as sanitation of the urinal and irrigation of the farm.

Urine harvesting system

The UHS was designed and constructed with locally available materials with appropriate drainage. The flow was by gravity. In the first phase 2 urinals were built one for men and the other for women. Each unit measured 90 cm X 90 cm fitted with a 10 cm diameter shower rose to serve as funnel. A slope was provided at 1:5 for easy flow of urine. Privacy was provided by 6.2 mm ply wood sheet. The units were under a permanent roof in the corridor and were accessible for the users. These were connected to a PVC storage tank of 500 litres capacity. Appropriate pipelines were provided for dilution with water and distribution on to the farm (Fig. 1).

Figure 1: Urinals connected to a storage tank outside the building

Experiments

For greenhouse experiments, black polythene bags (holding 2.5 Kg soil) were used into which appropriate amounts of soil and manures were placed. The nutrient value of urine was compared with normal organo-mineral fertilizer made from urban municipal solid wastes and NPK fertilizer. The treatments included: urine 260 ml/pot (14,000 l / Ha); organo-mineral fertilizer developed at Ibadan 18 g / pot (2000 Kg / Ha which has 5 % N), NPK (15:15:15) chemical fertilizer 2.7 g/pot (300 Kg/Ha). These application rates were based on the common practices in the region and vary with the nature of the crop being grown. A second experiment was repeated using wide mouthed empty clean paint tubs using 10 Kg soil before translating into field trials. The test crops included 'okra', a fruit bearing crop, maize, a grain yielding and sodium sensitive crop, 'tete', a leafy vegetable, and tomato, a fruit-yielding crop. For the field trials 12 plots measuring 1m X 1m were prepared using random block design and the treatments were appropriately computed. Six to seven seeds were put in the pots and when germinated, they were thinned to 2 per pot.

Samples of soil and urine were analysed for physical-chemical characteristics (pH value, C, N, P, K, and soil parameters) and common parasites (*Schistosoma* ova). The effect of urine and other fertilizers on the plant growth, number of leaves, and stem girth during a 12 weeks growing period was followed. Appropriate controls were used without any amendments and tap water was used to maintain the moisture level of the soils. Standard methods were followed for all the analysis (APHA, 1999; AOAC, 1954).

Questionnaire survey

A questionnaire was developed to assess the cultural beliefs and acceptability of urine separation and use for growing edible crops. Volunteers numbering 21 were randomly picked up from the school and were used for the assessment.

Results and discussion

The composition of urine (Table 1) shows the documented normal values and the percent of people clinically abnormal as seen in Nigeria. While the chemical components do not matter for harvesting and use, the presence of pathogenic organisms particularly *Ascaris* and *Schistosoma* ova is a matter of public health concern particularly when used for farming purposes. Urine is also known to carry other pathogenic bacteria (*Salmonella typhi* and *S. paratyphi*) and viruses whose die off varies depending on the environmental conditions. However, if urine is properly stored and used, the pathogen burden will be considerably reduced (Esrey et al, 1998). There are also methods to treat the urine chemically to prevent any infections to those working on farms. According to Drangert (1998), storage of urine for 6 months should be sufficient to eliminate all pathogens.

The greenhouse experiments revealed that urine is comparable to organo-mineral fertilizer or NPK chemical fertilizer as evident from the plant height and the number of leaves during the 12 weeks growing period (Figs. 2 and 3). More data are needed to find out the rate of urine application, mode and frequency of application. The planting of the crops for plot experiments were initiated and data are being collected.

The population involved in the study and their demographic characteristics are given in Table 2. The respondents are mostly men and follow Christianity as religion. Most of them were married and the educational background is National Diploma certificate or graduates. Very few have completed post graduation. The respondents' attitude towards urination and its utilization are given in Table 3. It is evident that 76.2 per cent of them use toilets for urination even though about 30 per cent of them go to bush. Some of them use both depending on the convenience. All the respondents except one visited the UHS site. The general observations were: (a) urine is comparable to other manures and urine promotes better growth; (b) no body complained of the unpleasant smell around; (c) about 81 per cent of them eat crops grown on urine; (d) about 95 per cent of them were prepared to work with urine if occasion demands; (e) most of them were prepared to use urine diversion toilet if provided; and yet (f) two-thirds of them were afraid of urine for its possible pathogens which may affect their health.

Conclusions

The results obtained in this study revealed that urine is comparable with other chemical fertilizers and organic manures in supporting the growth and yield of food crops. It is a valuable resource and harvesting is viable at institutional level. Similar to ours, Danish experience also showed that culture of the users influences its use for crop growth (Danish EPA, 2001). It is difficult to adopt on a large scale until the acceptance is obtained through continued health and environmental education using demonstration units. A participatory stakeholder approach coupled with effective sanitization of urine is suggested to overcome any taboos in the communities.

Tables

Characteristic	Normal urine (%) (Kolmer, 1944	% Population showing clinically abnormal composition in south west Nigeria
pH value	(pH scale)6,0-7,5	0,00
Water	95,00	--
Proteins, fats and other colloids	0,00	--
Glucose	0,00	--
Sodium	0,35	--
Chloride	0,60	--
Urea	2,00	--
Uric acid	0,05	--
Potassium	0,15	--
Ammonia	0,04	--
Calcium	0,015	(Ca oxalate)34,00
Magnesium	0,006	--
Phosphate (PO_4)	0,15	(PO_4 crystals)42,00
Sulphate (SO_4)	0,18	--
Creatinine	0,075	--
Erythrocytes and their pigments	65.750,0	12,00
Pus cells	Few	66,00
Spermatozoa	Usually absent	16,00
Yeast cells	Usually absent	20,00
Trichomonas vaginalis	Usually absent	20,00
Schistosoma haematobium ova	Usually absent	32,00

Table 1: Composition of normal urine and percent of Nigerians showing abnormal levels of the constituents

Characteristics	Number n=21	Per cent
Demographic		
Age	Between 17 and 50+	
Gender		
Male	12	57,10
Female	9	42,90
Marital status		
Married	13	61,90
Single	8	38,00
Religious affiliation		
Christians	14	66,70
Muslims	7	33,30
Educational background		
National Diploma	14	66,70
First Degree	2	9,50
Postgraduate Degree	3	14,30
Secondary school	2	9,50

Table 2: Demographic characteristics of the respondents

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Characteristics	Number* n=21	Per cent
Urination practices		
Urinal	3	14,30
Toilet	16	76,20
Bush / any where	6	28,60
Visit to the urine harvesting site		
Visited	20	95,20
Not visited	1	4,80
Knowledge on whether urine is good for plant growth		
Good (yields better)	21	100,00
Not so good (may damage crop)	0	0,00
Better than others (manures, etc.)	21	100,00
Willingness to use urine		
Yes	20	95,20
No	1	4,80
Reactions to the surroundings of the urine harvesting area		
Smelly	2	9,50
Not bad	19	90,50
Fear of pathogens affecting their health		
Yes	14	66,70
No	7	33,30
Willingness to eat vegetables grown on urine		
Yes	17	80,90
No	4	19,10
Acceptability of urine diversion toilet if installed		
Yes	20	95,20
No	1	4,80
Willingness to grow vegetables on urine, if given an opportunity		
Yes	20	95,20
No	1	4,80

Table 3: Respondents' attitude towards collection and utilization of urine *Multiple responses were obtained

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Further development of urban wastewater disposal systems in conurbation

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Abstract

Sustainable dealing with resources in the field of wastewater treatment is not only a question for rural but also essential for urban areas. Wastewater treatment technology in conurbation in industrialized countries is a well established End-of-Pipe (EOP) technology with a long history. Finding future solutions shall not focus on finding replacing alternatives but shall include further development of the existing system. For a conurbation in Germany like Hamburg, the highest potential in saving resources can not be found in saving water. This does not fit the boundary conditions of the developed wastewater collecting system based on water as a transport medium. Instead, creating subset flows at the origin of wastewater to recover included resources in human urine e.g. nitrogen or phosphorus is a necessary first step. The question is how to utilize the obtained values. Utilization as fertilizer may be difficult if there is no equivalent agricultural area in the neighborhoods of conurbation compared to the possible amount of recovered nutrients. What are reasonable alternative applications for recovered values from wastewater in conurbation? To raise this question and to search for answers is the contribution of the HSE Hamburger Stadtentwässerung to a worldwide sustainable dealing with resources.

Preface

160 years ago Hamburg started to establish a systematic urban sewage system according to modern standards. It can be considered as one of the oldest sewage systems in continental Europe. The know-how about the handling of wastewater is a valuable legacy for the HSE - Hamburger Stadtentwässerung. Besides, according to the companies philosophy, this is an obligation to look into the future. This is a responsible balancing act between preservation and innovation for over 2 million people in the Hamburg Metropol Region.

The slogan “ecosan-closing the loop” for the Lübeck symposium in the year 2003 is not new. It was discussed in detail already 140 years ago by British agricultural-scientists Sir J.B. Lawes and Sir J.H. Gilbert. At this time there was no artificial fertilizer, but a high knowledge about the nutrient content of urine and feces. Nutrient recovery from human excrements contra improvements in public health and the slowly achieved level of modern convenience were crucial topics at this time. The decision made, led to a sewage system with water as transport medium as we find it today in all industrial countries. The value of human excrements as fertilizer was rated second and the pollution of surface water was accepted because in the beginning untreated wastewater was discharged into the receiving water. The foundation was laid for the EOP-system dominating the wastewater treatment in industrial countries. Experts in Europe at this time were aware of different techniques of wastewater handling for example in

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India, China, Japan or Africa. The efforts of the above mentioned two scientists are still highly esteemed today.

We will have to answer the question if the present level of knowledge does still lead to the same reasonable answers to the questions asked 140 years ago. Are there unanswered questions? Are there problems in the foreseeable future that require a further development in wastewater handling?

Introduction

The Hamburger Stadtentwässerung HSE is a municipal service provider. The primary tasks are seen in the regional responsibility and not in a profit–minded global market. Water supply and wastewater treatment in the future will be a question to be discussed globally. This is especially the case regarding the newly developed and growing conurbation areas. Progress cannot be achieved with the maxim of profit optimization. The HSE wants to take its stand as a competent and traditional sewage work company with its part to the conference.

The forecasted global population growth until the year 2050 is another 2.7 billion people. This growth will mainly take place in the developing countries especially in urban areas. The HSE has gone through a process of long experience and innovation in the area of wastewater treatment in the Hamburg Metropol Region. It can now be of a growing international interest. What seems to be a solved problem in industrialized nations according to today's standards is a big problem for the large cities in the developing countries. Millions of people die as a result of insufficient wastewater treatment (so called Waterborne diseases).

HSE deals with the evident tasks of an urban precaution of future society as a consequence of the incoherent development of the EOP-system. The reached status quo in global treatment technology is very different. Its universally valid assessment and the necessary, future stage goals make the solution of the problem very difficult. – It will be a reorientation, finding the conscious of the own position. Important right now is to point the way for a sustainable wastewater treatment.

Industrialized countries do not have to replace their existing successful way of wastewater collection and treatment. But it is important to enable changes. Now is the time for innovations to create an advanced picture of urban wastewater collection and treatment that fit the level of today's know-how. Breeding ground for such a sustained progress can be the increasing understanding of global nutrient and energy fluxes. This includes a new assessment of regional circular processes and the effects of climate changes. The resulting action will have to be integrated in long-term strategies.

The point of view represented in this paper may sound provocative to some of the readers. Under the circumstances given in the Hamburg Metropol Region a reduction of the total amount of wastewater produces a conflict. The average amount of water used per person and day in Hamburg is 120 l. Based on the existing EOP-system it is fateful from an ecological and economical point of view to propagate further progress in water saving. To start necessary further development of wastewater technology in the Hamburg region, water saving is the wrong attempt. It is the wrong location at the wrong time.

Analysis

The further development of wastewater disposal is not only an urban concern. In long-term it can become a vitally important problem, if there is no development for the urban future, nowadays. Why that? Because urban sewage disposal results in irreversible losses of resources in numerous ways. On the one hand, the disposal process consists of an energy taking destruction of valuable substances. On the other hand, the EOP technique does not eliminate pollutants efficiently enough to avoid continuos amount of environmental pollution. In addition supply and disposal in growing conurbation increase the effort for transportation. Some facts help to illustrate the situation in Germany:

- In Germany losses of soluble minerals into the receiving water and therefore into the sea are up to 1 metric ton per hectare and year. In conurbation there are even larger losses up to 5-6 metric ton per hectare and year, e.g. caused by the large urban sewage works. In conurbation and the surrounding this will leave impoverished soil, that is less capable for recyclable biomass production. Elutriation of soluble substances is connected to the enrichment of insoluble pollutants in the soil. The compensation of this effect is very difficult to manage, if at all. The causes themselves have to be changed to limit the damages.
- Besides losses by irreversible dispersion, the losses of valuable substances by elimination in the wastewater treatment process have to be mentioned. On the one hand nutrients such as nitrogen or phosphorus are eliminated with a high energy demand. On the other hand production of these nutrients has consumed a relatively high amount of primary energy. A sustainable dealing with valuable substances does not allow the destruction of value.
- Supply and disposal services for large populations in the conurbation areas generate an increase in transportation effort. The distances covered to supply goods to such areas become ever longer. The total amount of supplied material increases. At the same time due to the high transportation effort the specific efficiency decrease. Each separate substance has a different value that has a different profile of how it can be used. The EOP-System mixes and dilutes these valuable substances, so that no efficient recovery is possible.
- This well established End-of-Pipe-Technology has reached a kind of equilibrium status of positive and negative effects. Adding for example another treatment step to a process may reduce the environmental pollution in the first place but it may be neutralized by negative co-effects resulting from the same step. Additional reduction of surface water pollution is technically possible, i.e. removal of pollutants down to ever smaller concentrations but this can be of a contra-productive effect for environment protection after all. It is important to look at the root causes of environmental pollution. Only recently the maxims of ecopolicy started to consider the roots of environmental pollution, the complex environmental protection, interactions and possible shift effects to fight against. The focus has to be on the total emissions caused by wastewater disposal. This includes direct and indirect gaseous and solid emissions integrated in the assessment of regional and global necessities.
- Problems of growing interest are micro pollutants in the wastewater. Residues of drugs enter the wastewater via human excrements. Other micro pollutants enter via Personal-Care-Products into the wastewater. These pollutants and their metabolites have in common that they have or can have carcinogenic, teratogenic or mutagenic characteristics. It is most probable that these substances are not accumulated in the sewage sludge. A reduction or elimination of micro pollutants in the EOP wastewater treatment process is not possible or at least does have a very poor efficiency due to the high dilution factor. The drugs entering the receiving water of a sewage system also include antibiotics. As a consequence the number of resistant bacteria increase. It is not yet clear if the sewage plants just fail to remove antibiotic resistant bacteria or if they are responsible for the increase of resistant bacteria populations.
- Traditional EOP-sewage systems do have in most cases a mixed sewerage with emergency outlets. Heavy rains can cause emergency overflows. Diluted wastewater enters into the environment without any treatment. The discharged annual polluting load resulting from emergency overflows may reach the amount of polluting load in the treated water leaving the treatment plant. During the last years an increase of heavy rains in Germany could be noticed. Whether or not this indicates a climate change, it seems to have a negative effect on the quality of surface waters. The ongoing decline of consumed fresh water increases deposits in the flush-sewerage-system. As a result more pollution load could enter the surface water by combined sewer overflow during heavy rains.

- The used flocculants and precipitation agents, e.g. help to eliminate phosphorus. But they also bring additional substances into the treatment processes that are showing undesirable side effects.
- Assessment of the resulting residues of the sewage treatment to the current standards of sewage disposal means, that the EOP-system works very powerful. Otherwise the residues, which are not usable are the indication, that the preservation of resources, in particular the recovery of nutrients, are no objective of this technology. The EOP-system is orientated to eliminate and not to recycle valuable components.
- EOP-sewage systems in industrialized countries have a setup that does not favor resource recovery. Treatment technology improvements followed other priorities. The technology and its boundary conditions were developed over a long period of time. For example a fee/tax system that is based on the consumed fresh water, stands in the way of a sustainable sanitation concept. Major goal not only in the conurbation is the level of households connected to the sewer system. In Germany the average connection level is 95 %, in Hamburg it is even 99 %. This is no scope for new alternative concepts but it provides an option for further development of the existing system.

Chain of cause and effect requires further development of EOP-systems

The example of the element nitrogen is discussed in order to clarify the necessity of the further development of the wastewater-disposal system in conurbation.

The enormous growth of the (world)-population during the 20th century from 1.5 to 6 billion people, was only made possible by large-scale industrialized production of nitrogen-containing fertilizers. At present 13 kWh of primary energy are needed for the production of fertilizers containing 1 kg nitrogen. The production of by far over 100 million tons of fertilizer-nitrogen, synthesized by atmospheric nitrogen, currently consumes 3 % of the world-energy-demand.

A nowadays well known but unsolved problem is the insufficient length of stay of synthetic nitrogen-fertilizers within the biomass-producing nutrient-cycle in contrast to naturally generated soil-nitrogen. The rate of loss is about 50 %.

Nevertheless, since the technical triumph in 1915 when artificial fertilizer was produced in unlimited amounts for the first time, it seems to be possible to provide enough food for the growing world population. At the moment 2 billion people owe their lives to artificial fertilizers. Without nitrogen-containing artificial fertilizers the harvest of 1 ha land can feed 10 human beings, with intensive application of artificial fertilizers 1 ha of land nowadays nourishes up to 40 people. It can be calculated that a world-population of about 9.4 billion in the year 2050 can be sufficiently supplied with artificial fertilizers. Limiting factors is not the lack of food but rather negative effects that result from a high consumption of primary energy for the production of artificial fertilizers, a necessary increase of traffic for distribution of food. Another negative effect is the environmental damage by nitrogen losses, among other things caused by an insufficient utilization of organically bound nitrogen. As a result all media are harmed at the same time: climate, water and soil.

From the beginning of the industrialized agriculture during the last 100 years, especially urban population grew tremendously. Looking into the future 80 % of the growth of the world population until 2050 is expected to take place within cities. Urbanization pushed the food-production for urban population further into more remote areas. Within conurbation green space is constantly transformed into settlement area, in Germany about 130 ha per day. Routes of transport for supply and disposal extend more and more by expanding cities.

Because of the reduction of production area for biomass-production inside conurbation, the amount of regional nutrient cycles also decreases, i.e. there are hardly any possibilities for the utilization of nitrogen-containing recycling-material. Recycling of organic nitrogen is firmly integrated into global cycles. The disposal of organically bound nitrogen or the costly destruction thereof is a step into the wrong direction and on a long term basis "future-destructive". The ecological agriculture (with utilization of organic matter) reduces the demand of primary energy – with regard to nitrogen-demand this is a improvement of efficiency, a minimization of nitrogen losses.

One of the aims of today's wastewater treatment in Europe is to remove nitrogen and as a result protect surface water from eutrophication. This is done by nitrification and denitrification, releasing at the end all the treatment steps molecular nitrogen N_2 into the atmosphere. In Hamburg a population of about 2 million people is connected to the central sewage plant. The amount of human excrements into the wastewater system is about 4,5 kg nitrogen per person and year in total 9.000 metric tons reaching the sewage plant every year. Assuming that this amount of nitrogen has its origin as atmospheric nitrogen bound into artificial fertilizer then entering the food chain and finally ending up in the wastewater, this amount of nitrogen has a considerable value. Assuming furthermore an energy ratio of 13 kWh per kg nitrogen (e.g. urea) the amount of 9.000 metric tons correspond to an amount of 120 million kWh per year.

The efficiency of nitrogen removal is currently about 75 %. To remove 75 % of 9000 metric tons = 6.750 metric tons of nitrogen in the wastewater in Hamburg about 30 million kWh per year are required. In total the amount of 150 million kWh is available for (re)utilization. This corresponds with about 17 kWh per kg nitrogen. Instead of using the described effort to transfer the nitrogen back into the molecular status, it is an economical as well as an ecological duty to look for cascades of direct utilization.

About 85 % of the total amount of nitrogen enters the sewage in concentrated form as urine. Sanitation technology offers the opportunity of urine separation from feces. Together with other nutrients contained in the yearly amount of urine per person a cultivation area of about 200 m^2 could be supplied with fertilizer, especially since this form of fertilizer is very well accessible to plants. Compared with other fertilizers, urine concentrate shows the lowest contamination with heavy metals. The values for cadmium and chrome are even below the values for phosphorus fertilizer obtained from mining. The fertilizer potential of the Hamburg urine concentrate is an area under cultivation of about 400 km^2. It is obvious that urine is a worldwide inexhaustible resource. Regarding the finiteness of the phosphate reserves and the possibility to reduce the overall energy consumption this utilization must be reassessed.

Valuable substances in the sewage are not present in an isolated state but mixed and diluted up to the 200 fold. This is a dilemma of the EOP system. How can the resources of sewage be recovered in a usable form? – The first step to a solution has to be a management of the material flows. Creating subset flows at the origin of sewage is the urban form of decentralization This is the key to a further development of EOP-systems and of course the basic condition for utilization of valuable components in wastewater. In addition this separation is an important requirement to improve pollutant removal.

What has to be done, what is possible?

Evolution needs a cause, likewise the initiation for a change of the prevailing waste technology. An analysis of the situation and the chain of cause an effect have shown that there already exists enough pressure for change, which calls for development an adjustment of the EOP-technology. Future "maxims of disposal" demand for the use of original material flows, close to their sources, prior to mixing and their uppermost utilization within the region.

The fundamental questions are: How can the desired subset flow be obtained, where shall it be directed to by which means, and what is the target-utilization?

The driving force is the target-utilization. Where to initialize the formation of subset flows?

Nowadays, in a well developed urban EOP-system for wastewater treatment the incineration of residues from wastewater drainage and treatment is state of the art. The utilization by incineration is the current transient technology before more effective possibilities of utilization will take their place. In Hamburg we have almost a complete utilization of the carbon load of raw wastewater through incineration of sewage sludge and an intelligent energy recovering strategy. The ratio of electricity production and consumption for the wastewater process in the Hamburg Metropol Region lies by over 60 %. By continuous optimization of this process this ratio can even be slightly improved. But there is a limit: with a constant carbon-input into the EOP-system and within strict limits confined carbon:nitrogen:phosphate (C:N:P)-ratio in municipal raw wastewater the utilization/production ratio can hardly be improved. For a waste disposal process with the elimination of nutrients, nitrification, denitrification and phosphate precipitation this improvement can only be achieved by reduction of the energy consumption of this process. Decisive for saving of energy is an influencing control of the C:N:P-ratio primarily by withdrawal of nitrogen, secondarily by phosphate-compounds. This can best be done by urine-separation from the system. This makes clear how complex the preference for urine separation from the wastewater flow is.

An area of about 400 km² of agricultural land can sufficiently be supplied by the fertilizing capacity of separated urine from the city of Hamburg. Within the Hamburg Metropol Region this is by far not possible. In the catchment areas conurbation and megacities there are not enough utilization-areas available for biomass production. Cities grow by conversion of agriculturally used land into settlement area. All these facts stand against the anticipated regional utilization of separated urine. The seasonal appointed fertilizer demand leads to the conclusion that urine has to be processed into a storable product with a low weight/volume that allows the transport to biomass producing areas. Thus the aim of utilization of closing the cycle process within short distances is slightly disarranged.

If the aim of direct utilization of urine is questionable, there is also the possibility of fractionating the separated urine into its different compounds to assemble the recycling process.

With regard to the limited phosphate reserves the phosphorus content of urine has a rising value which is emphasized by the assured availability for growing plants.

The potential for the utilization of the nitrogen in separated urine has not been analyzed yet. There is widespread market for industrially produced urea, where maybe urea from urine can be used as a substitute. E. g. for NO_x-removal of flue gas from incineration processes. There will be an EU-law which will stipulate that SCR-technology, which has become a standard process in industry, will have to be applied in utility vehicles. The flue gas cleaning with the selective-catalytic-reduction-technology (SCR) reduces NO_x in flue gas by use of an aqueous urea solution.

The above described relations of this publication show a clear transitional aim for the further development of the EOP-system. In Hamburg there will shortly be determined how to relieve the wastewater treatment process by urine separation with help of mathematical simulation. The anticipated result of this research should be an optimal C:N:P-ratio at he inflow of the wastewater treatment plant, that can be adjusted by urine separation. The first step is an idealized nutrient elimination by the biological step. By simulation and calculations it will also be analyzed which effects can be expected if in some defined catchment areas urine separation is installed in order to exonerate the sewage plant. How can the composition of the storm-water runoff be possibly affected at defined outlets?

With those assessed results the course can be set with regard to an improvement of the EOP-system e.g.:

- Alternatives for a future extension of the wastewater treatment plant with changed demands can be designed, adjusted to regular renewal-cycles of the equipment.

- For the whole waste process there would be the perspective of a considerable potential for a reduction of consumption of energy and resources.
- Possibilities of a well directed elimination of problematic compounds will arise since the major part of residues from medicine is transferred into the wastewater mainly by urine.
- A promising step for the recovery of phosphorus would be done.

Conclusions

HSE - with a successfully developed EOP-technology - is discussing the conversion of the prevailing wastewater removal system: a quantum leap with regard to health precaution, an all media affecting protection of the environment and saving of resources in Hamburg.

Inevitably there will be solutions for problems of urbanization in emerging nations and developing countries.

Into waterbodies discharged, systeminherent residue loads of the EOP-technology make innovative further development difficult by legally regulated wastewater levy - the EOP-technology is thus dictated. It is a novelty in Germany. It would be a novelty as well to make the wastewater levy available for a start of a change of the EOP-technology, a German contribution to technical development aid.

With the development of the technical wastewater process the basic conditions that hinder the further development of the EOP-system, developed, too. The connection of financing of the waste process and individual water consumption leaves little room for future investments, especially as the prevailing waste technology has a high fix-cost share. The regionally continuing trend towards water saving is based on a misunderstanding of ecological and economical connections and backgrounds. The unlimited propagation of measures for water saving or even subsidization there of is disastrous, because this does not lead to the above mentioned potential for the saving of energy and resources. On the contrary, this door will be closed. Today's blackwater - urine and feces – holds an utilization-potential from more than 100 kWh per person and year. This matter was not completely shown in this paper. In comparison with this utilization-potential the saving-potential due to use less toiletwater is very little and drops to zero because finally maintenance of the EOP-sewage-system will rise.

The efficient use of energy and resources is the key to sustainability. Water-saving - just now - makes incapable of necessary actions. Water saving is affecting the income by charges of a sustainable waste management, finally endangers the already achieved standards of the EOP-system.

To sum it up it can be said that the further development of the EOP-system needs the following investment: subset flows have to be obtained at the origin of wastewater. This enables nutrient recovery in regional cycles. Such a development can be seen as an urban contribution to efficient and sustainable dealing with resources like energy, nutrients and not least water.

The above mentioned British pioneers of urban wastewater management about 140 years ago may well identify with the currently changed targets of a future waste technology. In retrospect it becomes clear that system-developments have to be integrated into long-term directed strategies. The course is set today.

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Implementation of a closed–loop sanitation concept in Yang Song township, China

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Feasibility study

Introduction

This paper presents the feasibility study of the GTZ ecosan project for the town of Yang Song Township, located in Beijing province, China. This study was carried out in co-operation with the IEEP, Beijing, and supported by Chinese consultants Wang Gehua, Wang Li Xian and Han Di. From June to October 2002 a baseline data collection was carried out to subsume the development planning and the environmental conditions for Yang Song Township. This is the initial basis for recommendations in the field of integrated ecological sanitation, preferably suitable for innovative technologies.

With urbanization and modernization, Yang Song, like other developing towns in China, is facing a huge environmental challenge, particularly with regard to waste and wastewater treatment. The implementation of flushing toilet systems and the planned construction of a conventional wastewater treatment plant deprives the local farmers, who are still dependent on the traditional use of night-soil, of valuable nutrients. As Yang Song local council is currently considering various treatment technologies for municipal wastewater, this study aims to produce a definition of a jointly developed ecosan-strategy for the urban and rural district. With regard to the model-status of the township and the upcoming Beijing Olympic games in 2008, the GTZ ecosan project expects an announcement effect for other townships and cities in China, and worldwide.

Description of Yang Song Township

Yang Song township is located in Beijing province, 45 km from the Chinese capital. It consists of a city surrounded by 15 villages. It has a total population of 21.00 inhabitants.

Yang Song was named as a "model township" for small-town construction in 1997. This status obliges the government to develop the industrial and urban sector, and to protect and improve the environmental conditions. In the township development plan the government plans to combine the 15 villages into 9, and to resettle the village population in the city by 2010, increasing the total population to 50.000. For this purpose the construction of new apartment houses, in the form of panel buildings, started in 2001. Additionally the government wants to attract middle and upper class Beijing residents to move to this suburb, investing in a new countryside villa-district by providing an environmentally friendly atmosphere.

The economy of Yang Song is still dominated by the agricultural sector. The main agricultural activities are animal breeding, with a projected increase in the number of cattle over the next years. In addition, there is a turning from classical crop production (corn, hops) to economic plants (medical plants, ging-seng, aloe vera, flower farms, etc.).

Yang Song is located in the main catchments area for water supply to Beijing. The high water demand and consumption in Beijing province leads to serious extraction of the groundwater resources, with levels declining at up to 1.5 meters annually. Yang Song relies heavily on the groundwater resources, as all freshwater for household, industry, greenery and agricultural purpose is derived from that source. Additionally in the last years the flows of 3 rivers in Yang Song area have decreased, even in the rainy summer months.

The construction of sewerage for the city and industrial district finished in November 2002, leading to a site 2km south of the city. Presently there is no treatment of municipal wastewater, and it is discharged onto fields nearby. Yang Song council is seeking a solution, with a capacity of approximately 2000 m^3/day, with the possibility a future increase to 5000 m3/day. All new houses are equipped with modern flushing toilets.

For the villages a sewerage system has not been planned and population relies on on-site sanitation. The design and the hygienic conditions differ with the economic status of the population and the village committee: the poor villagers have simple pit latrines, while the wealthier villagers have squatting toilets connected to septic tanks, and use collected greywater for flushing. In 3 villages a greywater flushing device and a 3-compartment septic tank latrine have been introduced with financial support by the committee. Vacuum tankers collect the content of the tanks, and the night soil is spread on the local fields. The household pays 10 Yuan/m^3 (~1,2 $) to the private collector for this service.

Potentials of ecosan strategies in Yang Song:

Yang Song township represents a closed area, with both urban and rural components, that can guarantee the utilization in local agriculture. Further promotional terms for an ecosan concept are:

Environment:

- Pressure of water saving and groundwater protection in water scarcity area.
- High potentials in substitution of fresh water- groundwater- for example: as irrigation water in gardens, agriculture, city greenbelts and in the existing water park.
- There is a loss of the high organic content (60% and more) in household and market waste, because of landfill disposal. Existing landfills are open pits without drainage, groundwater protection, gas capture, cover or leachate capture.

Sanitation

- Sanitation improvement in the poor villages is demanded.
- A hygienic disposal and sanitary latrines with greywater flushing are already promoted.
- The households of the villa area can decide about sanitary equipment.

Agriculture sector

- Farmers still depend on night soil from village households and manure from breeding farms. No social prejudice about excrement utilization, but an over-fertilization with artificial fertilizer, manure and night soil can be estimated.
- Breeding farms have to comply with a new law on pollution prevention from livestock production adopted in October 2001.
- Increasing demand of fertilizer for economic plants, but under stricter environmental regulations.

Government level

- Existing willingness and public pressure to improve environment ("model character").
- Government is interested to implement advanced technologies and strategies
- is seeking a solution for the treatment of municipal wastewater from existing flush systems and non-polluting industries and offering financial support and free land.

Drawbacks for ecosan

- The construction of sewerage for the town was finished in November 2002. The location is fixed and a modification of the first steps is almost not possible.
- Limited experience with ecosan strategies in urban areas/ large settlements.
- Industrial wastewater has to be treated anyway, and a separation of components is not achievable easily.
- Low water price, which includes fees for wastewater, will not cover the cost for operation and maintenance. Financial support is necessary.
- The future development of the township (construction, agricultural and industrial sector, population, etc.) is strictly connected to the economic development, which makes forecasting and detailed planning difficult.

Other considerations

As the farmers in Yang Song rely on night soil, manure and artificial fertilizer, the need for urine or compost from faecal sludge and organic wastes has to be carefully investigated. Therefore it is important to contact and co-operate with the local Bureau of Agriculture, which can give advice and support.

Urine separation:

Urine separation is a traditional device in China, and even proved their function in modern eco-toilets in Guanxi province. But in Yang Song a separate collection was not found in any part of the township. For implementing urine-separating toilets in the new buildings the panel construction would support a standardized design. On the other hand the small bathrooms limit the installation possibilities, and failures can be expected, because of the high number of inhabitants.

Night soil or compost:

Night soil and manure is still used in Yang Song to fertilize the fields. But nevertheless, no control of the hygienic quality and the utilization of the product are carried out. The existence of the reliable collection business should be considered and integrated in the concept.

The processing and the utilization of compost were not observed in Yang Song. Compost would represent a new kind of fertilizer for the farmers, and it would demand a change from traditional habits. The implementation of a "new" technology, like composting, for Yang Song can be considered as rather extensive.

Water concept

The water concept focuses specifically on water saving, rainwater infiltration, reuse and a discharge control to protect the water resources.

Water saving:

Water saving is possible for the households, industry and farming areas. In the villages, with low water consumption and utilization of greywater for toilet flushing, further water saving is hardly achievable.

Rainwater infiltration:

As rainwater is collected in separate pipes, and precipitation is mainly in the summer months, a separation from the municipal wastewater is very promising. This will minimize the capacity of the plant, and secondly benefit from the recharge of the groundwater.

Discharge control:

For water resource protection, especially of the groundwater, a discharge control is very important. Particular focus should be put on the control of non-point source pollution from agriculture activities, such as fertilizer overspill and the infiltration of manure from animal husbandry, that are responsible for nitrogen eutrophication in the water courses. For the future treatment plant the effluent has to be controlled. This should be done regularly by the Environmental Protection Department of Huai Rou County, and supported by measurements of Yang Song government.

Reuse:

There is a huge potential in the township for water reuse instead of groundwater. Especially in the case of irrigation, groundwater can be replaced to a greater or lesser extent by greywater, process water from industry, rainwater and in the future by treated wastewater. In the summer months, when demand for irrigation water is very high, the greenbelts and the water park can benefit from recycled water. Crops, plants and especially flower irrigation with pre-treated wastewater are possible.[1]

Nutrient concept:

The nutrient concept emphasizes the recovery of nutrients from the urine, faecal sludge and wastewater. The nutrients benefit local agriculture and can support - and to a certain degree substitute- artificial fertilizer.

In the villages the utilization of faecal sludge from latrine pits and septic tanks is still common, and the intention is to guarantee a safe utilization, by approved design and sufficient storage time[2].

For the town, a construction of a conventional wastewater plant will eliminate and not recover the nutrients and the resulting process sludge will have to be disposed of. But in an ecosan concept the production of valuable fertilizer from the treatment process is an important factor. Sludge produced by sewage treatment plants can be used as a soil conditioner-fertilizer after treatment. Composting the sludge will control most pathogens and, if properly marketed, can contribute to the economic feasibility of the treatment plant. However, the agricultural application rate of composted sludge should be carefully calculated. The build-up of toxic metals in the soil can be neglected, because for Yang Song only household water and no hazardous components are considered.

According to agricultural legislation, the treatment of animal manure before use in agriculture is now imminent. Additionally the treatment of a separately collected organic waste fraction of the

[1] *In China irrigation with wastewater has to fulfill the 'national Standards for irrigation water quality [GB5084-92]' that are considering the type of irrigation area, and type of crops.*

[2] *National 'standards for Safe disposal of Excreta' were promulgated in 1987 [GB 7959-87]. 5 types of sanitary latrines are currently promoted in China: three-compartment septic tank latrine, double Urn latrine, Triplex biogas latrine, VIP latrines, urine diversion eco-latrines*

municipal waste can be included either in biogas plants or on separate composting piles that also compost faecal sludge.

Technical and practical proposals

Proposals are made in the fields of sanitary equipment (see table 1) and for the treatment of wastewater streams (see table 2). For a better understanding and to give appropriate proposals a matrix is set up. With respect to the different conditions the township area is divided into village and town (subdivision residential area and industry), and with respect to the development planning into existing, new and planned structure.

Villages

The design of on-site sanitation must be improved to assure a hygienic utilization of night soil. The implemented squatting toilets with greywater flushing and connection to a septic tank are a well suitable technology. For the collection of greywater there are alternatives to the conventional sewerage system: simplified sewerage and settled sewerage. If this household breeds animals, the well-known simple Chinese biogas systems with toilet connection seem to be the best solution.

Recommendations for existing residential areas

For the existing panel building area and the new panel building area only rainwater and household wastewater can be divided, due to economic reasons as the investors are real estate companies and they are not yet willing, without extra subsidies, to invest in two internal wastewater piping systems. All changes will be hardly possible at once, but for further restoration and rehabilitation work ecological solutions should then always be respected. To permit a decentralized reuse of the wastewater combined „Decentralized Wastewater Treatment Systems“ as developed by CEEIC (Chengdu) and HRIEE (Hangzhou) are recommended.

