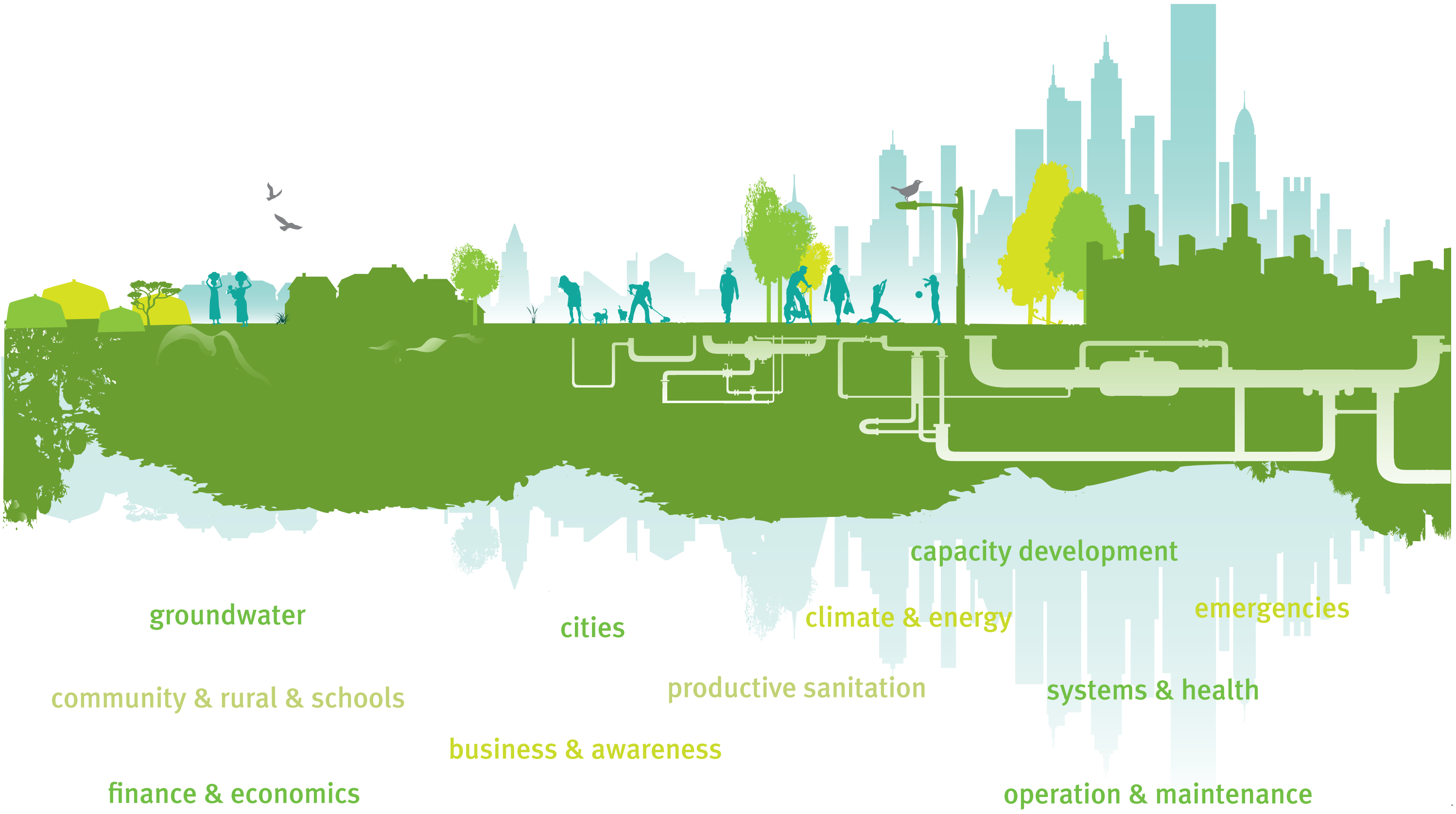

sustainable sanitation alliance

Compilation of 13 factsheets on key sustainable sanitation topics

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Sustainable sanitation ecosan program
Postfach 5180, 65726 Eschborn, Germany
T +49 61 96 79-4220
E *susana@giz.de*
I *www.susana.org*

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Editors:
Dr. Elisabeth von Münch, Rahul Ingle, Doreen Mbalo, Leonie Kappauf

Responsible editor:
Dr. Elisabeth von Münch

Contact:
Dr. Elisabeth von Münch (*susana@giz.de*)

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Foreword

Sanitation remains one of the most pressing challenges that we need to tackle in order to allow humankind to live in dignity and free of threats from a contaminated environment. For this reason, I together with my colleagues of the UN Secretary General's Advisory Board on Water and Sanitation (UNSGAB) and many other partners and friends are continually lobbying for sanitation to receive higher visibility at the international level as well as more determined actions on the national and local level. We already know that we will not reach our goal at a global level to halve the proportion of those who do not have access to sanitation by 2015. Nevertheless, we need to keep trying. For this purpose, the UN Secretary General has launched the Sanitation Drive to 2015, which calls on all stakeholders, state or non-state, private or public to speed up, to double efforts and to end open defecation in order to solve the sanitation crisis for as many people as possible until the 2015 deadline.

What we need is a clear political commitment together with investments from public as well as private sources. But probably most importantly, we need creative ideas. We have seen over the past years that there are no "one-size-fits-all approaches" for designing sanitation systems for those most in need, for spreading and scaling-up good ideas, and for developing truly sustainable sanitation solutions, that look at the full sanitation chain and cater to human and environmental health alike.

This is where SuSanA comes in. For me, SuSanA represents a wonderful source of ideas and solutions for sustainable sanitation; as a unique network of experts from around the world, SuSanA is poised to develop, disseminate and implement those solutions to make sanitation access achievable, socially acceptable and affordable.

The core of SuSanA are its working groups, where experts get together on specific issues pertinent to sanitation ranging from technical questions around sanitation, such as sanitation systems, operation and maintenance, via governance aspects, such as planning, community involvement, to interconnected issues, such as renewable energy, climate change and food security.

I find SuSanA's holistic approach particularly appealing: looking not only at sanitation at the household level, but asking what does this mean for wastewater management; how are sanitation and food security interlinked? What benefits can be reaped from improved sanitation for developing a green economy, promoted as one of the outcomes of the Rio Plus 20 Conference? SuSanA's work shows that sanitation has a great potential to not only help realise the human right to sanitation and to bring dignity to billions of people, but to be so much more.

The wealth of this knowledge is contained in the factsheets prepared by the expert working groups and published in a compiled form for the first time. I congratulate SuSanA on this important publication and hope that the factsheets will contribute to making this important knowledge widely available.

Dr. Uschi Eid
Vice Chair – UN Secretary General's Advisory Board on Water and Sanitation (UNSGAB)

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Preface and acknowledgements

This factsheet book is a compilation of 13 thematic factsheets which were produced by the eleven SuSanA working groups. What makes these factsheets special is that they are multi-authored by people from different organisations and by free-lance consultants. The factsheets were developed in a long process involving many discussions and review loops which were mostly carried out in public, e.g. at working group meetings, with the working group mailing lists or, since July 2011, also in the open SuSanA discussion forum.
http://forum.susana.org/forum/categories/6-susana-working-groups

The SuSanA working groups were established in 2007 in order to cover a variety of different thematic aspects of sanitation and to increase the understanding and knowledge exchange about these aspects. They are a platform for experts and interested individuals to share and exchange their knowledge on specific aspects of sanitation. We invite you to join the pool of experts and contribute to the discussions by joining some of the SuSanA working groups.
www.susana.org/working-groups

We thank all the authors and contributors to these factsheets who have often volunteered their own private time, outside of their normal work commitments, to work on this. Their names are given on the following pages.

I also wish to thank my team at the SuSanA secretariat – which is hosted by GIZ in Germany – who were part of this factsheet compilation process since July 2011 and who have helped to raise the quality of the factsheets to a consistently high standard, in terms of content as well as layout: Enno Schröder, Martina Winker, Philipp Feiereisen, Christian Rieck, Doreen Mbalo and Bismark Yeboah. Special thanks are due to Leonie Kappauf and Rahul Ingle from my team who worked on numerous factsheets and the layout, as well as to Trevor Surridge who proof-read the entire compilation and gave detailed critical feedback on each factsheet. We are also grateful to Sunder Subramanian, a SuSanA member from India, for writing the first version of the executive summary.

If you spot any errors or omissions in this factsheet book please e-mail us at *susana@giz.de*. The individual factsheets and this book are available on the SuSanA website. *www.susana.org/library*

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Dr. Elisabeth von Münch

On behalf of the SuSanA secretariat
Located at GIZ, Eschborn, Germany
Eschborn, April 2012

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Madeleine Fogde (SEI, Sweden), Arne Panesar (GIZ, Germany), Markus Starkl (BOKU Vienna, Austria and IWA-SWMDC), Ayesha Irani (Luis Berger, Panama), Norbert Brunner (CEMDS, Austria), Valentin Post (WASTE, Netherlands), Alexander Krohs (RWTH, Germany), Annika Schöpe (formerly GIZ, Germany), Elisabeth von Münch (GIZ, Germany).

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Elisabeth von Münch (GIZ, Germany), Patrick Bracken (AHT, Germany), Mirko Hänel (TTZ, Germany), Dexter Lo (Xavier University, Philippines), Christoph Platzer (Rotaria del Perú, Peru), Rob Lichtman (e-systems, the Netherlands), Kim Andersson (SEI, Sweden).

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Elisabeth von Münch and Rahul Ingle (GIZ, Germany), David Del Porto (Ecological Engineering Group Inc, USA), Alexander Grieb (KfW, Germany), Ian Pearson (consultant, South Africa).

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Moussa Bonzi (CREPA, Burkina Faso), Dierk Demand (consultant), Axel Drescher (University Freiburg, Germany), Philipp Feiereisen (GIZ, Germany), Jörn Germer (University Hohenheim, Germany), Richard Higgins (Nutrition Through Food, United Kingdom), Robert Holmer (AVRDC, Thailand), Ester de Jong (GWA), Håkan Jönsson (SLU, Sweden), Cecile Laborderie (ECODOMEO, France), Analiza Miso (XU SUSAN Center, the Philippines), Elisabeth von Münch (GIZ, Germany), Thilo Panzerbieter (GTO, Germany), Gerhard Pelzer (consultant, Germany), Gopal Poyyamoli (Pondicherry University, India), K. V. S. Prasad (AME Foundation, India), Anna Richert (consultant, Sweden), Arno Rosemarin (SEI, Sweden), Emery Sindani (SuSan Design, Kenya), Laurent Stravato (iDE, Burkina Faso), Christine Werner (GIZ, Morocco).