For on-site wastewater effluent improvement, additional anaerobic filter chambers could be constructed for the **villa area**, which is already under construction, treating wastewater after existing septic tanks. The future inhabitants can decide on their sanitary equipment, for example UDS (urine-diversion-System) can be one appropriate solution.

Recommendations for new residential areas

Separated blackwater/greywater collection systems and decentralized wastewater systems with a secondary treatment should be implemented. On-site treatment of blackwater using baffled septic tanks with up-flow anaerobic filters is one of the feasible alternatives with promising high cost-benefit efficiency. After pre-treatment, treated blackwater is discharged through vacuum sewers into sludge post-treatment biogas stations where the organic solids fraction from municipal solid waste are added and than the effluent should be earthed in sludge decomposition lagoons and/or can be used directly as liquid soil conditioner.

Greywater is collected in decentralized community treatment plants, that consist of Imhoff tank / waste stabilization ponds or constructed wetland, integrated into the greenbelts.

<table>
<tr><th></th><th>Village</th><th colspan="4">Town</th></tr>
<tr><th></th><th></th><th>Residential Buildings</th><th>Communal Buildings</th><th>Villa area</th><th>Industry</th></tr>
<tr><td>Existing</td><td rowspan="2">Improved latrine design: greywater flushing or separation toilettes</td><td colspan="2">(Changes hardly achievable)</td><td rowspan="3">Owner can decide about sanitary equipment:
Implementation of Urine diversion toilets difficult, vacuum toilets and -sewer system preferable, Separate blackwater and greywater disposal</td><td>(Changes hardly achievable)</td></tr>
<tr><td>New</td><td colspan="2">Upgrade toilets with water saving device</td><td>Upgrade toilets with water saving device</td></tr>
<tr><td>Planned</td><td>-</td><td colspan="2">Separate blackwater and greywater disposal.
Toilets with water saving device, greywater flushing</td><td>Separate blackwater, greywater and process water disposal.
Toilets with water saving device, greywater flushing, process water reuse</td></tr>
</table>

Table 1: Recommendations for sanitary equipment

<table>
<tr><th></th><th>Village</th><th colspan="4">Town</th></tr>
<tr><th></th><th></th><th>Residential Buildings</th><th>Communal Buildings</th><th>Villa area</th><th>Industry</th></tr>
<tr><td>Existing</td><td rowspan="3">Improved pit design with retention time
Or:
Simplified sewage with biogas or dry separation toilettes</td><td colspan="2">DEWATS
Modular expandable</td><td>-</td><td rowspan="2">Treatment with residential wastewater (Wastewater quality meet household quality)</td></tr>
<tr><td>New</td><td colspan="2" rowspan="2">Separate treatment of blackwater and greywater
Black water: baffled septic tank with up-flow anaerobic filter, sludge post-treatment biogas stations
Greywater: decentralized community's treatment plant. Consisting of Imhoff tank or constructed wetlands</td><td rowspan="2">Owner can decide:
On-site treatment: Septic tanks with anaerobic filter chambers, dry separation etc.</td></tr>
<tr><td>Planned</td><td>Pre-treatment up to household wastewater quality</td></tr>
</table>

Table 2: Recommendations for treatment of wastewater streams

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Implementing large-scale and urban dry sanitation: an agenda for research and action*

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Keywords

Ecological sanitation, composting toilets, dry toilets, Mexico, peri-urban, program implementation

Abstract

Relatively little is known about modern, large-scale, urban Dry Sanitation (DS) implementation. A broad range of large scale and urban DS experiences in Mexico were studied to assess DS viability in these contexts, with particular emphasis on aspects of program implementation and user satisfaction. Based on the cross comparisons of multiple sites, lessons learned and further research and development needs were identified. Several results and recommendations of this study confirm those from other international experiences. Recommendations for improved program implementation and user satisfaction include aesthetic, operational, and structural strategies. Recommendations offered for DS development include consolidation of baseline information, coordination of research with program implementation, and systematic exchange of information across sites. Suggested approaches to implementing these recommendations include action research; adaptive management; social marketing; participatory technology assessment; externally-facilitated participative, diffusion of innovations; and a willingness to implement intermediate DS options. Whether DS can fulfill its potential will only be known in practice and by testing it under a variety of circumstances. It is our hope that this paper will contribute to these developments.

Introduction

Dry Sanitation[1] (DS) may ease some of the social, economic and environmental challenges faced by centralized waterborne sanitation today (First International Conference on Ecological Sanitation, 2001). Although many have proposed DS as an important strategy for urban areas, experience at large scales and in urban settings is still limited (Holmberg, 1998; Winblad, 2000; Esrey, 2002). This study assessed DS viability in large-scale urban contexts by researching a wide range of such experiences in Mexico. In that country, a large number of dry toilets (DT's) have been installed under a wide variety of program modalities, using diverse toilet models (Cordova, 2001). The diversity of social, institutional, technical, and climatic conditions allowed research on a large set of DS implementation possibilities and the identification and analysis of variables that apply to other settings beyond Mexico. Further relevance of the Mexican results is evidenced by consistency between user satisfaction and program implementation results with those reported from other international experiences (see Cordova, 2003).

*This paper has been peer reviewed by the symposium scientific committee

[1] With this term we refer to on-site sanitation systems, which do not use water or use minimal amounts of water to sanitize excreta and process them into a safe soil-amendment material.

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This paper presents results from the analysis of DS experiences in Mexican urban areas and proposes recommendations for research and action in large-scale and urban DS development, with particular emphasis on program implementation and user satisfaction. To focus attention on research and policy needs, this paper does not describe in detail the analyses of the cases that led to these recommendations; those analyses have been presented in Cordova (2003).

Methods[2]

The field research for this study was conducted between August 1999 and December 2000. Research methods included: semi-structured, in-depth interviews with 50 practitioners and professionals associated with DS implementation in various regions of the country; collection of written and video documentation of DS projects; site visits; toilet inspections; informal conversations with dry toilet users; and a quantitative survey among 284 DT users at five urban sites. The initial stage of research included both rural and urban cases of DS, but site visits and interviews with users were limited to six urban sites. These were the largest-scale and most-recent urban experiences identified and include: Acapulco, Ciudad Juárez, León, Puerto Morelos, Tepoztlán, and Xochimilco (Figure 1). Visits to various DS programs in the USA, work with local organizations in Tompkins County, NY (USA), and a literature review of user satisfaction and DS program implementation in urban areas worldwide provided information to complement the analysis of Mexican experiences.

Figure 1: Urban dry sanitation study sites. (Map created by K.A. Schafft)

Results

The analysis of Mexican experiences evidenced that:

a) DS has been implemented widely in Mexico including at a large scale and in a diversity of urban settings. Several organizations (public, private, non-profit, and community-based) as well as individuals have independently created DS programs and diffused this technology and approach.

b) The diversity and number of promoters and participants in DS programs shows that DS implementation takes place over a complex topography of organizational cultures and locally-specific social conditions. Acknowledging and understanding this complexity is important in efforts to advance and improve DS implementation.

c) User satisfaction was high at most Mexican sites –among both high-income and low-income users, in large- and small-scale programs, under different climates and institutional settings, and with various different toilet models. Proper dry toilet (DT) function, user motivation, and creation of demand were important elements in user satisfaction.

d) User satisfaction and acceptance of the technology can be increased by improved DT convenience and aesthetics, operation and end-product management support services, and

[2] For a detailed account of methods, see Cordova (2003).

economic incentives.

e) Programs have faced a number of structural and recurring operational problems, which can be adequately addressed with a comprehensive set of strategies listed below[3].

Recommendations for improved program implementation and user satisfaction

The following recommendations derive from the results of this research.

1. To increase urban users' satisfaction and acceptance of this technology, it is important to improve DT aesthetics, strive for maximum user-friendliness and low user labor, provide effective support services, and develop social and economic incentives.
2. Operationally, program effectiveness can be improved by communicating clearly that a DS program includes the *full* set of stages: toilet model(s) selection; promotion/dissemination; toilet production/construction; toilet delivery; user training/retraining; follow-up and support services; end-product management; and evaluation and feedback. Neglecting any stage can seriously jeopardize program success. Large-scale program success also hinges strongly on maintaining a balance between hardware, software, and program operational capacity. This balance has tended to get lost in large-scale programs as insufficient resources and planning shift emphasis heavily to hardware. DS programs will be more successful if promoted alongside the appropriate provision of greywater and solid waste management systems.
3. Structurally, DS program implementation can be improved by transforming DS from an experimental technology, supported by small or special programs, to formal infrastructure supported by public or utility enterprises. This would be aided by a general sanitation approach that contemplates a repertoire of both wet and dry sanitation systems as adequate and socially-acceptable. To this end it will be important to disseminate information amongst professionals and policy-makers that counter the resistance to alternative sanitation options, and increase the social status of DS through its use by high-income residents, to reduce misperceptions of DS as a second-class technology.

Recommendations for DS development

Cross-comparisons of multiple sites led to the identification of lessons learned and additional development needs. The implementation of the above-mentioned policy recommendations and further development of DS would benefit from a three-pronged approach: a) the consolidation of strong baseline data and identification of information gaps; b) the structuring of research in coordination with program implementation to reveal the effects of important variables on program success as well as clarify knowledge and information gaps; and c) the systematic and timely exchange of information across sites to accelerate learning (Figure 2). Breadth and depth are needed in our understanding of current DS implementation, as well as horizontal and vertical communication within and between DS experiences worldwide. Multi-site research and structured cross-comparisons will help for both purposes. Following is a discussion of the needs identified, particularly

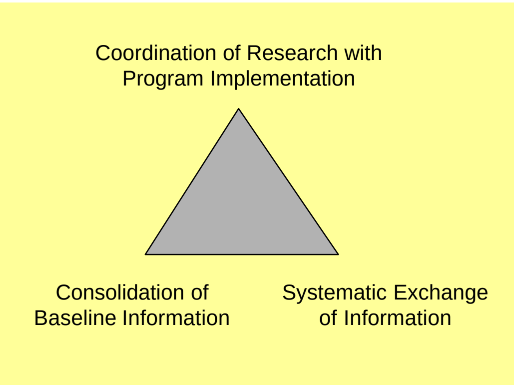

Figure 2: Three areas of dry sanitation research and development needs

[3] For a comprehensive description of problems and detailed explanation of strategies, see Cordova (2003).

as they relate to program implementation and user satisfaction. Several of these needs have already begun to be addressed in some regions, but they may be further developed and systematized as suggested below.

I. Baseline information

Future research and improvement of programs depends on continued identification and description of DS experiences, by country, by region, and worldwide. The research in Mexico evidenced that there are many DS experiences that are not recorded, reported, or known of by an established DS practitioner network. These undescribed experiences neither have the benefit of joint learning that DS networks and symposia provide, nor do the DS networks and symposia have the benefit of learning from them.

For the consolidation of baseline information we suggest the generation of:

a) Censuses of DS experiences (described by a set of agreed-upon variables which can include program variables such as number of households/individuals serviced, toilet model(s) used, costs to program and to user, program motivation, implementing organization(s), type of setting (rural/urban), type of training used, type of follow-up services provided, date of initiation/program duration, current status of program, and user variables such as income-level, level of choice, level of demand, types of motivation, etc[4]). These statistics on DS should be published regularly and made available.

b) National, regional and worldwide research and literature clearinghouses. Some have already been created (e.g. GTZ Ecosan Project library; RedSeco in Mexico), but extending their geographic and thematic coverage, creating physical libraries/collections in several regions and languages, forming a directory of international clearinghouses, and establishing formal sharing and exchange mechanisms would strengthen these collections.

c) Directories of DS providers, promoters, trainers and funders, internationally and by regions.[5]

As efforts to integrate DS into the mainstream water and sanitation sector continue, the data collection and dissemination channels may be institutionalized (e.g. through World Bank, World Health Organization, and other national and international statistics publications). Through the systematization of baseline information, conceptual and research tools will be developed, including agreement on definitions ('urban', 'sustainable sanitation', 'ecological sanitation'), survey instruments, research protocols, etc. As more experiences are studied, the conceptual and research tools can be refined.

II. Coordination of research with program implementation

a) The set of Mexican experiences studied did not have sufficient overlap to adequately decouple the effects of toilet model, program set-up, and population income-level as factors for **program success**. To tease out the effects of such confounding factors, new DS programs should be set up in ways that allow for testable comparisons between population characteristics (income, education, region, country, ethnicity, etc.); toilet models (self-contained, urine-diverting, etc.); program modalities (user attraction methods, training, support services, etc.); and incentive systems (economic, social, direct, indirect, etc.).

b) To better understand **user preferences, needs and satisfaction**, experiments should be done with different types of incentive programs for users (including combinations of marketing or status-raising strategies, economic incentives and disincentives, regulatory incentives, etc.). Assessment of satisfaction should be routinely included in program implementation and/or elements of satisfaction should be monitored in other types of DS studies (e.g. technical, microbiological, etc). Longitudinal research on what happens at DS sites (with the programs, with the users) after 5, 10, 20 years will also generate important insights.

[4] Such a format has been used to describe Mexican experiences in Cordova (2001).

[5] Several independent websites and clearinghouses include this type of information.

c) To create conditions of appropriate **institutional support** for DS programs, it will be important to: identify information and incentive needs for businesses, public officials, and communities; understand how contextual factors (such as local economic activities, water policy, institutional relations) play a role in the evolution of DS programs; and identify which toilet models and support systems are better accepted in different cultures/regions/socio-economic levels. If users are to be given a choice of the DT model they wish to install, it will be important to assess, both organizationally and technically, how many different DT models it is feasible to service and provide secondary processing for in one area or under one single service provider[6], as well as how many sanitation systems (both wet and dry) are compatible and management-effective in one single site.

d) In the Mexican cases studied, **end-product management** was a commonly neglected program element. The organizational and technical aspects of end-product management can be very susceptible to local conditions, including climate, type(s) of available cover material, type(s) of DT processing system (desiccating/composting/ biodigestion), local feasibility of secondary processing systems, type(s) of soil to which end-product is to be applied, types of crops or vegetation to be grown, and organizational aspects such as collection system frequency, modality (emptied by service providers or households), etc. These conditions can vary even within one large city. In terms of policy and program implementation, local decision-makers must be aware of this number of factors and the need to understand their local feasibility, in order to make informed decisions. To this end, end-product management research must cover a wide range of varying conditions and be translated into formats (flow charts, matrices, etc) and language that local decision-makers can grasp easily.

e) Discussions with city officials, DT developers, and urban residents, revealed **regulations** research and development needs. These included: identifying current regulations for sanitation, sludge, and greywater at each site[7]; identifying gaps, overlaps, consistencies, and inconsistencies vis-à-vis DS; proposing regulations specific for DS; and considering different requirement stringencies for different zoning categories. It was also deemed important to strengthen and standardize criteria for a certification system (or minimum performance criteria) for DS[8], and where DS is not formally supported by a city or utility, develop regulations requiring DT distributors or program implementers to: pilot-test their model(s) at each site (or another site proven to be similar), provide an Regulations would not have the intent to make DS difficult for the users, producers, or promoters but rather to guarantee that the DT's on the market will work, as well as to avert large-scale failures and disrepute for the technology. Regulations may be end-product management plan, ensure commercial and/or local availability of cover or texture material, and provide technical support throughout the life-time of the DT.[9]

f) developed collaboratively, with the participation of users, promoters, producers, and public officials[10], and will likely vary across sites.

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[6] Different container sizes and shapes and different end-product qualities and characteristics could make collective management complex and costly.

[7] found in codes on solid waste, environmental protection, public health, urban development, and/or zoning & building.

[8] These might include technical specifications, required user training (e.g. Washington state, USA was considering permitting DT's if the user took a 2-3 day training course in DT operation and maintenance (Holm, 2000)), minimum specifications for cover material, DT use-intensity, end-product disposal/re-use criteria, and the secondary treatment requirements (if any) for each DT model or system.

[9] This may include investing in a revolving fund and/or training local technicians in case the company goes out of business. This regulation would become unnecessary once DT's are common enough that a critical mass of DT service providers exist in each city (like auto mechanics exist to service cars).

[10] An example of such collaborative regulation development is the USEPA negotiated rule-making for the development of regulations affecting industry.

III. Systematic exchange of information

Because the DS field may not collectively have the funds to set up new experiments to clarify all the knowledge gaps identified thus far, and because each site will likely not be able to conduct in-depth research on all the aspects of DS (program implementation, technical design, economic assessment, epidemiological studies, etc), cross-comparisons between a diversity of well-described programs and sites provides an alternative, complementary means for generating knowledge and improving our ability to influence program success. Such cross-site research will require effective communication and coordination mechanisms between sites. This may be aided by formal and systematized exchange channels that ensure mechanisms to reach all the appropriate stakeholders, from international agencies, to individuals and communities[11].

Suggested approaches for implementing recommendations

Because the research agenda is very ambitious, this field is in rapid development, and the effectiveness of recommendations can only be assessed in practice, we propose that the most effective way to carry out the development of DS will be through parallel action and research, where a diversity of social actors collaborate to design, assess, and carry out actions; where results are communicated within and between programs; and where planning and management are adaptive. To this end, we suggest a combination of complementary approaches, which may offer productive ways to pursue the recommendations proposed thus far (Figure 3). These approaches derive from experiences in various fields and well-developed disciplines, described briefly below.

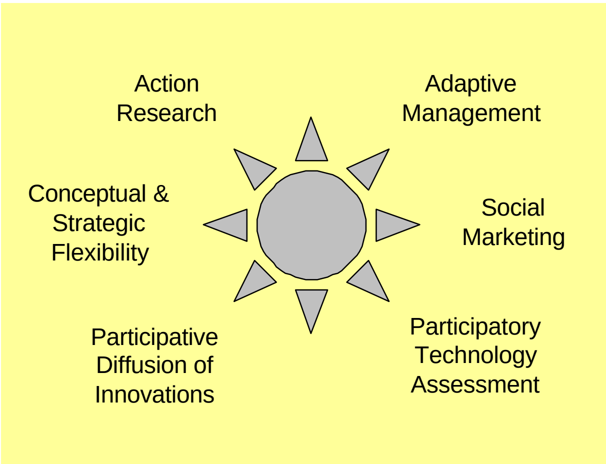

Figure 3: Six complementary approaches to enhancing dry sanitation development

Action Research (AR) emphasizes iterative reflection and action (research and implementation) between collaborating partners, for the purpose of meaningful local change (Greenwood and Levin, 1998). AR can be useful in DS development because it enables us to conduct research *as we implement programs* and *promptly incorporate the findings* of research into the programs as they are being carried out. The timely conversion of research results into action is made possible to a large extent by the involvement of local actors in establishing research and program goals. ***Adaptive Management*** (AM) emerged in the field of natural resources management as an approach to work more effectively in the context of complex, dynamic, heterogeneous, and highly variable ecological systems[12]. AM sees management as always aiming at a moving target, with an awareness that knowledge is always incomplete and the system is constantly evolving (Light, 2001). It proposes that programs and policies are not one-time, final products, but rather *experiments* from which we are to learn and upon which adjustments are to be made (Lee, 1993). AM in DS implementation would increase program responsiveness to locally changing contexts, throughout all program stages described earlier.

[11] E.g. journals, conferences and international meetings for certain stakeholder groups; workshops, training courses and study tours for others; community-based activities and diffusion of simple, basic fact sheets for individuals; academic curricula in many disciplines (engineering, architecture, urban planning, public health, agriculture, etc.), etc.

[12] Sanitation is as much a social phenomenon as it is a natural or technological one and is influenced by many complex, dynamic, heterogeneous, and variable social and institutional systems.

Many DS researchers and practitioners have proposed ***Social Marketing*** in DS (Wegelin-Schuringa, 2000; Winblad, 2000; Breslin, 2002). Particularly relevant principles are: a) a *focus on the target audience*, its needs, perceptions, and motivating factors (privacy, status, economic considerations, hygiene, environmental values, etc.); b) s*egmenting audiences* or understanding that populations are not homogeneous but have various perceptions and require different types of incentives[13]; and c) *sustaining demand* once it has been created, which derives from a clear grasp of the dynamic "marketplace" (competing behaviors, obstacles to placing the product, etc.) and makes monitoring, evaluation, and timely adaptation of strategies essential program elements[14].

Scandinavian experiences in ***Participatory Technology Assessment*** and large-scale, externally-supported, ***Participative Diffusion of Innovations*** may also provide insights and tools from which the development of DS could benefit. The Danish Board of Technology, based on an understanding of society and technology as interrelated and framing one another, has sought to build bridges between citizens, experts, and politicians for technology assessments and communication of those assessments (www.tekno.dk). Since 1998, the Board has successfully implemented a range of participatory tools in assessing new technology including Perspective Workshops, Future Searches, Scenario Workshops and Consensus Conferences (www.tekno.dk). Such enriched deliberation might be used in sanitation system selection processes in cities or neighborhoods, or in the assessment/introduction of specific alternative sanitation options not known broadly to the public in various societies.

The state-sponsored Swedish Working Life Fund facilitated a process of diffusion of innovations in industrial organizational development, between 1990 and 1995 (Gustavsen, Hofmaier et al., 1996). The Fund took the roles of advisor, discussion partner, and generator of ideas, as well as provided funds for enterprises to engage in processes of organizational change. It also enabled direct exchanges between participants. Such an externally-supported model for funding and facilitation of change in the DS field could serve as a means to formalize the support structure for exchanges that are currently already taking place between programs at different sites and promote a broader understanding of environmental sanitation (including Bellagio principles) among water sector professionals and local government decision-makers.

Finally, we believe, along with other DS researchers (e.g. Harper and Halestrap,1999; Breslin, 2002), that ***conceptual flexibility*** will be beneficial in DS promotion: steering away from universal, one-size-fits-all solutions, and maintaining awareness that intermediate options[15] are valuable. In many contexts, intermediate options may achieve significant savings of water or retention of nutrients, which would mitigate strongly the impact of sanitation. If such options increase user adoption significantly, they may be more effective than the implementation of a "pure" DS solution that only few users would accept. Throughout the research and development process, DS would need to be compared continually to other sanitation options within a framework that considers the environmental, economic, and social implications of each.

Conclusions

Modern, large-scale, urban DS is still in its infancy and shows signs of great promise. Based on our research of Mexican experiences we have proposed a set of policy and research recommendations to strengthen and further develop urban DS implementation. Whether DS can fulfill its potential will only be known in practice and by testing under a variety of circumstances. The social and natural complexity of sanitation systems warrants the adoption of approaches

[13] This particularly important at increased scales of DS operation.

[14] rather than unattended "add-on's" that programs do not have the time and money to carry out.

[15] Intermediate options include possibilities such as: a) urine-diversion from conventional sanitation and b) dry toilets as complementary toilets in homes which also have conventional sanitation. In our survey we found that several homes wished to have a DT as a complementary option. Even if only some of the residents of a household used a DT or if the DT was used only for urination or only for defecation, water savings and nutrient retention would be achieved. This phased introduction would also allow users to gradually assess the technology, without having to risk an all or nothing situation.

that share concerns of iterative reflection and action; a focus on target audiences; the involvement of stakeholders; and the integration of institutional learning and adaptiveness into policies and programs. An awareness of these approaches and tools and the willingness to implement intermediate options (both in sanitation technologies and in strategic approaches) will likely be beneficial in developing the field of DS and carrying out the recommendations of this research.

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Innovative sanitation concept shows way towards sustainable urban development. Experiences from the model project “Wohnen & Arbeiten” in Freiburg, Germany

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Keywords

Case study, biogas, vacuum-toilets, membrane-filter, participation

Abstract

In Vauban, a suburb of Freiburg, Germany, a new model house built in 1999 combines highly innovative energy, waste and sanitary concepts with a framework for a comfortable social environment.

Social, legal and financial framework of the project “Wohnen & Arbeiten”

Figure 1: The Model-House “Wohnen&Arbeiten“

The special situation in the Freiburg Vauban district is that citizens are encouraged to form groups and to apply for plots of land in the new district. The association “Forum-Vauban e.V., Freiburg” [http://www.forum-vauban.de/], founded by citizens of Freiburg, is the legal organizing body of the extended citizen participation. It has been successful with its concept to give the land in the Vauban district to groups of citizens with clear priority, while only a small part of the land will be given to conventional building constructers.

The group “Wohnen & Arbeiten” is one of about 30 such groups of citizens having developed houses according to their wishes and ideas [http://www.vauban.de/wa].

In order to develop an innovative energy concept and an innovative sanitation concept for “Wohnen & Arbeiten”, an Association had to be formed being able to cooperate with research partners. Therefore, the “Ökobauverein e.V., Freiburg (Association For Sustainable Buildings)” [http://www.vauban.de/oekobau.html] was founded. This association is able to apply for funds and to handle the financial aspect as well as to run the experimental project phase. All future residents of the model house became members of the “Ökobauverein” and signed a contract that they will cooperate with the research projects.

Funds for the development and implementation of the innovative energy concept were allotted by the DBU (Deutsche Bundesstiftung Umwelt). “Wohnen & Arbeiten“ implemented this project

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jointly with the Fraunhofer ISE, Freiburg.

Funds for the development and implementation of the innovative sanitation concept (vacuum plant, biogas plant, water filter) were allotted by the DBU (Deutsche Bundesstiftung Umwelt), Fraunhofer Institute ISI in Karlsruhe, and TBW GmbH in Frankfurt. TBW and Fraunhofer implemented the project jointly with Ökobauverein e.V., Freiburg. A subcontract was given to the company Roediger, Hanau, for the construction and maintenance of the vacuum system. The biogas tanks were developed with and built by Mall-Umweltsysteme who also sponsored parts of the greywater filter.

General Data:	
dwelling and effective space	1.500 m^2 (16.250 squ. feet)
number of flats	20 (incl. 4 offices)
number of residents	40 (incl. 10 children)
co-generation plant:	
electrical power production	5,5 kWh
heat energy production	14,5 kWh
Solar power :	
photovoltaic device	3 kWp*
thermal solar installation	15 kWp* (45 m^2 = 475 sq. ft.)
Triple-glass windows:	
k(or u)-value**	0,7
g-value***	0,6
Energy consumption:	
heating energy consumption per m^2 and year	13,2 kWh/m^2a (= 1,4 kWh/square foot*a)
total energy consumption for heating	20.700 kWh/a
total energy consumption for warm water	23.500 kWh/a

* = kilo watt peak ** = heat loss *** = light loss

Table 1: Technical and general data of the solar-passive house “Wohnen & Arbeiten“

Sustainable energy management

Due to the energy concept, residents need only 20 % of the primary energy (electricity and heating energy) used in conventional houses. All energy saving investments is strictly controlled by the cost-efficiency ratio. The costs are only about 7 % higher than in conventional houses and amortize over 10 - 20 years, which makes the house affordable for average German citizens.

In summer, hot water consumption is 100 % provided by a thermal solar installation, in winter it is supplemented by a small co-generation plant using natural gas.

Electricity is 60 % provided by the co-generation plant (50%) and a photovoltaic device (10 %). Optimal insulation, the utilization of active and passive solar energy, the triple-glass windows, and an 80 % reduction of aeration heat loss save 85 % of the heating energy over the year, compared to conventional houses (Fraunhofer ISE, Gruppe Solares Bauen 2001).

Sustainable water management

A combined vacuum sanitation system was projected for the model house. The idea of the sanitation concept is that biological waste, faeces and urine (the so-called "blackwater") are transported from the water saving vacuum-toilets to a biogas reactor with vacuum pipes. The reactor produces liquid fertilizer as well as biogas used for cooking. After having been cleaned in a grey-water-filter, the remaining wastewater from kitchens and bathrooms (greywater) is used again for flushing the vacuum-toilets and rinsing the garden. Rainwater flows through open gutters and is collected in two ditches. These two ditches are connected to the groundwater strata with packages of gravel, so the rainwater is filtered before reaching the ground water.

Some data and experiences for the development of the Biogas-Bio-Fertilizer Module were gained with the help of a pilot plant. This experimental Biogas plant was operated during 6 months in preparations of the Project "Solar-Siedlung, Freiburg Vauban". (Lange 1997, Müller 1997)

A detailed analysis (Schneidmadl et al. 1999) compared conventional and sustainable water management and assumed the following reduction of water consumption and emissions into water:

- water consumption is reduced by about 50%
- carbon emissions by about 70%
- nitrogen emissions by about 90%
- phosphorus emissions by about 60%
- AOX (absorbable, organic halogens) emissions by about 48%, respectively, and
- copper emissions by 47%

The separate treatment of grey and blackwater and the recycling of nutrients to agriculture could be an energy-efficient long-term solution for water management.

The Primary-Energy-Consumption of the innovative sanitation concept in the Model House "Wohnen & Arbeiten" was analysed and compared to the situation in Lübeck Flintenbreite and in conventional houses (Peters 2002).

Experiences gained in the project "Wohnen & Arbeiten"

The experiences gained during three years with the vacuum-system and the greywater filter, as some information on the biogas plant are given below.

The grey-water-filter

The grey-water-filter was implemented in 1999 in form of an aerated sand filter and its performance was monitored (Steeger-Ballbach 2001). Due to technical problems, this filter is now replaced by a membrane-filter-module (Ultra-Sept-Pendelmodul) provided and co-sponsored by the company Mall-UMWELTSYSTEME (Donaueschingen, Germany).

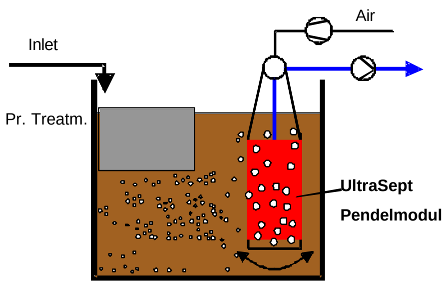

Figure 2: The UltraSept Pendelmodul

The vacuum-system

The vacuum system has been working since 1999 with hardly any technical problems. The acceptance of the vacuum-toilets by the residents is very good. In the initial stage of the project, the residents assumed, that the unusual noise of the vacuum-toilet could be a problem but this aspect turned out to be absolutely uncomplicated.

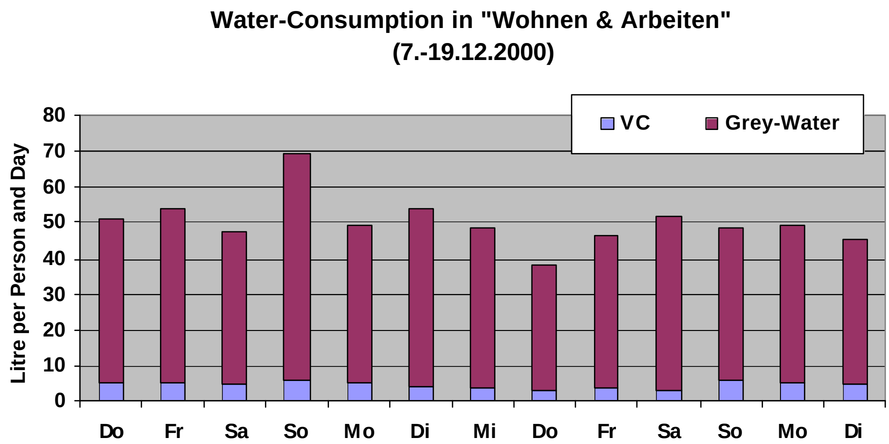

Figure 3: Daily water consumption in the model-house “Wohnen & Arbeiten”

Figure 4: Vacuum pumping station (left) and vacuum-toilet of the model-house

The Vacuum-System is maintained by the company ROEDIGER, (Hanau, Germany). It reduces the amount of Black-Water produced per person and day to about 6 litre - which is a reduction of 80% if compared to an average German household.

The biogas-bio-fertilizer module

The first biogas plant for an apartment building in Germany consists of a concrete digester for treating blackwater and organic household waste, a post treatment with an internal plastic bag gas storage and a storage tank for the fertilizer.

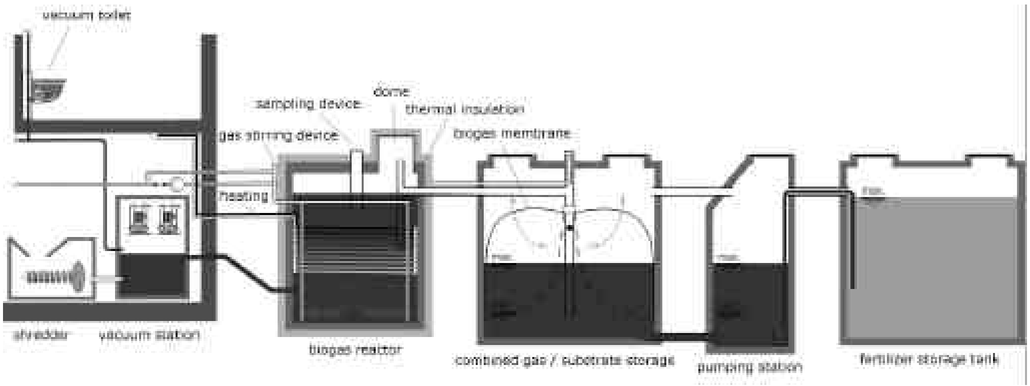

Figure 5: The Biogas-Bio-Fertilizer-Module projected for „Wohnen & Arbeiten" in Freiburg, Germany

The biogas plant is connected to the internal gas system of the house; it will provide cooking gas for the 16 households. The plant is almost ready – only the automatic regulation of the gas pressure and the feeding device for organic household waste need modification and adjustments.

The following table summarizes general and technical data of the sanitation concept of the model house "Wohnen & Arbeiten" in Freiburg Vauban, Germany.

Number of Residents	40 (incl. 10 Children)
Vacuum-System	
number of Vacuum toilets	25
amount of water needed for flushing	1 l
amount of air used for flushing	20-40l
Biogas-Bio-Fertilizer-Module:	
Biogas-Reactor	6 m^3
Bio-Fertilizer Storage-Tank 1	3 m^3
Bio-Fertilizer Storage-Tank 2	14 m^3
Bio-Gas Storage-Tank	9 m^3
Bio-Gas Production (anticipated)	2-3 m^3/d
Black-Water input per day (anticipated)	0,24 m^3/d
Organic Waste input per day (anticipated)	0,02 m^3/d
Bio-Fertilizer Production (anticipated)	0,26 m^3/d
Grey-Water-Membrane-Filter :	
grey-water-input per day	2 m^3/d
Membrane surface	16 m^2 (Mall Ultrasept)
primary treatment	1 m^3 (Mall Ultrasept)
sludge treatment	4,5 m^3 (Mall Ultrasept)
power for aeration pump	500 W
Black-Water-Production reduced by:	**80%**
Black-Water-Production (average German Household)	35 l/d*****
Black-Water-Production (Model-House "Wohnen & Arbeiten")	6 l/d

***** = Data from: „Bundesverband der deutschen Gas- und Wasserwirtschaft, KA 12/97"

Table 2: Technical and general data of the sanitation concept of "Wohnen & Arbeiten"

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Wet or dry ecological sanitation in periurban areas

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Keywords

Africa, ecological sanitation, periurban sanitation, promotion, waterborne alternatives

Abstract

Doubtlessly, “do and forget” is the preferred solution for most people. Lack of space or talent for urban agriculture reduces motivation. In many periurban settings municipal rather than individual solutions are preferable.

This paper presents three periurban cases in Africa where waterborne sanitation seems to be the more realistic approach to ecological sanitation. The author questions the “don’t mix” rule as a holy principle in ecological sanitation as the sector might become insensible to felt needs, user friendliness and demand sensitivity.

Excluding waterborne sanitation as an alternative to dry “don’t mix” approaches may lead to slow progress, where conventional waterborne solution become the preferred alternative, with no ecological benefits.

Figure 1: Dry ecological sanitation can be made comfortable and look urban, but there may be an emptying and collection problem and surviving germs.

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Introduction

What is the promotional value of the WC?

In order to protect the ground water and reduce water consumption, we have opted for dry sanitation. For ecological sanitation the “don’t mix” approach has become a golden rule. An evaluation of alternative sanitation technologies in Luanda (Angola) low-income areas caused the author to question dry sanitation as the appropriate solution. Waterborne sanitation may at times be a solution, which could save the environment. Similar conclusions could be drawn from the situation in other cities like Antananarivo (Madagascar) and Nampula (Mozambique).

Findings in this paper are based on discussions, observation and experience. The author has over the last 25 years had the opportunity to visit some 20 developing countries as a sanitation adviser. The clear trend is to become more and more sensitive to demand and consumer participation.

Three case studies

Three cities have been chosen as examples of where waterborne sanitation could be a necessary approach in order to achieve a sustainable sanitation development.

Figure 2: Space is a common problem in many low-income settlements.

Luanda

Luanda is the Capital of Angola and has approximately 5 million people. The town is situated on the coast of the Atlantic Ocean. The profile of the town is characterised by high-rise buildings in the downtown, which have deteriorated during three decades of civil war, financial difficulties and mismanagement, surrounded by well built and well maintained 1-2 storey houses embedded in green trees, and of high density slum areas from the colonial time where not a single green leaf can be spotted. The outer fringe where the majority of the population lives is characterised by simple houses with unplastered cement walls, stagnant dirty pools or dust (depending on the season), and mountains of garbage.

Due to a long and violent civil war Luanda has had a substantial urban growth due to influx of rural people leaving war and landmines behind. It is anticipated that the population growth will slow down but that the vast majority of the new inhabitants will stay, as they have adapted to the urban life.

Existing practices

The vast majority of Luanda's population are defecating in hidden places and "defecation fields". Waterborne conventional sanitation using sewers or septic tanks was introduced by the Portuguese before independence. The Portuguese also introduced the simplified flush water toilet with a soak away pit "pia com posso roto" as a solution for the indigenous population. Garbage collection is a serious problem aggravated by the fact that faecal matter is deposited with the garbage.

Introducing dry sanitation

Water supply is a serious problem in Luanda as the water table is low and the ground water quality generally unsuitable. The piped water system is from colonial days and is "leaking as a sieve". A big business has developed selling semi treated surface water, which is trucked out to the consumers around the city. Families commonly spend up to 50 % of their cash income on water. In spite of this water flushed latrines are preferred before dry ones.

Figure 3: Luanda dry latrines are converted to pour flush, and they are impressively clean.

Figure 4: A short tube connects the latrine to an off set pit, which later can be connected to a small-bore sewer.

For 15 years the Angolan Government and NGOs have been struggling to break the trend of water-flushed sanitation in periurban areas. For 15 years people have rebuilt the provided dry latrines changing them into pour flush toilets, this in spite of that water supply in Luanda is a disaster and that water is trucked out into the periurban areas and sold for prices that may amount to 50% of the cash income of the families.

The resistance to dry latrines is best understood when looking at the dry latrines which has been provided free of charge by Government and NGOs. 90% of them have been converted to pour flush latrines. Reasons mentioned are that:

1. The faecal matter is not seen by others
2. Less smell
3. Less flies
4. Longer durability
5. Higher status (dry latrines are "rural")

Alternative solutions

Given that there is a massive resistance against dry latrines principally because of the visibility and status problem alternative solutions have been discussed. Dry ecosan latrines with urine diversion are one of the options. It is felt though as if the status aspect, mimicking the conventional WC, is the strongest one. In many areas the problem of space for replacement latrines and access roads for emptying vehicles, asks for permanent solutions. Waterborne alternatives can therefore not be ignored in the discussion.

Given the need for permanent solutions and that the population has a great resistance to handling, and even seeing, faecal matter one solution may be to connect existing pour flush latrines to small- bore sewer systems. where the old pit latrine/soak away become the retention tanks and emptying is made with waste water and stirring, converting sediment to suspended solids that travels with the waste water to ecological treatment plants where the fertile value is recuperated for compost, production of bio fuel and food, eventually feeding the city.

Amtananarivo

Antananarivo is the naturally ecological city. It is the capital of the great island of Madagascar and has approximately one million inhabitants. The presence of water and rice fields is one of the characteristics of the city. Water supply is not a problem. After more than 40 years of independence the city practically looks the same as during the colonial time. Even the City Centre is characterised by low buildings built in local bricks. Burnt clay bricks is the most common (and cheapest) building material.

Discussing alternatives

During a sanitation seminar in Antananarivo last year a number of sanitation options were discussed. The dry ecosan toilet with urine diversion got especial attention. The key question, however, was: Do we need it? What does it offer to Antananarivo more tha n the novelty of a modern solution? It is low cost. It looks like a WC but it isn't.

Naturally fertilized ground water and rice production in urban marchlands

The city is crossed by a number of watercourses and marchlands, which are explored to the last square meter. Water is abundant and, to a high extent, people use water-flushed toilets with septic tanks or soak ways pits. The ground water is being fertilized by the decomposing human waste and filtered by the soil before reaching the rice fields, which feed the city. The rice husks are used as bio-fuel for making burnt bricks and roof tiles. Burnt local clay, fired with rice husks, is the principal building material in the city.

The ecological loop is already closed

In Antananarivo the ecological loop has already been closed and introducing the dry ecosan toilet with urine diversion may result in problems more than benefits. By dissolving the human waste in the water and allow it to seep through the ground to the rice fields is a solution which is feeding the city since its beginning.

Nampula

Nampula is a military city in central Mozambique with around 0.5 million people. It is the third largest city in the country. The population is predominantly Muslim and the use of water for anal cleansing is general in the periurban areas. Latrines are problematic due to poor soil stability, religion and traditions.

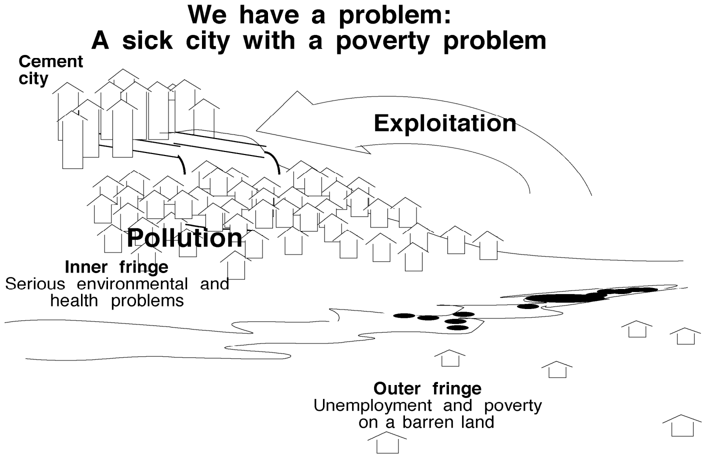

Figure 5: The existing city is an ecological parasite on the hinterland consuming fertile value and creating pollution and disease.

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The city

Nampula town was built on top of a plateau, where the sewers ended at the hillsides. Unaware or ignoring the risks a fast growing periurban population has chosen to establish itself on the hillsides, close to job opportunities. Regular cholera outbreaks are the proof of serious sanitation problems.

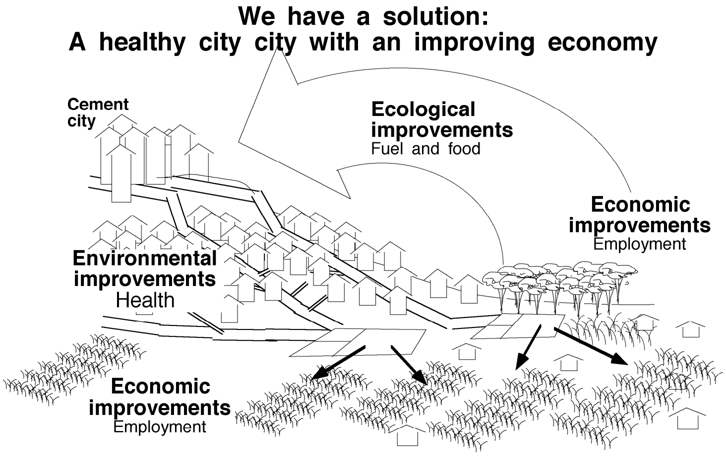

Figure 6: The ecological city is s resource to the hinterland producing fertile water for irrigation resulting in food, fuel, health and wealth

A logical solution to the sanitation problem of Nampula seems to be to establish treatment ponds and wetlands at the bottom of the hillsides for ecological treatment of sullage water, producing wood fuel, compost and eventually food for local consumption and export and eventually create plenty of job opportunities.

Small lined pits connected to trunk sewers would be an economic and feasible solution.

Conclusions

Space for building and emptying of latrines in periurban areas is a serious problem. Land for urban agriculture is rarely available and the crops are difficult to protect from animals and hungry visitors. “Do and forget” is the preferred solution by most people.

In the case of Luanda, trying to reintroduce dry sanitation resulted in a conflict with the population, which triggered the need of rethinking sanitation approaches for the periurban areas.

In Antananarivo the existing system using soak ways and septic tanks is ecologically sound, producing food and building material for the city. Trying to change would lead to problems rather than benefits.

In Nampula introducing waterborne small-bore sanitation systems might create enthusiasm for latrine building, as the technology is adapted to the traditional use of water and the ambition to adopt an “urban” lifestyle not to forget the ecological and economic benefits it may have for the city.

In many cases municipal sanitation solutions can be privatised and made economic if the scale is feasible. Small-bore sewers are excellent for transporting suspended solids, also longer distances. Technologies for ecological treatment of sullage water are well known and can be adapted to serve large communities.

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Figure 6: "Do and forget" is the preferred solution by most people. Using a low volume flush and a small retention tank, the rich fertilized water can be used after ecological treatment

Using the "don't mix" rule as a mantra for ecological solutions may lead to conflicts with the population and lack of progress. The solution to hygiene problems, which is a basic need, must not be jeopardised.

There is a strong tendency among the periurban population to copy the patterns of the "cement cities" where status is linked to an "urban" lifestyle often leading to major environmental and hygienic problems.

The status of the WC is cemented in the urban culture. Wisely used it may become a promotional asset.

There are two alternatives:

1. Attempting to introduce ideal solutions
2. Accepting people's preferences and do the best of it.

Research on dry and wet ecological sanitation needs to be carried out in parallel to find solutions that also match people's preferences and culture.

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Subterra–constructed wetlands for wastewater treatment (examples and experiences)

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Keywords

Constructed wetlands, subterra, ecological village, highway service station, hotels

Abstract

Planted soil filters or reed-bed purification systems are one of the oldest and most natural means of purifying wastewater. They are mainly installed in urban areas. These constructed wetlands have been built for more than 40 years. In the same way as water in nature seeps into the soil, flows along roots, is filtered by various sand- and gravel layers and is purified by micro-organisms. Constructed wetlands have been a mayor part of scientific studies during the last 15 years – today they are accepted as state of technology. Implementations for small households as well as for large communities and Tourism are common.

This paper informs about "*subterra*"-constructed wetlands, which use a special subterranean system for the distribution of the wastewater. Several examples of implementation under different conditions and climates show how the system works, experiences made and which applications are possible.

Method

Modern reed-bed purification systems use a combination of mechanical and biological resources to process wastewater. There is a difference between vertical flow, horizontal flow and combined systems. All systems have the advantage to offer a huge buffer capacity and an enormous surface on their filter media for the microbiological population. Vertical flow systems have to be designed with a surface between 2 and 4 m² per 150l daily load depending on the climate. Horizontal flow systems require more space – they have to be designed with 5 to 8 m² per 150l daily load. The German water authorities publish technical descriptions for the construction of wastewater treatment facilities. Constructed wetlands are specified in work sheet A262 of ATV (Abwassertechnische Vereinigung) and in legal regulations of the German states. These descriptions are the basis for the design of applications but have to be adopted to other than European climates. Local resources have to be taken into account as well.

The *subterra* reed-bed purification system is a pure vertical filter system with a subterranean high-pressure distribution system. It can be installed for houses or communities of 4 to 10000 inhabitants. Besides that, there are further advantages, which are of particular importance to rural communities with specific local requirements:

- Low construction costs
- Low operation and maintenance costs
- Long life-expectancy of the system

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- System can easily be maintained
- No smell or mosquito problems on account of subterranean treatment
- Especially suited for seasonal influent quantity changes and resorts
- Local resources can be used to minimise the part of imported technology

The mechanical pre-purification of wastewater takes place in a multi-chambered pit. The minimum size is 4 m³, but it ultimately depends on the number of connected households or the daily wastewater quantity. Otherwise, constructed according to the German water authorities inflow specifications of 150 litre per person and day. The subsequent transport of wastewater to the reed-bed is brought about by a pressure pipe system, which guarantees an even distribution of effluent over the filtration bed. The bed consists of different layers of sand and gravel and is planted mainly with reeds, e.g. phragmytes.

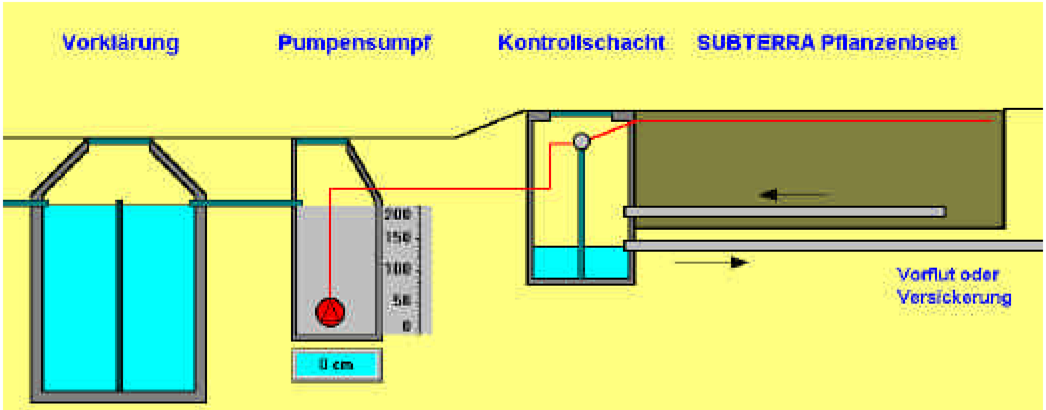

Figure 1: Technical principle of the subterra vertical soil filter system

The root system of the plants, i.e. the rhizomes, ensures an aeration into the soil for aerobic microorganisms. Soil aeration results from the oxygen inflow via the vascular system of the roots and the loosening of the soil by root development, which allows far going diffusion between the irrigation intervals. The rhizomes also ensure the hydraulic flow-through on a long-term basis. A layer of microorganisms forms on the roots. Nitrifiers and denitrifiers break down organic components. The purified water is then collected in pipes, from where it flows to a control tank, where it can be monitored. After that it is discharged to a river, pond, to the ground or reused in a secondary water circle.

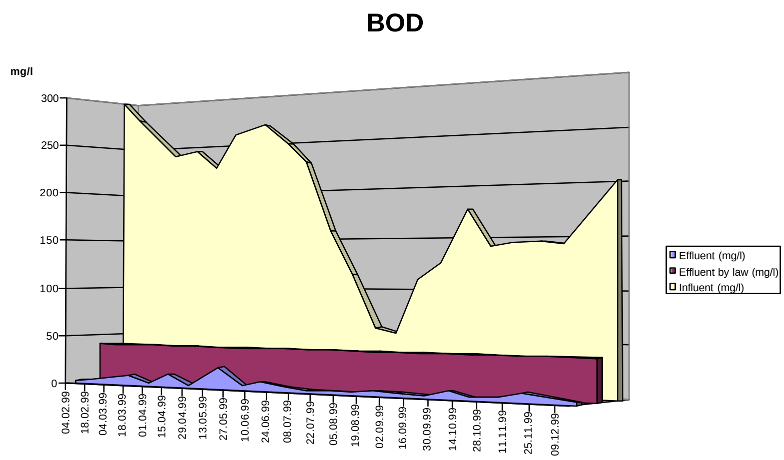

Figure 2: Typical effluent values of *subterra*-systems at hotels

Seasonal fluctuations have minimal effect on this process and therefore a satisfactory quality of effluent is also guaranteed during European winters. Central to the system are the subterranean

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high-pressure inflow pipes, made of high grade EPDM, and high-pressure distribution fittings of refined steel. The pipes can be individually closed and back-washed. Influent quantity fluctuation do also not harm the system because of the huge buffer capacity of the planted soil filter. The soil filter has an average depth of approximately 1,2 m, what means that 1,2 m³ are available for an average hydraulic load of 50 litres per day and square meter. For a period of several weeks this amount can be doubled or reduced without harming the microorganisms activity. This advantage in comparison with compact wastewater treatment stations leads to implementations at touristical applications and at places with high influent fluctuations, like hotels, water parks, highway service stations and holiday bungalows. More than 100 stations have been installed in the past years – below you will find some examples of installations in Germany, Greece, South Africa and Thailand:

Ecological village "Wohnhof Braamwisch", Hamburg / Germany, 54 p.e.

Figure 3: View on the *subterra* reed-bed and the solar equipped house

In this case the treatment of wastewater is done in two separate ways. Composting toilettes are used which reduces also the water consumption. The greywater of the households is handled by a septic tank for the mechanical pre-treatment and a planted soil filter for the biological treatment. The *subterra* reed-bed has a surface area of 90 m² only. The effluent is led into a storage tank for irrigation purposes.

The effluent values reached are usually: BOD_5 5 mg/l and COD 40 mg/l. Very low values have to be met for phosphate and total nitrogen. The energy consumption is about 400 kW/h per year. Due to the subterranean wastewater distribution system no smell comes from the reed bed itself and the treatment station is located with an average distance of 3 m to the houses.

Highway station „Dwarsfontein", Mpumalanga Province / South Africa, 300 p.e.

Figure 4: View on the *subterra* reed-bed and the exit road to the highway

At South African highways petroports offer petrol pumps and restaurant services to the public. At Dwarsfontein between Johannesburg and Witbank a *subterra* wetland has been installed to purify this very difficult sewage with high urinacid loadings under the semi arid climate. It was constructed according to German standards for vertical flow filters.

High evapotranspiration had to be taken into consideration: Up to German standards 20 % evapotranspiration is calculated – in the south African region up to 50 % is reached. As water is the main problem, the reuse and re-circulation of biologically treated

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wastewater is most important. Roughly 60 % of the treated water is reused for toilet flushing and irrigation on site. The *subterra* system has to handle high fluctuations of influent quantities. It was designed for an average load of 48 m³ daily and has to handle up to 90 m³ per day on weekends and holiday peaks. The effluent values vary between 40 to 60 mg/l COD related to an influent between 400 and 800 mg/l. Faecal coliform bacteria are reduced down to 5 per 100 ml. These results show, that even under arid climate and high ammonia loadings constructed wetlands are highly efficient.

Hotel „ALFA BEACH“, Kolymbia, Rodes / Greece, 500 p.e.

This *subterra* station treats the wastewater of a four star hotel at one of the most favourite beaches on the island of Rodes. The construction includes the landscaping of the hotel area and integrates the wastewater system. The system is made to look like a typical Rodian river and is installed along the borders of the site, as the available space was limited. The surface of the reed beds is appr. 1.000 m². They are located very close to the apartments and the swimming pool as no smell disturbs the guests. Average effluent values: BOD_5 3–10 mg/l and COD 30–50 mg/l.

Figure 5: View on the subterra reed-bed alongside the apartments

The seasonal changes of wastewater quantity and quality were taken into account – during off-season no sewage is discharged into the system. The treated wastewater is used for irrigating the hotel garden and public eucalyptus alleys. The energy costs only € 250, - per year.

Dealing with hotels and the wastewater of restaurants it is most important to plan for the right size of the grease traps to hold back the fat from the biological reactor “reed bed”. The water consumption of hotels depends on the standard, its technical equipment and water saving facilities. At Alpha Beach the consumption is reduced to 250 l per person. In other cases up to 500 litres per person are being used.

Hotel „PP Princess“, Phiphi island / Thailand, 750 p.e.

This hotel is situated on one of the most beautiful islands of Thailand. The *subterra*-purification system located at seven different places on the premises, done to reduce the piping length and integrate the sewage works into the gardens. The reed beds are in the back or at the side of groups of bungalows and near public buildings like restaurant and wellness facilities. The effluent values vary between 3 and 15 mg/l for BOD_5 and 30 to 50 mg/l for COD.

Figure 6: View of the *subterra* reed-bed no.4 in direct neighborhood of the bungalows

The seasonal fluctuation of wastewater quantity and quality is lower than in other hotels as the PP Princess is booked between 60 and 100 % throughout the year. Again the treated wastewater is used for irrigation. The reed-beds treat all types of sewage: normal household blackwater, kitchen and laundry water with high loads of tensides.

The survey of the treatment plant is effected by a GSM telematic control system, which allows to control the station even from Germany. There has been training of the maintenance staff and engineers of local consultants on the handling of this natural treatment system. We learned, that it is not enough to just export technical equipment from Germany. Local resources and products as well as training should be major part of the installation, which makes it easier to introduce advanced European technologies.

Solar-autarkic highway stations "Warnowtal", „Quellental" and "Selliner See" near Rostock/Germany, 50 p.e.

As the construction of sewer systems and electrical grids in urban areas is not economical for small consumers, new ideas had to be put into action. Three parking and resting areas at the highway A20 in northern Germany stand for a new approach to solve a common problem at highways not only in Germany. These resting areas are equipped with a combination of several renewable energy installations. It consists a photovoltaic system, solarthermic collectors, small-sized wind power generator, bio-diesel co-generator and solar-architecture. The wastewater treatment is done by a 8m³/50p.e. *subterra*-system. Again the *subterra*-installation was chosen because its buffer capacity and ability to handle high ammonia loadings.

Figure 7: view from the pergolas to the solar toilet

The technical details for energetically compounds are:

- 26m² solarthermic collectors
- 10m² Photovoltaic panels

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- 4kW wind Generator
- 15kVA Bio diesel co-generator
- 1500Ah battery station
- low energy well system
- 150m² *subterra*-wetland

The solar-autarkic highway stations are in operation for two years now. The smooth operation proves that new technologies like those are sustainable, applicable and efficient.

Greywater treatment in combined bio-filter/constructed wetlands in cold climate

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Keywords

Greywater, bio filter, constructed wetland, cold climate

Abstract

In Norway systems consisting of an aerobic bio filter followed by a subsurface horizontal flow constructed wetland has been very successful in reducing organic matter, indicator bacteria, nitrogen and phosphorus in greywater. Because of phosphate free detergents are used in Norway and no toilet waste is included, the average influent total phosphorus concentrations (measured as septic tank effluent-STE) are about 1mg P/l and the average influent total nitrogen concentrations are in the range 8-10 mg N/l. The aerobic bio filter prior to the wetland is essential to remove BOD in a climate where the plants are dormant during the cold season. When combined with a horizontal flow constructed wetland the concentrations of indicator bacteria in the effluent meets European standards for swimming water quality. The effluent concentrations for phosphorus are generally < 0.2 mg P/l and for nitrogen < 5mg N/l. The combined bio filter /constructed wetland systems require 1-3m^2 surface area per person. The compact design opens for urban use.

Introduction

Norway has substantial experience from using source-separated systems for wastewater treatment (Jenssen and Skjelhaugen 1994, Jenssen 1996, 1999, 2001). In traditional sewer systems greywater constitutes 60-80% of the wastewater volume flow. In a recycling system based on source separation of wastewater fractions, water saving or dry toilets are used, hence, the greywater volume increases to >90% of the total wastewater flow. The toilet waste contains the majority of the nutrients and only 10% of the nitrogen, 26% of the phosphorus and 21% of the potassium is found in the greywater (Vinnerås 2002) . Nutrient removal then becomes a minor issue. However, greywater may contain more than 50% of the organic matter in wastewater (Rasmussen et al. 1996) and a substantial amount of bacteria and viruses (Ottosen and Stenström 2002). Systems that can remove organic matter and pathogens are therefore needed in order to facilitate discharge or reuse of the greywater.

The extent of greywater treatment will depend on the final discharge and use of the water. If discharged to the sea, no treatment or maybe only a primary treatment step is required. If discharged to lakes or rivers a secondary treatment step is often needed. Before discharged to streams or use in irrigation or groundwater recharge, the hygienic parameters must be reduced. For in-house reuse and drinking water, sophisticated tertiary treatment may be necessary. Wherever natural conditions allow, soil infiltration is a cost-effective option for greywater treatment (Westby et al. 1997). Norway has developed its own set of sizing and design criteria for greywater soil infiltration and sand filter systems (Jenssen and Siegrist 1991, MD 1992). This paper describes design details and performance of constructed/constructed wetland systems for greywater treatment in cold climates.

Greywater composition

Representative data for wastewater production and composition on the household level are scarce and more data are needed to reliably predict the pollution potential from greywater. Rasmussen et al. (1996) performed a literature survey of greywater composition and found total phosphorus concentrations varying from 1,4–18,1 mg/l. The highest concentration is from Sweden (Olsson et al. 1968). In Olsson's study, it was stated that the detergent contributed with 2,5g P/person and day or 912 g/person and year, this alone explaining the high phosphorous concentration. The total nitrogen varied from 6,7–42 mg/l. Vinnerås (2002) has studied the present day wastewater composition in Sweden and showed that heavy metals in greywater seem to have decreased over the last years, but the mass discharge of nitrogen and phosphorus is somewhat underestimated compared to Naturvårdsverket (1995). After 1997 more data on greywater composition has accrued in Norway due to building of several larger systems. It is therefore interesting to compare some data on greywater composition (Table: 1).

Source	Phosphorus		Nitrogen	
	g/p and year	mg/l	g/p and year	mg/l
Torvetua*	58	1,07	406	7,1
Kaja*	56	0,97	470	8,2
Vinnerås 2002	190	5,0	500	13,2

*Measured in septic tank effluent (STE)

Table 1: Mass (g/person and year) and concentrations (mg/l) in greywater.

The data from Kaja and Torvetua in Norway are based on average flows and adjusted to 100% presence assuming 70% of the wastewater production occurring at home. For nitrogen the values from Torvetua and Kaja are somewhat lower than the Swedish values (Vinnerås 2002), however for phosphorus the Norwegian values are only 1/3 of the Swedish. The Norwegian values are based on STE. 5-20% removal of nitrogen and phosphorus may occur in the septic tank (Pell and Nyberg 1985), hence, the difference in mass nitrogen may be due to the septic tank. The most probable reason for the difference in phosphorus content is the cloth- and dishwashing detergents. In Norway the majority of the cloth- and dishwashing detergents sold are phosphate free, whereas in Sweden they contain phosphorus.

When looking at the average concentrations of Norwegian greywater in samples taken after 1996, the average STE concentrations are 1,03 mg P/l for total phosphorus and 8,4 mg N/l for total nitrogen. These samples reflect the greywater composition from nearly 200 people. This means that the nitrogen meets the WHO drinking water standards of 10mg/l without any treatment. The Norwegian discharge consent for total phosphorus for many small chemical precipitation plants releasing their effluent to inland waterways is 1mg N/l. In many cases greywater meets also this requirement with no or only primary treatment.

Bio filter and horizontal flow constructed wetlands-design and performance

The general concept (Figure: 1) consists of pre-treatment of the wastewater in a septic tank, pumping to a vertical down-flow single pass aerobic bio filter followed by a subsurface horizontal-flow porous media filter. The bio filter may be integrated (Figure: 1) or located separate from the horizontal flow section. The wetland section is usually vegetated with common reed (*Phragmites*). Evaluation of the role of plants in these systems when treating wastewater (including toilet waste), both in field and mesocosm scale systems, showed that the root-zone had a positive effect on N-removal, but no significant effect on P and BOD removal (Zhu 1998, Mæhlum and Stålnacke, 1999). Some of the later systems have therefore been built with grass over an insulating soil cover. The grass-covered systems do not fulfil the strict definition of a wetland, although the filter is water saturated.

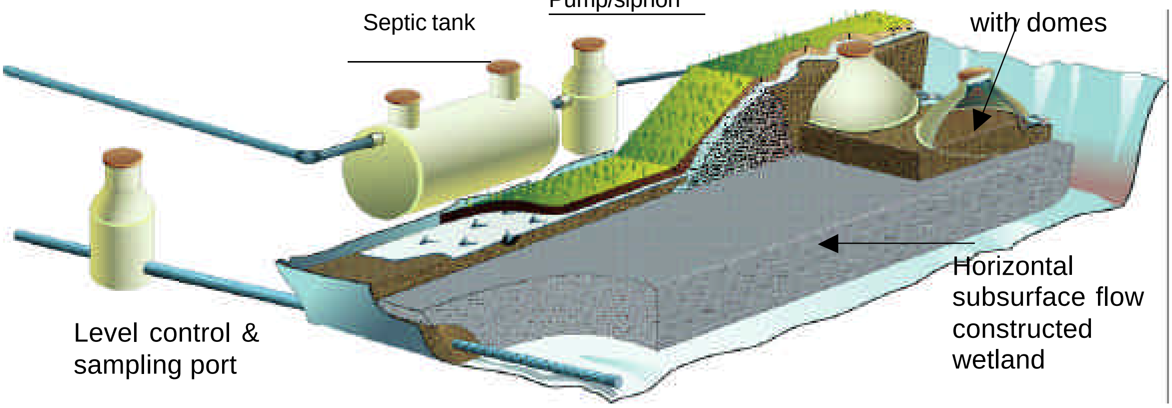

Figure 1: The latest generation of constructed wetlands for cold climate with integrated aerobic bio filter in Norway.

The aerobic bio filter

The bio filter (Figure 1) is covered by a compartment (e.g. a hemispherical dome), which facilitates spraying of the STE over the bio filter surface. The bio filter has a standard depth of 60 cm and a grain size within the range 2–10mm is recommended. In Norway lightweight aggregate (LWA) in the range 2-4mm is the most common filter media, but gravel or other type media in the above size range may be used. The effect of filter depth on removal of BOD and bacteria in LWA and sand filters was studied by Rasmussen et al. (1996). The study concluded that BOD removal was independent of filter depth for LWA filters in the range 20-60cm, but the bacteria removal was lower for the shallow filter depth. [MA1]

Bio filters and constructed wetlands using lightweight aggregates (LWA) or similar porous media are pioneered in Norway (Heistad et al. 2001, Jenssen and Krogstad 2002, Mæhlum and Jenssen 2002). The single pass bio filter aerates the wastewater and reduces BOD and bacteria. Using such bio filters for treating greywater more than 70% BOD reduction and 2-5 log reduction of indicator bacteria has been obtained at a loading rate for greywater up to 115 cm/d. Assuming a greywater production of 100 day/person/day a bio filter of 1 m^2 surface area can treat greywater from about 10 persons, hence, very compact bio filters can be made. Clogging has not been observed even at loading rates exceeding 100cm/d, however, earthworms are observed living in the bio filter. Their grazing of the bio film probably reduces clogging and enhances the hydraulic capacity of the filter. The key to successful operation of the bio filter is uniform distribution of the liquid over the filter media and intermittent dosing (Heistad et al. 2001). In order to further improve the quality of the effluent, the bio filter can be followed by a subsequent sand filter or a constructed wetland (Figure: 1).

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The horizontal subsurface flow constructed wetland

According to the Norwegian guidelines (Gaut and Mæhlum 2001) the recommended depth of the horizontal subsurface flow constructed wetland is minimum 1 m. This is more than suggested in other guidelines (Vymazal et al. 1998, Kadlec et al. 2000). The reason is the cold climate. In Norway the systems are sized so that the upper 30cm of the system can freeze while still leaving sufficient hydraulic capacity to transport the water below the frozen zone. The final geometry (length, width) of a system is based on hydraulic considerations, but for systems treating combined grey- and blackwater, sizing also depends on the phosphorus sorption capacity of the media. For commercial systems treating greywater the resulting surface area is 2-3m^2/person. For systems treating combined grey- and blackwater the recommended surface area is normally in the range 7-9m^2/person. In experimental systems treating combined black- and greywater and for greywater systems only, more compact designs are being examined. All present systems in Norway are built with an aerobic bio filter preceding the horizontal subsurface flow constructed wetland (Figure 1). Some systems use sand in the horizontal flow section, but the majority of the systems in Norway use lightweight aggregates (LWA) both in the bio filter and the horizontal flow section.

Combined aerobic constructed/constructed wetland systems

Three large combined constructed/constructed wetland systems are in operation in Norway. (Table: 3) The first system built according to the configuration (Figure: 1) is the plant at Kaja that treats greywater from student dormitories at the Agricultural University of Norway. (Table: 2) The Kaja plant has 2-4mm LWA (Filtralite™) in both the bio filter and the horizontal flow wetland section.

Parameter	Average concentration out of each unit				Percent removal %	Percent removal %	Total removal %
	Unit	Outlet Septictank	Outlet Prefilter	Outlet Wetland	Biofilter	Wetland	Biofilter and Wetland
pH		6,72	6,78	7,43			
Total phosphorous	mg P/l	0,97	0,32	0,07	67,0	78,1	92,8
Ortho phosphate	mg P/l	0,56	0,10	0,04	82,1	60,0	92,9
BOD 7	mg O/l	130,7	38,2	6,90	70,8	81,9	94,7
Total nitrogen	mg N/l	8,20	5,00	2,50	39,0	50,0	69,5
Ammonium	mg N/l	3,2	2,4	2,3	25,0	4,2	28,1
Nitrate	mg N/l	<0,03	<0,03	<0,03			
Termotol. Colif. Bacteria	TCB /100 ml	106	10^3-10^5	0-10^3			

Table 2: Average concentrations and treatment performance (%) for the Kaja greywater treatment plant, fall 1998 and spring 1999 (n = 11).

Table 2 shows the performance of the Kaja system during its second year of operation. For total phosphorus and total nitrogen the effluent from the bio filter is very low. However, in order to reduce BOD_7 to below 10mg O/l, and to meet the present European requirement with respect to indicator bacteria in swimming water (<1000 termotolerant coliform bacteria/100ml) the horizontal subsurface flow wetland is needed. With a retention time of 6-7 days in the wetland (Gulbrandsen 1999) the fluctuations in the outflow concentrations are small. Figure 2 also shows that the BOD removal does not vary significantly with season. This may be attributed to the long retention time, but also the high greywater temperatures. During the winter the STE temperatures varied from 10-15^{O}C and the temperature drop through the wetland section was 2-3^{O}C (Gulbrandsen 1999). Nitrate is not detected. This may indicate that nitrification does not occur or that the produced nitrate is immediately denitrified.

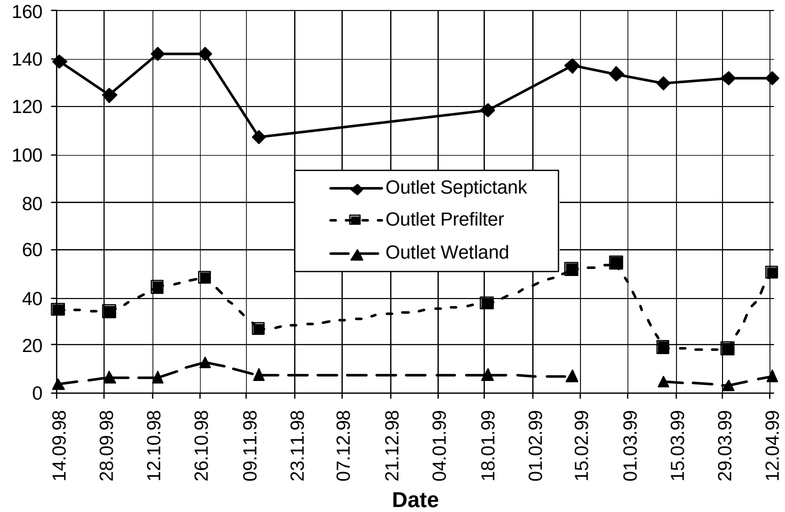

Figure 2: BOD_7 concentrations vs. time in the STE, bio filter effluent and wetland effluent.

The high phosphorus sorption of the system (Table 2) is due to the sorption capacity of the LWA used. Phosphorus sorption in the bio filter is only expected in the initial years. The wetland has a much higher total sorption capacity than the bio filter because of more volume. With the type of LWA used high phosphorus removal can be expected for 10-15 years.

The Kaja system is now running on its 6th year and no decline in phosphorus or nitrogen removal is observed. The last winter the BOD_7 was <3mg/l in all 3 samples in the outlet which indicate that the performance regarding BOD_7 may have improved. The Termotolerant Coliform Bacteria (TCB) counts in the outlet are generally below 100 TCB/100 ml and 7 out of 21 samples have shown 0 TCB/100ml.

The two treatment systems at Torvetua (42 condominiums) and Klosterenga (33 apartments) show very similar treatment values to the Kaja system. (Table 3)

System	Persons connected	Built year	TP		TN		COD		BOD_7[a]		TCB[b]
			%	Cout	%	Cout	%	Cout	%	Cout	
Kaja	48	1997	94	0,05	70	2,6	94	15,8	94	5,6	sw
Torvetua	140	1998	79	0.21	60	2.2	88	41,0	97	5,5	sw
Klosterenga	100	2000		0,03		2.5		19,0			0

a) 7-day BOD is standard in Norway, b) Termotolerant coliform bacteria

sw = swimming water quality < 1000 TCB/100ml

Table 3: Average outlet concentrations and treatment performance (%) for 3 combined constructed/constructed wetland systems. Average over total service time.

At Klosterenga, in the city of Oslo, the greywater is treated in the courtyard of the building. The space required for this experimental system is about 1 m^2/person, and the treatment area is also used as a playground. The compact design is due to making the horizontal flow section 1,8m deep instead of the standard 1m, thus saving area and still having sufficient porous media volume in the horizontal flow section. Additional aeration, in the summer season, is provided by a flow-form system (Wilkes1980). No inlet samples are presently available at Klosterenga. The outlet samples show better performance with respect to phosphorus and bacteria than the systems at Kaja and Torvetua (Table 3). This is due to a new LWA, FiltraliteP™, which has very high phosphorus sorption and bacteria reduction capabilities. It is estimated, assuming similar inlet phosphorus concentrations as for Kaja and Torvetua that saturating the wetland media with phosphorus will last more than 40 years at Klosterenga. With such high qualities of the effluent water, as shown in (Table 3), the need for a secondary sewer collection system is reduced because local streams or water bodies can be used for receiving treated water even in urban areas.