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Elisabeth von Münch and Rahul Ingle (GIZ, Germany), Paul Okan-Adjetey (student, Germany).

WG 7a: Sustainable sanitation for schools

Eugene Dusingizumuremyi (KIST, Ministry of Infrastructure, Rwanda), Tabbie Mnolo (CCODE, Malawi), Agnes Mugure (formerly ROSA project, Kenya), Annie Shangwa-Kanyemba (Aquamor, Zimbabwe), Edward Bwengye (UNICEF, Zimbabwe), Hanna Sterve (formerly SEI, Sweden), Ron Sawyer (SARAR, Mexico), Christian Rieck (GIZ, Germany), Marielle Snel (IRC, the Netherlands), Margriet Samwel (WECF, Germany).

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WG 8: Sustainable sanitation for emergencies and reconstruction situations

Madeleine Fogde (SEI, Sweden), Julien Eyrard (ACF, France), Gert de Bruijne (WASTE, the Netherlands), Daudi Bikaba, Andy Bastable, Tim Forster (all three from Oxfam, United Kingdom), Elisabeth von Münch, Doreen Mbalo, Leonie Kappauf (all three from GIZ, Germany), Deepa Patel (consultant, USA).

WG 9a: Sanitation as a business

Jürgen Eichholz (Saniblog, Germany), Trevor Mulaudzi (The Clean Shop, South Africa), Arne Panesar (GIZ, Germany), Claudia Powers and Katharina Kurianowski (both formerly WTO, Singapore), Marius Kriening (Ecoloove, India), Dorothee Spuhler (seecon, Switzerland), Aleksandra Drewko (TU Hamburg-Harburg, Germany), Elisabeth von Münch (GIZ, Germany), Rafael Ziegler (GETIDOS, Germany).

WG 9b: Public awareness raising and sanitation marketing

Jürgen Eichholz (Saniblog, Germany), Surveyor Efik (Climate Change Network, Nigeria), Thorsten Kiefer (WASH United, Germany), Ajit Seshadri (The Vigyan Vijay Foundation, India), Jack Sim (WTO, Singapore), Saskia Castelein (WSSCC, Switzerland), Denise Scrase (WTO, Singapore).

WG 10: Operation and maintenance of sustainable sanitation systems

Jonathan Parkinson (IWA, United Kingdom), Elisabeth von Münch (GIZ, Germany).

WG 11: Sustainable sanitation and groundwater protection

Christian Olt (formerly GIZ, Germany), Jan Taat (Xavier University, Philippines), Rabani Adamou (FAST, UAM, Niger), Michael Klaus (National Environmental Protection Agency, Afghanistan), Ian Pearson (consultant, South Africa), Declan Page (CSIRO, Australia)

Executive summary

The target audience for this document includes a wide range of readers who are interested in aspects of sustainable sanitation and their links with other environmental and development topics. Possible readers include practitioners, programme managers, engineers, students, researchers, lecturers, journalists, local government staff members, policy makers and their advisers or entrepreneurs. The emphasis of this document is on developing countries and countries in transition.

The Sustainable Sanitation Alliance (SuSanA) is a loose, informal network of organisations such as NGOs, private companies, governmental and research institutions as well as multilateral organisations that aim to contribute towards achieving the Millennium Development Goals (MDGs) by promoting sustainable sanitation.

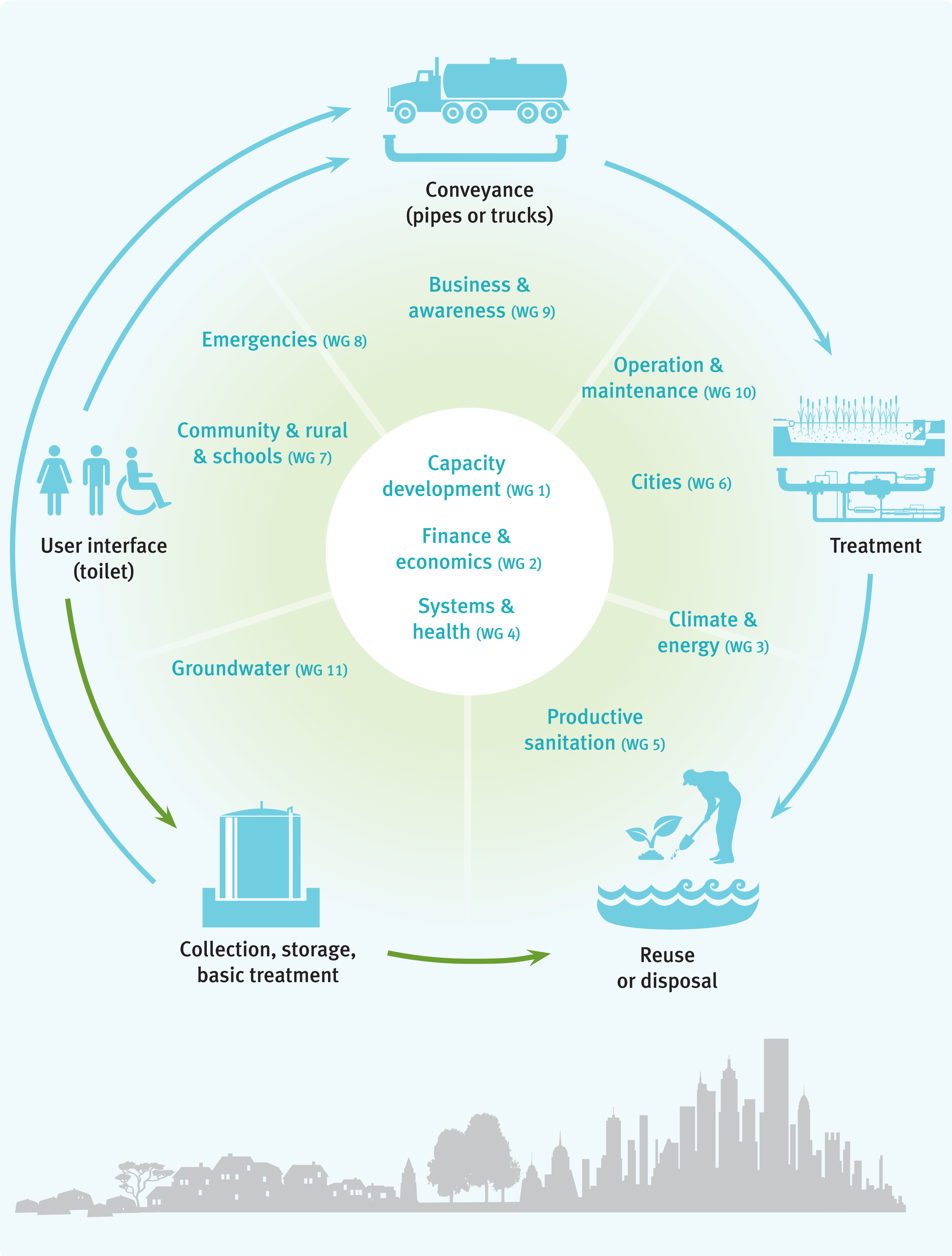
Sanitation generally refers to the provision of facilities and services for the safe disposal of human excreta and domestic wastewater. Personal hygiene practices like hand washing with soap are also part of sanitation. Sanitation also includes solid waste management and drainage but these two aspects are not the focus of this publication. In order for a sanitation system to be sustainable, it has to be economically viable, socially acceptable, technically and institutionally appropriate, and protect the environment and natural resources.

SuSanA contributes to the policy dialogue towards sustainable sanitation through its resource materials and a lively debate amongst the members during meetings, in the working groups, bilaterally, through joint publications and via various communication tools like the open online discussion forum. This publication showcases the broad knowledge base and state of discussions on relevant topics of sustainable sanitation. All of the working groups have published one or two factsheets providing a broad guidance relating to their specific thematic area.

The 11 working groups of SuSanA have the following titles:

WG 1 Capacity development
WG 2 Finance and economics
WG 3 Renewable energies and climate change
WG 4 Sanitation systems, technology, hygiene and health
WG 5 Food security and productive sanitation systems
WG 6 Sustainable sanitation for cities and planning
WG 7 Community, rural and schools (with gender and social aspects)
WG 8 Emergency and reconstruction situations
WG 9 Sanitation as a business and public awareness
WG 10 Operation and maintenance
WG 11 Groundwater protection

Due to the inter-relationships between the working groups, the factsheets are inter-related and where appropriate, are cross-referenced. The factsheets relate to different parts of the "sanitation chain", which consists of user interface, conveyance, collection/storage, treatment, reuse or disposal. We have attempted to visualise the linkages between the different working groups and the sanitation chain in *the following schematic*. There are some working groups which are dealing with overarching themes and these have been placed in the centre of the schematic.



Schematic to indicate how the 11 working groups of SuSanA relate to the sanitation chain and to each other.
In brackets are the numbers of the respective working groups.

Key messages of each factsheet are provided below:

Factsheet of WG 1 on "Capacity development for sustainable sanitation" provides an overview on basic principles of capacity development and addresses current challenges and gaps in capacity development for sustainable sanitation, as well as possible strategies and instruments to address those. Furthermore it contains a list of examples and contact details of capacity development initiatives from the sector. The key messages are:

- Capacity development for sustainable sanitation requires cross-sectoral cooperation with individuals and within organisations from health, infrastructure, water, environment, agriculture, education, economic development etc.
- It considers the complexity of sanitation systems and takes place along the sanitation chain, considering all technical, financial, social and institutional aspects.
- It includes a variety of methods: education, professional training, support for documentation of appropriate local infrastructure and sharing knowledge in print, online and multi-media.

Factsheet of WG 2 on "Financial and economic analysis" introduces concepts of costs and economics in connection with sustainable sanitation, and describes the application of and differences between financial and economic analyses. It provides an overview of analytical approaches for comparing sanitation interventions, and illustrates these approaches using evidence from existing studies. The main focus is to provide a basis for financial decisions concerning the scaling up of sanitation services. The data generated by financial and economic analyses have major implications for the programming and design of sanitation projects.

Factsheet of WG 3 on "Links between sanitation, climate change and renewable energies" argues that sustainable sanitation projects can contribute to both climate change mitigation (through energy or nutrient recovery) and to climate change adaptation (through innovative sanitation systems and wastewater management). Measures for renewable energy production consist of either biogas production from wastewater or biomass production through the use of wastewater to grow short rotation plantations for firewood. Measures of nutrient recovery are primarily based on nitrogen reuse. Adaptation measures in the area of sanitation aim at coping with increasing water scarcity or flooding.