The excellent effluent quality (Table 2 & 3) facilitates reuse of the water for irrigation, groundwater recharge or for in-house applications. For flushing toilets and car wash it may be possible to use the effluent water (Table 3) without further treatment. However, recent results show that greywater may contain virus and bacterial pathogens that are not represented by the indicator bacteria (Ottosen and Stenström 2002). This may call for further treatment before use as suggested above. In order to upgrade to drinking water quality or for washing, micro filtration, reverse osmosis or carbon filtration may be needed as a single step or in combination.

Conclusion

A combined vertical flow bio filter followed by a horizontal flow wetland filter is developed. More than 70% BOD removal and up to 5-log reduction of indicator bacteria is possible in the single pass porous media bio filters using about 0,1m^2 surface area/person. For the combined bio filter /constructed wetland system the total area requirement is 1-3m^2/ person and the effluent meets European swimming water standards with respect to indicator bacteria and WHO drinking water standards with respect to nitrogen. The low area requirement of the system and the high effluent quality facilitates use in urban settings, discharge to small streams or open waterways and subsequent treatment producing water for in-house use.

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Community based sanitation program in Tangerang and Surabaya, Indonesia

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Keywords

BORDA, Community Sanitation Centre (CSC), participation, informed choice, Indonesia

Abstract

The City of Tangerang with it's 3 Mio. inhabitants is one of the big satellite-cities of Jakarta and with more than 1000 factories Indonesia's biggest Industrial agglomeration. Close to factories, next to the wall of neighbouring production lines, more than 250 000 inhabitants live in poor worker's settlements, not providing even a minimum of basic sanitation facilities.

Together with the Indonesian NGO "BEST" and user participation, community sanitation centres "MCK plus++" have been developed. They provide facilities such as bathrooms, toilets, washing facilities as well as drinking water through a community "water point". Furthermore, they integrate underground wastewater treatment with part-stream treatment of "black" and "greywater" from toilets and bathrooms. Since 1999, 35 units have been implemented the city centres of Tangerang and Surabaya with a demand driven approach. Operation and service is provided by full-time staff on-site. Maintenance is secured by BEST sanitation experts. User fees cover operation and maintenance. Today, recycling is practiced for digested sludge, biogas utilisation and irrigation of surrounding gardens.

The "MCK plus++" have proven to be an ideal community sanitation solution for densely populated urban low-income settlements where toilets, bathrooms and drinking water facilities are not available in private households. However, more research is needed in order to elaborate a catalogue of solutions complying with ecosan principles, where users can choose. A co-operation with the Technical University Hamburg-Harburg (Prof. Otterpohl) and local Partner Universities has started, aiming at further improvements and new solutions like urine diversion and market analysis for recycled products. New developments have to cope with socio-cultural reality, user acceptance and financial viability. New partners a welcome to join.

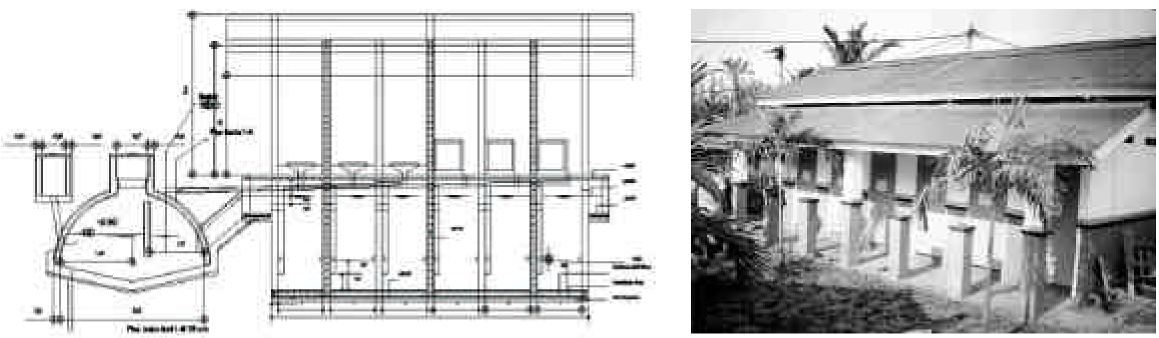

Figure 1: Technical design of community sanitation centre "MCKplus++"

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Introduction

The islands of Java and Bali are among the most densely populated areas in the world. 125 Mio people living on 150.000-km² discharge about 10 Mio m³ wastewater/day or 3,65 Billion-m³ wastewater/year into the environment. According WHO standards, well and tap water in most Indonesian cities does not fit human consumption due to e.coli contamination. Only 6 major Indonesian cities do have centralised wastewater treatment plants. However, it's sewerage systems serve only 10-15% of the population. Sceptic tanks, often in neighbourhood to boreholes are currently the state of the art of wastewater treatment on community level. Most on-site sewerage systems do not function efficiently. Like in most South-East Asian mega-cities, livelihoods and natural resources especially in poor urban settlements are increasingly threatened. People from low-income classes often live under conditions characterised by an extreme deficiency of drinking water supply and sanitation infrastructure. The few existing facilities are inadequate and not acceptable in terms of hygiene, dignity and ecology.

Community Sanitation Centres (CSC)

Since 1999, BORDA in co-operation with the local Indonesian partner NGO "Bina Ekonomi Sosial Terpadu" – BEST (Institute for Integrated Economic and Social Development) has implemented the construction of 35 "MCKplus++" (Community Sanitation Centres) consisting of toilet, bathroom and washing facilities including an integrated community "water point" for drinking water supply. The beneficiaries are inhabitants of densely populated low-income workers' settlements located in urban areas of industrial concentration near the conurbations of the cities Jakarta and Surabaya, Indonesia.

Before CSC were introduced, the existing sanitation infrastructure mainly consisted of open rainwater drains and empty lots, which were used for defecation and the disposal of other waste. As municipal water is rarely piped to the rapidly growing settlements, most of the inhabitants have to buy drinking water from itinerant water sellers or fetch it over long distances from municipal water taps.


Figure 2: Biogas Digester (left) for part-stream treatment of "blackwater", brick construction with waterproof airtight plastering. Baffled reactor (right), based on anaerobic up-flow principles.

Technology

35 CSC are built and operating successfully in urban areas of Tangerang and Surabaya. Each unit has about 1 000 visitors daily. The advantages of this system are:

- Integrated underground wastewater treatment with part-stream treatment of "black" and "greywater" from toilets and bathrooms.

- Anaerobic treatment processes work without external energy inputs.
- Low maintenance costs, no high-tech equipment/movable parts required.
- Spare-parts are locally available.
- Wastewater pollution is reduced by up to 90% (BOD/COD), thus reducing surface water pollution caused by untreated wastewater emission (Table 1).
- Groundwater is not polluted as the wastewater treatment plant is waterproof and airtight.
- Treated wastewater is safe to be discharged into the environment, and is partly reused for gardening or fishponds – according to customer demand. Volume ≅ 35 m³/d.
- Emerging Biogas is captured and used for cooking in neighbouring households.
- De-sludging measures are long between; de-sludging is required every 2-3- years only.
- Sludge is collected and treated by the municipality and reused for soil improvement.

LOCATION	MONTH	PARAMETER							
		pH	BOD5			COD			TSS
			Influent mg/l	Effluent mg/l	% reduction	Influent mg/l	Effluent mg/l	% reduction	mg/l
Alam Jaya	09.02.2001	7,28	310,89	49,52	84,07%	729,79	116,53	84,03%	48
	07.02.2001	6,34		45,60	85,33%		107,30	85,30%	28
	20.04.2001	6,78		32,90	89,42%		77,60	89,37%	36
National Water Discharge Standards (mg/l)									
Class B				50			100		200
Class C				150			300		400

Note: BOD_5 = Biological Oxygen Demand (5 days), COD = Chemical Oxygen Demand, TSS = Total Suspended Solids

Table 1: Laboratory analysis of wastewater treatment efficiency

Operation and maintenance

Operation and maintenance are provided by BEST as turnkey operator.

- User fees between 0.05 and 0.1 US$ cover operation and maintenance costs, and in addition are used for social development contributions to local community self-help groups.
- On-site staff is responsible for cleanliness of the facilities.
- BEST Sanitation experts ensure service and maintenance of the system components.

Costs

Costs are given based on CSC implemented in Tangerang:

- **Primary Investment** per CSC (land + construction): US$ 12000 –15000
- **Annual** turnover (user fees): US$ 2000 –2500
- **Annual operation costs:**
  - Salary for cleaning staff : US$ 500
  - Electricity : US$ 250
  - Cleaning Materials : US$ 100
  - Social Contribution : US$ 150
  - Overheads : US$ 500

  Total annual operation costs: **US$ 1500**

Once investment is done, no further financing is required, even in poor workers settlements. Scaling up the number of units will bring the costs down. Implementing CSC on more profitable locations (markets, railway stations, main roads) could lead to pay back periods of 10 years.

Participatory implementation of CSC projects

Participation of target groups in planning and implementation of projects constitutes one of the conceptual mainstays of BORDA's approach. However, local cultural perceptions concerning decision-making processes on group level have to be taken into account.

In practice, it is proven that community-based sanitation systems are significantly more sustainable, e.g. have a longer lifetime, function more efficiently and are better maintained, if they fully reflect preferences of communities and local stakeholders.

In the following will be demonstrated the course of measures undertaken in the participatory implementation process of CSC introduction.

Figure 3: Community-planning sessions with women and men groups

Methods

Before a participatory decision-making process can be initiated, certain indispensable facts and figures have to be ascertained (baseline data), consisting of:

Official Data

- Demographic data
- City Development Plans (especially plans on sewage and sanitation)
- Political guidelines and declarations of intent in the framework of regional development

Based on these macro-data, micro-data have to be found out by way of realising

Exploratory Surveys

Inspection by technical staff and social workers on <u>objective situation:</u>

- identification of apparent needs indicated by
  - density of population
  - inadequate or total lack of sanitation
  - low income strata of inhabitants
  - general neglect of environment
- topographic situation
- technical situation (existence of drains, sewers, piped water, electricity)
- land tenure

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- composition of inhabitants regarding geographic, ethnic and religious background (homogeneous or heterogeneous)

Preliminary findings: area and sites are physically, technically and socially eligible for CSC introduction.

Interviews by social workers/facilitators concerning subjective situation:

- demand exploration with pre-constructed random-sample questionnaires:
  - respondents are stakeholders
    - members of the target group (beneficiaries according to gender/age)
    - members of the local administration
- demand exploration by qualitative interviews:
  - interviewees are stakeholders
    - individual prospective beneficiaries
    - key informants (e.g. local officials, informal leadership)
    - focus groups (e.g. women's groups)

Both quantitative and qualitative surveys should include the mentioning of possibilities of change and remedy of the situation, eventually touching on solutions (social marketing), and induce opinions and comments.

If and when the analysis of all baseline data lead to a defined eligibility of areas and communities (e.g. neighbourhood units) the subsequent step will be entering into the concrete form of the

Planning and decision making process

Participation of stakeholders, especially members of the target groups (beneficiaries), during the planning stage is the main key for successful program implementation.

In response to objective needs and subjective demands community members are approached by BEST for "socialisation", i.e. the imparting of educative explanatory information on sanitation, hygiene and health on the one hand, and the possibilities of solution on the other.

The method of choice is the arrangement of group meetings with participants from eligible communities.

From a wider range of technical and social solution possibilities, a pre-selected catalogue is presented (technically and socio-culturally impracticable varieties have been omitted beforehand), from which the target group members can choose the proper technical option, including infrastructure, maintenance and cost factors completed by information on

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opportunities, merits and risks of each technical option (informed choice). Furthermore, informed choice is offered concerning the management of the completed installation, i.e. technical, economic and social operation.

The benefits of elaborating and working with an “Informed Choice Catalogues” (ICC) can be summarised as follows:

- it informs about major component options of sanitation systems – Toilets, Collection System, Treatment System and Disposal/Re-use – and thus helps to identify suitable options
- facilitates the assessment of different sanitation system components with regard to stakeholder preferences
- is a powerful tool for technical bottom-up planning
- serves as reference to get overall information about technical options at a “glance”

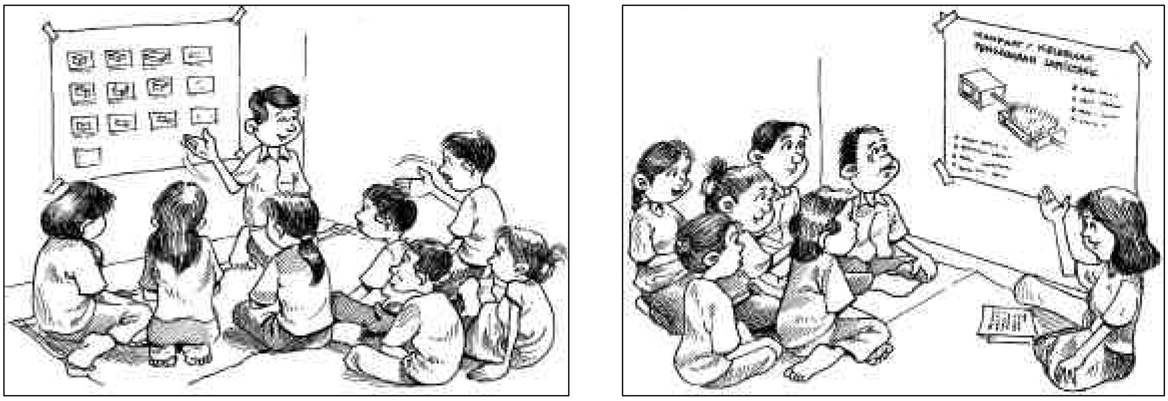

Figure 5: Informed choice catalogue, a powerful tool for bottom-up planning

After in-depth discussion among the participants, when needed interspersed with additional explanations from BEST staff, the forum decides on a feasible option. In order to forestall future constraints only unanimous decisions are accepted. Even one single substantiated dissenting opinion can give cause for the cancellation of CSC introduction in a specific area. However, further explanations from BEST and fellow occupants of the area can help to overcome dissenting opinions. This is one of the reasons why the BORDA/BEST project has been acknowledged as extremely successful.

According to evaluators commissioned by the Federal Ministry for Economic Cooperation and Development (BMZ), the BORDA-project is one of the rare examples where such an approach really works[1].

In the present case, the communities have decided to choose the MCKplus++ model as described above. Concerning the management, communities decided on varying approaches; at least one community decided to manage the daily operation on their own, relying only on technical control by BEST. However, most of the communities decided to leave the daily management to technical and social experts from BEST, i.e. the implementation of a “user model” which includes technical control, supervision of operation and maintenance, and the accountancy of user fees.

In the further course of action, the target groups take part in the technical planning, organised in an elected implementation committee, like choosing eligible sites for construction, and the planning for operation (fulltime personnel for operation and maintenance, decision on user fees

[1] Report on the partial evaluation “The Activities of Bremen Overseas Research and Development Association (BORDA) in Indonesia”, BMZ, Bonn, December 2001

and their utilisation etc.).

Implementation

- acquisition of land for building site (BEST assisted by suggestions from the target group)
- construction planning (technical staff from BEST)
- construction (local building contractor, construction supervision by BEST)
- operation and maintenance (selection and employment of fulltime caretakers by Committee and BEST)
- inauguration (formal and informal leadership)
- utilisation of user fees (surplus used for development of local community self-help groups, e.g. “Posyandu” = Information and treatment centre on health and hygiene).

After-care and Follow-up

Possibilities of appeal to BEST are:

- for complaints
- for suggestions
- for replication (Requests/proposals from other communities)

Dissemination

- in other areas, in the present case realised in Surabaya
- taking-up of the model by government institutions (Municipality of Tangerang, Ministry of the Interior)

Results

Since 1999, the main results are:

- 35 Community Sanitation Centres “MCKplus++” built in poor urban communities
- Sanitation facilities cover the needs cover the needs of 17.000 persons
- About 13.000 m³ domestic wastewater is treated every day
- 80 households and the CSC use biogas for cooking (user fee = 2US$ per month)
- All sludge, after treatment on municipal sludge treatment plants, goes back to farmland
- Permanent/part-time employment created for over 100 staff and many craftsmen.

Furthermore, capacity building for the partner NGO in the field of dissemination and implementation of CSC, training of trainers, social activities such as hygiene and awareness training with the target group and last but not least contributions to local community self-help groups resulted in broad acceptance and utilisation of the CSC.

Impacts

Implementation and utilisation of the CSC do have a positive impact on the community while motivating the neighbourhood to improve their living environment on their own. Main impacts to be registered are:

- the renovation of houses,
- repairs of alleys, gutters and ditches and
- the construction of sport facilities (badminton court)

Conclusions

The present project of introducing “MCKplus++” has proved to be an ideal community sanitation solution for densely populated urban low-income settlements where toilets, bathrooms and drinking water facilities are not available in private households. However, “conditio sine qua non” is the participation of the beneficiaries.

The technical design of the “MCK plus++” integrates underground wastewater treatment with part-stream treatment of “black” and “greywater” from toilets and bathrooms. Since 1999, 35 units have been implemented the city centres of Tangerang and Surabaya with a demand driven approach. Operation and service is provided by full-time staff on-site. Maintenance is secured by BEST sanitation experts. User fees cover operation and maintenance. Today, recycling is practiced for digested sludge, biogas utilisation and irrigation of surrounding gardens.

More research is needed in order to elaborate a catalogue of solutions complying with ecosan principles, where users can choose from. A co-operation with the Technical University Hamburg-Harburg (Prof. Otterpohl) and local Partner Universities has started, aiming at further improvements and new solutions like urine diversion and market analysis for recycled products. New developments have to cope with socio-cultural reality, user acceptance and financial viability. New partners a welcome to join.

Introducing urine separation in Switzerland: NOVAQUATIS, an interdisciplinary research project*

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Keywords

Alternative wastewater treatment, consumer attitudes, No-Mix toilet, technology transfer, urban sanitation concepts, wastewater professionals

Abstract

Successful urine source separation (NoMix technology) poses a challenge to scientists, stakeholders, and society. Low-tech approaches are appropriate for rural areas; for large urban areas – in Europe and fast-industrializing countries – other solutions are needed. NOVAQUATIS focuses on NoMix technology in modern households, transport strategies, methodology to eliminate micropollutants (pharmaceuticals, hormones), and technologies to produce a fertilizer. First results are promising: feedback from consumers and farmers was positive, provided that high safety and comfort is maintained at low costs. To overcome the lock-in effect of the present system, technologically advanced transition strategies are needed, which allow to gradually implement NoMix technology into the urban wastewater system. Computer simulations of a strategy with small urine storage tanks integrated into the toilet indicate a positive effect on nitrification capacity (+30%) and emissions from combined sewer overflows (-50%). Results from experiments and modeling of precipitation in urine conducting pipes will help solving maintenance problems of NoMix toilets due to clogging. So far, engineering technologies for urine stabilization, nitrification, denitrification, and P-recovery via forced struvite precipitation have been proposed. Hopefully, the early implementation of NoMix technology in pilot projects and the integration of emerging countries into our scientific research will enhance successful technology transfer.

Introduction

Traditional and modern approaches to urine source separation.

Urine source separation (NoMix technology) has been proposed by different authors as a promising option to introduce the concept of sustainability to urban water management (e.g. Larsen and Gujer, 1997; Otterpohl *et al.*, 1999; Larsen *et al.*, 2001a). This idea is receiving increasing interest from large water authorities in Stockholm, Wuppertal, Basel, Berlin, and Hamburg, which is resulting in different pilot projects (Johansson, 2001; Bastian *et al.*, 2002; Kühni *et al.*, 2002; Peter-Fröhlich, 2002; Rakelmann, 2002).

Low-tech approaches to urine separation with nutrient re-use in agriculture have been carried out in rural areas of various cultures. In China, urine separation with simple toilets and application of raw urine as fertilizer has been practiced for millenniums (Esrey *et al.*, 1998). In Denmark and Sweden, simple urine separating toilets were used in the mid-19th century, a tradition that

*This paper has been peer reviewed by the symposium scientific committee

was revived in the 1970s to solve sanitation problems of remote holiday houses (Johansson, 2001). It was also in Sweden, where modern urine separating toilets (NoMix toilets) were first invented and installed in pilot projects in the 1990s (Hellström and Johansson, 1999). However, to date even the modern approaches to urine source separation have only limited applicability in large urban areas.

We believe that urine source separation offers many advantages, not only for rural, but especially also for urban areas with a modern wastewater system – both in Europe and in fast-industrializing countries. However, in such a situation, modern, highly-advanced technological solutions are needed, and acceptance of the idea by important stakeholders such as consumers and wastewater professionals is essential (Larsen and Lienert, 2002). The development of new technology, the integration of the NoMix technology into the existing urban wastewater system, and the participation of society poses a challenge to all involved actors. These are the topics of the interdisciplinary research project NOVAQUATIS.

Why urine source separation?

Closing nutrient cycles: The traditional reason for urine separation is nutrient recycling to agriculture. Urine contains most nutrients excreted by humans: ca. 85–90% of nitrogen (N), 50–80% of phosphorus (P), and 80–90% of potassium (K; Larsen and Gujer, 1996). In modern agriculture, nutrient re-use from urine could partially replace synthetic mineral fertilizers; in Switzerland, this would amount to ca. 37% of N, 20% of P, and 15% of K (Lienert *et al*., 2003). A second main argument is the limited availability of phosphate rock, which could be depleted in 200–300 years (based on Jasinski, 2002). Already today, science and the phosphate industry aim at recycling P from wastes; recycling from urine might prove to be far easier than from wastewater treatment plants (WWTPs). Moreover, the production of mineral fertilizers produces problematic wastes and consumes large amounts of energy. Recycling of N from urine might prove to be advantageous also from an energetical point of view (Maurer *et al*., 2003).

Saving water: NoMix toilets help saving large amounts of drinking water, since little or no water is needed for flushing away urine. Many emerging countries face severe water shortage problems, whilst water flushing toilets are desired as symbols of progress. Because the expansion and maintenance of sewers and WWTPs often does not keep up with the growing use of flushing toilets, the export of the conventional western technology can result in increased water shortage, severe hygienic problems, and eutrophication of surface waters. In the long term, the introduction of a water saving toilet is beneficial for industrialized and emerging countries alike.

Advantages for the urban wastewater treatment system: NoMix technology offers several advantages: (1) urine constitutes ca. 1% of the wastewater, but necessitates large elimination steps because it contains most nutrients in wastewater. Nitrification and P precipitation would become superfluous with effective urine separation (Larsen and Gujer, 1996) and would allow downsizing WWTPs. (2) Most industrialized countries transport waste- and rainwater in the same sewers and discharge this mixture directly to surface waters via combined sewer overflow (CSO) during rain periods. Separate collection of urine could reduce chronic and acute toxicity due to N compounds, eutrophication due to P and N, and oxygen depletion due to nitrification. (3) Micropollutants (pharmaceuticals, hormones) are not completely eliminated in WWTPs. To date, over 80 compounds have been found in sewage effluents, surface waters, and even in ground waters (Heberer, 2002). Although the potential impact on the environment is largely unknown (Länge and Dietrich, 2002), micropollutants are giving rise to increasing concern. Since many pharmaceuticals from the human metabolism are excreted via urine, NoMix technology would improve water pollution control also in respect to micropollutants, especially when combined with other source control measures, for instance in agriculture.

Methods

The interdisciplinary research project NOVAQUATIS

NOVAQUATIS focuses on NoMix technology in modern households, transport strategies for large urban areas, methodology to eliminate micropollutants, and technical solutions to produce an attractive nutrient product from the raw urine for agriculture or industry. It includes socioeconomic research, natural sciences, engineering technology, and a cooperation with the emerging country China. Strong interactions with local water authorities and sanitary firms are maintained, and participatory research is conducted with important stakeholders such as consumers, farmers, and wastewater professionals thus paving the way for a large-scale implementation in Switzerland. NOVAQUATIS is organized around the nutrient cycle in eight workpackages (fig. 1).

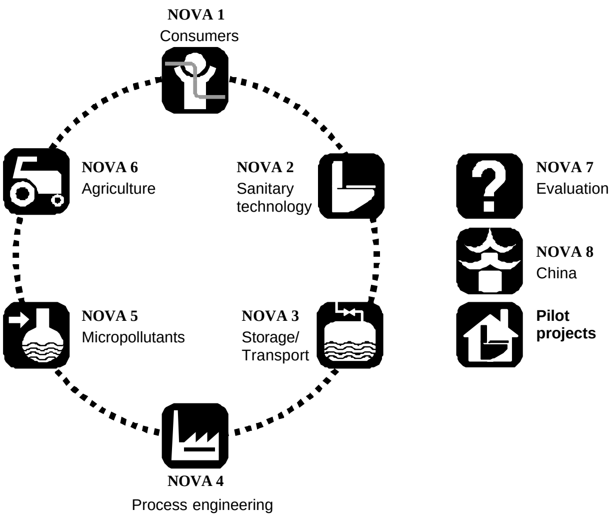

Figure 1: The anthropogenic nutrient cycle as it would arise if urine were separated at the source and returned to agriculture as fertilizer. NOVA 1–8 are workpackages.

The concept of NOVAQUATIS is to allow for conventional disciplinary research in projects assigned to the different workpackages (NOVA's; Table 1) with subsequent integration of the results at an interdisciplinary level. Associated pilot projects enable real-world testing of urine separation and in turn profit directly from the research results gained in NOVA 1–8. The integration of emerging countries into scientific research at an early phase aims at enhancing successful technology transfer. NOVAQUATIS runs from 2000 until 2005. This paper gives a first overview of the results obtained so far (see Lienert and Larsen, 2002 for a summary in German).

Results

Acceptance of NoMix technology by important stakeholders (Nova 1, 6)

Preliminary investigations revealed a high acceptance for urine separation and re-use of nutrients among consumers (NOVA 1) and farmers (NOVA 6). The attitude of Swiss citizens was assessed with focus groups (Pahl-Wostl *et al*., 2003). The 44 participants informed themselves on NoMix technology with a specifically developed computer tool (www.novaquatis.eawag.ch/ NoMix Tool) and visited the NoMix toilets at EAWAG. The groups met twice for discussions and answered a questionnaire. They generally had a positive attitude towards NoMix technology: 89% women and 71% men regarded the NoMix toilet as a good or very good idea. A majority would move into an apartment with a NoMix toilet (79% women, 88% men), and many were willing to purchase such a toilet (63% women, 42% men). They were very interested in practical aspects of NoMix toilets (e.g. design, cleaning) and men were particularly intrigued by technical details. Interestingly, only 16% of the men regarded it as problematic to sit when urinating. Proper functioning of today's NoMix toilets depends on this condition and it is often a prime argument against their introduction. These results are not representative because the participants had a higher environmental awareness than average citizens. However, they do indicate that

NOVA	Workpackage	Project partners
1 Consumers	**Acceptance of the NoMix technology.** Which are the consumer attitudes to wards the NoMix toilet and a urine-based fertilizer product? Traditionally, specialist engineers developed new wastewater technology without participation of the public. Obviously, this is not adequate for urine separation in households. Therefore, NOVAQUATIS in volves relevant stakeholders already in an early phase of the research process.	• Prof. Ruth Kaufmann-Hayoz, IKAOE, Univ. Berne, Switzerland • Pilot projects
2 Sanitary technology	**Does the sanitary technology work?** Sanitary appliance manufacturers – in cooperation with EAWAG – explore design issues related to the NoMix technology in bathrooms. Additionally, the problem of precipitation, which can lead to clogging of urine conducting pipes, is investigated in detail at EAWAG. This workpackage also relates information between manufacturers and the project participants.	• Prof. Ralf Otterpohl, Tech. Univ. Hamburg-Harburg, Germany • Sanitary firms • Pilot projects
3 Storage / transport	**Storage and transport of urine.** Open questions regarding the storage and transport of urine still need clarification. Research mainly fo cuses on transition scenarios, which enable integrating the NoMix technology into the current urban wastewater management system without necessitating the renewal of the entire system. Therefore, NOVA 3 investigates different strategies of urine transportation in the existing sewers.	• Prof. Wolfgang Rauch, Dep. of Environmental Engineering, Univ. Inns bruck, Austria • Pilot projects
4 Process engineering	**Processing of urine and production of a fertilizer.** Different procedures to stabilize urine, to reclaim the nutrients (N, P, K), and to eliminate micropollutants are being developed and tested. Possible technologies are biological processes (e.g. biofilm reactors), chemical processes (e.g. precipitation in fluidized bed reactors), and physical processes (e.g. membrane technologies).	• Univ. of Applied Sci ences Basel (FHBB), Switzerland
5 Micropol-lutants	**Are micropollutants in urine a problem?** Micropollutants are pharmaceuticals and hormones excreted via urine. The ecotoxicological effects of single substances and mixtures are analyzed with in vitro biological test-systems. Advanced analytical-chemical methods allow quantification of the degradation process of micropollutants in urine samples treated by different process engineering methods in NOVA 4.	
6 Agri–culture	**Urine as fertilizer?** It was planned to estimate how large the demand for a urine-based fertilizer product in agriculture could be – especially in organic and integrated farming – and to generate nutrient balances. The attitude of farmers towards such a new fertilizer product is also investigated in NOVA 6.	• Only a very limited part will be realized due to lack of financial resources
7 Evaluation	**Evaluation of the NoMix technology.** NOVA 7 integrates the research results generated in the other workpackages and covers some additional topics. The goal is to comprehensively evaluate the consequences of urine source separation. The NoMix technology will be evaluated with help of a scenario analysis, which assumes varying levels of implementation. This evaluation will provide important information to decision makers, and will allow customization to different contexts.	• Pilot projects
8 China	**NoMix technology also for emerging countries such as China?** In emerging countries, the introduction of flushing toilets often has severe impacts on the environment, because it is only rarely accompanied by adequate water pollution control measures. NOVA 8 adapts the results of the other workpackages to this special situation and investigates whether the implementation of urine source separation technology in emerging countries could contribute to improved surface water conditions.	• University Kunming, China • Swiss National Science Foundation (SNF) • Swiss Agency for Development and Cooperation (SDC)
Pilot projects	**Does NoMix work in real life?** To test the NoMix technology in reality, several pilot projects are performed in both private and institutional settings. Four apartments of a housing estate in a larger Swiss city were equipped with NoMix toilets in 2001. Additionally, EAWAG and the FHBB are testing some NoMix toilets. Larger pilot projects are planned by the AIB in the canton Basel-Landschaft (BL). For instance, it is planned to fully equip the cantonal library in Liestal with NoMix toilets.	• ?Bau- und Umweltschutzdirektion? (BUD), BL • ?Amt für Industrielle Be triebe? (AIB), BL • Univ. of Applied Sci ences, Basel (FHBB)

Table 1: The workpackages of NOVAQUATIS (NOVA's) and associated project partners of EAWAG

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there is goodwill and interest towards NoMix technology and that it is possible to inform a lay public on complex technology issues. Furthermore, consumers are not willing to carry additional costs and maintaining today's level of comfort and esthetics is essential. The participants were also questioned on their attitudes towards food fertilized with a urine-based fertilizer. Indeed, 72% were willing to regularly purchase such food, even though nutrient recycling was not a major argument for technology acceptance, whereas they regarded the short-term positive impacts on ecosystems (i.e. water pollution control) as especially convincing aspects of NoMix technology. Absolutely essential for the acceptance of a urine-based fertilizer was a hazard-free product. Hence, adequate hygienization and elimination of micropollutants will presumably be extremely important for the widespread introduction of a urine-based fertilizer product.

This opinion is shared by 127 Swiss farmers of a mail survey (Lienert *et al*., 2003). Again, results are not quite representative, because the response rate differed among groups of farmers. The 467 randomly sampled farmers were informed with a letter and answered questions on personal details, their opinion towards a urine-based fertilizer product, and nutrient demands. Acceptance of the NoMix technology was surprisingly high: 57% thought it was a (very) good idea and 42% would purchase a urine-based fertilizer product if it were cheap. Market chances are highest among farmers with large nutrient demands (i.e. integrated production, vegetable production). They preferred an ammonium nitrate fertilizer and a grainy, rather than a liquid product. Like consumers, farmers were worried about hazardous substances in the fertilizer: 30% of all farmers mentioned concerns regarding micropollutants. Hence, our first surveys indicate that the NoMix technology is acceptable for Swiss people provided that the costs are low, but comfort and safety standards are high. Whilst the attitude of consumers and farmers is important, a recent analysis indicates that it is not the driving force for the successful introduction and fast diffusion of the NoMix technology (Larsen and Lienert, 2002). The main decision-makers are wastewater professionals (e.g. engineers, wastewater authorities) and *their* opinion is absolutely crucial. *They* will have to introduce the new concept and carry consequences of drawbacks. Hence, a strong commitment from the part of wastewater professionals is needed. Our analysis indicates that the technologically advanced transition strategies, focusing on a gradual implementation of NoMix technology into the existing wastewater system, might be far more attractive to wastewater professionals than the more low-tech approaches (see NOVA 3).

Sanitary professionals and sanitary technology: precipitations (NOVA 2)

NOVAQUATIS has several years of contact with sanitary professionals. Different NoMix toilets are available on the market today; however, our ongoing surveys with users indicate that various design-related problems still need to be solved. The main problem is clogging of urine-conducting pipes due to precipitation, which would hardly be accepted by users of NoMix toilets in Switzerland. Presumably, sanitary professionals will only carry the costs for the necessary technology development if there are high market chances (Larsen and Lienert, 2002). Precipitations were intensively investigated (Udert *et al*., 2003b,c,d). A high fraction of phosphorus is incorporated into the precipitates. The main crystalline compounds are struvite, hydroxyapatite, and calcite. The composition depends on dilution with flushing water; computer simulations indicate that dilution diminishes the precipitation potential and thus the risk of blockages. Rainwater is more effective than tapwater. Microbial urea degradation triggers precipitation; the bacteria mainly grow in the pipes and are flushed into the tank. In undiluted urine, a degradation of only 8% urea resulted in 95% of the maximum precipitation potential. Few days are necessary for complete urea depletion, and precipitation begins soon after ureolysis has started. Struvite and octacalcium phosphate are the precipitating minerals in undiluted urine. The results show that there are no easy solutions to overcome the clogging problems in urine conducting pipes. Effective handling of precipitates from urine still demands large efforts and technological ingenuity.

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Integrating the NoMix technology into the urban wastewater system (NOVA 3)

The ultimate aim of the NoMix technology is to gain an attractive nutrient product for application in agriculture or industry. NOVAQUATIS proposes to collect the urine at the source in households and to use the existing sewer system for transport at nights without rainfall (Larsen and Gujer, 1996). Real time control would ensure that urine arrives as concentrated as possible at the WWTP, where it could be treated separately. To bridge rain events, a tank for storage during 3–7 days would be necessary. Such a system enables a cost-efficient, stepwise introduction of the NoMix technology, which allows for technological learning and gradual development.

Adequate technologies for processing the urine into an attractive nutrient product have not yet been developed (but see NOVA 4, 5). Therefore, NOVAQUATIS also proposes a transition scenario, which allows integrating NoMix technology into the current system, hereby improving the capacity of WWTPs. A possible scenario consists of a very small urine tank integrated into the toilet for storage during 1–2 days. Transport of the urine is also via the existing sewers, albeit without further processing into a nutrient product. Here, the main goals are (1) leveling out the nitrogen dynamics at the WWTP caused by diurnal variations in urine production (peak shaving), and (2) avoiding urine in CSO during rain events (Larsen *et al*., 2001b; Rauch *et al*., 2003). Stochastic modeling with realistic storage tank volumes (10 liters/toilet) provided promising results: over 50% of urine released via CSO could be avoided, and the ammonia peak loads at dry weather could be decreased by ca. 30%. The latter increases the nitrification capacity of the WWTP in the same dimensions (Rauch *et al*., 2003). Because this version only involves a new toilet, but not new tubing, large storage tanks, and complicated processing plants, it could be implemented very quickly and at fairly low costs. This allows a faster diffusion of NoMix technology, with minimal risks and – again – ample room for technological learning. Therefore, we regard this transition scenario as the most promising solution for the immediate introduction of NoMix technology in a modern, urban context.

Urine processing to produce a urine-based fertilizer without micropollutants (NOVA 4, 5)

Fresh urine (pH 6.2–6.8) has a high amount of biodegradable substrate, which triggers rapid microbial growth. A dominating reaction is the microbially catalyzed hydrolysis of urea, which results in ammonia production and a pH increase (>9). As a result, the saturation for several phosphate minerals is exceeded and they precipitate (NOVA 2). This would enable to recover nutrients (P, some N) as solids. Various elimination technologies for nutrient solutions exist, but the adaptation to urine needs efforts (Larsen and Boller, 2001; Maurer *et al*., 2003). Different procedures to stabilize urine, reclaim nutrients, and eliminate micropollutants are being developed (NOVA 4). A first proposed technology is based on known biotechnology (Udert *et al.*, 2003a): with aerobic biological treatment of urine (including partial nitrification), the pH was stabilized, which helps avoiding corrosion problems and evaporation of ammonia, thus enabling an application in agriculture. As further option, the urine was denitrified via nitritation and anaerobic ammonium oxidation (Annamox). A possible technology for the recovery of P from urine is presented separately: forced struvite precipitation ($MgNH_4PO_4$; Ronteltap *et al*., subm.).

Further processing technologies and analytical methods to detect micropollutants in urine are under development. The ecotoxicological risk of micropollutants (NOVA 5) is assessed with a mechanism-based test battery. It includes nonspecific test systems, which allow quantifying the overall cytotoxicity and estimating the total molar load of toxicants (Escher *et al*., 2002). It also comprises tests for specific modes of toxic action (e.g. endocrine disruption, inhibition of photosynthesis, DNA damage). After validation with single compounds and designed mixtures, the test battery is used to test the ecotoxic potential of the treatment products of NOVA 4. Two chemically-oriented projects in NOVA 5 are closely cooperating with European research projects (Eggen *et al*., subm.) and adapt analytical methods from wastewater to urine. This allows quantifying the degradation process of micropollutants in urine samples processed by NOVA 4.

Could NoMix technology be an option for emerging countries such as China (NOVA 8)?

Source control could also offer an alternative to the conventional end-of-pipe wastewater management in emerging countries. NoMix technology has great potential for improving desolate conditions of surface waters. In cases where the sewer system is not yet established, there are more degrees of freedom in the planning process than in a typical European country. Kunming was chosen as pilot region. First results of a methodology for wastewater and pollutant mass flux analyses in emerging countries are presented separately (Huang *et al*., subm.). The challenge here is to take into account the specific uncertainties, most importantly the lack of data and the rapid urban development. The methodology is tested in Zürich and will then be implemented in Kunming. The results will be the basis for an additional project that investigates the institutional and technical possibilities for introducing source control measures in wastewater management in South East Asia.

Pilot projects to test NoMix technology in the real-world

Currently, several small pilot projects are performed in private and institutional settings in Switzerland: (A) four apartments of a municipal housing estate in a large city were equipped with NoMix toilets in 2001. The main idea is to assess social acceptance and design-related problems of NoMix toilets in households, and to test their functioning in daily life (NOVA 1). Additionally, a stochastic model for simulation of the at-source urine occurrence is being developed to understand storage and transport-related processes (NOVA 3). (B) Several NoMix toilets and waterfree urinals are installed at EAWAG since 1997, mainly to collect urine samples (NOVA 4, 5) and data on precipitation in urine-conducting pipes (NOVA 2). The NoMix toilets were also used for the sociological surveys with focus groups and currently with long-term users (NOVA 1). (C) The University of Applied Sciences Basel (FHBB) installed some NoMix toilets and waterfree urinals in a vocational college in 2002. The main goal is to test the sanitary models available on the market and to gain experience with the urine-conducting pipes and storage tanks. The attitude of the users is being assessed with quantitative surveys (NOVA 1). (D) Finally, the wastewater authorities of canton Basel-Landschaft (BL) have initiated a large urine separation project (Kühni *et al*., 2002). The general aim is to evaluate more flexible and sustainable alternatives in urban wastewater management, with special focus on waste design and urine separation. Based on experience from other pilot projects, the NoMix technology will be fully implemented on a technical scale in the cantonal library in Liestal (BL) in 2005. Currently, a microsimulation model is being constructed to simulate material flows and direct costs associated with different scenarios of NoMix market penetration (NOVA 7). The model is based on Swiss residential census data in an urban and a rural model region. It simulates the spatial and temporal distribution of urine yield and the adoption of NoMix technology over time (Peters *et al*., 2002). (E) Given successful results of the real-world tests and the computer simulations, NoMix technology will be implemented in the entire catchment area of a small WWTP in BL.

Conclusions

Interdisciplinary research is a challenge and chance alike. Detailed disciplinary research within NOVAQUATIS has provided some promising answers to major questions of engineering techniques and sociology associated with urine source separation. For instance, feedback from consumers and farmers was positive, under condition that high standards of safety and comfort are maintained at low costs. Although these stakeholders are important, a third group might prove to be absolutely crucial for the successful introduction and fast diffusion of urine source separation: the wastewater professionals. Technologically advanced transition strategies, which allow for a gradual implementation of NoMix technology into the existing modern wastewater system, will help to overcome the current lock-in situation. NOVAQUATIS proposes such transition scenarios. By realizing pilot projects in an early phase, the NoMix technology can be directly tested in the real-world. Likewise, the early integration of emerging countries such as China into the research process might enhance successful technology transfer from industrialized regions to fast-industrializing ones; whilst successful technology transfer in turn can strongly promote the idea of NoMix technology in our highly industrialized urban centers. Continuing disciplinary research with integration of the results at an interdisciplinary level will help finding sustainable alternatives in urban wastewater management.

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Practical examples of DESAR concepts in urban areas in the Netherlands

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Keywords

Decentralised sanitation and reuse (DESAR), source separation, urban areas, practical examples, monitoring programme

Abstract

This paper contains a short summary of case studies into the realization of Decentralised Sanitation and Reuse (DESAR) concepts based on source separation in urban areas and highlights several organisational and technical aspects that play a role in implementation and operation.

Introduction

Decentralised Sanitation and Reuse (DESAR) concepts based on source separation enjoy increasing attention in The Netherlands. Since the beginning of the 1990s several urban projects were initiated in which various forms of source separation were considered and taken into practice. This paper highlights a monitoring programme into the realization of these projects. The programme is aimed at increasing the knowledge on practical implementation and management of DESAR concepts. Information on technical, institutional and legislative aspects is collected through interviews with local stakeholders and a review of available literature and Internet sources. In addition several workshops and symposia are organised in order to disseminate the collected information and increase the chances of success of future projects.

Overview of practical examples of DESAR concepts based on source separation

Table 1 gives a brief overview of urban source separation projects in The Netherlands that have been identified within the monitoring programme (update January 2003). The paper describes three projects with different wastewater collection and treatment systems in more detail.

The table shows that application of source separation in The Netherlands is at this moment (January 2003) mainly limited to local greywater treatment by, in most cases, constructed wetlands. The treated water is discharged into local water systems that are usually part of the architectural design as a measure to create an attractive urban environment. Two projects use this 'urban water' as a source of second quality water for toilet flushing and washing machines after a simple treatment step (filtration). The application of local blackwater treatment in city areas has so far been limited to one project with composting toilets. However, several projects are in preparation in which vacuum and urine separating toilets will be applied.

Name of area and year of construction	Characterization of DESAR concept					web address
	Local greywater treatment and infiltration	*Blackwater, compost toilet*	*Blackwater, vacuum toilet*	*Urine separation toilet*	*Local rainwater infiltration*	
Current projects						
Groene Dak, Utrecht (1993)	X	X			X	www.groenedak.nl
Drielanden, Groningen (1995-1997)	X				X	www.drielanden.nl
Lanxmeer, Culemborg (1999-2003)	X				X	www.eva-lanxmeer.nl
Schutterstraat 1, Delft (1995)	X	X			X	
Polderdrift, Arnhem (1996)	X				X	
Waterspin, The Hague	X				X	
Projects in preparation						
EcoPark, Emmeloord (2003-2005)	X				X	www.ecopark.nl
Wageningen (2004-2005)	X		X		X	
Water Museum in Arnhem (2003)				X		www.watermuseum.nl

Table 1: Overview of DESAR projects in urban areas The Netherlands (January 2003)

Het Groene Dak, Utrecht

Residential area 'Het Groene Dak' is an ecological housing project in Utrecht that was completed in 1993. It consists of 40 rental and 26 private-owned houses. The project was initiated by some of the current inhabitants through Foundation 'Het Groene Dak'. Major attention in the project has been put on the usage of sound construction materials and energy and water saving measures.

The area contained an experiment with ten houses that had no connection to the sewer system. Physiological (black) waste was collected with composting toilets. The collected wastes were composted in the basement of the dwellings combined with kitchen wastes. Moisture was drained off through a sieve and led to the greywater treatment system. After seven years of operation the experiment was stopped by urgent request of the inhabitants. Unfortunately (and for reasons not clear) the moisture drainage appeared not sufficient and the composting process became severely disturbed for some years. Despite huge affords of the inhabitants, anaerobic conditions prevailed in the composting room and led to severe nuisance and potential risk through the formation of methane and ammonium gas. The composting toilets were subsequently replaced by conventional (water saving) toilets that were connected to the city sewer. The removal of the accumulated black 'cake' got national attention because of the suspected danger for an explosion and the evacuation of the whole block (which appears quite unlikely since a strong ventilator had already been installed years before).

The greywater was (and is) treated in an oxidation bed with carrier material followed by a sub-surface reed bed filter (5 houses) or a wetland in a greenhouse (5 houses). A measurement campaign by the University of Amsterdam (Matthijs and Balke, 1997) showed that very acceptable treatment results are obtained that comply with the effluent discharge standards.

De Drielanden, Groningen

This housing project was initiated by a group of ecologically interested citizens, united in the *Vereniging Ecologisch Wonen* (VEWG - Ecologically Living Society). In cooperation with the Municipality Groningen and the local housing agency the settlement Drielanden (166 dwellings;

both rental and private-owned) was established in 1995-1997. The houses have advanced isolation measures, are located favourable to the sun and have water saving devices. The Dutch Ministry of Housing, Spatial Development and Environment awarded a prize to the project in 1997 as being an innovative example of a sustainable and energy saving residential area.

The largest part of the settlement (110 households) is equipped with grey and black wastewater separation and greywater treatment. Blackwater is discharged into the central sewer system. The VEWG had originally proposed to implement composting toilets. However the constructor, the architect and the municipality objected to this idea because of proposed high costs of creating extra composting room in the household's basements and expressed doubts concerning the long-term operation of these systems. After thorough debate it was ultimately decided to install water saving toilets of 4 litre per flush. Unfortunately, in practice it appeared that more flush water was required to prevent clogging of the blackwater gravity sewer pipes.

The greywater of 110 households in De Drielanden is treated in a free surface constructed wetland system. The effluent is discharged, along with rainwater, into the surface water basin in the residential area. The constructed wetland system consists of a 30 cm deep horizontal-flow canal system that contains reed. It is constructed as a carrousel and has a hydraulic retention time of 18 days (ca 10 m^2 per person). Because the system is open to the surface, it is located outside the residential area and is not open to the public. It is only operated in the summer, because of possibility of freezing in the winter. The municipality provides the system operation and management.

Extensive monitoring of the constructed wetland system and the urban surface water system was done by Van Dijk (2002). The wetland system shows a very good treatment performance as illustrated by table 2. A remark is made by the author (who is inhabitant of the neighbourhood) about malodour due to the direct contact between wastewater and open air. However, no official complaints on this have been received until now. Long-term measurements have shown that the water quality of the urban water basin is of constant and good quality.

Parameter	Influent (greywater)	Effluent 1996	Effluent 1997	Effluent 1998	Effluent 1999
COD (mg O_2/l)	550	38	51	44	45
BOD_5 (mg O_2/l)	298	2	7	4	2
N-Kjeldahl (mg N/l)	12,6	1,7	2,4	2,0	1,6
NO_3-N, NO_2-N (mg N/l)	< 0,03	< 0,03	< 0,02	< 0,17	0,11
P-total (mg P/l)	1,8	0,24	0,49	0,31	0,31
pH	7,1	7,6	7,6	7,4	7,3
Chloride (mg/l)	68	52	55	27	51

Table 2: Influent en effluent of the grey wastewater treatment system (yearly averages) (van Dijk, 2000)

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Lanxmeer, Culemborg

A recently developed project with alternative sanitation is the residential area Lanxmeer in Culemborg. This project was initiated by the EVA Foundation (Ecological Centre for Education, Information and Advise) and the Municipality of Culemborg and is based on an integrated approach towards sustainable urban development. The Lanxmeer district will ultimately consist of 200 houses and apartments, a number of company offices, workshops, an ecological city farm and a conference and hotel centre of the EVA Foundation. A large part of the area has been built in 2000; the remaining parts will be constructed in the coming two years. The water situation of Lanxmeer is special because it is situated on top of a water abstraction area. In order to protect the ground water special measures have been taking to avoid ground water pollution.

Domestic wastewater is collected separately in a black and greywater sewer system. The houses in Lanxmeer are equipped with water saving toilets. This toilet type uses 4 litre to flush faeces and 2 litre to flush urine. To minimize the chance of clogging of the blackwater sewer a so-called booster is installed for temporary storage of the blackwater. At this moment the blackwater is brought into the central (back up) sewer system. The future objective is to digest the black wastewater in the area in combination with kitchen wastes and recover energy through the production of biogas. The grey wastewater in Lanxmeer will be treated in three vertical flow reed bed filters (2 m^2 per person) that are embedded in the innovative urban architectural design. Rainwater is locally collected and stored in five retention basins that are spread throughout the area.

Some conclusions regarding system choice

Practical application of source separation in The Netherlands is at this moment (January 2003) mainly limited to local greywater treatment by, in most cases, constructed wetlands (designed as open air or sub surface system). The treated water is discharged into local water systems that are usually part of the architectural design and contribute to an attractive urban water environment. The experience with application of constructed wetlands in or close to urban residential areas is largely developed and positive although figures on the monitoring of the effluent quality are scarce. Monitoring results in Groningen show that greywater treatment in (in this case an open air) constructed wetlands is effective in removing BOD and nutrients and ensuring good local surface water on the long term.

The (limited) experience with separate collection and treatment of blackwater shows that the choice of the toilet system has major influence on local transport, treatment and potential of reuse. A project with composting toilets had unfortunately to be taken out of practice after some years of operation. Experience with low water consuming toilets in combination with separate blackwater collection show that there is a high risk of clogging of gravity sewers. Ultimately the quantity of water used will also determine the feasibility of on-site digestion of blackwater (Zeeman and Lettinga, 1999). However, recent developments and experience in vacuum and urine separating toilets offer new possibilities. Several projects with application of these alternative toilet systems are in preparation, visibly in urban (Wageningen, Water Museum in Arnhem) and rural areas (Swichum, Reeuwijk).

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The Skogaberg Project – a blackwater system with waste disposers under development in Göteborg, Sweden

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Keywords

Blackwater, dual piping, gravity flow, nutrient recovery, waste disposer

Abstract

The Skogaberg housing area is being built with a wastewater system that can recycle plant nutrients back to the farmland. The Skogaberg project is a pilot project initiated by the City of Gothenburg in order to create a closed loop in the wastewater management. From every household in the Skogaberg area there are two separate pipes collecting blackwater (i.e. urine, faeces, toilet paper and flush water) and greywater respectively. Every household also has a waste disposer for organic wastes, which is grinded and flushed into the blackwater pipes. There is a small local treatment plant that will treat the blackwater and the organic waste from the waste disposer. It is important to notice that this blackwater system is not totally optimised regarding the technique but rather an attempt to build a system balanced between the Real Estate Company's requirement about a marketable housing area and the objective to recycle nutrients. Hence an important aim of the study has been to browse a selection of suitable techniques and to evaluate them in terms of estimating what level of nutrient recovery to adopt in the construction of the pilot plant. The study is followed by a detailed projecting and by the building of the actual pilot facilities i.e. wastewater system and local treatment facility.

Introduction

This pilot project has been initiated by the City of Gothenburg (Recycling Office, Egnahemsbolaget Real Estate Company and the Water and Sewage Works) as a step towards building a sustainable society. There is an agreement in The City of Gothenburg to build and evaluate pilot projects that are considered most suitable for urban areas. Virtually all municipalities in Sweden are struggling with this challenging question of how to recycle nutrients from urban areas to the agriculture in a safe, cost-efficient, and by other means appropriate way. The Skogaberg Project is a contribution to the extensive research that this challenge requires.

Gothenburg, as all other Swedish towns, has only one wastewater system, in which the nutrients coming from society, mainly from toilets, are mixed with contaminants from households, industries, landfills etc. This mix is then discharged to the local sewage treatment plant, Ryaverket, where separation of pollutants takes place. The sewage sludge produced on Ryaverket stays below national limit values for contaminants, stipulated to secure that critical loads of heavy metals and organic pollutants are not exceeded in farmlands fertilised with sludge. Even so, a widespread apprehension is topical amongst the Federation of Swedish Farmers (LRF) and the Food Industry for farms using sewage sludge as fertiliser. Due to the intense debate concerning enrichment of pollutants in food products from such farms, a need to try separating wastewater system in a large-scale facility became obvious. Hence the Skogaberg Project developed.

The reason for having two separate pipes for the household wastewater is to only take care of what is desirable i.e. the urine, faeces, toilet paper and the food leftovers. From a number of studies it is already known that most of the plant nutrients are found in the blackwater and that most of the unwanted pollutants (derived from household detergents etc.) are found in the greywater. The separated flows in this dual piping system also leads to a nutrient solution that will be diluted to a lesser extent than a mixed flow. By excluding greywater from a nutrient recycling system like Skogaberg, that which is taken care of and treated by the system then contains as much of the nutrients as possible and as little of the contaminants as possible. Although this blackwater system is not totally optimised regarding the technique, it is a system balanced between the efforts to recycle a sludge with as much nutrients as possible but with a minimum of pollutants and at the same time fulfil the Real Estate Company's requirement about a marketable housing area. This means that some compromises with reference to the dilution of nutrients in the blackwater were necessary to make due to the resistance against installing vacuum piping. Water pipes and installations in the houses will be non-copper, to avoid copper pollution in the sludge create a possibility to evaluate a copper-free system through measurements.

Methods

The City of Gothenburg through the Recycling board has the main responsibility for the project managing, co-ordination and financial follow up. A preliminary study is performed concerning treatment facilities and utilisation of blackwater sludge and nutrients in farmland by means of literature studies, excursions, calculations, interviews and meetings with parties concerned. A student, Kristina Fermskog, at the Swedish University of Agricultural Sciences (SLU), Department of Agricultural Engineering, is performing this study. After that a detail projecting takes place followed by building the actual pilot facilities i.e. wastewater system and local treatment facility, later on building the houses and follow up reports.

The system and the treatment

The Skogaberg area, northwest of Gothenburg is a small valley that slopes gently towards a little creek where the housing area is under construction. In 2005 the area will consist of 110 small houses and 17 flats in three apartment blocks. According to the Real Estate Company's time-schedule all flats are ready for occupation at the time of the ECOSAN-conference and about 50 of the houses will be ready for occupation by the start of 2004.

What characterises the main structure of the Skogaberg system is in the first place that there will be two separate pipes collecting blackwater (i.e. urine, faeces, toilet paper and flush water) and greywater respectively. Transportation of both black- and greywater is managed by the use of gravity flow. The reason for the choice of gravity flow to transport the black- and greywater is, among other things, that this valley makes it possible, and will be an excellent site to evaluate the combination of blackwater system and gravity flow.

For future research purposes the greywater passes a control point where e.g. samples can be taken for analysis, and then the greywater is connected to the regular waste pipes leading to the conventional local treatment plant, Ryaverket.

Every household will also be equipped with a waste disposer for the organic wastes, which can be grinded and flushed into the blackwater pipes. The waste disposer in every household is a very convenient way for the residents to handle the food wastes, otherwise brought to compost. Waste disposers are not very common in Sweden today and using waste disposers in Skogaberg gives an excellent opportunity to evaluate this technique in prevalent circumstances.

The third characteristic element in the system is the small local treatment plant that will treat the blackwater and the organic waste from the waste disposer. What happens at the small local treatment plant is primarily that plant nutrients are separated from the blackwater. The purpose is not to treat like conventional plants do, with the objective to protect the environment, but rather to optimise nutrient recovery. Subsequently the rest of the blackwater follows the greywater to treatment at Ryaverket. Incoming blackwater is diluted since transportation occurs by gravity flow and this creates a great challenge for the local treatment plant.

Considerations

Instead of using the small local treatment plant to treat and prepare the sludge for agricultural use there is a second alternative, namely co-treating the blackwater with other organic wastes at a central plant. These other organic wastes originate from food industries, food stores, and restaurants in and around Gothenburg. It would be a large benefit to integrate these wastes in the Skogaberg system, which has the mission to deliver it to farmland, and close the circuit between the urban and rural nutrient flow.

A main purpose of the study has been to browse a selection of suitable techniques, adoptable to both the local treatment plant and the central treatment plant, and to evaluate these techniques in terms of estimating what level of nutrient recovery they will provide and from that get a guideline in the constructing of the pilot treatment plant.

At present there is still an investigation going on to decide what kind of treatment technique to set in Skogaberg. Alternatives under consideration are based on a wide range of techniques, from relatively simple, mechanical separation and chemical precipitation, to more complicated ones like ultra filtration and ion exchange. Further on there are treatment alternatives that also give hygienisation of the obtained blackwater sludge. Aerobic treatment by wet composting or aerobic thermopile digestion, heat and pH treatment by lime stabilisation, complete hygienisation in Super Critical Water Oxidation and anaerobic digestion.

Different techniques give different results and to evaluate the outcome, a number of parameters are balanced against each other. Besides nutrient recycling, economy is an important parameter as well as management of resources (chemicals and energy). It is also of great importance that the pilot plant can be reliable to run and at the same time be flexible in the meaning that adjustments can be made by relatively small efforts. These adjustments could be for instance to alter the facilities to better match the characteristics of the incoming blackwater.

At a local treatment plant it is very valuable to avoid exposing the residents to odour, which may occur. In analogy with disturbing odours, operating this plant should not have to be dependant on a large number of transports with trucks. Trucks carrying chemicals to or sludge to and from the pilot plant site would of course not only be disturbing for the residents but also lead to air pollution and most probably carry a large part of the costs for a small pilot plant. This line of argument implies that co-treating the blackwater with other organic wastes, originating from other parts of Gothenburg, is preferable at a central plant and that other organic wastes should be treated at a local plant only if it is needed to manage and improve the process.

Considering what technique to adopt is also based on what terms and conditions the farmers and the Food industry has on fertilising with a sewage product like the one from Skogaberg. For this reason a part of the study has been to look into this line of business policies and demands on the build-up and management of a system like Skogaberg. At a preliminary basis the Skogaberg system comes to terms with these demands (regarding factors like hygienic safety, pollutants, origin of the nutrients, management etc.) and there are no great obstacles to deliver the Skogaberg product to farmland.

Conclusions

The Skogaberg housing area is still under development and any final conclusions are difficult to draw. However, conceivable conclusions will be possible to draw from the use of waste disposers, the dual piping system with gravity flow, running stoppage from the small local treatment plant, the behavioural aspects in association with technical function in the future use of the system. The conclusions can then take into account if the techniques are successful or not and if they should be modified in some way.

To ensure the quality of the sewage sludge, it is necessary that the house-owners/tenants use the system in the intended way. Most importantly, harmful substances may not be introduced into the system, i.e. into toilets or waste disposers. Therefore, an agreement will be made between the Recycling Office and the house-owners/tenants to clarify how the blackwater system is to be used.

These experiences will reveal if a system like Skogaberg is viable to adopt elsewhere in Gothenburg and Sweden where a closed loop in wastewater management is the objective.

Low flush toilet systems for water saving, nutrient recovery and soil improvement in Hamburg and Berlin

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Keywords

Saving water, nutrient recovery, low flush toilet systems

Introduction

The necessity of saving water, especially in using water for flushing toilet waste, is a primary task and a postulate for recovering human-borne nutrients and organic matter as well as to improve health aspects and the quality of drinking water. During the last twenty years, mainly Swedish inventions took part of these aspects, offering a variety of intelligent solutions. Some of them are in use in Germany for many years, so effects, experiences and technical development can be shown.

Methods

Beside the possibilities of using rainwater or greywater for flushing conventional toilets with 6 or 9 litres, the technique and the acceptance of the user itself is significant for the effect in water saving. So the best technique might be the one, where the user has not to change any habit and even does not notice any change in using the toilet.

The technique and practises of different Low Flush Toilet Systems are introduced in urban settlements in Hamburg and Berlin, using 1 to 4 litres for flushing. Further urine diverting flush toilets, also in combination with separating devices for faeces, are presented. In this way, water still remains as a medium for transport human waste with all its positive and negative aspects, but offers new possibilities and options for the further treatment and recycling of less contaminated waste water.

Results

Costs of investment, installation and operation of the different Low Flush Toilet Systems are evaluated and compared with conventional Flush Toilet Systems in Germany. Effects on discharge, treatment systems and environment are described, as far as possible. Based on these ecosan modules, different scenarios for different requirements can be projected.

Conclusions

Learning from our own experience should be determining for future concepts in ecological sanitation, before transferring them to other countries that need new solutions. Nevertheless, we have to consider other cultural, social and technical circumstances, so development and improvement of ecological sanitation systems has to take place together with the future user and controller from the beginning. In this way, we all can learn from each other to help good things going.

References

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Local recycling of wastewater and organic waste - a step towards the zero emission community

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Keywords

Blackwater

Abstract

If blackwater and wet organic household wastes are source separated and co-treated, more than 90% of the nitrogen, 80% of the phosphorus and 60% of the potassium can be reclaimed and recycled. Blackwater is collected with a vacuum toilet. More than 4-years experience with vacuum toilets (in two housing developments, 48 and 120 persons) has provided data on their effectiveness. The latest toilet development is vacuum on demand (VOD), i.e. vacuum is generated only when flushing. The system is more robust than earlier vacuum toilets and consumes less energy (<10 kWh/person/year), with solar powered systems under construction. Food waste is collected via a kitchen grinder and discharged to the blackwater storage facility. The amendment increases dry matter, nutrient, and energy content of the effluent for recycling. A liquid-composting (aerobic) reactor sanitizes the effluent. The reactor operates on a semi-continuous mode and generates energy, which may be extracted as heat. It is suggested to use algae or bacteria to produce hydrogen for increased energy production. The deodorized waste meets European standards for sanitation. Seven aerobic reactors are currently operating in Norway, and a small-scale biogas reactor designed for cold climates is being developed. The end product is a nutrient-rich liquid intended as fertilizer. The liquid is injected into the ground using tractor-mounted equipment, which is well suited for stony soils and consumes less energy than many other fertilizer application systems. By use of algae the recyclable waste also has potential for conversion to fodder for aquaculture.

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Ecosan-options for single households

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Keywords

Ecosan-technologies, wastewater

Introduction

Purpose of the work is to demonstrate the applicability of EcoSan – Technologies aiming at avoiding any discharge of wastewater from single households. Basic principle was to proof that this is possible – in the contrary to what is often assumed – without any reduction in the standard of living.

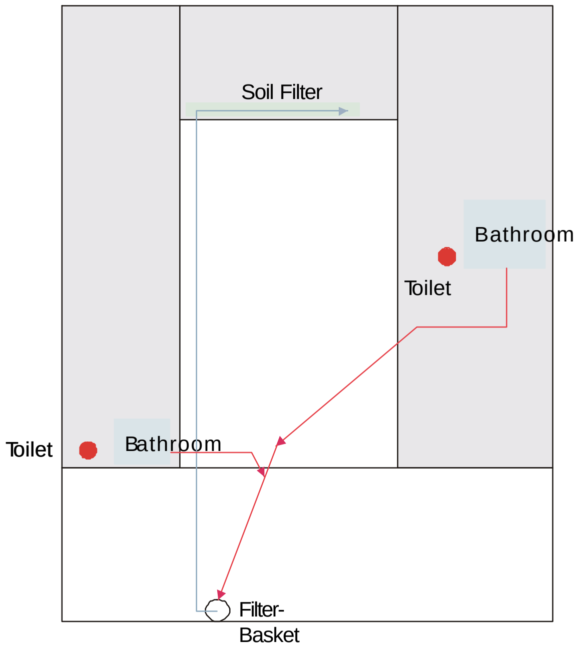
Methods

The strategy was to prevent the production of wastewater as far as possible at the source and reuse the remaining greywater within the house.

The house, an old farmhouse constructed around 1850, consists of two wings (one used as an office and the other for living) connected by a roofed gate which was, by simply closing the open south oriented side with glass, transformed into a living room, connecting now both parts of the house. In total there are three toilets and as many bath rooms.

Results

To avoid the production of blackwater completely in order to reduce the quantity of wastewater to be treated, increase it's initial quality and allow optimal nutrient recycling dry toilets are foreseen. Urine is stored in two separate tanks, one on each side of the building, and used for gardening. The faeces are stored in a textile (air permissible) sack, which can be simply changed, the available storage volume thus becoming variable (compared to a concrete chamber only). The initial problem was the availability of sufficient storage volume since no basement exists thus limiting the available space. With the chosen system the storage volume is extended by simply transporting filled sacks out of the house.



The remaining greywater from kitchen and bathrooms is collected in a conventional plumbing system. For further treatment / use of greywater various options exist. Reuse in agriculture (subject to sufficient quality) would

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be an appropriate way but requires storage for a min. of 5 months considering the climatic conditions in Austria. Treatment in, e.g. reed bed filters, to a quality sufficient for discharge is also an option but not reuse-oriented as postulated for the proposed solution.

Therefore treatment and reuse options were combined by pumping the water after mechanical pre-treatment (filtering) to a 5-m² soil filter located in the living room of the house. The soil filter is constructed comparable to a vertical flow constructed wetland and shall be planted with elephant grass, papyrus, etc., aiming at achieving a sufficiently high evapotranspiration rate to reduce the effluent to near zero. Studies carried out over the last 4 years on constructed wetlands in Africa showed that under conditions of average annual temperatures of 25°C and hydraulic loading rates of 200 l/m² evaporation rates of more then 100 l/m² can be achieved.

The house is presently under construction, first practical results will be available beginning of 2003. Technical data and construction details will be presented in the paper, at the time of the conference operational data shall be available.

Conclusions

Technologies focusing on prevention and reuse applied in-house have quite some tradition in industrial pollution mitigation (and are legally enforced in Europe) but although theoretically legally required are only rarely applied in households. One main reason is the existence of projects demonstrating the possibility and practicability of such solutions. At present all these technologies are viewed as exotic solutions for a peculiar minority. This project is meant to help overcome these prejudices.

Decentralised water sanitation loop – a case study from Bangalore, India

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Keywords

Bangalore, rainwater, eco-san, sewage

Abstract

Bangalore, India needs to move to Eco-San quickly. Water demand is increasing rapidly, there is a shortage and a limit to the availability of fresh water and 'fouling the nest' is happening with surface water bodies and groundwater bodies. As wastewater is not being managed properly valuable water and nutrients are getting lost and polluting water. The movement towards Eco-San will need to be managed and phased into the city's conventional wastewater management system. Information dissemination and implementation of pilot projects from the household to the neighbourhood level will become essential for the transition to Eco-San. A current example of the transition is the movement towards decentralised wastewater management and individual household treatment of wastewater. (Figure: 1). More such examples and a thorough documentation are needed quickly to scale up and popularise Eco-San. An example of a decentralised system in a suburb called Vidyaranyapura is documented and presented as a learning model.

Introduction

Bangalore, India situated at an average elevation of 920 metres above sea level has certain unique features placed as a demand on its water requirement and sewage treatment. 1500 million litres per day of water needs to be pumped into the city from a river Cauvery 95 kilometres away and 300 metre below. Ceiling in availability of fresh water for the city is likely to be reached by 2011 when the population of the city will be 7 million. In terms of a water sharing agreement with the neighbouring state no further water can be expropriated from the source river unless a reallocation is made from agricultural use to urban use. After the water is consumed in the city, sewage flows out in 3 major valleys and is treated at the outlets of these valleys. Only primary treatment is possible and it is estimated that less than 50% of the sewage from the city receive this primary treatment. Within the city itself surface water bodies like lakes and tanks are on the decline from impacts of urbanisation such as encroachment by houses, their numbers coming down from 262 to about 80 and almost all of them are polluted with sewage. This pollution of lakes has had its impact on ground water. Over 50% deep bore-wells report nitrate contamination, which is a result of collected untreated sewage in the lakes percolating down to the groundwater.

The suburban colony of Vidyaranyapura in Bangalore has seen some attempts at sustainable management of water, sewage and the conservation of lakes, which may be a forerunner for future directions to the cities water management.

Method

Ecological-sanitation or Eco-San has been defined more as a process than a technique. It is the process by which water and nutrients are recovered from human waste in a hygienic manner and used as a resource. Pollution impact especially on water bodies is eliminated due to Eco-San thus ensuring sustainability. "…every approach that ultimately leads to closing the loops and to reuse of nutrients, water and energy should fall under the term 'ecosan'." (Werner, Christine–2000).

A progress towards eco-san in the city context of a developing world could entail the following steps:

- Existing centralised sewage collection and treatment systems or septic tanks/pit latrines
- Decentralised conventional sewage systems linked to constructed wetlands and surface water bodies
- Household and apartment level mechanical treatment of sewage and recycling of wastewater alone
- Household and apartment level digesters and biological filter systems. Reuse of wastewater and nutrients
- The twin leach pit combined urine and faeces digestion and reuse system
- Household level urine segregation and reuse and faeces collection and composting in dry toilets

The steps above would suggest a more holistic perspective and would also open up choices to individuals and communities. The horizon would also broaden to include protection of surface and ground water resources as well as reusing nutrients. One example of perhaps the first step is cited below:

The colony named Vidyaranyapura has a geographical spread of about 4 square kilometres and typical residential houses, which are two storied and about 2500 in number. Taking advantage of the topography of the suburb, which represents a shallow valley, 2 artificial lakes called 'tanks' in local parlance have been created by the Forest Department of the State government. The 'tanks' are named as Narsipura –1 and Narsipura-2. Narsipura –1 receives fresh rainwater in its catchments and stores the water primarily for purposes of recharge of the ground aquifer. Narsipura-2 stores the overflow of rainwater from Narsipura-1 as well as is the area for location of a domestic effluent treatment plant. All the sewage received from approximately 2500 houses in the colony is collected and subjected to sludge removal and aeration using a 4 floating aerators. After passing through a constructed wetland acting also as a biological filter the treated sewage is stored in the 'tank' again to recharge the aquifer below.

The entire water supply to the colony of 2500 houses is through a battery of 25 bore-wells mainly located adjacent to the tanks.

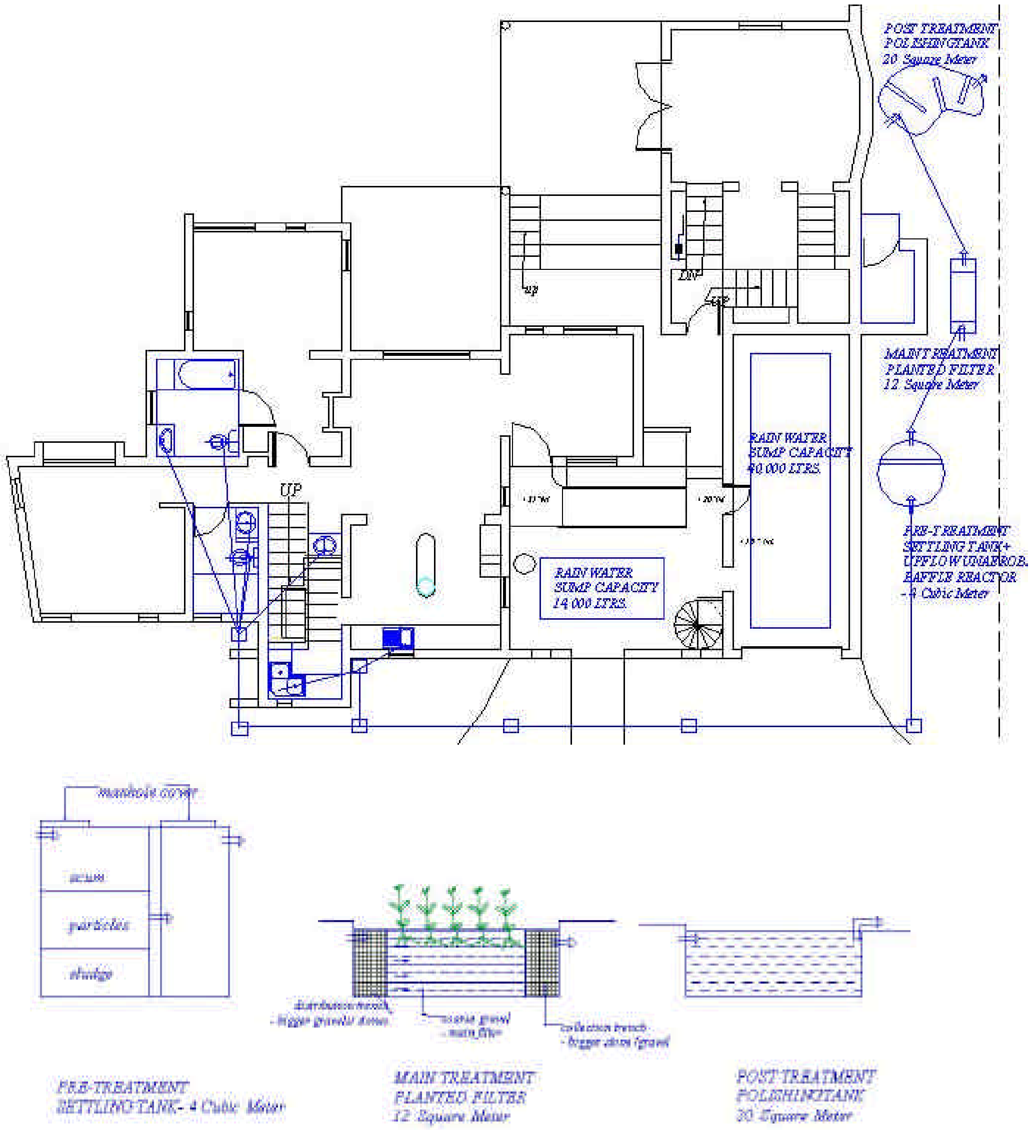

Figure 1: EcoSan using planted filter, house at Vidyaranyapura, Bangalore, India

Results

The colony has been able to cater to the water demand of an expanding suburb for the last 18 years. Though water supply to houses is limited to about 1 hour every alternate day it is possible to supply an average of 100 litres per person per day. Families store the water in underground sump tanks and in overhead water tanks for use during the time of non-supply.