Factsheet of WG 4 on "Sanitation systems and technology options" highlights the fact that with so many innovations and existing technologies for different settings, difficulties with knowledge dissemination hinder informed decision making and the integration of all sanitation elements with each other and the water and nutrient cycle. This factsheet makes a plea for a sanitation system approach where technologies are categorised based on their "product-process" characteristics and then linked into logical systems using a "flowstream" concept. This method for organising and defining sanitation systems helps facilitate informed decision making and consideration of an integrated approach. By using the sanitation system and its technology configurations other aspects can be further highlighted such as the inherent implications for operation and management, business and management models, service and supply chains, possible involved stakeholders, and finally the associated health risks by exposure of different groups of people to waste products.

Factsheet of WG 5 on "Productive sanitation and the link to food security" provides information on the link between sanitation and agriculture as well as related implications on health, economy and the environment. It shows examples of treating and using treated excreta and wastewater in food production and describes the potential for urban agriculture and resource recovery in rural areas thereby contributing to food security and helping to reduce malnutrition. Institutional and legal aspects, business opportunities and how to manage associated health risks are also discussed. Productive sanitation is the term used for the variety of sanitation systems that make productive use of the nutrient, organic matter, water ansedd energy content of human excreta and wastewater in agricultural production and aquaculture. The implementation and scaling-up of productive sanitation systems is inhibited by weak, non-existing and sometimes prohibiting legislation. It is therefore necessary to develop relevant legislation along the sanitation chain taking into consideration the type of crops, occupational health, food hygiene and other preventive and risk management measures.

Factsheet of WG 6 on "Planning of sustainable sanitation for cities" deals with the planning of sustainable sanitation for urban and peri-urban areas to achieve comprehensive and inclusive sanitation coverage in cities. It elaborates on the shortcomings of supply-driven planning and presents three demand-led approaches which recognise that stakeholder involvement is a prerequisite to effective planning. Guiding principles for better sanitation planning in cities of developing countries are proposed. The key messages of this factsheet are:

- Recent innovations in sanitation planning include a more integrated planning approach; a greater emphasis on the actual needs and financial capacity of the users, close consultation with all stakeholders and a systems approach to sanitation, integrating all domains of the city.
- Improving sanitation coverage especially for the urban poor means tackling vested interests and corrupt practices of regulatory authorities, the private sector and politicians. Planning must openly deal with these issues and seek to increase incentives for anti-corrupt behaviours and to achieve greater transparency at community and city levels.

Factsheet of WG 7a on "Sustainable sanitation for schools" emphasises that schools should educate children and provide a healthy environment but are often unable to fulfil these obligations. This is mostly due to the lack of motivation and attention to sanitation and hygiene. Behaviour is typically formed during childhood and therefore education and learning life-skills on health and hygiene in schools are vital to improving conditions of people's lives from childhood to adulthood. The guiding principles for successful and sustainable school sanitation are:

- Creating demand through stakeholder involvement (demand-driven approaches) and identification of suitable sanitation technologies for local conditions including reuse options in school gardens.
- Monitoring outcomes, impacts and processes, including health and hygiene assessments, school attendance and usage of facilities.
- Establishment of an enabling environment with relevant government ministries through the development of guidelines and standards, legislation and enforcement and sufficient budget provision.

Factsheet of WG 7b on "Integrating a gender perspective in sustainable sanitation" is based on the premise that access to safe sanitation is a basic human right for all women, men and children. Integrating gender in sanitation requires comprehensive information about the gender specific local context provided by assessments such as socio-economic analyses and impact assessments of policies and programmes on females. Key messages from this factsheet are:

- Gender equality is an integral part of sustainable sanitation meaning that the sanitation system should consider the differing needs and should be suitable for women, men and children. Females are often involved in water, hygiene and sanitation but lack support to deal with these issues.
- There is a widespread lack of suitable sanitation facilities compounded by a lack of privacy. This increases female vulnerability to violence and impacts their health, well-being and dignity.
- The special needs of menstruating females need to be considered in appropriate sanitation programme designs by providing adequate female hygiene materials, discreet disposal and washing facilities.

Factsheet of WG 8 on "Sustainable sanitation for emergencies and reconstruction situations" emphasises that to reduce the risk and potential effects of disasters, sanitation solutions need to be robust to buffer against certain challenging environments. In emergency situations, groups with specific needs need to be considered (i.e. children, women, elderly, injured and people with disabilities) and appropriate emergency relief measures for each stage of an emergency situation need to be selected. The factsheet recommends the following to the actors in the emergency and reconstruction sectors:

- When implementing immediate sanitation solutions, apply those which can be adapted in later phases to become more sustainable.
- In between emergencies incorporate risk reducing measures in local and urban planning which will prevent and reduce the need for response efforts.
- Engage in learning activities, and experiment together with other professionals to increase innovation of options.

Factsheet of WG 9a on "Sanitation as a business" illustrates activities that can create revenues for investors and local entrepreneurs and also highlights some of the challenges in delivering sustainable sanitation services to the poor. The key messages of this factsheet are:

- Sanitation can be a viable business opportunity and has the potential to provide multiple benefits to the poor. Market-based approaches seek to address the challenges of financial sustainability and to strengthen the role of the private business sector while empowering local communities and individuals to make their own informed decisions about obtaining sanitation products and services.
- The challenge is still to identify effective, scalable, and sustainable sanitation solutions with economic potential and to allocate investment capital and funding to implement these solutions on a large scale.

Factsheet of WG 9b on "Public awareness raising and sanitation marketing" highlights the importance of public awareness raising and sanitation marketing to increase the efficiency and sustainability of sanitation improvements. Four key approaches to awareness raising include (i) raising overall public awareness, (ii) professional marketing of sanitation to those lacking access, (iii) stimulating private sector interest in the sanitation market, and (iv) advocating to decision makers in the public, private and civil sectors. The twin fields of awareness raising and sanitation marketing lay the groundwork for successful advocacy and highlight business opportunities in sanitation. These approaches, moreover, make it possible to scale-up and increase the efficiency of current efforts towards improved sanitation for all.

Factsheet of WG 10 on "Operation and maintenance of sustainable sanitation systems" is based on the understanding that effective and efficient operation and maintenance (O&M) is crucial for the sustainable implementation and long-term functioning of sanitation systems. However, issues related to O&M services are often neglected in the design and set-up of sanitation systems and thus non-functioning O&M services are a widespread challenge. The guiding principles for the design of sustainable O&M services are:

- The level of O&M is closely linked to ownership of a facility and the basic understanding of the technology and its functions.
- Clearly defined roles and accountabilities as well as appropriate support and training are essential for the management of O&M services.
- Institutional responsibilities as well as effective mechanisms for cost recovery are needed to ensure sustainable O&M.

Factsheet of WG 11 on "Sustainable sanitation and groundwater protection" stresses that groundwater quality and sanitation are often linked. Pollution of groundwater from unsafe sanitation systems can include pollution by nutrients, pathogens and organic micro-pollutants (including emerging contaminants). Key messages of this factsheet are:

- Land-use planning plays an important role in protecting areas that are vulnerable by restricting the use of these areas.
- Accessible and safe sanitation and good groundwater quality are critical elements for sustained growth in developing countries that require policy and legal support systems to remain effective. This includes developing educational curricula (focussing on groundwater and sanitation) as well as institutional capacity building programmes at all political levels of government.

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SuSanA factsheet

Capacity development for sustainable sanitation

April 2012

1 Summary

This factsheet provides an overview on basic principles of capacity development and addresses current challenges and gaps in capacity development for sustainable sanitation, as well as possible strategies and instruments to address those. Furthermore it contains a list of examples and contact details of capacity development initiatives from the sector. The factsheet is intended for individuals who require or are engaged with capacity development for sustainable sanitation.

The key messages are:

- Capacity is knowledge, information, and attitude.
- Capacity development is the process of unleashing, strengthening, creating, adapting and maintaining capacity over time. It takes place on three levels: individual, organisational and enabling environment. An enabling environment encourages sustainable sanitation thinking and action at local and national levels, which is necessary for policy development.
- Capacity development for sustainable sanitation requires cross-sectoral cooperation with individuals and within organisations from health, infrastructure, water, environment, agriculture, education, economic development etc.
- It considers the complexity of sanitation systems along the sanitation chain (from the user interface, collection, treatment, reuse and safe disposal of sanitation products), considering all technical, financial, social and institutional aspects.
- It is an internal process of change led by communities and nations.
- It insists on knowledge sharing and management and involves development, transfer and use of both explicit and tacit (undocumented) knowledge.
- It includes a variety of methods: education, professional training, support for documentation of appropriate local infrastructure and sharing knowledge in print, online and multi-media.

2 Background

The Millennium Development Goals (MDGs) aim to achieve poverty reduction and sustainable development. The target for water supply and sanitation services is to halve the proportion of people without access to safe drinking water and basic sanitation by 2015. Although extending safe sanitation facilities is neither prohibitively expensive nor technologically unattainable, progress on sanitation actually slowed according to the 2010 report of the Joint Monitoring Programme of UNICEF and WHO.

Sanitation protects and promotes human health by maintaining a clean environment and breaking the cycle of diseases. Sustainable sanitation is far more than toilet availability. Toilets are part of a system that should be economically viable, socially acceptable, and technically and institutionally appropriate. Moreover, sustainable sanitation should also protect the environment and natural resources. This definition results in five key criteria for sustainable sanitation (SuSanA, 2008): a) protection of human health; b) protection of the environment and natural resources (including water resources, ecosystems, fuel wood, etc.); c) viable technologies and operations; d) financial and economic sustainability; and e) socio-cultural acceptability and institutional appropriateness.

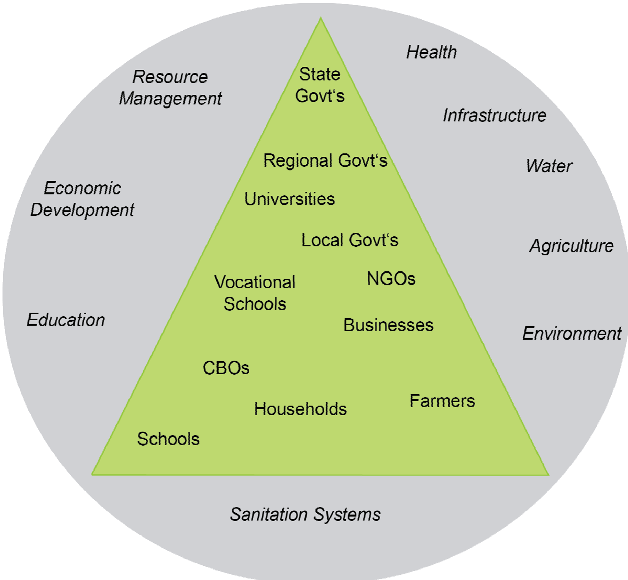

Figure 1: Capacity building takes place at individual, organisational and at the level of an enabling environment. It requires a trans-sectoral approach to health, infrastructure and water, environment, agriculture, and education (source: seecon GmbH).