All the sewage generated from the houses is treated though only to primary levels. With 100% primary treatment followed by a constructed wetland the colonies level of sewage management is far superior to that of the city. The cost of supply of water to every household is about Rs 5 a kilolitre again cheaper than the city's cost of water, which is about Rs 15 a kilolitre. Water tariffs are set in an annual general body meeting of the society on a year-to-year basis and based on actual costs incurred in the management and distribution of water and treatment of sewage. This is a more democratic and decentralised process. The integration of rainwater, surface

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water bodies, ground water and sewage treatment has resulted in the surface water bodies - the' tanks'- being preserved and used also as recreation places and for ecological biodiversity. These water bodies are unlikely to be filled up with debris and converted into other land-use because they represent a water lifeline to the colony.

Individual houses are now harvesting rainwater from terraces to augment their water supply. With an annual average rainfall of 920 mm it is possible to harvest nearly 82800 litres per year from a 100 square metre roof. A 100 square metre roof is typical for the colony. Harvested rainwater is enough for a family of 4 for 207 days of its water requirement given an average year of rain. Storage of the harvested rainwater is also easily possible since a sump tank in each house is the norm rather than the exception and a 6000 litre sump tank is the average size for new houses.

Greywater reuse is also being practised in some houses with clothes wash water being used for flushing toilets. Water efficient flushes are being used extensively.

Urine segregation and composting dry toilets are being introduced in 2 houses to explore the feasibility and to introduce the concept to the neighbourhood.

Conclusion

Integration of rainwater, surface water bodies, ground water and sewage treatment is critical to establishing sustainability of water demand of cities. Given the principles of 'subsidiarity' – meeting requirements and addressing issues at the smallest possible scale- each house can harvest rainwater, recycle greywater and nutrients, reduce demand through water efficient devices and possibly take care of its sewage. Closing the loop at the household level and at the neighbourhood level is possible and is a viable cheaper alternative to city level management of water. If sewage treatment is managed at residential colony levels, since the sewage is free from industrial pollutants it is relatively easy to treat. Treated sewage can also be used to be stored in lakes and make possible that water is available in the lakes throughout the year. Perennial lakes prevent encroachment into the water spread by houses. This decentralised method is also likely to provide the cheapest water for a neighbourhood and be the most cost effective in ecological management of water and reducing the ecological water footprint of cities.

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Website www.bwssb.org

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Additional poster presentations

Poster presentations

Wastewater - management, reclaiming and reuse
Peter Gichohi (Pemagi Energy Ltd., Kenya)

Ecological sanitation: Bangladesh perspective
Musa Khan (Institute for Environment and Development Studies, Bangladesh)

The impact of urbanization on sanitary conveyances and sewage treatment facilities in the city of Lusaka, Zambia
Obed Kawanga (Central Statistical Office, Zambia)

Study on ecological sanitation and anaerobic digestion models in China (2001-2003)
Wu Libin (Training Centre BRTC, China)

Sewerage management at Delhi, India
Anwar AliKhan (Indian Institute of Technology, India)

Decentralized wastewater treatment technology extension in Lesotho
Christopher Kellner, Alice Leuta (DED, Lesotho)

Wastewater - management, reclaiming and reuse

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Keywords

Education, energy, recycling, sanitation

Abstract

This paper is a review of the wastewater treatment and reclaiming technologies being implemented by our private company, PEMAGI ENERGY LTD. PEMAGI Energy Limited is a Renewable Energy (RE) Technology enterprise committed to development and diffusion of renewable energy and waste management technologies in East African region and beyond.

Introduction

We implement our wastewater treatment systems in collaboration with our clients, local and foreign experts. We have several objectives in our work. The main ones are:

- To improve sanitation
- To reclaim wastewater for re-uses in agriculture
- To conserve clean water
- To recycle nutrients
- To recover biogas from the wastewater, which is used as a fuel, which saves on the use of firewood. Reduced use of firewood helps to reduce in-door air pollution
- To educate communities on the need to re-cycle waste which is normally discarded and forgotten etc.

The idea of reclaiming wastewater has been used by our company to counter demand for fresh water and fertilisers for our clients. Thus PEMAGI Energy Ltd views wastewater as not just another waste but as a useful resource.

The initiative of PEMAGI Energy Ltd has been first to provide practical solutions in wastewater management for institutions that have realised that wastewater is a problem to them. For such institutions, we design systems to fit under their circumstances. Usually, this group of institutions is the main clientele of PEMAGI. They are the easier to work with since these institutions have already acknowledged that wastewater is a problem that needs to be addressed. Wastewater management is thus prioritised highly in the development programmes of such institutions. The second approach by PEMAGI has been to create awareness among institutions on the need to incorporate wastewater management systems in their development programmes. The key issue is to sensitise the heads of institutions to realise that wastewater is an issue to be thought about early enough before it presents itself as a problem to the institution. In the view of PEMAGI, it is an issue that should be considered at the earliest planning stage of institutions. In our experience, we have come across many situations where land that could best be utilised for wastewater treatment facilities being occupied by other infrastructure. Under such circumstances, there are several limitations, which present themselves in the course of planning of wastewater treatment facilities. Examples of such limitations are limited connectivity to the wastewater facility, limitation in re-use and re-cycling have treated effluent, limitation in the use of gravity flow etc. The worst scenario is where the institution has covered all its land with buildings and non at all has been spared for wastewater treatment facility.

Methods

The projects we propose to our clients are driven by the needs of the clients. The primary need among them is usually the need to improve the sanitary conditions in the environment of the client. So we design our projects to target this primary need. We then apply anaerobic wastewater treatment technologies adapted to the local site conditions. With consultation with the client we integrate wastewater disposal-by-reuse methods either in agriculture, tree growing, fish farming or a combination of all of them.

The biogas generated from the anaerobic process is usually collected and used in the clients' kitchen where it replaces firewood. Thus we focus on wastewater management solutions that are ecologically, economically and socially sustainable with no additional waste output.

Results

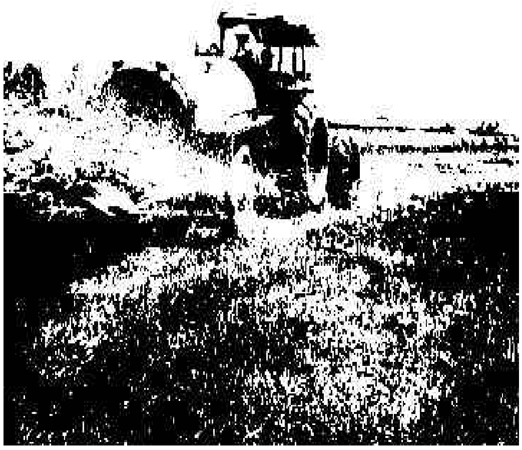
Since the founding of our company in 1993, we have built bio-latrines for 100 families and three schools. These are modified pit latrines where we have the ordinary cubical on top of anaerobic digester, which is built in place of the ordinary pit. This set up is usable for unlimited time without filling unlike the pit latrines: The biogas generated in the digestion process exerts pressure, which cause continuous discharge of the decomposed waste into an adjoining compost pit. The effluent is used as organic fertiliser.

We have also installed anaerobic wastewater treatment systems for the following: Two hospitals each with above 200 beds, one agricultural training college, one boarding school with about 250 students and two church institutions. These wastewater treatment facilities consist of a number of digesters for the primary treatment and biogas recovery, depending on the volume of wastewater available. Down stream of the digesters we may have conventional wastewater stabilisation ponds, biological filters consisting of sand-ballast- water plants zone for post treatment. The combined digester capacity for the six installations above is about 900M^3. The volume of wastewater treated and reclaimed ranges from 40M^3 to 100M^3 per day for individual systems.

The installation of our wastewater disposal and re-claim systems has led to dramatic improvement of the sanitation conditions in the premises of our clients. In some situations the systems have saved some institutions from eminent closure by public health authorities. We have transformed the swampy smelly corners of our clients' compounds into dry and clean environments. These had previously attracted the wrath of public health officials and neighbours. After satisfying our clients with this primary objective, there is biogas, organic fertiliser and reclaimed water suitable for agriculture for our client to use as extra bonus from the treatment facility. Our unique projects have thus played a significant demonstration role for those who would like to improve their wastewater management practices.

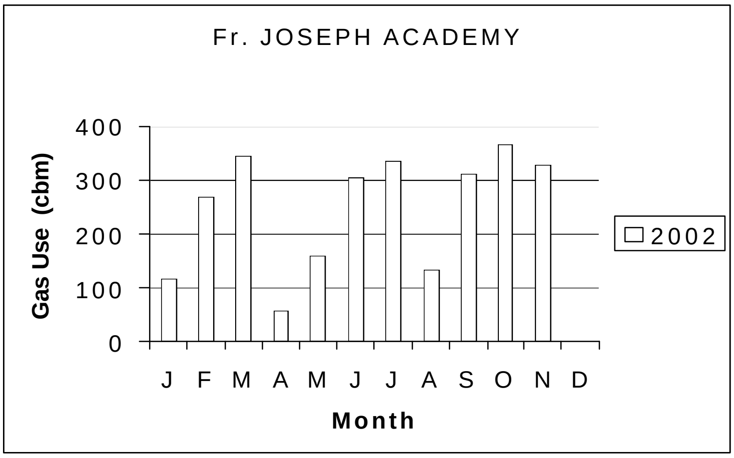
Here below are just three examples of our projects:

One 220 bed rural hospital has used our system for the last four years. The organic manure is spread in the farm where fodder is grown with better results and more sustainable supply. (See photo above) Biogas is used to cook for the patients where about 9 M^3 is used daily for the last three years. As the treatment process includes ponds for improved quality of effluent, we have introduced fish in the ponds primarily to control mosquitoes; but the community around is gradually accepting that the fish could also be eaten.



Our clients are using the re-claimed wastewater from one of our systems in Nairobi to grow bananas. After only 18 months, the client has begun to harvest the bananas. Previously the raw wastewater effluent had generated animosity between our clients and the neighbours.

In a boarding school with 250 pupils the biogas generated from the wastewater is used to cook some of the meals for the pupils (See graph). Some of the reclaimed water is applied in a pasture area where goat and cows graze. More is being applied in an oats field by sprinkler irrigation. Another smaller portion of the water is used on a lawn through some underground sprinklers.



Conclusions

The need for wastewater management systems will continue to increase as the demand for fresh water supply increases. The increasing awareness on the need to control the pollution of our environments and the increase in awareness of people's rights is other factors that will accelerate demand for the systems. As the population continues to increase, there will be less and less space to freely damp our wastewater. These circumstances will call for the need to re-use wastewater after treatment to decrease the demand on fresh supplies. The anaerobic systems also offer a chance to generate some biogas, which can be used as a fuel in the institutions. With this background PEMAGI ENERGY LTD is hopeful for improved business in the future and an improved product quality for our clients.

Additional poster

Ecological sanitation: Bangladesh perspective

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Keywords

Worst sanitation, piles of wastes and water born diseases.

Abstract

Bangladesh has not yet been able to provide safe drinking water and sanitation facilities to its entire people. According to a WHO report 50% of Bangladesh people do not have hygienic sanitation facility. The sanitation condition in the rural areas is worse than it is in urban areas. People without sanitary latrines in the villages still use the hedges behind their house, river, ponds or open space to defecate.

The condition of sanitation in the urban slums is the worst. The unimaginable density of population in the slums has compelled their residents to sleep, cook and excrete almost at the same place. In many cases all of the dwellers of the slum have to use only one latrine.

The houses in cities, particularly in Dhaka are being constructed without proper planning. As a result, the sewerage system is breaking down. Piles of wastes are seen on the streets, which often overflow through the broken, or stolen sewerage leads in the cities. Living with waste ultimately causes various diseases and epidemics. Diarrhoeal diseases and other water-born diseases are caused largely for poor sanitation facilities. Oral saline provides immediate relief to Diarrhoeal diseases, but the problem of underweight, the poor physical and mental growth of the children persists.

The sanitation problem extends to the work places also. Most of the offices do not have adequate latrine facilities. The few lavatories that the offices have are rarely cleaned. The women personnel suffer most from the ill sanitation system. The sanitary condition in the Educational institutions also raises concern. A UNICEF survey reveals that sanitation in schools is in the worst condition in Bangladesh, Nepal and the Maldives among the world countries. In rural Bangladesh there is only one latrine for every 90 students, and most of these are unhygienic. Forty percent of these toilets are not cleaned regularly.

The sewerage and sanitation systems in the urban areas of Bangladesh are far short of modern standards and even where in modern systems of sewerage has been established, it is at best, inadequate in coverage. The human waste disposal system is a mixture of several modes, including the traditional mode of bucket latrines. Even in Dhaka city only about 35 percent of households have access to the sewerage lines and a very large percentage of the capital city's population do not have access to any sanitary latrines. In Chittagong, only 38 percent of the populations were served by septic tanks in 1985, 4 percent by pit latrines and almost 30 percent relied on bucket latrines, 5 percent used communal latrines, 19 percent used open latrines, while 4 percent had no specific sanitary facilities at all.

The conditions in district and Upazila towns are even worse. According to the Department of Public Health Engineering, no water-born sewerage system existed in any of the district towns in 1983. According to the department, only 12 percent of the people of district towns use septic tanks, 10 percent use pit latrines, and 5 percent use bucket latrines, while 68 percent use either

Additional poster

surface latrines or no specific facility. In the Upazila centres, only 4 percent have access to septic tanks, 5 percent to water seal latrines, 56 percent use surface latrine and 35 percent have no specific facility.

The high cost of installation of proper sanitary facilities, the cost of maintenance, lack of adequate space for installation and other factors stand in the way of improvement of the sanitary environment in urban and also rural areas.

Reference

IEDS Date Base

The impact of urbanization on sanitary conveyances and sewage treatment facilities in the city of Lusaka, Zambia

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Keywords

Conveyances: sanitary drains and sewerage that convey soil, waste and storm.

Sanitary facilities: conveyances and treatment systems.

Waste stabilization ponds: which includes facultative anaerobic and maturation ponds they are biological treatment plant.

Abstract

The overall aim is to promote ecological and sustainable management of sanitation systems in urban settlements of Lusaka, induce economic growth, health and environmental protection. The paper brings out information on the status of systems of sanitary conveyances and Waste treatment facilities. It highlights the impact of urbanization to sanitary infrastructure and the urban environment. It also shows how poor sanitation has contributed to outbreaks of most human infections. The paper points out how inadequate design and maintenance of drains causes rainwater stagnation leading to road damage and breeding grounds for malaria carrying mosquitoes.

Urban sanitation is a world wide common failure to regard disposal problem as less important than the consideration of portable water supply. Without effective community-wide method to contain excremental, the full health impacts of a plentiful water supply will not be appreciated. The key issues to achieve ecological sanitation are: - political recognition of the importance of sanitation, poverty alleviation, capacity building, rural economic development (ruralisation) and the development of policies. Ecological sanitation is eco integration through total cooperation among decision makers, researchers and the public. It requires systematic planning, adequate organisation and recycling of urban wastes to prevent environmental damage and health risks.

Introduction

The increasing and fast growing urban population of Lusaka, Zambia has brought about a number of adverse effects on the public amenities and environment. At independence (1964) the population of Lusaka was 195,700. The Population of Lusaka is now estimated at 2 million, (Central Statistical Office 2000). The sewer network and sewage treatment plants were built in the late 1950s, with the most development being in 1980 when an extension was made to the Manchinchi sewage plant.

Despite Lusaka experiencing a rapid growth of population over the last 25 years, no study has been conducted to determine the effective operation of the sanitary conveyances and sewage treatment plants (Wamukwamba and Share 2001). These facilities were designed using the population at that timeserving. Manchinchi and Chunga sewage works design capacity 36,000 and 9,000m^3/day, Matero ponds 7,100m^3/day, Ngwerere 8,350m^3/day, Kaunda square 3,600m^3/day, Chelstone 2,700m^3/day and Garden maturation ponds 36,000m^3/day.

The increasing pressure on existing sanitary systems is reflected in the break down of conventional treatment plants. Leakages, over loading and chocked sanitary facilities have resulted into the production of offensive odours (air pollution), contamination of ground and surface water bodies by spilled un-treated (raw) sewage that poses a health hazard and degradation of the environment. The city of Lusaka sewer network covers a total length of about 450 kilometres with about 10,000 manholes and seven pumping stations in the serviced areas, which include high, medium and low cost.

The prevailing poor sanitation caused by unsatisfactory operation of sanitary systems has led to outbreaks of most human infections such as water borne, water based and water related diseases. These include diseases whose transmission will be reduced following an increase in the volume of water used for hygienic purposes, like diarrhoeal diseases an example is cholera. Water related diseases are these diseases spread by insects which either breed in water or bite near water, and an example is Malaria.

The poor design and maintenance of the drains (underground and surface) results in stagnation of rainwater, which contributes to road damage and creates nuisance in the city as well as creating breeding grounds for malaria carrying mosquitoes. See table 1 showing the top 5 cases of morbidity in Lusaka in 2001.

No	Causes	Cases	Incident
1	Malaria	32,699	285
2	Diarrhoea	16,534	144
3	Respiratory	13,861	121
4	Pneumonia	7,105	62
5	Intestinal worms	3,171	27

Table 1: Top 5 cases of Morbidity overall in 2001. LDHMT/JICA-PHC April 2002

The conceptual framework in (Diagram.1) shows the importance of collecting data on the status, the effective operation of sanitary systems and calculated capacities of sanitary infrastructure. This could be a possible and participatory way of improving sanitation in urban communities and promoting wastewater reuse, hence, will positively trigger development in various aspects of the environment. It is clear from the framework that effective operation of sanitary facilities can with little doubt lead to: - Improved Sanitation in Urban Communities, Integrating the Environment to insure the right of citizens to clean and health environment, Poverty reduction through increasing food production by the use of wastewater by small-scale farmers and creating employment during maintenance of sanitary facilities. To increase the effectiveness in the enforcement, there is need to review existing sanitary legislations and intervention strategies. It also gives a clear understanding of sanitary systems suitable to local conditions (separate, combine and partially combined systems).

With the framework in mind and the reality of the sanitation situation in the city, it would be fair to conclude that the effective operation of sanitary facilities can partially, if not wholly prevent adverse effects brought by poor sanitation in urban serviced communities.

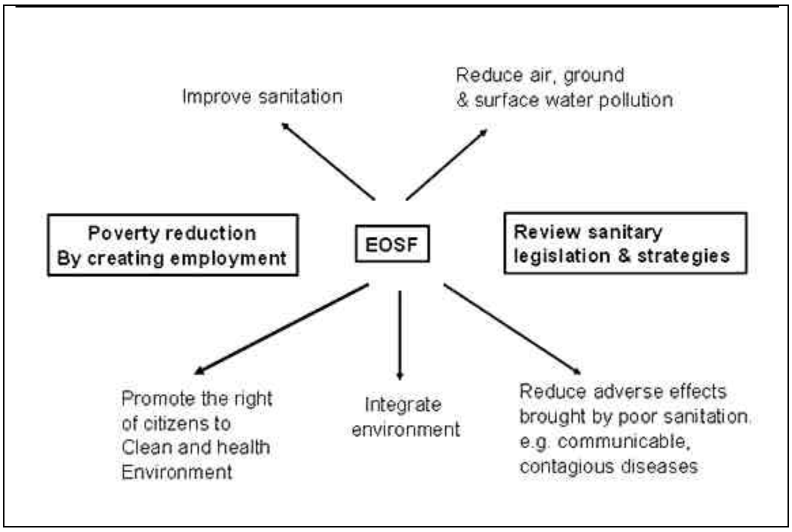

Figure 1

Justification

The study assessed capacities of sanitary systems and gathered information on status and satisfactory operation of private and public sanitary conveyances, Waste stabilization ponds and Conventional treatment plants in relation to the population it is serving. It also assessed the possible utilisation of wastewater in small-scale farming. Potential risks likely to affect the communities ware analysed too. The data will be useful in improving sanitation in urban settlements and review of existing legislation on sanitation. The study is in line with the overall objective of the National Environmental Action Plan (NEAP): to gather data, which will help to integrate the environmental concerns into social, economic development and planning process of the Country. In addition, it is within one of the three fundamental principles of the NEAP " the right of citizens to clean and health environment (NEAP 1994).

Zambia is one of the developing Countries of the World. Developing Countries of the World are those, that are poor and behind in many things, such as level of education, health service provision, inadequate sanitation and wholesome water supply to their population. They have high death rates and high birth rates and their population often increases at such a rapid rate that they can handily keep up with new jobs. (Monica and Bennett1986).

UNESCO-UNEP, give a world- wide overview on water and sanitation. Lack of safe drinking water and adequate sanitation for a great number of people in the world is one of today's most critical environmental problems. While the estimated water and sanitation coverage is close to 100% in industrialized countries, the situation in the poor developing countries is far from satisfactory (Egil 1998).

In 1980, the General Assembly of the United Nations declared the period 1980 – 1990 as the International Drinking Water Supply and Sanitation Decade. The global target " Safe drinking water and adequate sanitation for all people in 1990" was widely published and a mood of enthusiasm and high expectation was generated. It soon became obvious that the goal of the decade was unrealistic. However, increased efforts during the decade created awareness about the sector and more systematic approach to the problems. Even the goal of the Decade was clearly unrealistic; two factors particularly had a negative impact on the development. Firstly, the world population continued to grow rapidly, from about 4.5 billion in 1980 to 5.3 billion in 1990, with most of the increase (about 614 million) in the developing countries, particularly in urban areas. Secondly, the downturn in the world economy made fewer funds available for the sector

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in many countries. In the early 1970s it was estimated that only one third of the people in the developing world had access to safe drinking water and adequate sanitary excreta disposal.

Furthermore, population growth and increasing urbanization make the prospects of the decade target grim. Inadequate Urban Sanitation, Urbanization is often the major source of pollution of ground and surface water bodies (Egil 1998). This may be through leaks from sewer pipelines and sewage treatment facilities.

Inadequate urban Sanitation is worldwide common failure in regard to excremental disposal problems, which in the developing world the situation is more serious, Zambia inclusive. To solve these environmental health problems, the Government of the republic of Zambia has embarked on Environmental Support Program (ESP), which is a long-term commitment to stimulate the interest and investment in environmental and natural resources management with the framework of the economic growth. The NEAP has identified five major environmental issues water pollution and inadequate sanitation, soil degradation, air pollution wildlife depletion and deforestation. The NEAP is founded on three fundamental principles that is the right of citizen to a clean and health environmental. Local community and private sector participation in natural resources Management. Obligatory Environmental Impact Assessment (EIAs) of major development in all sectors.

The rapid demographic changes especially in urban cities, such as Lusaka are caused by an annual population growth rate of 3.5%, urbanization, industrialization, increased social amenities demand and general economic decline, pose a threat to sustainable use of the natural resources which, in return threatens economic, social and environmental sustainability in the long run (Central Statistical Office 1990).

The city of Lusaka attracts numerous migrations because of its various small-scale businesses and both formal and informal employment. However, since the mid 1990s when the country began to experience serious economic downturns job opportunities became very limited and most migrations ended up in the informal sector. The high level of urbanization taking place in Lusaka and the constant lack of adequate management of the city have constrained the city authorities in providing basic services such as adequate road drainage, sanitation, water and many other public amenities.

A survey conducted by (CSO and University of Zambia 1992), on country profiles identified that Government has recognized the need to promote and maintain the welfare of the people by adopting sustainable policies, for the benefit of both the present and the future populations. An implementation program to achieve these goals regimes appropriate policies, incentives, guidelines and public awareness at local, provincial and national levels could be done by carrying studies and provide information in order to promote citizens right to clean and health environment and for policy formulation. On urbanization it reported that the high population concentration in urban centres have put pressure on meagre urban resources especially sanitary facilities. Most urban municipalities have failed to provide social services such as clean water, adequate sanitation and waste disposal. Migration into urban centres has lead to the sprouting of unplanned settlement areas (shantytowns). Inadequate sanitation and lack of clean water supply pose great health dangers and environmental hazardous. Out breaks of diseases formerly rare in Zambia such as cholera have now become endemic problems.

(Bland and Kilama 1985) conducted a study to determine the causes of most infectious diseases; the investigation identified that poor sanitation is the major cause of most human infections. Infections spread through inadequate sanitation include: viral diseases like cholera, typhoid, paratyphoid and bacillary dysentery; protozoal diseases like amoebic dysentery and worm infections like ascariasis, pinworm spread through direct contact, indirect via water, soil and food or via carriers. The study further finds that; without effective community-wide method to contain excremental, the full health impacts of a plentiful water supply will not be appreciated.

The major sources of water supply for the city of Lusaka are derived from two sources, ground water 53 boreholes around the city and surface water from Kafue River. The average annual production of water is 200, 000 cubic meter with each source accounting for 50% of the production quantity. Further more, the paper states that the water borne sewerage systems cover about 30% of the area to which the company has water supply services and the total length of about 450 kilometres with about 10,000 manhole. These are usually poorly constructed or located, posing a risk of contaminating ground water. The areas, which are serviced, include high cost and medium cost areas (Mtine 2000).

From the foregoing review of literature, it is evident that a number of studies have been conducted in Lusaka. Most of these have concentrated in the water supply, water quality and solid waste management. The reviewed studies also show that there are a number of water projects under taken in Lusaka and elsewhere in Zambia. Therefore, the importance of conducting this study cannot be over emphasized, if the trend cannot be reversed the quality of the ground and surface water could be effected and bring about adverse effects to the environment and human life.

The literature cited indicates that there has been no detailed study to review the status and satisfactory operation of sanitary Conveyances both (under ground and surface drains) and sewage treatment facilities in relation to population growth. Therefore the importance of this proposed study cannot be over emphasized and it requires support, in order to meet the national goals to integrate the degrading environment.

Methods

Data collection involved review of literature; stakeholder interviews using questionnaires (10 institutions and 300 household core informants), focus group discussions and inspection (observation) of sanitary systems. Both qualitative and quantitative data was collected. The 30 wards in Lusaka urban were stratified and a sample of 6 wards was selected representing two (2) wards from each residential category namely high, medium and low-density areas. The circular systematic sampling method was used in the selection of wards, which assumes the following relationship: Let $N = nK$

Where N = total Number of wards assigned sampling serial numbers in the case 30 $n =$ The sample size of wards i.e. the required number of wards, which in this case was 6.

$K =$ The Sampling Interval calculated as $K = {}^{N}/_{n}$

$= {}^{30}/_{6} = 5$

A random Number was obtained from a table of random numbers. This number was between I and N (both inclusive). In this case, the N was 30, as there were a total of 30 words. The sample interval $K = {}^{N}/_{n}$ was calculated. In this case was K = ${}^{30}/_{5} = 6.$ The sampled numbers of wards required were then selected using the circular systematic sampling method. The ward whose sampling serial number corresponded to the random start was the first selected ward. Then the $K,$ i.e. the sampling interval was applied by adding K to each selected wards, serial number until the required sample size $(n = 6 wards)$ was achieved. In all, 6 wards were selected.

Results

It is evident that Lusaka is the most urbanised, populated city in Zambia and one of the urbanised in sub Saharan Africa. The public sanitary facilities are overloaded because they were designed with the capacity follow of 36,000 m^3/day in 1950s but currently they are serving more people. The service providers' are strained due to limited capacity to maintain the existing

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sanitary systems in the city. It was found that extensions are made in private cartilages with or without permission from the local authorities, especially in low and medium cost areas, see figure 1. Showing a housing structure extension within a yard, drains and sewer are connected illegally.

Figure 2: Building extensions, source: field data 2002

It was evident that the socio-economic and practices of urban communities have contributed to unsatisfactory operation of sanitary infrastructure in the city. The street vendors use drains to dispose solid waste most of which are Inorganic nature. The Inorganic substances are trapped as screens before entering the waste treatment plants. These inorganic materials are usually block and damage the drains. There are no source separation of solid waste in the city of Lusaka and most waste generated are indiscriminate damped, especially in low and medium cost areas. In some case vendors remove lids from the manhole and inorganic waste materials are found into sewer lines up to the screen. See figure 2, showing inorganic screens.

Figure 3: Screens out for sewer, source: field data 2002

Most infectious diseases common in Lusaka are spread through inadequate sanitation. Especially malaria, cholera, dysentery, and typhoid have become endemic in urban settlements. In 1997/1998-rain season, the Central Board of Health reported that by February 19, 1999 there were 1,540 cases of cholera in 14 districts countrywide. There were 43 deaths, 19 of them from Lusaka alone. Urbanisation has contributed greatly to poor sanitation, which is often the major source of pollution of the ground and surface water. This is through leaks from sewer pipes, waste stabilisation ponds and discharge of raw sewage from dilapidated sewer system into water bodies' figure 3, showing ponds of sewage fro dilapidated manhole and figure 4 showing dry up waste stabilisation ponds.

Figure 4: Dilapidated manhole, source: field data 2002

Figure 5: Dilapidated manhole, source: field data 2002

Conclusion

The conclusions drawn are that urban sanitation is a common failure especially in developing countries like Zambia. The disposal problem of solid and wastewater are regarded as less important than the consideration of portable water supply. The fact is that without effective community-wide method to contain excremental, the full health impacts of a plentiful water supply will not be appreciated. The historical roots of such an assumption originated in times when it was acceptable to pour the wastewater into the nearest watercourse. Urbanisation is often the major problem in Lusaka and other cities in developing countries. The concept of ruralisation is not fully implemented so as to control urban drift. Capacity building and political will can contribute to improve sanitation situation in urban settlements were leaks from sewer pipes, waste stabilisation ponds and illegal sewer connections are common.

Regarding developing countries, the key issues to achieve ecological sanitation are: - political recognition of the importance of sanitation, poverty alleviation and rural economic development (ruralisation), recycling of urban wastes and the development of adequate policies. Ecological sanitation is eco integration through total cooperation among decision makers, researchers and the general public. It requires systematic planning, adequate organisation and recycling of urban wastes and wastewater to prevent environmental damage and health risks. Efficiency, equity and vitality are the three dominating agents in ecological sanitation. Ecological sanitation requires totally functioning design, management and help local people through capacity building.

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Study on ecological sanitation and anaerobic digestion process models in China (2000-2003)

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Abstract

This paper presented the study on the Chinese explorative research and successive design and anaerobic digestion process models as well as the various case examples, research activities of anaerobic digestion projects for environmental protection in China during 2000 to 2003. The illustrated wastewater treated anaerobically are organic industrial wastewater, hard to biodegrade, hazardous, non-hygienic and chemical, covered the mixed domestic wastewater discharged from large sized steel and iron enterprises; and industrial wastewater from chemical plants, soybean source factory; black liquor from paper mills; industrial wastewater from textile and dyeing industry, antibiotics production, Coca-Cola drinks production, pharmaceutical industry, fiber production etc. In addition, the newest research, design and applied results in the circle of anaerobic digestion were briefly highlighted, including the optimization of industry practice and experience as well as operational management ability, e.g. alkali method straw pulp and chemical pulp-paper making wastewater, wastewater from medical industry, bio-pharmaceutical production, antibiotics as penicillin, erythromycin etc. Chinese medicinal herbs processing, antibiotics, tanning, brewery, distillery, agricultural chemicals, pesticide and insecticide, animal medicine, dyeing production, textile and printing industry, petroleum-chemical processing (PTA-phenyl terephthalic acid), coke processing, explosive production as RDX, hospitals, can and food processing, sugar-processing, municipal sewage with mixed industrial and domestic wastewater etc. All the mentioned research and practice show that both Chinese people and Chinese government have made great efforts in the last two decades in purifying the environment of water, soil and atmosphere via combining good understanding and application of anaerobic digestion with the local environment and economic development conditions. In addition, some theoretical treatment principles, bio-reaction types, and biodegradation pathways are briefed as the fundamental knowledge and expertise for the anaerobic digestion.

Keywords

Ecological sanitation, sustainable development, anaerobic digestion, process

Introduction

Ecological sanitation alike ecological safety is very important issue in sustainable development for developing countries and even developed countries concerned by the international society. Ecological sanitation covers many fields such as water ecological sanitation, plant ecological sanitation etc. If something wrong with the water ecology sanitation, it will impact the other ecological sanitation as soil, plant and animals even the food ecological chain of human beings and animals, which has been well known by many people.

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If a water body either a river, lake, sea or a reservoir, pond, well etc. is polluted by some hazardous, non-hygienic, and/or chemical industrial wastewater, some pollutants are hard to biodegrade, which can go into the food chain of human and livestock resulting in diseases of poisoning, cancer and malformation, and viscera malfunction. Additionally, the increasing use of pesticides, chemical fertilizers, and various agrochemicals has no doubt left hazardous substances on grains, vegetables, fruits, eggs and meat, and even in honey products which have affected on people's health and export of agricultural products into the world markets. Though Chinese government issued regulations in the early 1984 on the use of quality, high efficient, and low remnant pesticide, the estimated annual pesticide consumption still increases by 7-8%. In accordance with the statistic report done by the Ministry of Public Health, P.R. China, in last two years, the poisoning event caused by agricultural chemical remains in food poisoning occupied greatly, and the rate of disabling and death were higher. The same astonishment was shown for the impact from the animal medicine remains or animal feed additives. Some animal feed additives could influence the standard of meat quality, and even cause diseases of human body. The Chinese government again and again bans to adopt hormone, antibiotics and some chemically the synthesized drugs to stipulate the growth of animals. It was reported by China National Environment Agency that the annual output quantity of wastewater discharged in China reached by 62 billion ton, which greatly polluted 25% of big rivers, lakes, off-shore marine water impacting the quality of water and soil in the irrigating areas along a few rivers.

In the Chinese State Council issued "Some decisions concerning environment protection", it is clearly stated that as a target up to 2000, all the pollutant discharge in the country must meet the national or local standards. This target involves in many important industries such as chemicals, light industry, leather product industry, food, pharmaceuticals, petroleum-chemical processing industry, and etc. which are backbone industries in national economy in one hand, and produce large amount and various kinds of industrial wastewater on the other hand due to their multiple sources of raw materials, complicated processing techniques. Processing of this wastewater for the purpose of water environmental improvement and wastewater reuse is a difficult task and requires advanced technology on anaerobic digestion and environmental protection. For instance, in harnessing papermaking wastewater by anaerobic digestion, core technologies will include dealing with paper pulp wastewater, organic phosphorous wastewater and organic chloride in insecticide production, naphthalene and benzene and high concentration colored wastewater in dyeing production. Therefore optimal biological processing techniques of anaerobic digestion, anaerobic-aerobic technique, and high efficient typical anaerobic digestion facilities combined with pretreatment and post-treatment processing technologies can be used to process effectively various hard-to-biodegrade organic industrial wastewater in order to improve and purify water, soil, and atmospheric environment.

Organic pollutants in industrial wastewater, which China's government will control

The names of organic pollutants that China's government would like to control firstly are briefed as follows:

No.	Name	No.	Name	No.	Name
1	Dichloromethane	21	Polychlorinated biphenyls	41	Benz[k]fluoroanthene
2	Trichloromethane	22	Phenol	42	Benzo[a]pyrene
3	Carbontetrachloride	23	m-Cresol	43	Indeno[1,2,3-c,d]pyrene
4	1,2,-Dichloroethane	24	2,4-Dichlorophenol	44	Benzo[g,h,I]perylene
5	1,1,1-Trichloromethane	25	2,4,6-Trichlorophenol	45	Dimethlphthalate
6	1,1,2-Trichloromethane	26	Pentachlorophenol	46	Di-n-butylphthalate
7	Syrn-Tetrachloroethane	27	p-Nitrophenol	47	Dioctylphthalate
8	Trichoroethylene	28	Nitrobenzene	48	Hexachlorocyclohexanes
9	Tetrachloroethlene	29	p-Nitrotoluene	49	DDT
10	Bromoform	30	2,4,-Dinitrotoluene	50	DDV
11	Benzene	31	Trinitrotoluene	51	Dimethhoate
12	Toluene	32	p-Nitrochlorobenzene	52	Parathion
13	Ethlbbenzne	33	2,4-Dinitro-1-chlorobenzene	53	Parathion-methyl
14	o-Xylene	34	Ariline	54	Nithofen
15	m-Xylene	35	Dinitroaniline	55	Trichlorofon
16	p-Xylene	36	p-Nitroaniline	56	Acrylonitrile
17	Chlorobenzene	37	2,6-Dichloro-1-nitroaniline	57	N-Nitrosodimethylamine
18	o-Dichlorobenzene	38	Naphthalene	58	N-Nitrosodi-n-propylamine
19	p-Dichlorobenzene	39	Fluoroanthene		
20	Hexachlorobenezene	40	Benio[b]fluoroanthene		

Table 1: Organic pollutants in industrial wastewater.

Processing technique models and experience for anaerobic digestion of several typical industrial wastewaters in China

1. Shanghai Baoshan Steel and Iron Group (Large State-owned Enterprise) SBR Domestic Wastewater Treatment and Reuse Project.

   Process Flow:

   Wastewater → Screen Bar →De-silting (sludge transportation) / Sludge storage →Regulating →Pump for Influent → SBR → Intermediate → Pump → Filtration → Biocarbon → Measurement → Adding NaClO → Contact →Medal Water → Reuse

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2. Anhui "Mini-electrolysis-UASB-PACT" Process Treating High Concentration Wastewater of Nitrobenzene.

Process Flow:

Wastewater →Regulating →Pump →Mini-electrolysis with addition of H_2SO_4, activated carbon, Fe powders and air → Water-collecting → centralization with addition of lime water plus PAC and PAM →UASB in addition with one time dilution water and discharging sludge →Retarding with addition of 1 time dilution water →PACT →Effluent discharge →Sludge Storage →Compress and Filtration →Sludge

3. Chongqing Soybean Source Plant "Anaerobically Acidification Hydraulysis-Activated Sludge" to Treat Soybean Source Wastewater Project.

Process Flow:

Wastewater →Screen Bar and Screen Net → Regulating → Pump → Anaerobically-Hydraulysis-Acidification → Pumping → Aeration → Sedimentation →Filtration with Coal Dust →Discharge

4. Shenzheng Jiede Textile (Joint Venture with Hong Kong) Wastewater Anaerobic Treatment Project.

Process Flow:

Wastewater → Adding $FeSO_4$ → Regulating → Contact Aeration → Sedimentation → Coagulation Floatation →Effluent

Sewerage management at Delhi, India

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Keywords

Sanitation, wastewater, water drainage system

Abstract

The population growth and rapid urbanization in Delhi has led to immense pressure on basic amenities such as water supply, wastewater collection and treatment. River Yamuna the second largest river in India having length1376 km, having catchments of the basin 10% of the total; landmass of country is highly polluted within 22 km stretch along Delhi (70% pollution is discharged) and unfit for designated water uses. High organic and pathogen levels in all the urban surface water have resulted from huge discharges of municipal wastewater (sewage and industrial wastewater) and urban drainage into the river. Average annual BOD and total coliform in river at downstream of Delhi are in the range of 30-40 mg/l and 10^4 -10^6 MPN/100ml respectively. Thus river stretch along Delhi is most critical segment from pollution angle. All environmental aspects were considered in Yamuna Action Plan of Indian Govt that support an immediate progress and a long range plan to create improvement in sanitation, public health and quality of the people of Delhi with the affordable solution to the problems of sewage collection, treatment and disposal, including the improving to the quality of river Yamuna. This paper describes the present sewerage and sanitation condition of Delhi.

Introduction

Population of Delhi has grown to around 14 million in year 2001. Delhi as a state comprises urban and rural segment. The growth of population has mainly been in the urban sector. The average density of population per squire km was 12361 in urban area as against only 1190 in the rural sector. The rural sector has been shrinking rapidly and green area of Delhi is under considerable pressure of habitation on account of population influx and urban push. Over 45% of population of Delhi today live in slums, JJ clusters and unauthorized colonies where practically no sewerage system exists.

Sanitation and wastewater condition in Delhi

The principal of Public Health Engg demands that satisfactory wastewater disposal arrangements should be provided along with the water supply to every citizen. However, during earlier five year plans in India the emphasis was mainly on the provision of drinking water to both urban and rural areas. As a result, sewerage facilities commensurate with the sewerage generation did not develop. Even today only 55% of population of Delhi is served by sewerage system. Existing sanitation conditions vary widely throughout the Delhi .The habitation in the Delhi is in the following categories:

1. Planned developed- approved colonies
2. Un- authorized - regularised colonies
3. Resettlement colonies

4. Urban village
5. Rural village
6. Un authorized non regularized colonies
7. Slums and JJ clusters

According to the present policy of Delhi Water Board, sewerage system is provided or to be provided in all the categories from no 1 to 4 above. The existing un- sewered parts in these colonies are being attended to in a phased manner depending upon the response of the residents towards payment of development charges. Nearly 45% of the population of Delhi live in UN authorized colonies, JJ clusters and rural villages and presently their population do not have access to sewerage system. As per the present policy of Water Board, sewerage system is not to be provided in these colonies in the near future. Therefore, these areas will remain un-sewered till the present policy is amended. Most of the households in the unauthorized colonies have constructed septic tanks. Overflow from such tanks are connected to surface drains, which finally find way to the Yamuna River. There are total of 219 rural villages with an estimated population of about 0.6 million, where the rate of water supply is only50 lcpd .No sewerage system has been provided in these villages because of dense population an it is technically not feasible unless the water supply is increased to a minimum of 135 lcpd. The wastewater generated in the area finds its way into river Yamuna either through open drain. There are total of 1080 identified JJ clusters in Delhi. In these clusters, a family of 4to 5 persons live in one hutment about 150 sq ft without any access to sanitation facilities. In JJ clusters lo w cost toilet facilities are provided. Under such facilities community toilet complexes are constructed near the clusters. However, many hutment dwellers do not use these toilets and prefer to defecate in the open area around the clusters creating the health hazards. Human wastes that are not properly treated and disposed off pose parasitic infection through contamination of water and foods Sewerage overflow from such complexes are generally let off into the nearby surface drain and ultimately pollute the river. Based on the water quality modelling analysis, by Central pollution Control Board it is estimated that slum clusters along the river banks of Yamuna within its reach passing through Delhi, contribute appx 5% of pollution as a non point source load. Additional non-point source from slum clusters on bank s of drains flowing into Yamuna contribute additional non point source pollution load. Sewerage facilities have been extended to all the planned developed and approved colonies of Delhi.

In the 22 km stretch along Delhi between Wazirabad and Okhla, the entire sewerage of Delhi, in partly treated and mostly untreated condition is discharged into river from both banks. In addition, industrial effluents from 30 odd industrial estates of Delhi also flow into the river through sewers or directly in untreated condition. The total quantity of wastewater received by river in Delhi is of the order of 2870 MLD comprising 2670MLd of sewerage and 200 MLD of industrial effluents. The present sewerage treatment capacity in Delhi is about 2145MLD. Due to silting and settling of sewerage system at many places only 950 MLD of sewerage reach the Sewerage Treatment Plants. There are a number of sewerage treatment plants around the city most of which are based on Activated sludge process. At present 15 STPs are under operation, their existing capacity is 2145 MLD and 3 are under construction with the capacity of 135 MLD. There are 77 numbers of main and intermediate pumping stations. About 15% of the trunk sewers are functioning satisfactory. The remaining sewers are affected by accumulation of silt. The level of silt deposition ranges from 30-60% of the capacity .The sewers are silted due to insufficient velocity in sewers, flooding of sewers, blockage of sewers with floating matter/ debris, surcharging of sewers due to power cuts and open manholes. At least 10% of sewers are affected by settlement or structural weakness.

Storm water drainage system

There are 19 storm water drains in Delhi which outfall into Yamuna River downstream of Wazirabad. (Table: 1)

No.	Description of Drain	Discharge (mid)	BOD (mg/l)	Total BOD (t/day)	Drainage (sewerage) zone
01	Supplementary drain	180	22	4	Out of Delhi
02	Najafgarh drain	1,180	125	147.5	Rithala, C. pillar, Keshopur
03	Magazine road drain	4	190	0.8	Okhla
04	Sweepers colony drain	27	88	2.4	Okhla
05	Kheybar pass drain	23	65	1.5	Okhla
06	Metcalf house drain	11	85	0.9	Okhla
07	Quadsia Bagh	24	155	3.7	Okhla
80	Mori gate drain	24	85	2	Okhla
09	Moat drain	2	195	0.4	Okhla
10	Civil mill drain	55	180	9.9	Okhla
11	Rajghat/Delhi gate drain	43	190	8.2	Okhla
12	Sen-Nursing home	100	280	28	Okhla
13	Drain no.14	153	320	49	Okhla
14	Bara pula drain	255	165	42.1	Okhla
15	Maharani Bagh drain	64	370	23.7	Okhla
16	Kalkaji drain	11	210	2.3	Okhla
17	Tehkhand drain	34	310	10.5	Okhla
18	Tuglakabad drain	8	150	1.2	Okhla
19	Trans Yanmuna	672	240	161.3	Trans Yamuna
	Total (Average)	2,870	174	499.4	

Table 1: Observed discharge, BOD levels and total BOD in storm water drains of Delhi during April 2002

Out of these 19 drains, 15 drains (no1-15) outfall into the Yamuna between Wazirabad and Okhla barrage along its right bank. These drains are now carrying untreated sewage from entire Delhi and finally discharge it into the Yamuna.

The Najafgarh drain is the largest drain carrying nearly 1200 MLd of combined sludge into the Yamuna. This drain has 38 tributary drains, which carry domestic and industrial wastewater from its command area.

River water quality

The desired water quality according to “Designated Best Use “ criteria of Central Pollution Control Board is of “Bathing Class” along the city limit of Delhi. This require inter alia, a BOD of 3 mg /l (maximum), Dissolved oxygen 5 mg/l (minimum) and total colifom count of 500 0/100 ml. Poor waste water collection, treatment and disposal system in Delhi, inadequate solid waste handling system and discharge of untreated or partially treated wastewater into Yamuna have resulted in deteriorating water quality in river Yamuna. (As shown in table 2) In the 22 km stretch along Delhi, with practically no perennial flow of its own is the most critical segment from pollution angle.

Parameter	Water quality standards	Current status in Delhi Stretch
Total coliform MPS/100 ml	5000	1.9×10^6
pH	6-9	6-9
Dissolved Oxygen	5	0
BOD_5 mg/l	3	36

Table 2: Present water quality of river Yamuna – source CPCB annual report 2002

Hence in order to keep BOD_5 values of river water 3 mg/l all the wastewater generated in Delhi and reaching the river needs treatment up to the tertiary level with BOD_5 up to 3mg /l. One may examine the technical and financial feasibility to achieve the limits or look for some alternate solution such as land treatment of municipal wastewater and augmentation of minimum freshwater flow through the river.

Low cost sanitation community toilet complexes

Delhi has certain areas along river banks/drains occupied by slums dwellers belonging to economically weaker sections of the society. These people do not have toilets in their houses. Therefore, they defecate in open, which in turn deteriorate environmental sanitation and consequently lead to water pollution through surface runoff. As these slums are too congested to have a sewerage system, proper sanitation facilities in the form of LCS/CTC are proposed to be provided with the community to provide the sanitation .A large number of LCS/CTS facilities have been created under Yamuna Action Plan, but it has been felt in due course that there is no or very little acceptance of these facilities by people. We may list various possible reasons for under utilization of different facilities. Some of them are given below.

1. Lack of people involvement in earlier stage of planning of the project
2. Non-Cooperation of urban local bodies of the town
3. Lack of socially motivated O&M operators
4. Improper site selection like distant location of toilets from the habitation, in appropriate approach to the toilets etc.
5. Lack of intensitity towards gender, age, disability and dignity related issues while designing the toilets
6. Improper supply of water and intermittent supply of electricity
7. Non- willingness of users to pay the fees

Conclusion

Economically weaker sections of the society living in Delhi do not have toilets and defecate in the open area. This leads to in sanitary living conditions in the city and runoff after a rain carry waste into the river which has adverse impact on the river water quality during dry season as when very little fresh water flow exists in the river .By addressing the slum settlements sanitation problems, direct benefit would be a significant reduction of the estimated daily average pollution load on the river.

References

Delhi Urban Infrastructure and Environment Improvement Report 2002

Annual Report 2002-Central Pollution Control Board

Acknowledgement Mrs. Mehvish and Aamir

Decentralized wastewater treatment in Lesotho

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Keywords

Sanitation problems

Abstract

Lesotho is a poor, mountainous country, surrounded by South Africa, with 2.2 million inhabitants, mainly in rural areas.

Sanitation in Lesotho

VIP-latrines are widely spread.

Modern houses are equipped with septic tanks, mainly in urban areas.

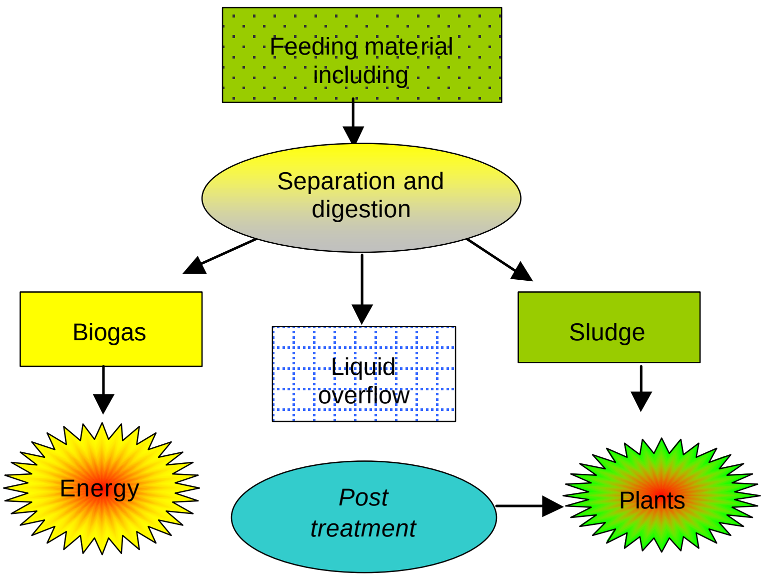
Many houses have both, a flush latrine inside the house and a pit latrine outside the house.

Emptying of septic tanks is a big problem for the house owners (costly).

Closed loop sanitation

The idea of closed loop sanitation does not exist.

- The authors have started an extension programme for Bio digester Septic Tanks, connected to constructed wetlands, irrigation and fertilization of vegetable plots.



Additional poster

Principle of extension

Commercial Approach (Minimized subsidies)

Creating demand

The first system was established close to town, where many visitors have the chance to see this in operation.

Convinced customers demand the technology. Best conditions are for those who are constructing a septic tank in their yard but for those who already have a septic tank, the system can be constructed aside.

Creating supply

Seven trainees, who are potentially unemployed, have been identified and learn enthusiastically all aspects of the technology on the job. Part of the training is to equip the trainees with a tool set each.

The training costs 10 000 Euro. Transport and engineering supervision is covered by DED.

Since January 2003, 3 systems have been completed and 4 are under construction. The customer covers work and material expenses.

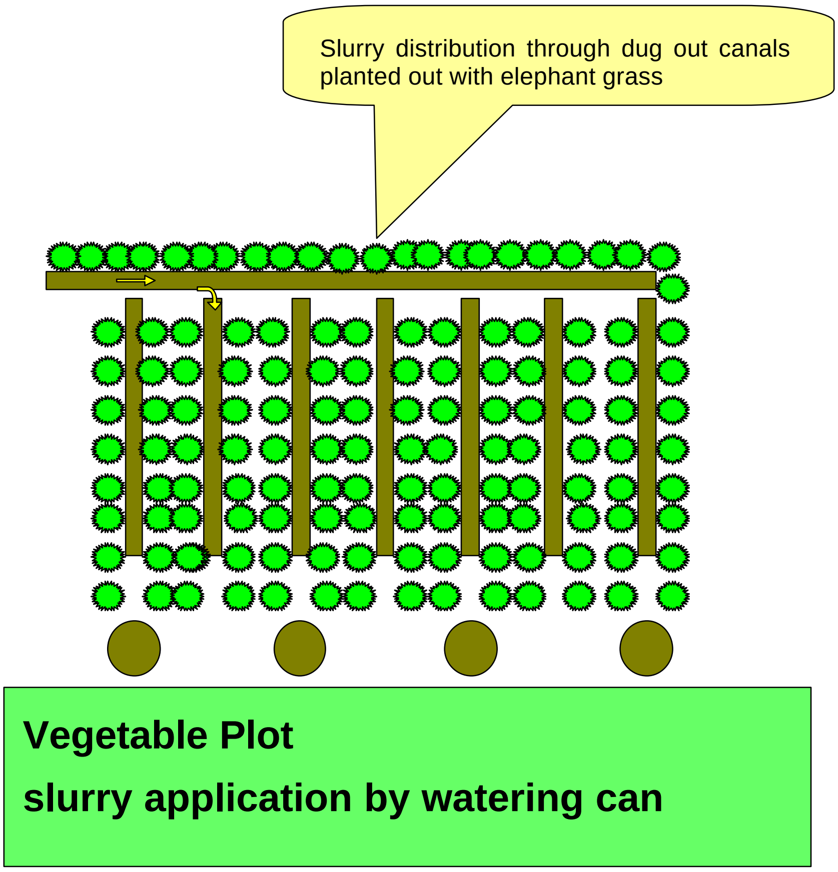


Figure 1: Example for the distribution of slurry through dug out canals

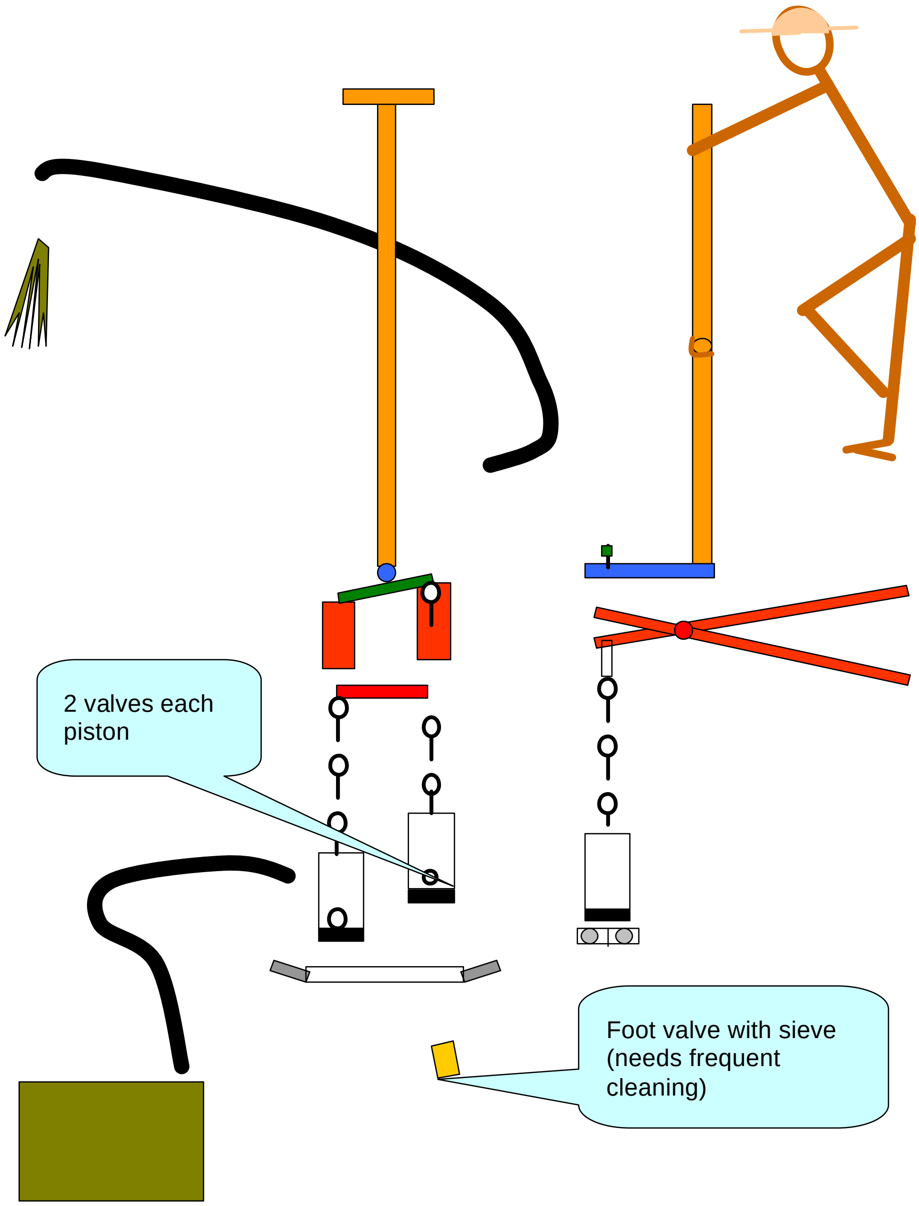


Figure 2: Sketch of a pedal pump, sucking and pushing liquid slurry. (*Super Money Maker)* produced at Selam Technical and Vocational Centre, Ethiopia

References

Bio Digester, Constructed Wetland, Gravity Irrigation, Grey water Separation, Use of Plastic Waste as Fixed Film Aerobic Treatment, Vegetable Production

Annex

- Summarised programme
- Minutes from the side event “awarenesss, participation and acceptance in ecosan projects”
- Minutes from the meeting of the IWA specialist group on Sustainable Sanitation
- 10 Recommendations for Action from the Luebeck Symposium o n ecological sanitation
- List of participants
- Technical excursions

Summarised programme

Sunday, 06.04.2003

17:00 – 20:00 h	Registration
19:00 – 20:00 h	Preparatory meeting for chairpersons and co-chairs

Monday, 07.04.2003

8:30 – 9:30 h	Registrationm and coffee
9:30 – 11:30 h	Greeting and opening session
11:30 – 12:30 h	Panel discussion: ecosan – a realistic tool to achieve the Millenium Development Goals.
12:30 – 14:00 h	Lunch / press conference
14:00 – 16:20 h	Session A: progress, policies and legislation
16:30 – 17:00 h	Coffee break
17:00 – 18:50 h	Session B: social and economic aspects
19:00 – 21:00 h	informal reception

Tueday, 08.04.2003

8:30 – 11:00 h	Continuation session B: social and economic aspects
11:00 – 11:20 h	Coffee break
11:20 – 13:05 h	Session C: rural and peri-urban case studies
13:05 – 13:55 h	Lunch
13:55 – 15:30 h	Continuation session C: rural and peri-urban case studies
15:30 – 16:00 h	Coffee break
16:00 – 19:00 h	Parallel sessions D and E
	session D: hygiene and environmental assessments
	session E: new technological decelopments and experiments
19:00 – 21:00 h	Side event: preparation of recommendations for action

Wednesday, 09.04.2003

8:30 – 18:30 h	One day ecosan excursions
19:00 – 21:00 h	Side event: awareness, participation and acceptance in ecosan projects

Thursday, 10.04.2003

8:30 – 10:55 h	Session F: hygienic agro-reuse
10:55 – 11:25 h	Coffee break
11:25 – 12:55 h	Session G: feasibility studies
12:55 – 13:55 h	Lunch
13:55 – 15:55 h	Session H: decision making tools
15:55 – 16:25 h	Coffee break
16:25 – 17:55 h	Continuation session H: decision making tools
18:00 h	Side event: IWA – specialist group sustainable sanitation meeting
19:00 h	Boat trip and joint conference dinner

Friday, 11.04.2003

8:30 – 9:00 h	Hotel check-out etc.
9:00 – 11:00 h	Session I: urban case studies
11:00 – 11:30 h	Coffee break
11:30 – 13:00 h	Continuation session I: urban case studies
13:00 – 14:00 h	Panel discussion: recommendations for action

7. - 11.04.2003 Poster exibition

12. - 19.04.2003 One week ecosan study tour (Germany, Denmark, Sweden)

Minutes from the side event awareness, participation and acceptance in ecosan projects, 2nd ecosan symposium, Lübeck, 09.04.03, 19h00-21h00

Elisabeth-Maria Huba, consultant of GTZ and presenter of the side event, opened the meeting by welcoming every one.

Reasons and objectives

The side event on awareness, participation and acceptance in ecosan projects was organised by the GTZ in the course of the 2nd International Symposium on ecological sanitation. The aim was to embrace the experience of an international range of ecosan-experts in discussing these aspects and to begin to develop conjointly guidelines and tools for the implementation of ecosan-projects.

The starting point for this event was the current lack of information and tools specific to ecosan projects regarding these issues, and the realisation that while many of the approaches used in "classical" sanitation projects could be adapted to some degree, the interdisciplinary nature of ecosan, the reuse aspects and the intended application of the Bellagio-Principles and the HCES of the WSSCC require a wider range and a more specific set of tools.

People should be involved in assessing a range of ecosan options addressing their needs, thus placing, as far as possible, the decision for the type of system they wish to use directly in their hands. In ecosan projects, all stakeholders must be comprehensively informed about the closed-loop ecosan philosophy, the use of the sanitary facilities, and the safe treatment and application of the recyclates with respect to hygiene and the environment.

First experiences revealed, that we often still lack experience as to how we may best plan and implement ecosan-projects in order to ensure their succes. For the promotion of ecosan and the dissemination of the related know how, guidelines and tools are needed to let the concerned stakeholders know about the concept, the wide range of existing technical and organisational ecosan solutions and the hygienically safe treatment and reuse of the recyclates.

Through this side event, all symposium participants interested in these topics, were invited to share their experiences on the development of strategies, approaches and tools to meet the needs of initiators of ecosan-projects, decision-makers and practitioners.

The overall objective of this side event was to reach a consensus regarding an informal cooperation between the participants to work on the topics of awareness and participation in ecosan-projects on an international level (international working group). The group would therefore benefit from lessons learned and best practices all around the world, thus supporting the elaboration of practical oriented guidelines for the implementation of ecosan-projects and the creation of a toolbox, which may help initiators, planners and implementers of ecosan-projects to raise awareness and create demand, to ensure participation of all stakeholders in the planning, design, implementation and monitoring processes and to provide for decisions on an informed basis.

Agenda

The agenda of the side event was short, concentrating on 3 main items:

Presentation of the draft results of a recent short study on the literature available concerning awareness, participation and acceptance in ecosan projects, carried out by Michela Baldi, GTZ, supported by information from several international institutions and organisations working in the ecosan sector.

Brainstorming on open questions related to these issues

Discussion and consensus on how to work together in this field

Summary of the recent short study on literature about awareness, participation and acceptance in ecosan projects, presented by Michela Baldi, GTZ:

The study is the result of a 16-day literature research, both as hard copies available in the GTZ-ecosan office and on internet web pages, using the google search machine and the links mentioned on the GTZ ecosan webpage. Important information has been gathered with the support of international ecosan professionals.

This literature and internet based research has been conducted with the focus on project implementation tools in the water and sanitation sector. Little ecosan-specific material has been found, as the topic is either still too new, or the experiences documented did not go far beyond single case studies. Nevertheless, several socio-cultural tools applied in the conventional water supply and sanitation sector may be adapted to the ecosan concept.

It is recognised that the research conducted is not exhaustive. 114 publications (reports, studies, articles, papers), on acceptance of, and participation in ecosan have been viewed with a focus on publications in English:

- more than 1/3 of the publications related to African experiences,
- about 10% related to European experiences,
- 5 % from Asia
- 5 % from South America
- and about 45 % concerning either the conventional water supply and sanitation sector or the ecosan approach in general

A great number of publications relate to case studies. Older publications on conventional water supply and sanitation lack the ecosan approach; however, they may provide useful more general information on awareness raising and participation. Since 1999, an increasing interest in the socio-cultural aspects of ecosan projects can be seen in the publications.

Most of the publications are addressed to a more restricted circle of experts' than to practitioners.

A wide range of different approaches and methods, both old and new, have been applied in ecosan projects and reported in the literature. These include:

- Bellagio Principles and HCES (Household-Centered Environmental Sanitation approach)
- PHAST (Participatory Hygiene and Sanitation Transformation)
- WASHE (Water, Sanitation and Hygiene Education)
- PRA (Participatory Rural Appraisal)
- SARAR (Self esteem, Associative strength, Resourcefulness, Action planning, Responsibility)

- GRAAP (Groupe de Recherche et d'Appui pour l'Auto-promotion Populaire)
- DDA or DDR (Demand Driven Approach or Demand Driven Response)
- DESAR (Decentralised Sanitation and Reuse system)

Guiding publications about the importance of socio-cultural aspects in ecosan projects are edited by:

- WSSCC / SANDEC (HCES and Bellagio Principles)
- EcoSanRes (guidelines for sanitation promotion and planning as well as socio-anthropological studies on norms and attitudes towards the ecosan approach are in process)
- EAWAG - NOVAQUATIS research project
- Sustainable Urban Water Management, (Swedish national research programme)
- Decentralized Sanitation and Reuse Systems (DESAR) as a social-scientific research project + Wageningen University
- MVULA Trust, South Africa and Aquamor, Zimbabwe
- WaterAid and ESTAMOS, Mozambique
- Mexican NGOs like CECIPROC, ESAC and the TepozEco pilot programme – among others

The study comes to the following conclusions:

- Ecosan-specific guidelines for project planners, professionals and fieldworkers are currently being discussed.
- Ecosan-specific training manuals on awareness raising for community workers do not yet exist.
- Ecosan–adapted toolbox for planners, professionals and fieldworkers do not yet exist.

Therefore the study gives the following recommendations:

- Intensify the cooperation and information exchange among ecosan experts on socio-cultural topics by means of an "international working group" using e-mail dialogue
- Develop a resource package on participatory approaches and communication related to the ecosan concept
- Work out a comprehensive system of guidelines for planners and practitioners concerning awareness raising, participation and acceptance, based on Best Practices in ecosan projects
- Prepare and facilitate an ecosan-adapted toolbox for planners and practitioners

GTZ will continue this study and publish it to an interested audience as a resource kit for further literature research and updating.

Brainstorming on open questions

To get an impression of the degree to which socio-cultural issues influence in a positive or negative way the successful dissemination of ecosan concepts and systems, the participants collected within 5 minutes the following 55 open questions concerning awareness, participation and acceptance in ecosan projects:

Nr	Question
1	Is there a need for fertiliser?
2	Strengthened role of local NGOs, who know the situation and the people --- learn from NGOs!
3	How will you convince people that it does not smell?
4	Should we define a north or south focus at the outset?
5	Operation - maintenance - reuse
6	Identify the different target groups
7	What is / are the most appropriate methods for evaluation after implementing an ecosan project?
8	How to promote local production of ecosan toilets (income generation)?
9	How does the promotion of issues for ecosan differ from sanitation in general?
10	Level of community involvement. Are they convinced to use them?
11	Differences between participation process in developing countries and industrialised countries
12	Ecosan specialists might want to promote their system. Are there methods that help decide between different ecosan alternatives?
13	Why do people want a toilet?
14	Over-fertilising through urine application?
15	People need to identify with a technique to accept and do it. What strategies have we in place to ensure the barrier on attitude by both community members and professional are addressed?
16	Is eco-sanitation organic?
17	How to maintain a dry sanitation system as old people?
18	How can user's participation be integrated to improve existing solutions?
19	Why eco-sanitation is more expensive?
20	What is the consequence if a project failed – what to do, how to react?
21	Who in the international or regional frame (champion) is supporting ecosan – particularly political leadership?
22	Elaborate guidelines on how to address the different stakeholders
23	Who should participate?
24	Awareness needs a lot of logistics and tools … how can the ability for small organisations be enhanced?
25	Accepting urine diversion!
26	Why do we turn us to the poor and not to rich opinion leading people, politicians, and tourists, as pilot users?
27	How to choose technology? (esp. urban)
28	How much cost the maintenance of the system?
29	On child related – have we developed appropriate child-friendly ecosan furniture
30	How to strengthen the financial capacities of the potential consumers regarding the use of ecosan toilets?
31	Is there any other indicator for acceptance than: people are buying the technology?
32	Eating veggies grown with treated shit?
33	How to convince users/consumers that it is safe?
34	Participation guideline for engineers needed
35	No space for "ecosan" systems in urban areas?
36	How can we spread experiences with ecosan as far as possible?
37	Can you handle shit?
38	What if other people laugh at me?
39	During the evaluation and the monitoring what is the best way?
40	An international working group for whom?
41	How can we offer a product, which is so attractive for the poor that no convincing is needed?

42 Can we convince architects/engineers/builders to set examples to generate a “trickle down” effect?
43 Urine, anyone?
44 Cooking on “shit”-gas
45 After the impleme ntation (activities) what kind of approach do we need?
46 If you want to implement a project what is the best approach you need?
47 How long is monitoring needed by outside organisations?
48 In some countries in Asia, there needs to be some modification in design of toilet (ecosan) to be acceptable
49 Facing faeces?
50 Why do people on the ground (users) choose ecosan above pour flush/pit latrine?
51 Is the technology completely convincing?
52 Is the society ready to participate in toilet design… if they have not done this during the last 40 years?
53 If I am aware… do I buy it then?
54 What could we do if we have intention to attend ecosan technical training or professional education activities? (BRTC China)
55 How do we join ecosan international cooperative projects? (BRTC China)

This variety of open questions concerning different target groups and stake holders addresses at the same time different professions, regions, and cultures, but is at least nothing more than a first impression of the long way to go.

To make the picture even more complex, the participants listed – within one minute - some target groups or stake holders of ecosan projects and approaches. This list id presented below:

- Community
- Municipality
- Central Government
- Opinion leaders
- NGOs
- International Agencies
- Planners
- **Users of fertiliser**
- Farmers
- Product Developers
- Professionals
- Service Providers
- Hospitals
- Real Estate
- Manufactures
- Families
- Women *(of different ages)*
- Men *(of different ages)*
- Children *(different age and gender)*
- Neighbours
- Slum People
- Schools
- Technical Educators

The participants recognised that this is far from being complete. Moreover, each target group or stake holder in a different socio-geographic context may require appropriate methods and tools to raise their awareness, and to encourage their participation in and acceptance of ecosan concepts and systems - another impression of the long way to go. This is another reason, why this work should be done in close cooperation between international ecosan institutions.

The next steps

As a result of this side-event, the participants decided to found an international working group to address the issues of awareness, participation and acceptance in ecosan-projects. The group will work via internet with ideas being exchanged to help in outlining a guideline and establishing a box of tools which ecosan planners and practitioners will be able to draw upon. As a next step, GTZ offers to bring together the know-how of the participants and even more resource persons in order to elaborate a first draft of the guidelines for the implementation of ecosan projects and to fill a toolbox with appropriate tools for awareness raising on, participation in and acceptance of ecosan projects. The participants in the side event agreed that they will share as far and deep as possible their experiences to answer even more open questions in an ongoing informal e-mail exchange, which will be coordinated in the beginning of the process by GTZ.

Time schedule

The draft results of the guidelines and first tools are to be presented up to November 2003.

Elisabeth-Maria Huba closed the meeting, thanking everyone for his or her attendance.

Writing the notes: Elisabeth-Maria Huba, consultant GTZ

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Annex

Minutes from the meeting of the IWA specialist group on Sustainable Sanitation in Lübeck April 10th 2003-05-18

1. Ralf Otterpohl, chairman of the Specialist group on Sustainable Sanitation, opened the meeting by welcoming every one.
2. The agenda of the meeting was agreed upon as are given in these minutes.
3. The name of the specialist group. When the group was formed in Berlin in 2001 it was named “Sustainable Sanitation”. Ecological Sanitation is meanwhile the internationally most widely used term for the type of sanitation studied and promoted by the “Sustainable Sanitation” group. Therefore, Ralf suggested that the group should change its name to “Specialist group on Ecological Sanitation”. This suggestion was agreed on by all attending the meeting.
4. Ralf informed of EcoSan activities within the IWA. He had been asked by IWA managing director Paul Reiter to chair a session on Ecological Sanitation at the IWA Leading Edge Conference in Venice, 2002. This resulted in a request to arrange an IWA session on EcoSan at the 3rd World Water Forum 2003 in Kyoto, Japan. This session was a great success and even attended by the IWA president Prof. Tambo. In total three EcoSan sessions were arranged in Kyoto. The one by IWA and two by EcoSanRes, Sweden. In addition EcoSan presentations where also given in two sessions organised by UNEP and the Japan Toilet Association. In total there were some 350 events at Kyoto, but the three EcoSan Sessions competed successfully for the audience. Videos of the sessions are to be published at www.ecosanres.org.
5. An important future event is the IWA biannual conference in the autumn of 2004 in Marrakech, Morocco. The specialist group is lobbying to have the term Ecological Sanitation included as a specific topic in the overhead call and to have a special session dedicated to Ecological Sanitation. We do not know how successful this will be. Therefore, it is important that the titles of the papers sent in contain the term Ecological Sanitation. This increases the chance of a special dedicated EcoSan session being arranged.
6. The forming of an EcoSan discussion forum on the internet was discussed. It was agreed that presently it is better that we use the existing EcoSan discussion forum of EcoSanRes (join on www.ecosanres.org) instead of forming a new one of our own.
7. Information was given on some neighbouring specialist conferences that might be of interest:
   Constructed wetlands, September 2004,
   Anaerobic digestion, September 2004, Canada.
8. Ralf plans an IWA handbook on Ecological Sanitation and asked for expression of interest to co-operate via email. The subject line of the email should read “IWA handbook” and details of the subjects that can be covered should be given. He pointed out that it was important that the contributions will be quantitative including design criteria.
9. The website of the group was discussed. Presently, it is located at the Technical University of Hamburg-Harburg. The address is www.tuhh.de/susan. Meanwhile Ralf could reserve the site www.ecosan.org (surprise it was free) that will be used for our IWA group. We are also working on having it linked from the IWA website. You are all invited to send material (NO commercials, please) and links to this websites describing your EcoSan activities. We will include these links on the website.
10. The meeting was closed by Ralf, thanking everyone for their attendance.