The Sustainable Sanitation Alliance (SuSanA) is a network of organisations that share a common vision on sustainable sanitation. Since 2007, SuSanA has served as a platform for exchange, coordination and policy dialogue and a catalyst for sustainable sanitation. SuSanA Working Group 1 concentrates on capacity development, which is widely recognised as a prerequisite for the achievement of the MDGs (Bos, 2006; Morgan, 2005).

In the field of sustainable sanitation, capacity development is particularly important due to system complexity and the various sectors and authority levels involved. Governments and decision makers need to be aware of the importance of sanitation and the benefits of sustainable sanitation in order to show leadership and allocate the resources necessary. Leadership involves coordinating different governmental and non-governmental institutions to create an enabling environment across sectors - health, infrastructure, water, environment, agriculture, and education. Institutions and organisations, local governments, planners and the private sector need technical and managerial capacities in order to implement sustainable sanitation within allocated resources. At the same time, the civil society needs to show a demand for sustainable sanitation to ensure that sanitation is put on the local political agenda and to activate the private sector to respond to this demand.

3 What is capacity development?

Although capacity building is promoted as central to development, people everywhere struggle to explain exactly what it is (Bos, 2006; Morgan, 2005). The past decade has witnessed a resurgence of interest in capacity development and with it the redefinition of the concept. Whilst the traditional view of capacity development was based on technical training and foreign expertise, today's approach captures the concept in its complexity and entirety.

For the SuSanA Working Group 1, capacity is the collective actions of groups of individuals, organisations and societies that possess as a whole a collection of specific abilities, which enable them to manage their affairs successfully (Bos, 2006; OECD, 2006).

In a more practical sense, capacities can also be described as knowledge, information, and attitudes (Bos, 2006). Capacity development is the process in which these groups unleash, strengthen, create, adapt and maintain their capacity over time (OECD, 2006). This implies that (Morgan, 2005):

- Individuals have personal abilities, attributes, or competencies that contribute to the performance of an organisation or a system;
- Organisations or broader entities have capabilities to do something (the building blocks of an organisation's overall capacity to perform);
- Organisations or entities try to connect these competencies and capabilities into a coherent combination or system that allows them to perform.

Inside the boundaries of an organisation or a network of organisations, capacity is shaped and influenced by the context: capacity development takes place in a broader, dynamic institutional and socio-economic context. Both planning and implementation of capacity building interventions need to take account of external influences on the context within which organisations operate. Capacity obviously depends not only on the individuals and the organisations in which people work but also on the broader environment of these organisations including the institutional framework and the structures of power and influence (OECD, 2006).

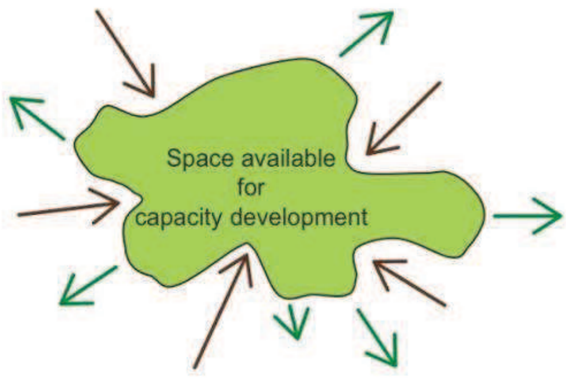

Figure 2: It is important to identify factors that enable capacity development (green outward arrows) and factors which block it (black inward arrows).

According to the above described spheres of capacity development, there are three levels on which to pursue capacity development objectives (OECD, 2006):

1) The individual level: people having abilities and competencies.
2) Organisational or institutional level: individuals make up organisations and institutions; the sharing of skills, knowledge, experience and values amongst the individuals will translate into the organisation's capacity, consisting of procedures, systems, policies and culture.
3) The enabling environment: incentives, policies and governance influence the behaviour of organisations or institutions and individuals.

These three levels of capacity development are equally important and interdependent. This implies that capacity development interventions at one level are likely to have an impact on other levels as well. Successful efforts to promote capacity development lead to:

- Increases in the knowledge and skills of individuals - the "micro" perspective (Baser and Morgan 2008);
- Enhancement of the quality of the organisations in which they work (organisational procedures);
- Creation of an enabling environment (e.g. the incentives, policies and governance influencing the behaviour of the organisations – the "macro" perspective).

4 Principles of capacity development in sustainable sanitation

Without developed capacity there is limited exchange and transfer of knowledge; inefficient use of available resources; poor service delivery, second-rate performance; inadequate infrastructure, that is poorly adapted to the local context and insufficient maintenance.

There are five key requirements for capacity development for sustainable sanitation:

- A multi-disciplinary approach with attention to the various social, political and institutional, environmental, technical and financial dimensions.
- A trans-sectoral approach.

- Attention along the entire sanitation chain – from the user interface, collection, treatment, reuse and safe disposal of sanitation products.
- Action at all three analytical levels: individual, organisational and enabling environment.
- Inclusion of local and national actors from civil society, the private sector and the government.

a) Capacity development at individual and the institutional levels

Local governments need capable sanitation engineers, health extension workers, policy makers, managers, and operators to plan and manage technical infrastructure and to adapt projects and programmes to the local context. A sound understanding of the whole sanitation system is crucial so that collaborating experts in health, infrastructure, resource management, agriculture and economic development can work effectively together.

Professionals form most of their ideas during their training. Education and training programmes in universities, technical schools and research institutes need to include sustainable sanitation in their curricula, develop appropriate materials, and serve as regional resource centres. Similarly NGOs, CBOs and local, regional and national governments can compile information on sustainable sanitation, share it with staff and organise workshops for professionals.

At the same time, understanding of local perceptions, needs and preferences facilitates efficient social marketing and demand creation. Information of end-users together with the practical training and access to financing opportunities for small businesses can activate the local private sector. User demand also helps integrate sustainable sanitation in local agendas.

b) Creating an enabling environment

Sanitation often lacks an “institutional home” because of its multi-disciplinary and trans-sectoral character. Governments commonly deal with different aspects of sanitation systems in several ministries; this hampers coordination, strategic planning and financing of capacity development.

Sustainable sanitation has to be integrated in key national policies, technical guidelines, sub-national guidelines and thematic strategies to stimulate good governance and political leadership. This will lead to ownership, participation and allocation of financial means. Thereby, the preparation of strategies and guidelines has to be part of an internal process of change (OECD, 2006). Furthermore, incentives for regional governments and private sector organisations can help to create an enabling environment. Information of the benefits of sustainable sanitation in the local language fosters the process of creating an enabling environment and supports the national government to do a good job. Thus busy government officials working with tight budgets can be provided with key arguments for sustainable sanitation. Local drivers for sustainable sanitation such as health or food security can be identified and included in the information.

5 Strategies and Approaches

Capacity building is neither an output nor project but a continuous process (Bos, 2006). It is important to develop strategies according to the specific level (individual, organisational, enabling environment) and the domain (knowledge and information, skills, and attitudes) of the capacity being built.

Organisations may have the following strategies and approaches:

- Assess gaps in capacity within a country and support planning, implementation and monitoring of performance for capacity development within the country.
- Consider a country-led approach and build on internal processes by identifying local drivers for sustainable sanitation (e.g. groundwater pollution, food security, etc).
- Adapt language and means of communication to the local context.
- Create strategic partnerships between different actors e.g. businesses, local governments and institutions that are actually implementing capacity development such as knowledge sharing and training.
- Focus on relationships between the enabling environment and other levels to align training and development of individual skills with organisational reforms and institutional changes.
- Increase awareness of sustainable sanitation through the media and special events, such as the World Toilet Day on 19 November each year.

6 Instruments

Education: Educational institutions need to acknowledge the importance of sustainable sanitation and incorporate this interdisciplinary topic into teaching curricula.

Training: Professional engineers, policy makers, managers and operators working in the field can be trained in special courses, workshops, seminars, and on the job training.

Research and documentation: It is important to document research, pilot projects and examples of scaling-up in the ongoing process of capacity development.

Knowledge and information management and sharing: The transfer and exchange of knowledge is a precondition of capacity development. Different users respond to different types of information and channels. New media on the internet make it possible to share and exchange knowledge much more easily. Academic books and journal articles require purchase but usually information is more carefully reviewed than that freely available online. Compiling and making relevant information accessible fosters capacity development. Universities and schools should be equipped with the skills to enable them to share and manage knowledge. Institutions that manage knowledge consistently are better poised to meet the ever-changing management and development challenges. Networks and learning alliances play a major role in improving knowledge sharing and management.

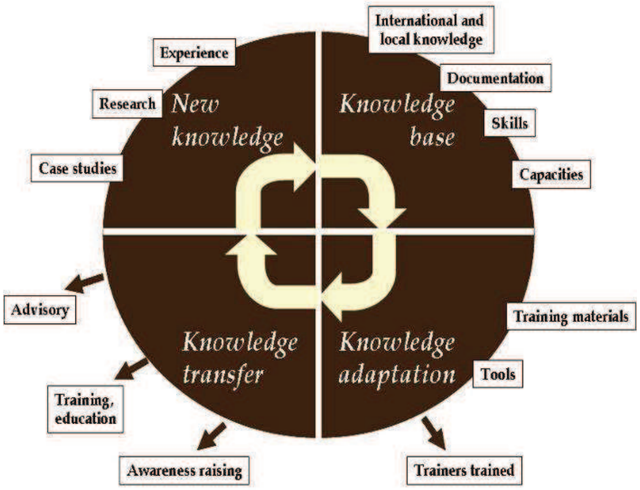

Figure 3: Knowledge management is the continuous process of generating new knowledge or repackaging old knowledge; of creating a knowledge base; of knowledge adaptation; and of knowledge transfer (source: Cap-Net, 2004).