Writing the notes: Håkan Jönsson, Co-chair of the specialist group Ecological Sanitation.

Participants of the meeting of the Specialist group on Sustainable Sanitation at Lübeck April 10th 2003

The meeting was attended by approximately 60 persons in total, but some left before signing the attendance sheets.

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10 Recommendations for Action from the Lübeck Symposium on ecological sanitation, April 2003

350 experts from 60 countries met in Luebeck from the 7th to the 11th April 2003, at the 2nd International Symposium on ecological sanitation organised by the GTZ and the IWA.

The World Water and Sanitation Crisis

The problems raised by the decreasing quality and quantity of water resources are becoming increasingly serious. All indicators show that they are getting worse and that we are facing a serious world water crisis, which will affect us all, particularly the poor. They suffer most from this decrease in fresh water resources, and bear the brunt of water related diseases and a damaged environment.

Both central and on-site conventional sanitation systems have proven to be unable to make a significant impact on the dramatic service backlog of nearly half of the worlds population. Moreover, present sanitation systems are coming under increasing criticism as in many cases they are unaffordable or do not function properly. Indeed, they are using surface and groundwater as a sink for human excreta and wastewater resulting in increasing health hazards, environmental pollution, steady degradation of natural resources and a permanent loss of nutrients and organics from the soil sphere. Instead of solving the problem they often contribute to the contamination of freshwater and increase the scarcity of freshwater resouces.

Need for a paradigm shift

To the participants of the Luebeck Symposium it is clear that in order to achieve the Millennium Development Goals and the Johannesburg Plan of Implementation, a new paradigm is required in sanitation, based on ecosystem approaches and the closure of material flow cycles rather than on linear, expensive and energy intensive end-of-pipe technologies. This paradigm must recognise human excreta and water from households not as a waste but as a resource that should be made available for reuse.

The new paradigm is called ecosan

Ecological sanitation (ecosan) is a holistic approach to sanitation and water management based on the systematic closure of local material flow-cycles. Ecosan introduces the concept of sustainability to sanitation.

Principles and objectives of ecosan

The basic principle of ecosan is to close the loop between sanitation and agriculture. The main objectives are to:

- reduce the health risks related to sanitation, contaminated water and waste
- prevent the pollution of surface and ground water
- prevent the degradation of soil fertility
- optimise the management of nutrients and water resources.

Closing the loop enables the recovery of organics, nutrients, trace elements and energy contained in household wastewater and organic waste and their subsequent reuse in agriculture. In order not to compromise health in ecosan approaches appropriate treatment and handling must be ensured. In making the organics, nutrients and trace elements available to agriculture, soil fertility is preserved and long-term food security is safeguarded. In practice the commonly applied ecosan strategy of separately collecting and treating faeces, urine and greywater minimises the consumption of valuable drinking water and enables treatment of the separate wastewater flows at low cost for subsequent reuse in soil amelioration, as fertiliser, as service or irrigation water or for groundwater recharge. Rainwater harvesting and the treatment of animal manure may also be integrated into ecosan concepts.

Ecosan can therefore greatly help in saving limited resources. This is particularly urgent with regard to fresh water and mineral resources – for example current estimates for phosphorus state that economically extractable reserves will be exhausted within the next 100 years. Ecosan does not favour a particular technology but is rather a philosophy in recycling oriented resource management and offers modern, convenient, gender friendly and desirable solutions, in accordance with the Bellagio Principles as formulated by the WSSCC (Water Supply and Sanitation Colloborative Council).

One of the objectives of the five-day symposium was to formulate priority actions for the further promotion and up-scaling of ecosan.

The participants agreed on the following 10 Luebeck Recommendations:

1. **Promote ecosan-systems as preferred solutions in rural and peri-urban areas**
   A variety of ecosan solutions, ranging from low to high-tech, exist for rural and low-density urban areas. These should now be implemented on a large scale, in accordance with local physical, cultural and socio-economic conditions.

   Technologies based on ecosan principles should be vigorously promoted for all new construction of buildings and for the refurbishment of older structures wherever feasible. Additionally, existing on-site sanitation facilities that pose a significant health risk should be upgraded in accordance with ecosan principles.

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2. **Accelerate large-scale applications of ecosan principles in urban areas**
   Urban areas with their rapidly growing populations are in greatest need of sustainable sanitation. Although initial experiences with ecosan systems are available from urban areas, further research and development is urgently required. Further ecosan pilot-projects should be carried out in order to develop a variety of technological, organisational and economically viable solutions for densely populated urban areas and to obtain results concerning the costs and performances of different systems in both industrialised and developing nations. The conversion of existing conventional systems towards ecosan should, wherever possible, be immediately started, adopting if necessary a step-wise approach.
3. **Promote agricultural use**
   Ecosan systems are not complete until the fertiliser products are reused. The promotion of agricultural reuse must therefore be a key element of every ecosan project. Reuse options for ecosan fertilisers need urgent field testing at medium and large scale, and appropriate pretreatment, distribution, marketing strategies and guidelines for safe handling and use for different local conditions must be developed. Particular care has to be taken to ensure that the pathogen cycle is broken.
4. **Raise awareness and create demand**
   To be willing to make a change, politicians, local and regional authorities and the public need to know that the current system can cause many problems and that the application of ecosan principles can solve several of them. Advocacy and lobbying is therefore essential. There is also an urgent need to showcase ecosan systems at a municipal or large neighbourhood level in order to convince decision makers ("seeing is believing").
5. **Ensure participation of all stakeholders in the planning, design, implementation and monitoring processes**
   Planning with a household or neighbourhood-centred approach should be adopted as it places the user at the core of the planning process. The Household Centered Environmental Sanitation Approach (HCES, as developed by the WSSCC) responds to the knowledge, needs and demands of the users. This approach attempts to avoid the problems resulting from either "top-down" or "bottom-up" approaches, by employing both within an integrated framework. Gender issues must be given particular consideration in all processes.
6. **Provide for decisions on an informed basis**
   People should be involved in assessing a range of ecosan options addressing their needs, thus placing, as far as possible, the decision for the type of system they wish to use directly in their hands. In ecosan projects, all stakeholders must be comprehensively informed about the closed-loop ecosan philosophy, the use of the sanitary facilities, and the safe treatment and application of the recyclates with respect to hygiene and the environment. Study and documentation of the health risks posed by the different sanitary concepts, and the necessary means to overcome these, is required.
7. **Promote education and training for ecosan**
   Ecosan is multidisciplinary and should be integrated in the teaching curricula of universities, schools and vocational training centres. The engineers, architects, farmers, developers, constructors, consultants, municipal planners, economists and authorities concerned should know about the concept, the wide range of existing technical and organisational ecosan solutions and the hygienically safe treatment and reuse of the recyclates. Ecosan principles should be integrated into capacity building and continuous learning programmes for all the actors involved.
8. **Adapt the regulatory framework where appropriate**
   The documentation and results of pilot-projects must be transformed into, among others, technical, socio-economic, and reuse guidelines reflecting the interdependencies of water supply, sanitation, waste management, health, hygiene, environment, agriculture and energy supply. Ecosan technologies should be codified into the local, national and international systems of technical standards and norms in order to provide reference for Best Practice and Best Available Technology. The regulatory framework should be verified or adjusted with the aim of authorising and promoting a closed loop with new innovative technologies and management concepts.
9. **Finance ecosan**
   Appropriate financing instruments need to be developed, putting particular emphasis on the possibility to finance the users investment for on-site and neighbourhood systems, recognising that ecosan systems have a different cost structure from conventional sanitation systems. Innovative financing alternatives including start-up funds, community based finance programmes and cost recovery mechanisms may be required. The possibilities for private sector participation are large and should be stimulated, thus opening opportunities particularly for small and medium-sized enterprises and job creation. Additional financing should also be provided to secure research activities.
10. **Apply ecosan principles to international and national Action Plans and Guidelines**
   Ecosan strategies should be implemented in national and international action plans including the Implementation Plans for the MDGs (Millennium Developments Goals), PRSPs (Poverty Reduction Strategy Papers) and the National Plans of Action within the UNEP GPA (Global Programme of Action for the Protection of the Marine Environment from Land-based Activities). The indicator system for safe and sustainable sanitation provision should be revised to reflect the real risks and dangers to the environment and public health posed by all forms of sanitation.

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Luebeck Recommendations for Action in English, German, French and Spanish to be found at: www.gtz.de/ecosan

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Technical excursions

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Tour A / 1

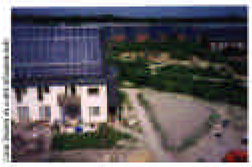
Composting toilets, greywater treatment and agricultural biogas plant

Meeting Point: Parking place beside the MuK

Departure: 8.15 am

Ticket color: (red)

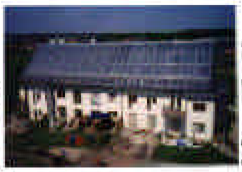
Ecological village Hamburg Braamwisch with composting toilets and constructed wetlands for greywater treatment



This ecological village was built between 1996 and 2000 in the northeast from Hamburg. The estate area consists of 40 living units in town houses and twin houses.

Each house carries 40 m² solar collectors. Furthermore 50 m² photovoltaic cell modules are installed on each row of five town houses. The "wohnhof braamwisch" with its ten town houses and 400 m² solar collectors is part of the short distance heating grid system of the Hamburg Gasworks, called "Solarprojekt Karlshöhe". All together 124 accommodation units are connected to that grid.

86 roofs facing south carry solar collectors of a 3.000 m² area. The produced heat is collected in the short-distance heating grid system and stored in an underground heat accumulator of 4.500 m³ volume.



The remaining roof area beneath the solar collectors has been used for a grid-connected solar photovoltaic system to produce regenerative electricity. The system occupies 50 m² and produces 4.000 kWh every year. The electricity is feed into the public grid.

All houses are low energy houses with composting toilets or toilets who use rainwater. Constructed wetlands are for greywater treatment.

Farm-Scale Biogas Plant in Behlendorf

Sumps 600 m³

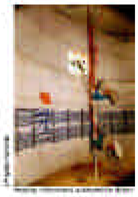
Digester 400 m³

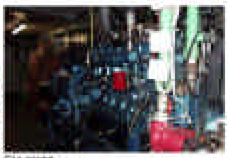
This plant with a digester made of concrete (Volume 400 m³) was built in summer 1998.

The manure of pigs, piglets and other organic substrates - so-called coferments - are digested in this plant.

The owner started with a Combined Heat and Power Unit (CHPU) of 45 kW electrical and 90 kW (thermal) power. The plant is upgraded to 75 kW electrical power.

The biogas produced by the digestion process is collected in a flexible PE gas store. The gas is used in a gas engine that produces 600.000 kWh per year. The former uses on his own 80.000 kWh per year. The rest of the produced electricity is feeded in the public grid.





Gas engine

Technical Data:

V_{Sumps}	= 600 m³
$V_{Digester}$	= 400 m³
$V_{Manure\ storage\ tank}$	= 1.200 m³
Temp.:	37°C to 38°C
CHPU:	75 kW_{el}

Tour Topics:

- composting toilets
- greywater treatment in constructed wetland
- short-distance heating grid system
- farm scale biogas plant

OtterWasser GmbH

Annex

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Tour A / 2

Composting toilets, greywater treatment and agricultural biogas plant

Meeting Point: Parking place beside the MuK

Departure: 8.30 am

Ticket color:

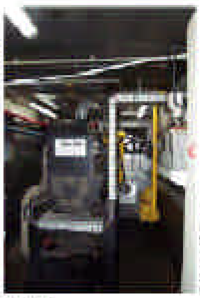
Farm-Scale Biogas Plant in Bornhöved


Digester

This plant was built in 2001. Biogas is produced by the digestion of manure and biowaste. The gas is used in a gas engine (CHPU) for the production of heat and electricity.

The manure of approx. 4.000 piglets is collected in two manure storage tanks. From this tanks the digester is feeded by a pump. The digester is a gastight completely sealed tank made of stainless steel (Volume 771 m³).

The mesophilic digestion process operates at 37 °C. An agitator is mixing the digester's contents. The average hydraulic retention time of the manure inside the digester is - depending on the substrate - between 20 and 40 days. Output is biogas and digested substrate.


Gas Engine

The biogas is stored in a gas storage tank above the digester. The gas engine is feeded from the storage tank. The heat produced is used for heating the digester, the stables and the farm house.

The latter is stored in a lagoon of 2.000 m². It will be used as a fertilizer because of its high ammonia concentration.

Technical Data:

$V_{Biogas\ Digester}$ = 771 m³

$H_{Digester}$ = 5,03 m

$D_{Digester}$ = 13,97 m

Temp.: 37° C

CHPU: 180 kW

Residential area Hamburg Allermöhe with different ecological buildings, composting toilets and reed-bed purification system


North yard

Located 15 km southeast of the city center of Hamburg. The history of planing and the development goes back into the 1970's. The first houses were occupied in 1986 - the last one in 1998.

The housing estate consists 34 houses, which were built in semi-detached and terraced formats and is grouped into three yards (north yard, central yard and south yard). 114 people live on the estate.

Different ecological innovations represent the path of ecological engineering development as there are photovoltaic systems, green roofs, rain water harvesting.


Central yard


Reed-bed purification system

Composting toilets are installed in each house. Reed-bed purification system is used for greywater treatment. 1994 - the purification system was upgraded for 140 people and a volume of 15 m³ sewage per day. The area of the constructed wetland is approx. 240 m².

Tour Topics:

- farm scale biogas plant
- green roofs
- composting toilets
- reed-bed purification system

OtterWasser GmbH

Annex

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Wasser Berlin

Meeting Point: Parking place beside the MuK

Departure: 7.30 am

Ticket color:

International Trade Fair and Congress Water and Wastewater

Water - the gold of the 21st century

WASSER BERLIN

International and national conferences, symposia, seminars ......

Brief Description

WATER BERLIN is the international Trade Show and Conference for the Water Industry. The event runs parallel to GAS BERLIN. The conference features dicussion forums with international experts on a variety of water-related topics. It is a capital investment exhibition for international water supiy and is an ideal interface for theery and practice.

Conference partici-pants and visitor target groups

Water experts from government and industry, engineers, experts in civil engineering, well drilling, waterworks construction, representatives from domestic and international organisations, purchasers, water management experts, scientists, representatives of industry associations and institutions, government officials, high-level administrators.

Messe Berlin

WASSER BERLIN

International and national conferences, symposia, seminars ......

- Conference WASSER BERLIN
- IWA- International Water Association Conference
- DVGW / ATV-DVWK / FIGAWA Conference "IT-Gas, Water, Wastewater"
- IOA- International Ozone Symposium
- FIGAWA / DVGW 3rd Well Construction

GAS BERLIN

Gas is a major component of modern energy concepts: it is economical, ecological, and reliable. Investor interest in gas technology reflects the dynamic growth of the industry - and this trend is not limited to western Europe. In fact, rapid economic development has triggered latent demand in central and eastern Europe. This trend is expected continue in the future.

Target Groups

Specialists from private and government suppliers, gas technology suppliers, engineers and buyers, as well as other specialists and commercial enterprises, city administrators and trade associations with a special interest in gas technology.

Tour includes only transport
Entrance fee: 20 € / person
excluding session fees

further information and the detailed program are available at the reception !

gtz — IWA — ecosan — OtterWasser GmbH

Annex

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Tour B

Source separation in a dwelling area, composting toilets, greywater treatment

Meeting Point: Parking place beside the MuK

Departure: 7.45 am (Bus 1) / 9.45 am (Bus 2)

Ticket color: 1 2

Separating Wastewater Treatment System: The Ecological Housing Estate Lübeck-Flintenbreite

Terraced houses

The housing estate:
In an area of 3.5 ha you will find 117 houses (twin houses and terraced houses) and flats with approximately 300 to 350 inhabitants when the construction of the whole housing estate will be finished.

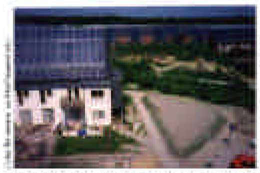
The "Flintenbreite" is located in Lübeck in the middle of an existing residential quarter.
At the moment 30 houses and flats have been build up, the technical equipment for the supply for all 117 planned units is in operation.

The separating wastewater concept:
By the use of VACUUM TOILETS with a very low water consumption (0.7 - 1.0 l per flush) the feaces and the urine (BLACKWATER) are transported in a vacuum pipe system. The BIOWASTE from the kitchen will be mixed and treated together with the blackwater in a DIGESTOR after a thermic hygienisation. The fertilizer can be used in farmland.

Vacuum Toilet

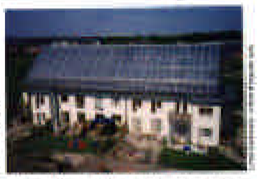
The GREYWATER (wastewater from kitchen and bathroom) is collected in gravity pipes and treated in several CONSTRUCTED WETLANDS that are situated in the housing area.
The stormwater of roofs and sealed areas is collected in small gutters on the surface of the ground and afterwards it is infiltrated in decentralized SWALES.

Ecological village Hamburg Braamwisch with composting toilets and constructed wetlands for greywater treatment

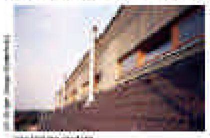


This ecological village was built between 1996 and 2000 in the northeast from Hamburg. The estate area consists of 40 living units in town houses and twin houses.

Each house carries 40 m² solar collectors. Furthermore 50 m² photovoltaic cell modules are installed on each row of five town houses. The "wohnhof braamwisch" with its ten town houses and 400 m² solar collectors is part of the short distance heating grid system of the Hamburg Gasworks, called "Solarprojekt Karlshöhe". All together 124 accommodation units are connected to that grid.
86 roofs facing south carry solar collectors of a 3.000 m² area. The produced heat is collected in the short-distance heating grid system and stored in an underground heat accumulator of 4.500 m³ volume.



The remaining roof area beneath the solar collectors has been used for a grid-connected solar photovoltaic system to produce regenerative electricity. The system occupies 50 m² and produces 4.000 kWh every year. The electricity is feed into the public grid.



All houses are low energy houses with composting toilets or toilets who use rainwater. Constructed wetlands are for greywater treatment.

Tour topics:

- vacuum toilet, waterless urinals
- composting toilets
- anaerobic treatment in a digestor
- greywater treatment in constructed wetland
- short-distance heating grid system

ecosan

OtterWasser GmbH

Annex

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Tour C

Source separation in a dwelling area and agricultural biogas plant

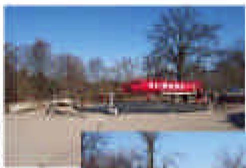
Meeting Point: Parking place beside the MuK

Departure: 9.15 am

Ticket color:

Farm-Scale Biogas Plant in Behlendorf

This biogas plant is located in Behlendorf 20 km south of Lübeck - a small village nearby Ratzeburg.



Sumps, 600 m³

This plant with a digester made of concrete (Volume 400 m³) was built in summer 1998.

Digester, 400 m³

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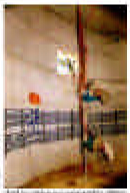

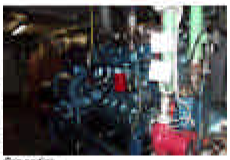

Gas engine

Technical Data:

V_{Sumps}	= 600 m³
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$V_{Manure\ storage\ tank}$	= 1.200 m³
Temp.:	37°C to 38°C
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Tour Topics:

- farm scale biogas plant
- vacuum toilets, waterless urinals
- anaerobic treatment in a digestor
- greywater treatment in constructed wetland

OtterWasser GmbH Engelsgrube 81 D-23552 Lübeck www.otterwasser.de

Annex

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Tour D / 1

Small treatment plants for rural areas

Meeting Point: Parking place beside the MuK

Departure: 7.45 am

Ticket color:

Self-sufficient water, wastewater and energie system for a rest area at the motorway A20:

An on-site well supplies te rest area with water. Before the water is offered it will be processed to achieve drinking water quality. The wastewater is treated in a vertical flow constructed wetwand (called "subterra plant", 150 sqm) that treats the used water. The outflow discharges in the drainage system of the motorway.
The electronical control of the treatment plant gets the power from regenerative energy production like a photovoltaic generator and a thermal solar collector, by a windmill and a "bio"-diesel engine.

Constructed wetland in Duckwitz Castle

SUBTERRA plant in Duckwitz

The vertical flow constructed wetland treats the wastewater of 23 inhabitants.
The system is the same as for the rest area at the motorway. The difference is the source of the wastewater: two flats, some flats for holiday guests, one office and a riding facility.
For retention of stormwater a green roof is installed on one shelter.

Sludge treatment in constructed wetlands in Niegleve/Lalendorf

Constructed wetland for sludge treatment

The wastewater of 1.000 total number of inhabitants and population equivalents is treated in an activated sludge plant.
For dewatering the sewage sludge is treated in a constructed wetland.
The sludge is pumped onto the reed bed for a periode of 5 to 10 years. After fulfilling the dumping stops and a further dewatering takes place. Afterwards the polder will be emptied and the dumping starts again.
The constructed wetlands get in operation in 1998. You will receive a report on the experiences made during the last years.

Tour topics:

- constructed wetlands in various sizes for the wastewater treatment
- regenerative energy plants (e.g. photovoltaic and solarthermic plant, windmill ...) as energy supply
- constructed wetland for sludge treatment
- green roofs

OtterWasser GmbH

Annex

2nd International Symposium on ecological sanitation

Information for the Excursion on Wednesday 9. April

"ecosan - closing the loop"

Tour D / 2

Small treatment plants for rural areas

Meeting Point: Parking place beside the MuK

Departure: 9.45 am

Ticket color: (orange)

Constructed wetland as secondary clarifier after wastewater treatment in a pond in Goosefeld

Constructed wetland in Goosefeld

The wastewater of the village Goosefeld (combined sewer system) is treated in a non aerated 20 year old pond system. To enlarge the capacity of the treatment plant (from 600 to 1000 on total number of inahbitants and population equivalents) a constructed wetland is added as a secondary clarifier. The constructed wetland should also reduce the phosphorous and nitrogen concentrations. The size of the constructed wetland is 3000 sqm. The hydraulic load from the combined sewer system is 260.000 m^3, that discharges in 6 separated fields.

The distribution of the wastewater from the pont and the treatment don't need any energy supply.

Wastewater distribution, Goosefeld

Ecological settlement Kiel Hassee with composting toilets and greywater treatment in constructed wetlands

Domestic building with green roofs, Kiel Hassee

Composting toilet

In Kiel Hassee 20 flats and houses have been build up. The first families moved in in 1992. It was one of the first housing areas where composting toilets have been installed in an urban area (Kiel:220 000 inhabitants). The remaining greywater is treated in constructed wetlands, the cleaned wastewater discharges in an surface water. Measurements have shown that outcoming concentrations are lower than in conventional wastewater treatment plants.

Tour Topics:

- **constructed wetland as secondary clarifier for 1000 inhabitants**
- **composting toilets in a residential area**
- **greywater treatment in constructed wetlands**
- **green roofs for stormwater retention**

gtz IWA ecosan OtterWasser GmbH

Annex

Photos

View of Lübeck

GTZ-Director addressing the opening session

A urine diversion toilet

View of Lübeck

Ralf Otterpohl, TUHH.
Dagmara Berbalk, German Federal Ministry for the Environment, (BMU).
Manfred Konukiewitz, German Federal Ministry for Economic Cooperation and Development (BMZ),
Wolfgang Schmitt, Executive Director GTZ, Germany

Conference participants

Participants during the opening session. Minister of State for Water Maria Mutagamba, Uganda. Senior programme officer UNEP/GPA Cees van de Guchte, Netherlands

Dagmara Berbalk, Head of division, (BMU) discussng with Cees van de Guchte (UNEP) during a break

An ecosan house mode (EcoSanRes)

Do you know what this means?

Candelight conference dinner in a historic warehouse in Lübeck

Sharing happiness

Sharing happiness conference dinner

Time to eat, conference dinner

Lets talk before desert

Wait a minute ecosan is bringing something!

We want to have a good photo

Sharing experiences

Oh! So delicious

Exchanging ideas

We are waiting

Petter Jenssen and the next ecosan generation

Oh! Dinner is so nice

Learning from each other

I like to take more photos, Jenny Aragundy, GTZ- ecosan

Boat trip in Lübeck



Sharing experiences

Enjoying the boat trip

Oh! Its nice time

Discussion during the excursion

Lunch time, excursion

An unexpected snow fall during the excursion

Annex

Manhole in sewerage system, excursion

We also contribute to environmental sanitation, excursion

We are just learning, excursion

We should see sustainability, excursion

Orientation at the time of excursion

Manhole, excursion

Detailed explanations during the excursion

Simataa Nakamboa (Zambia) with a self designed conference T-shirt

Farm scale biogas plant in Bornhöved, excursion

Committed to ecosan

A very busy schedule – participants during the excursion

The GTZ-ecosan team

Susanne Bolduan and Martin Oldenburg

Ron Sawyer during the final session

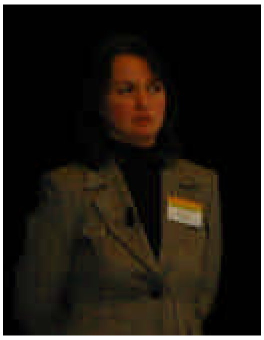
GTZ-ecosan team leader, Christine Wegner congratulating Prof. Peter Wilderer on receving Stockholm water prize.

Christine Werner, summarising the recommendations of the symposium

Singing the ecosan song

Closing the symposium

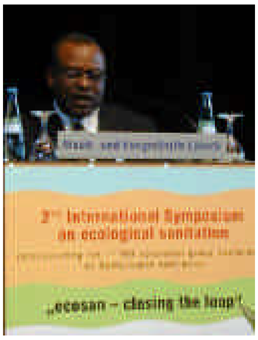
Abbott, Richard L.
Department of Water, City of Syracuse, USA



Adamsson, Marie
Göteborg University, Sweden

Andersson, Ingvar
UNDP, USA

Austin, Aussie
CSIR Building and Construction Technology, South Africa



Austin, Tushabe
Amaizi Marungi, Sutus-Project, Uganda

Bahlo, Klaus
Ingenieurbüro AWA, Germany

Baldi, Michela
GTZ-ecosan, Germany

Bark, Kerstin
OtterWasser GmbH, Germany

Baten, Harm
Rijnland District Water Control Board, Netherlands

Behnke, Stefan
Roediger GmbH, Germany

Beneke, Gudrun
University of Hannover, Germany

Berger, Wolfgang
Berger Biotechnik GmbH, Germany

Bracken, Patrick
GTZ-ecosan, Germany

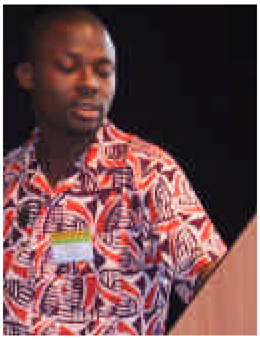
Brandberg, Bjorn
SBI Consulting & Supplier, Swaziland

Calvert, Paul
Ecosolutions, India

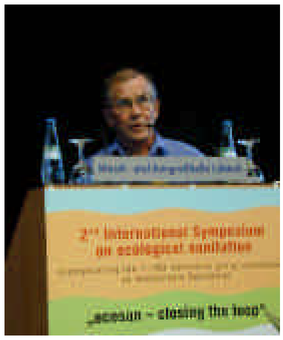
Choi, Euiso
Korea University, Korea

Clemens, Joachim
University of Bonn, Germany

Cordova, Ana
Cornell University, USA



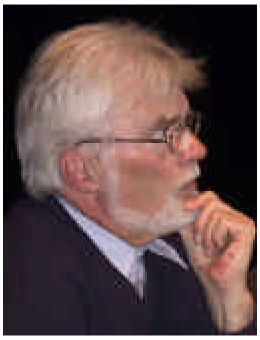
Danso, George
International Water Management Institute, Ghana



Davison, Leigh
Southern Cross University, Australia

de Bruijne, Gert
WASTE, Netherlands

Degaardt, Susanna
Kretsloppskontoret Recycling Office, Sweden



Drangert, Jan-Olof
Linköping University, Sweden

Eilersen, Ann Marie
Technical University of Denmark, Denmark

Elmitwalli, Tarek A.
Benha High Institute of Technology, Egypt

Euler, Hartlieb
TBW GmbH, Germany

Fermskog, Kristina
City of Göteborg, Sweden

Forster, Dionys
SANDEC/EAWAG, Switzerland

Gajurel, Deepak R.
Technical University Hamburg-Harburg, Germany

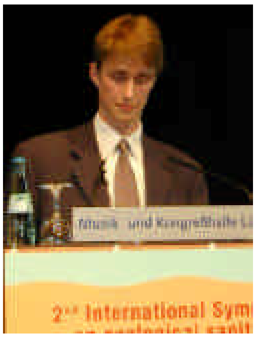
Geisler, Silke
Emschergenossenschaft / Lippeverband, Germany

Gumbo, Bekithemba
University of Zimbabwe, Zimbabwe

Heeb, Johannes
Seecon GmbH, Switzerland

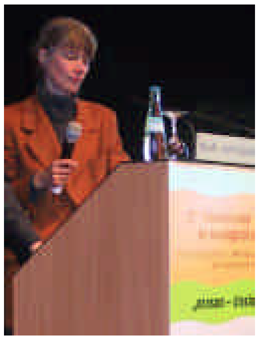
Annex

Heerenklage, Jörn
Technical University Hamburg-Harburg, Germany



Hellström, Daniel
Stockholm Vatten, Sweden

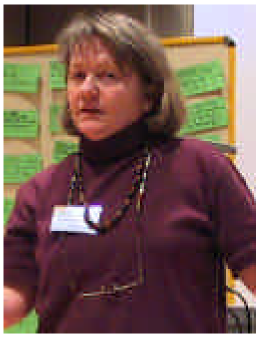
Hiessl, Harald
Fraunhofer Institute, Germany



Hoffmann, Beate
Senator for the Environment, City of Lübeck, Germany

Holden, Richard
The Mvula Trust, South Africa

Huang, Dongbin
EAWAG, Switzerland

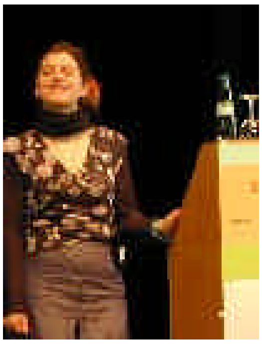


Huba-Mang, Elisabeth
GTZ-ecosan, Germany

Huber, Hans
Hans Huber AG, Germany

Jenssen, Petter D.
Agricultural University of Norway, Norway

Jönsson, Håkan
Swedish University of Agricultural Sciences, Sweden



Jurga, Ina
GTZ -ecosan, Germany

Kaggwa, Rose C.
National Water and Sewerage Corporation, Uganda

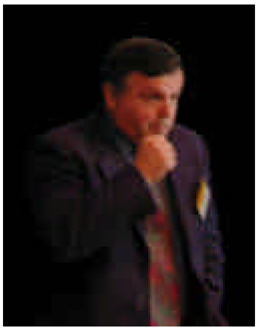
Kimmich, Susanne
GTZ-ecosan, Germany

Klaus, Uwe
AQUAPLANER, Germany

Klutse, Amah
CREPA, Burkina Faso

Konukiewitz, Manfred
Head of Division, BMZ, Germany

Köttner, Michael
International Biogas and Bioenergy Center, Germany



Kraft, Harald
Ingenieurbüro Kraft, Germany

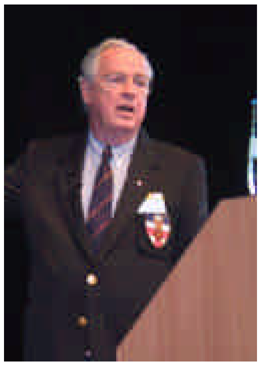
Krantz, Helena
Linköping University, Sweden

Kroh, Wolfgang
Executive Director, KfW, Germany

Krüger, Joachim
Pflanzenkläranlagen GmbH, Germany

Kujawa-Roeleveld, Katarzyna
Wageningen University, Netherlands

La Cour Jansen, Jes
Lund Institute of Technology, Sweden



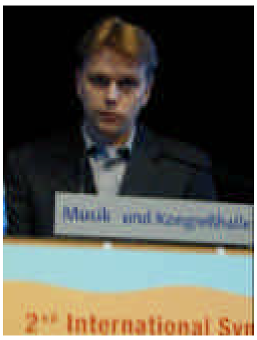
La Trobe, Brian
Enviro Options (Pty) Ltd., South Africa

Lamichhane, Krishna Mani
Department of Water Supply & Sewerage, Nepal

Langergraber, Günther
TBL/Ecosan Club, Austria

Li, Xianghong
Guangxi Medical University, China

Lienert, Judith
EAWAG, Switzerland



Lindner, Björn
Technical University Hamburg-Harburg, Germany

Malmén, Linda
Swedish Institute of Agricultural and Environmental Engineering,Sweden

Malmqvist, Per-Arne
Chalmers University of Technology, Sweden

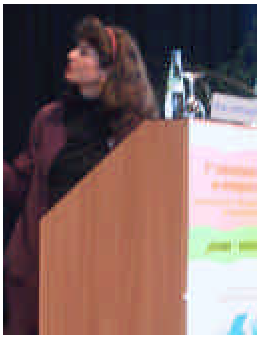
Mang, Heinz -Peter
GTZ-ecosan, Germany

Mattila, Harri

Häme Polytechnic Environmental Technology, Finnland

Mishra, Nawal Kishor

Department of Water Supply and Sewerage, Nepal



Moe, Christine L.

Rollins School of Public Health of Emory University, USA

Muehleck, Ralf

Berlin University of Technology, Gemany

Müllegger, Elke

University of Agricultural Sciences Vienna, Austria

Mutagamba, Maria

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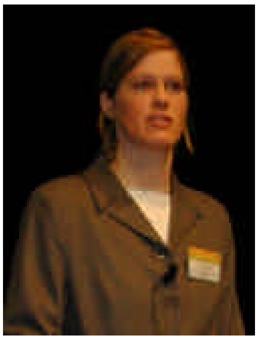

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Sawyer, Ronald
Sarar Transformación SC, Mexico

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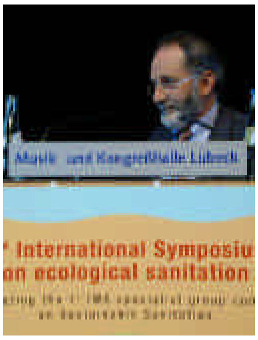

Schertenleib, Roland
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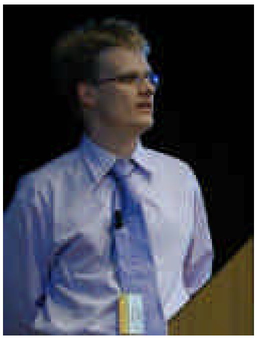

Scholz, Miklas
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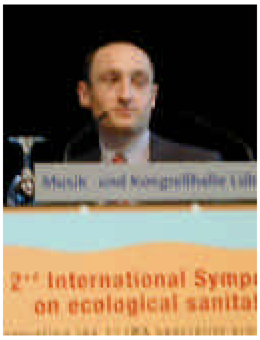

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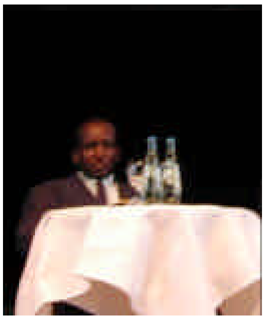

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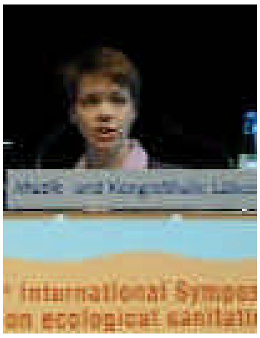

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Wilke, Isabella

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Wittgren, Hans B.

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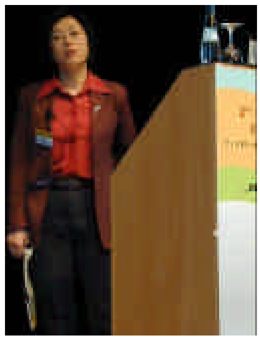

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