Box 1: Knowledge management nodes funded by SEI

In 2006 the Swedish Development Cooperation (SIDA) and the Stockholm Environment Institute (SEI) launched Phase 2 of their EcoSanRes Programme (2006-2011). The main intention of the initiative was to promote pro-poor sustainable sanitation through capacity building and knowledge management. The programme therefore facilitated the establishment and development of "nodes of expertise" ("knowledge nodes") that have conducted regional projects dealing with awareness raising, training, policy and regulation reform, R&D, testing and development, demonstration and social marketing. The programme has established eight knowledge nodes; one in the Philippines, China, Nepal, Southern Africa, Uganda, Burkina Faso, Central America and Bolivia. The nodes have been hosted by renowned research and knowledge management institutions and set the programme content and priorities for their respective regions individually. The knowledge dissemination and capacity development activities in the knowledge nodes have so far resulted in national policy changes in the Philippines, Honduras, El Salvador, Bolivia and Uganda and at a regional policy level the Manila Declaration was initiated. Although the funding for the nodes only lasted for about two years and stopped in mid 2011, SEI is still collaborating with all nodes and is planning to continue to support the node structure. Also, the nodes have brought and continue to bring financing and capacity to their hosts.

Further information: www.ecosanres.org

7 SuSanA partners in capacity building

Conventional capacity building and North-South knowledge transfer have proven inadequate for scaling up sanitation innovation. A number of SuSanA partners, however, have acted strategically and pioneered a variety of promising approaches. The list of examples that follows is not complete. A similar list, which is continuously updated, is available on the SuSanA website: www.susana.org.
The SuSanA secretariat welcomes corrections or additions to this list (info@susana.org or susana@giz.de).

a) Reference centres and knowledge nodes

Water Research Commission (WRC), (www.wrc.org.za/Pages/KnowledgeHub.aspx): South African knowledge hub offers research reports, technical and policy briefs, and magazine articles on water resource management, including agricultural water use, drinking water, wastewater, and water for mining, and sanitation. Formerly hosted the SADC Node for Sustainable Sanitation (SAKNSS) (www.afrisan.org); which offered learning events and study visits, a stakeholder database, case studies and publishes regional *Sanitation Matters* magazine.
Contact: Ditshego Magoro (ditshegom@win-sa.org.za)

African Regional Centre for Water and Sanitation (CREPA), (www.reseaucrepa.org): Intergovernmental organisation with 18 member states in West and Central Africa; training courses and practical experience in various technologies and reuse.
Contact: reseaucrepa@reseaucrepa.org)

NETWAS, (www.netwas.org): Hosts former Ugandan knowledge node; organises training and field demonstration of ecological sanitation (ecosan) installations; has influenced national sanitation strategy.
Contact: Cate Nimanya (netwasuganda@gmail.com)

ENPHO (Environment and Public Health Organization) (www.enpho.org/resource-center.html): Resource centre in Nepal; collects, stores and disseminates information for education and advocacy on the environment and public health; offers consultancy services.
Contact: Bushan Tuladhar (bushan.tuladhar@gmail.org)

Centre for Advanced Philippines Studies (CAPS), (www.caps.ph): Knowledge node of SIDA-founded EcoSanRes programme; secretariat of the Academic Consortium for Sustainable Sanitation (ACSuSan); offers formal and non-formal courses; has physical library and web database.
Contact: Dan Lapid (danlapid@caps.ph)

Asociación Centro Ejecutor de Proyectos Económicos y de Salud (ACEPESA), (www.acepesa.org): One of the first established knowledge nodes for Central America; based in Costa Rica; supports implementation of integral solid waste management systems based on models of communal micro-enterprises; offers online courses.
Contact: Victoria Rudin (vrudin@acepesa.org)

Regional Water and Sanitation Network of Central America (RRASCA) and the National Water and Sanitation Networks of El Salvador, Guatemala, Honduras and Nicaragua; have contributed to national guidelines for sustainable sanitation and to streamlining of gender equity in projects; helped introduce sustainability criteria in water and sanitation development plans in Honduras and Nicaragua.
Contact: Gloria de Avila (gavila.rases@gmail.com)

Netherlands Development Organization (**SNV**): La Paz office hosts Bolivia knowledge node directed by the national sanitation collaboration platform for local, regional, and national government entities (DINESBVI, sites.google.com/site/dinesbvibolivia/); recently contributed to national guidelines on ecological sanitation and gender equality in water and sanitation; introduced ecological sanitation into the university curriculum; supports eight demonstration projects.
Contact: Eduardo Quiroz (equiroz@snvbo.org)

b) Research institutions or degrees at universities

Xavier University (XU) Sustainable Sanitation (SUSAN) Center; in the Philippines, (www.susancenter.xu.edu.ph): Targets local governments, NGOs, practitioners and academia; research, training, and consultancy services for Southeast and South Asia. Sustainable sanitation is part of engineering curricula; research agendas and includes the use of urine as fertiliser, public health implications of dry sanitation and treatment methods including terra preta sanitation. Also offers training modules, based on the Sustainable Sanitation and Water Management (SSWM) Toolbox; courses in agricultural reuse of urine and faeces; low-cost dry toilet construction; development of urban sustainable sanitation plans; awareness raising and behaviour change strategies; and terra preta sanitation. Contact: Annaliza Miso (annamiso1980@googlemail.com)

University of Science and Technology in Beijing, China, (www.en.ustb.edu.cn): Offers MSc in Environmental Sanitation; established the Centre for Sustainable and Ecological Sanitation (www.susanchina.cn) for PhD and Master students. Jointly hosts the China Node for Sustainable Sanitation (CNSS) together with the Clean Water Alliance.
Contact: Prof. Li Zifu (zifulee@yahoo.com.cn)

National Agricultural University in Peru, (www.agricolaunalm.edu.pe): Diploma course in "Department of Land Management and Sustainable Development" for sanitation and health professionals.
Contact: Rosa Miglin (rmiglio@lamolina.edu.pe)

CINARA: Research and development institution based at the Faculty of Engineering at Universidad del Valle in Colombia, (cinara.univalle.edu.co); recognized throughout Latin America in the water supply and environmental sanitation sector. Formerly hosted the Columbian knowledge management node.
Contact: (cinarauv@correounivalle.edu.co)

UNESCO-IHE Institute for Water Education (Delft, The Netherlands), (www.unesco-ihe.org): Annual online ecosan course for mid-career professionals from developing countries; addresses ecosan topics in engineering, architecture, planning, financing, and health; scholarships available through the Bill and Melinda Gates Foundation. An MSc degree in Sanitary Engineering and an additional online course in Faecal Sludge Management with the taught part completely carried out through online courses. An additional online course in Faecal Sludge Management are planned to be introduced in the near future.
Contact: Mariska Ronteltap, (m.ronteltap@unesco-ihe.org)

Sandec - the Department of Water and Sanitation in Developing Countries at Eawag: Internationally recognised competence centre with 30 years research in low- and middle-income countries; develops concepts and technologies using Eawag's multidisciplinary knowledge; main activities are applied research, teaching and training, and knowledge management; conducts courses at universities in Europe and the global South (e.g. 2iE in Burkina Faso, Makerere University in Uganda and AIT in Thailand); offers downloadable training tools also available on CD-Rom: (www.sandec.ch).

The Norwegian University of Life Sciences (UMB) is converting sanitary systems on the campus to source separating/recycling systems; offers a joint MSc programme in "Sustainable water and sanitation, health and development" together wth the **Tribhuvan University** in Nepal and **COMSATS University** in Pakistan; prepares a web based course: "Introduction to sustainable water and sanitation" (ready in August 2012). To apply see: www.umb.no/study-options for Norway; www.ioe.edu.np for Nepal and www.comsats.edu.pk for Pakistan.
Contact UMB: Prof. Petter D. Jenssen, (petter.jenssen@umb.no)

Tampere University of Technology (TUT), (www.tut.fi/en): Organises International Dry Toilet Conference every three years with Tampere University of Applied Sciences, the University of Tampere and Global Dry Toilet Organisation of Finland; offers an annual online course about sustainable sanitation with selected lectures from pre-conference workshops.
Contact: Tuula Tuhkanen (tuula.tuhkanen@tut.fi)

Vienna University of Natural Resources and Life Sciences (BOKU), Centre of Development Research (CDR) (www.boku.ac.at): Multidisciplinary network of scientists from various BOKU departments; conducts applied research and training in sustainable natural resource management; collaborates with partners in Africa, Asia and Latin America.

Kristianstad University in Sweden, (www.hkr.se/templates/Programme____5898.aspx): One year MSc in Sustainable Water Management; explores sustainable alternatives to flush-and-discharge approaches, decentralisation, nutrient recycling, and biogas production. Contact: Lena Vought (lena.vought@hkr.se)

Linköping University, Swedish Institute of Infectious Disease Control, and Swedish University of Agricultural Sciences have developed the sourcebook "Sustainable Sanitation for the 21st Century" (http://www.sustainablesanitation.info): Intended for university training programmes for lecturers' use as well as for self-study; provides powerpoints commented in attached pdf files which can be combined with the trainer's own material.

Figure 4: Participants of SSWM Experts Training Course at the CHRDU Training Centre in Nagarkot, Bhaktapur, Nepal in 2010 interacting in group work (source: seecon GmbH).

c) Training courses for professionals

Sarar Transformación SC, (www.sarar-t.org): Multi-disciplinary Mexico-based consulting group; supports organisations in the region in sustainable sanitation; influences policy dialogue through strategic alliances with governmental organisations; offers regular training courses in sustainable development and participatory approaches. Contact: Ron Sawyer (rsawyer@sarar-t.org)

Sustainable Sanitation and Water Management (SSWM) Toolbox, (www.sswm.info): Open-source and quality-approved online capacity building tools that link up water management, sanitation and agriculture at the local level; can be used as teaching support as well as self-learning tool; designed as process and planning tool for planners; implementation tool for NGOs and practitioners; resource for leaders and decision makers; or learning tool for students; offers guided exercises to assess local problems, factsheets on hardware (technical solutions) and software (behavioural change), and project planning and implementation tools; includes supplementary readings, links, a library, glossary, ready-made PowerPoint and "train-the-trainers" materials; developed with support of SuSanA partners (www.sswm.info/content/partners) under the aegis of seecon.
Contact: (sswm@seecon.ch)

seecon International, (www.seecon.ch): Offers courses and training in sustainable sanitation and water management based on the **SSWM** Toolbox (www.sswm.info) acts globally; the portfolio includes basic to expert courses, hands-on training and training of trainers; innovative participatory learning in partnership with international and regional organisations.
Contact: (sswm@seecon.ch)

Linköping University, Swedish Institute of Infectious Disease Control, and Swedish University of Agricultural Sciences (see previous Section b.).

Ecosan Services Foundation, (www.ecosanservices.org): Based in Pune, India; provides training activities based on the Sustainable Sanitation and Water Management (SSWM) Toolbox; open source knowledge provider that works with a pool of private sector experts, NGOs, and research organisations; immense experience in developing urban sustainable sanitation plans; offers consulting services, including design of decentralised wastewater treatment systems.
Contact: (sreevidya.satish@ecosanservices.org)

Figure 5: Hands-on training in secondary composting at SIDA's International Training Programme in 2005 (source: SEI).

For further information on training courses see this SuSanA webpage (www.susana.org). For course materials from various courses see: www.susana.org/lang-en/conference-and-training-materials/materials-of-trainings.

d) Web-based libraries and Open Source Publications

SuSanA Library, (http://www.susana.org/lang-en/library): Has a large collection of materials on sustainable sanitation; SuSanA also provides a DVD with a large portion of library contents to those with slow internet connections.
Contact: (info@susana.org or susana@giz.de)

The **Sustainable Sanitation and Water Management (SSWM) Toolbox,** (www.sswm.info): Gives an overview of approaches and technologies in the water management and sustainable sanitation sector including both planning and implementation.
Contact: (sswm@seecon.ch)

International Water and Sanitation Centre (IRC), (www.irc.nl): Independent non-profit organisation based in the Netherlands that conducts research in areas where existing information is insufficient; works collaboratively with partners on literature reviews, advocacy meetings, publications and information sharing workshops, documents 40 years of sector progress, analysis and tools; provides direct access to ever-increasing number of documents; the database also contains externally-produced documents on sanitation at (www.irc.nl/page/116). Sanitation searches at online library: (www.washdoc.info/page/53887).

Water, Engineering and Development Centre (WEDC), (www.wedc.lboro.ac.uk/knowledge/know.html): Knowledge base maintained by Loughborough University, United Kingdom. Database of WEDC's own and other selected publications; available for registered users to download free of charge are WEDC's own resources, including 150 books, over 1700 conference papers and other key documents in pdf format.

Other Online Resources:

- www.giz.de/ecosan (with quarterly electronic newsletter in English and French)
- www.ecosanres.org
- www.sustainablesanitation.info/meny.html
- www.library.eawag-empa.ch and http://www.eawag.ch/forschung/sandec/training_tool/
- www.akvo.org and www.akvopedia.org/
- www.cap-net.org
- www.gwptoolbox.org
- www.grassrootswiki.org
- www.iwawaterwiki.org
- www.practicalaction.org/practicalanswers/
- www.genderandwater.org
- www.ecosan.at

e) E-mail discussion group, online forums, blogs, and newsletters

SuSanA Forum (www.forum.susana.org): Open discussion platform launched by the Sustainable Sanitation Alliance in July 2011; all postings are readable by everyone and searchable by search engines like Google; participants can create new topics, post queries, users may subscribe to receive email alerts.

Figure 6: Participants at the 13th SuSanA meeting in Kigali in July 2011 (source: SuSanA).

EcoSanRes email discussion group: Started by Stockholm Environment Institute (SEI) in 2001; registered members discuss technical questions, contacts, information on ongoing projects, funding opportunities and more (www.ecosanres.org/discussion_group.htm). Join the 800 member group via ecosanres website (www.ecosanres.org/discussion_group.htm) or directly via yahoo: tech.groups.yahoo.com/group/ecosanres/

Sanitation Updates: News feed jointly maintained by the International Water and Sanitation Centre (IRC) and USAID's WASHplus project; provides news, information and resources in support of the goal of sanitation for all (www.sanitationupdates.wordpress.com/).

IRC E-Source: WASH news and features in English, French and Spanish with an emphasis on rural and peri-urban areas in developing countries (www.source.irc.nl/).

Other web-based news and discussion:

- www.watersanitationhygiene.org (forum on water, sanitation and hygiene)
- www.assemblyonline.info (news service from Nigeria)

f) Learning alliances, communities of practice and networks

Sustainable Sanitation Alliance (SuSanA), (www.susana.org): Informal network of partner organisations sharing a common vision on sustainable sanitation; has served since 2007 as a coordination platform, a work space, a sounding board, and a catalyst; contributes to policy dialogue, conferences and events. Offers for example an extensive online library, a case study collection, and a partial copy of website on DVD; available are a vision document, a joint road map and factsheets authored by eleven thematic working groups and a discussion forum.
Contact: (info@susana.org or susana@giz.de)

Global Community of Practice for Sanitation and Hygiene: Initiative of the Water Supply and Sanitation Collaborative Council (WSSCC) launched in 2011 in response to sector demand for collaborative learning; global space for honest debate on sanitation and hygiene; platform for national-international and South-South exchange of successes, failures and lessons learned.

Cap-Net (Capacity Building for Sustainable Water Management), (www.capnet.org): UNDP programme that supports capacity development in water management towards achievement of the MDGs; global network made up of professional networks at country and regional levels and international partners; works with networks worldwide; seeks to expand reach, achieve on-the-ground impact and embed new knowledge into existing capacity building institutions.
Contact: (nick.tandi@cap-net.org).

Ecosanlac, (www.ecosanlac.org): Regional Latin America network of professionals and academics interested in ecological sanitation. Shares news of learning opportunities and organises events and conferences.
Contacts: Paula Paulo (ppaulo.ufms@gmail.com) and Ricardo Franci (franci@npd.ufes.br)

g) Video clips

New forms of digital media distribution allow widespread access to quality educational material. Educational films on sustainable sanitation worldwide are available on the SuSanA website: (www.susana.org/lang-en/videos-and-photos/resource-material-video) or on Youtube: (www.youtube.com/user/susanavideos).

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Authors and contributors

Main authors:

- Dorothee Spuhler, seecon GmbH, Switzerland (dorothee.spuhler@seecon.ch)
- Carol McCreary, PHLUSH, USA (carol@phlush.org)
- Madeleine Fogde, SEI, Sweden (madeleine.fogde@sei-international.org)
- Petter D. Jenssen, UMB, Norway (petter.jenssen@umb.no)

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For questions or comments please contact the SuSanA secretariat at info@susana.org or susana@giz.de. We invite you to join the SuSanA discussion forum: www.forum.susana.org. This document is available at www.susana.org.

sustainable sanitation alliance

SuSanA factsheet

Financial and economic analysis

April 2012

1 Summary

This factsheet introduces financial and economic costs and benefits in relation to sanitation systems. It provides an overview of analytical approaches for comparing sanitation interventions using financial and economic analyses and illustrates these using results from various studies. The target group of this factsheet includes sanitation practitioners, researchers, policy makers and their advisers. The main focus is to provide a basis for informed choice based on financial decisions concerning the scaling up of sanitation services.

Financial and economic analyses are a crucial part of feasibility studies assessing the benefits of improved sanitation and thus feed into policy decisions, sanitation programming and project design. The data generated by financial and economic analyses have major implications for the programming and design of sanitation projects, and are therefore crucial for the planning and delivery of affordable and sustainable sanitation services.

In order to assess the relative sustainability of sanitation options, a range if comparative studies need to be conducted to show the real costs and benefits of moving from unimproved to improved and more sustainable sanitation options.

A comparison of costs and benefits of different sanitation options using economic and financial analyses provides a justification for investments in sanitation in the first instance and enables decision makers to allocate limited resources more efficiently. Financial analyses only measure the costs and benefits that have direct and measurable financial implications, whereas economic analyses include all broader costs and benefits, including those that do not have financial implications. For instance the costs for premature mortality are economic rather than financial.

Capital expenditure (CAPEX), operational expenditure (OPEX) and capital maintenance expenditure (CapManEx) are the key parameters for both the financial and economic assessment of sanitation options. Important tools for financial and economic analysis include the cost-effectiveness ratio, Benefit-Cost Ratio (BCR), Net Present Value (NPV), or Internal Rate of Return (IRR). Key indicators for setting tariff structures and the assurance of affordability include: i) Full cost of sanitation per capita as a percentage of per capita GDP, ii) Cost of access to sanitation as a percentage of household income, iii) Annual cost of sanitation as a percentage of household income, iv) Long run marginal cost and cost of sanitation services as a percentage of water tariffs. Economic analysis can also be used to assess the cost benefit of investments in sanitation in relation to other types of development interventions.

2 Background

Financial investment costs are often stated as one of the major barriers to increasing sanitation coverage – next to the lack of political will. Therefore, it is important to know what cash sum is affordable for the beneficiaries (households, communities, schools) and which share has to be financed either by the government, through grants (subsidies), loans from banks, or in-kind contributions (Mehta, 2005).

Although improvements in sanitation are known to result in large economic benefit for society as a whole, the priorities of those who are responsible for investment, whether at the household, municipal or national government level, tend to set investment priorities differently, based on financial constraints and self-interest.

Figure 1: Excavations for a biogas digester in Livingstone, Zambia at a project of the Devolution Trust Fund (DTF) (source: P. Feiereisen, 2011)

Financial and economic analyses are key policy tools, which provide practical guidance on sanitation options, and can be used alongside other decision making frameworks such as multi-criteria analyses. These analyses enable assessment of intervention efficiency for different sanitation options and assist decision makers in maximising the return on limited financial resources available to sanitation programmes. Outputs of economic analysis can show the overall costs and benefits of improved sanitation compared to no or unimproved sanitation.

Financial and economic evaluation seek to provide further insight into the relative cost efficiency of different options –

not just one or two standard options, but the locally adapted range of feasible options – as a basis for an informed choice. The inclusion of all feasible options is of key importance to the process of informing decision makers and planners of the potential range of sanitation options in a single context.

Hence, financial and economic analyses need to provide the decision maker with specific information that helps to judge the real costs and sustainability of different technologies. This means not just knowing the purchase price or capital costs but also operation and maintenance (O&M) costs, and the associated additional (direct or indirect) benefits to the user such as health, comfort and protection of the local environment.

An assessment of the benefits of improved sanitation may be applied to the following activities:

a) Policy decisions
Results from an economic analysis can play an important role in influencing political decisions about the need to invest in improving sanitation (cost benefit analysis). Analyses of economic benefits can support sanitation advocacy efforts, with the aim of increasing political support and potentially household and community knowledge, leading to greater prioritisation of sanitation and hygiene.

Figure 2: Uschi Eid (UNSAGB) giving a speech on the importance of sanitation in the plenary session of the Second Africa Water Week in South Africa (source: A. Panesar, 2009).

b) Sanitation programming
Economic analysis may also be required to justify the rationale for a project or programme in the first instance. On the basis that there is economic justification, financial analysis is used to compare long term costs of different alternative solutions (cost effectiveness) taking into account capital investment (CAPEX), operational and maintenance expenditures (OPEX) and capital maintenance expenditures (CapManEx).

c) Project design
Sound financial analysis is fundamental for good project design. To be able to appropriately cost a project within a given budget, engineers need to base estimates on accurate unit costs and have a clear understanding of the uncertainties surrounding data sets.
Clearly, financial and economic evidence has value for a range of target groups – groups that have different roles and levels of influence in decisions on choice of sanitation technology or programme implementation:

- *For those controlling budgets* for allocation to sanitation programmes the primary concern is for overall programme efficiency; including household, community and external benefits of improved sanitation. Also important to policy makers are the overall financing needs for different programme components and the different sources from which to finance these programmes.
- *For implementing agencies* concern will be not only the overall gains, but also the equitable distribution of the programme gains, and targeting of subsidies to poor and vulnerable groups.
- *For the ultimate beneficiaries* – the households – the interest will be on private benefits and the investment and running costs that must be covered by the household.

3 Financial analysis: elements and indicators

Financial analysis focuses on expenditures and revenue streams and considers subsets of data that are identifiable as financial transactions. Financial assessment of sanitation options considers capital expenditure (CAPEX), operational expenditure (OPEX) and capital maintenance expenditure (CapManEx).

To ensure sustainability, investors of sanitation systems such as utilities or local authorities need to consider the recurring costs for the operation and maintenance to ensure sustainability and not only the initial investment costs. In addition, there is a need to take into consideration service charges and other sources of revenue such as from the sale of by-products (e.g. treated wastewater for irrigation, compost or digested sludge, or electricity derived from biogas).The capital cost of different sanitation options is a very important variable for the decision whether to invest or not, and for the choice of technology. Households, in particular poor ones, are highly sensitive to price in their purchase decisions, especially for sanitation which is not usually a priority item.

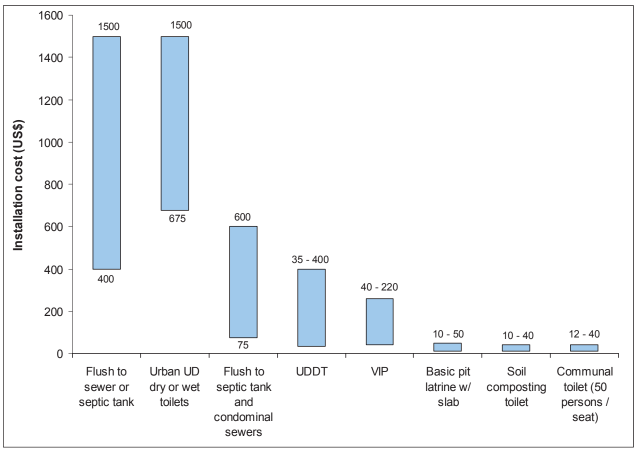

Figure 3: Example capital cost range for different sanitation options, per unit (source: Rosemarin et al., 2005). Note that most of these options do not cover the whole sanitation chain.

As shown in Figure 3, capital costs vary between different sanitation options, the project scale and even within one technology type **CAPEX** includes both hardware for household and shared toilet facilities as well as costs for waste collection, transport and treatment facilities. CAPEX also includes labour and management overheads for planning, construction and works supervision.

OPEX costs are those that are required to sustain the operation and maintenance of a system or facility. These include day to day costs such as labour, fuel, cleaning materials, and costs for repairs OPEX costs include for example pit or vault emptying, a fee for the treatment costs of faecal sludge and for software components.

Software components targeting community acceptance and behaviour change are essential for the uptake, compliance and long-term sustainability of all sanitation systems. Therefore, costs for sanitation promotion and advocacy are important costs that also need to be included in the analysis. Costs of "software" include sanitation promotion and demand creation (e.g. social marketing), awareness and educational campaigns to promote improved hygiene and system use, and capacity development of stakeholders (such as training of artisans, operators and sanitation suppliers). These costs should be planned and fully budgeted for implementation of programmes on a larger scale; these costs should also be considered in the project design and in the OPEX.

CapManEx[1] are costs that cover all expenditures to reduce the chances of asset failure and ensure the same level of service delivery as existed after construction. This includes the renewing, replacement, rehabilitation or refurbishing of broken system such as replacement of pumps.

The decision about which data to include in the financial analysis depends upon the boundary for the analysis which will be determined by the purpose of the analysis and the target group (see above). The most important boundary is between the private and public domains, which defines the costs and benefits to be allocated to the household and those to be allocated to the project respectively. The project expenses include costs that are not incurred by households directly but are incurred by agencies or institutions responsible for promoting and implementing sanitation projects and programmes.

Given the range of sanitation stakeholders, there may exist different interpretations of the word "cost" and the forms of cost presentation. Households are naturally interested in the costs of a single sanitation option as it relates to their particular household, including only the components they actually have to pay for. Therefore, a disaggregation of household and third party costs is useful to be able to account for these different perspectives:

- *Households* - at the time of investment (e.g. connection fee, toilet investment) and during operation (e.g. wastewater levy, cost of sludge removal); and
- *Third parties* - in the form of investment subsidies or recurrent subsidies sourced from donor funds, state budget or cross subsidies such as from water tariffs.

From a household perspective, the main consideration is the expenditure related to sanitation facilities. Household expenditures or costs may be subsidised with external financing in order to reduce the cost to the household. These subsidies are included as part of the total financial analysis, and are expressed as a project cost.

Figure 4: Hygiene promotion activities for Filipino children during Global Handwashing Day in 2008 (source: R. Gensch, 2008).

Financial costs to households can be reduced by encouraging in-kind contributions from household members, and hence not only increasing participation (which is likely to increase the use of and make it easier for the household to maintain and repair their sanitation facility) but also reducing the requirement for cash funds. Households, especially in rural areas, have access to materials such as sand, stone, wood or plant materials for latrine construction. Experience has shown that people are willing to contribute their time and effort as a substitute to local workmen who must be paid in cash[2]. Also, for toilets with reuse options, or simple pit emptying, there will be costs for the work involved, transportation and storage, whether covered through cash payments or in-kind contributions.
It is important to note that increasing the level of investment does not necessarily lead to increased level of service. The service delivery approach tries to shift the focus from the service delivery of physical hardware to the service itself and to differentiate between the different types of service. The IRC WASHCost project assumes that a cost-benefit decision can only be made relating to the level of service delivery (Moriarty et al. 2010).

The following indicators are relatively simple and can provide decision makers with information to support decisions about tariffs and affordability:

i) *Full cost of sanitation per capita as a percentage of per capita GDP (gross domestic product):* To allow for a comparison between different projects or different options within one region.

[1] See: IRC Briefing Note 1b: www.washcost.info/page/866. Further information on life-cycle cost approach on IRC WASHCost working papers: www.washcost.info/page/1293

[2] See for example SuSanA case study on UDDTS in rural Kenya: www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=129

ii) Cost of access to or annual cost of sanitation as a percentage of household income: If households are expected to make a significant up-front contribution without access to a credit mechanism, this single payment might constitute a serious barrier. This can be expressed as per capita access cost as a percentage of the per capita household income. However, average data such as household income should be treated with caution due the large income differences between poor and rich households.

iii) Long run marginal costs (LRMC): The cost for one additional unit with the best resource allocation. It is calculated in relation to per capita and year to compare different regions with different household income.

iv) Cost of sanitation services as a percentage of water tariffs: decision makers often *prefer the cost of sanitation r*elated to water sales. This allows correlating full costs to current sanitation tariffs.

Table 1 shows some examples for these cost indicators and illustrates considerable differences in the share of operation and maintenance costs as part of total costs, ranging from 0% in an Indian example of pour flush latrines to 42% in the case of a biological treatment plant in Turkey. Table 1 also shows total costs of sanitation options as a percentage of gross domestic product (GDP) per capita, and household costs as percent of income for some examples. However, the comparability of these examples is quite low as some options include wastewater conveyance and treatment while others do not.

Table 1: Total costs, average household costs and operation and maintenance (O&M) cost as a percentage of total costs, and software as a percentage of investment expenditure for some sanitation examples worldwide – just to give a rough indication of a possible cost analysis and ranges of figures.

Location and type of sanitation	Inhabitants served	Total LRMC[a] as % of GDP[b]	Annual costs of sanitation as % of household income	O&M[c] as % of full cost	Software cost as % of total investment	Source
Kuje, Nigeria Combined sewage and offline treatment	582 (rural)	1.14%	1.82%	N/A	N/A	Illesanmi (2006)
Berlin, Germany Conventional gravity based systems, wastewater treatment plant	4,891 (peri-urban)	0.86%	0.84%	15%	N/A	Oldenburg (2007)
Conventional gravity based systems, one stream, sequencing batch reactor (SBR)	4,891 (peri-urban)	0.64%	0.63%	10%		
Urine separation/storage, brownwater vacuum system and biogas reactor, greywater treatment SBR	4,891 (peri-urban)	0.69%	0.68%	5%	N/A	
Rajasthan, India Pour-flush and bathroom, on-site (mostly deep soak pit); no pit emptying included	1,050,000 (rural)	0.5%	N/A	(no cash)	11%	KfW (2008a)
Bahia, Brazil Mixed systems (ponds, anaerobic Imhoff tanks and gravel sand filters)	34,000 (rural)	0.6%	0.1 – 0.2%	27%	21%	KfW (2008b)
Haikou, China Centralised system, reuse of energy and nutrients (parts of the sewer already existed)	850,000 (urban)	0.7%	0.4%	31%	2.4%	KfW (2008c)
Fethiye, Turkey Mechanical-biological treatment, nutrient removal, disinfection	65,000 (urban + tourists)	0.7%	N/A	42%	5%	KfW (2008d)

[a] LRMC: Long run marginal costs; [b] GDP: Gross domestic product; [c] O&M: operation & maintenance

4 Economic analysis: elements and indicators

Economic analysis includes the financial costing as the core of the analysis and additionally takes a broader perspective, encompassing social and environmental costs and benefits that can be ascribed with a monetary value. Therefore input data will include not only the financial cash flows but also in-kind or external costs and benefits.

Economic benefits include those related to:

- Health benefits such as avoided deaths and avoided morbidity;
- Economies of time saved seeking sanitation facilities or waiting to use these facilities as well as fewer sick days which results in greater productivity
- Environmental benefits such as reduced water pollution
- Reuse of human excreta - fertiliser, biogas etc.
- Wider benefits for the economy related to increased attractiveness for tourism and the business community.

There are also other benefits such as perceived improvement of living quality through attainment of privacy, dignity, convenience and status, however these are difficult to quantify in economic terms.

Thus, economic analysis includes all costs and benefits of households – including the monetary value of in-kind contributions of materials and labour. The most common approach for "shadow price" valuation of own labour is the price of local non-qualified labour. Economic analysis also reflects the full opportunity cost of resources employed. This refers to the economic opportunity lost from using cash, in-kind labour and materials in sanitation that could be employed for another productive use.

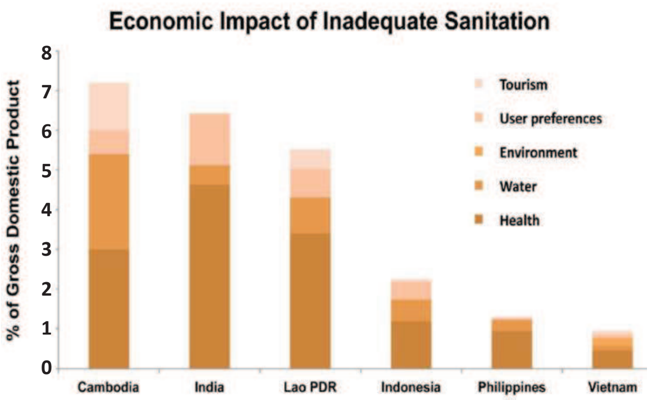

Figure 5: Economic losses resulting from poor sanitation and hygiene in seven countries of Southeast Asia, as a percentage of annual GDP (source: WSP, see Footnote 3).

Where reliable data are available, these economic benefits can be quantified and converted to monetary units to be included in full economic evaluation. A study conducted by WSP in South East Asia in 2007 found that poor sanitation and hygiene led to annual economic losses in the order of 1% (Philippines, Vietnam), 2.3% (Indonesia), 5.5% (Lao PDR) and as high as 7% (Cambodia) of GDP (Hutton et al., 2008).

A recent study by WSP found that eighteen African countries lose around USD 5.5 billion every year due to poor sanitation, with annual economic losses between 1% and 2.5% of GDP[3].

5 Economic benefits of resource-orientated sanitation

Different types of sanitation provide different levels of economic benefit in terms of mitigation of pollution impacts and environmental protection. Further financial or economic gains can be achieved with resource-oriented sanitation systems: reuse of treated wastewater, human excreta fertiliser and biogas. Human excreta (also in the form of sludge from central treatment plants) can be used as fertiliser and soil conditioner after composting. A detailed analysis of three ecological sanitation (ecosan) projects has been carried out by Schuen et al. (2008).

By reusing excreta, households can generate monetary benefits and increased crop production can have a positive impact on them financially. Evidently, poorer households seek to gain more in proportion to their household income (Schuen et al. 2008). The use of human excreta as fertiliser is especially relevant in land-locked countries where the cost of imported fertiliser is significantly higher. Given the increasing scarcity (and price) of phosphorus, the monetary reuse value of human excreta also increases (Gensch et al., 2012).

The value of excreta products which are produced and used on the person's own property can be estimated by comparing the value of the included nutrients at the shadow prices for synthetic fertiliser including transport costs minus the value of the additional personal labour required. If the nutrients are transferred to somebody else's farm, the effective payment (price) of the transaction can be included in the financial analysis.

In addition, biogas generation in sludge digesters of larger wastewater treatment plants and household or community biogas digesters produce biogas as well as fertiliser. A household biogas digester mainly relies on organic waste from animals, because human excreta can cover only 15-30% of a household's energy need for cooking (depending on climate and cooking habits). Similar to nutrient reuse, biogas for cooking can be valued at market prices of firewood or other locally used fuels for cooking. If faeces are converted to compost, the local price of compost can be used for economic estimates.

Other economic gains or cost savings which can be calculated:

- *Water savings* can be valued at the cost of provision of additional drinking water.
- *Treated wastewater or greywater* may be reused for irrigation or aquifer recharge. The market price for irrigation water from other sources can be used to value the benefit of reusing treated wastewater. The calculation

[3] See WSP: Economics of Sanitation Initiative (2012) for more information: www.wsp.org/wsp/content/economic-impacts-sanitation#top

would include the effective payment (market price) for water minus cost of transfer[4].

- *Households* who reuse their waste do not need to pay for pit emptying services or build a new pit when the old one is full.

Many of the argued (or predicted) benefits of reuse oriented sanitation are heavily related to context-specific programme conditions. For instance, the extent of the benefit will be closely related to the degree of community acceptance of excreta reuse, hygiene behaviour change and other factors that determine successful adoption of technologies.

Figure 6: A stove in a school kitchen running on biogas produced from human excreta in Rilima, Rwanda (source: P. Feiereisen, 2011). More photos on this school: www.flickr.com/photos/gtzecosan/sets/72157627230220319/with/6008002835/.

6 Tools for financial and economic analysis

Whole life-cycle analysis involves a long term perspective which takes into account all costs incurred and benefits received over the total duration of the planned project (including operation as well as construction), which is known as the planning horizon. Depending on the type of asset, the quality of construction and the chosen planning horizon, the design life for individual components of the sanitation system may be greater than or smaller than the planning horizon.

A concept similar to the accounting term of asset "depreciation" encourages long-term thinking and investment in technologies that are financially sustainable. For a comparison beyond specific requirements of programme implementers or national governments, some basic tools and ratios are helpful for comparing sanitation interventions with respect to monetary as well as non-monetary outcomes, and from several perspectives.

Costs can be annualised to aid judgments about affordability. Costs expressed in local currency and in real prices of the base year of the study (i.e. without inflation) are most appropriate for financial analyses where the results are to be used to support national or sub-national level decision-making. The discount rate used should reflect the opportunity costs of capital in a given national economy. If there is no accepted national discount rate, economists frequently use a discount rate of 5%.

While providing the results of financial and economic analyses to potential users, measures such as the cost-effectiveness ratio, Benefit-Cost Ratio (BCR), Net Present Value (NPV), or Internal Rate of Return (IRR) can be utilised. In each case, the tools are essentially the same for financial and economic analyses; but the input data will of course vary. Only larger programmes will justify research and full cost-benefit analysis. In these cases, the *ratio of total benefits divided by total costs* or the *internal rate of return* can provide additional information for policies and decisions.

a) Cost-effectiveness ratio

The cost-effectiveness ratio is a more specific tool that compares costs with a single outcome of sanitation improvement, expressed in physical (non-monetary) units such as inhabitants better served, health gain or reduction in pollution. It is generally used in public sector planning.

b) Benefit-Cost Ratio (BCR)

The benefit-cost ratio (BCR) is calculated by dividing the discounted benefits by the discounted costs of the sanitation intervention.[5] This indicator can be used to compare different sanitation improvement options and to compare a sanitation option with 'doing-nothing'. Two types of studies reporting BCRs can be distinguished: (i) those reporting the costs and benefits generally associated with improved sanitation on a regional or national level ('macro' studies); and (ii) those comparing the costs and benefits of alternative sanitation options in a single context on the household level('micro' studies).

c) Net Present Value (NPV)

Long-term outcomes of sanitation interventions can be measured either in monetary terms in cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA). This is used to assess financial costs over a period of time and is particularly relevant where sanitation projects achieve similar or identical outcomes. The narrower CEA can be used if valuation of benefits is difficult; while CBA is a broader method that combines multiple impacts of improved sanitation in a single framework expressed in monetary units.

For both CEA and CBA, the NPV is a common parameter for comparing sanitation technologies, which can be expressed in financial and economic terms. The calculation of these two values is similar, but the input data and costing factors are different in each case.

The combined investment and recurrent costs are expressed as a NPV over the useful lifetime of major investment components, and can be subtracted from the NPV of

[4] Until now the cost saving that can be achieved with treated wastewater is still however close to zero in most countries, but the concept might have importance in the future.

[5] The discount is the difference between the present amount and the amount in the future. The discount rate is usually given at 5% per year.

financial benefits to estimate the financial net present value (FNPV). The economic analysis of selected factors (e.g. reuse of nutrients and energy) can use the long run household costs and benefits per person served per year, as a percentage of local or regional per capita household income to calculate the costs and benefits as a percentage of household income.

d) Internal Rate of Return

The ratio of the financial benefits to the costs is termed the financial internal rate of return (FIRR). This measure takes into account investment and recurrent costs and provides a measure of the annual equivalent return on investment in percentage terms, taking into account monetary cash-flows over the life span of the investment. It allows comparison between the efficiency of the intervention with other potential uses of funds.

Economic internal rates of return (EIRR) tend to be significantly higher than financial ones because it also includes non-monetary costs and benefits (health, environmental and reuse benefits of sustainable sanitation options) over the lifetime of the sanitation improvement. For example, a study of three African countries on integrated household biogas and sanitation showed a financial IRR of around 10% compared to an economic IRR of over 70% (Renwick et al., 2007).

7 Limitations of these analyses

Economic analysis requires the valuation of economic costs and benefits and is limited to the availability of reliable data. The large diversity of measures and settings make it hard to compare the results from studies in different locations. There is therefore a need for greater awareness of the analytical methods and indicators by researchers and practitioners and the application of standardised methodologies for data collection and analysis.

Many projects promoting excreta reuse as fertiliser or soil conditioner and biogas production involve use of the products by the same households or the institutions, such as a school or a prison, which has produced the excreta in the first place. But so far, little data exists to suggest the actual financial or economic value of these products. In the absence of in-depth research, a careful use of shadow prices is most appropriate to reflect the upper limit of economic value (i.e. equivalent fertiliser).

Available estimates of economic benefit of excreta reuse in the literature are challenging as they are largely based on hypothetical returns using expected excreta production, quality and prevailing market prices, as opposed to actual household economic impacts (Rockström et al., 2005; Oldenburg, 2007; Renwick et al., 2007). Established markets for trade in human excreta are not yet documented, and it is not clear whether the same nutrient or fuel volume/weight would receive the same prices as, say, synthetic fertiliser, conventionally produced compost or liquefied petroleum gas (LPG).

To date, although some data exists, there is still relatively limited published cost and economic evidence relating to different sanitation options, and all available evidence has not been systematically estimated and compiled[6]. Quantifying sanitation impacts and converting to monetary values to give accurate estimates of economic impact or benefit is a challenging task for various reasons:

- Firstly, improved sanitation is one of many ongoing development ‘interventions’ that affect socio-economic outcomes, such as health, education, agriculture and private sector development initiatives. Hence, robustly designed studies are needed which conduct data analyses adequately, accounting for a range of confounding variables.
- Secondly, the step of monetisation adds a further layer of uncertainty on the already uncertain physical/natural measurements of sanitation benefits. Prices can be highly variable, or markets may be imperfect thus distorting prices from the market equilibrium price level (which is the standard measure of welfare impact in economics).
- Additionally, prices may not exist at all, such as for some benefits of sanitation (e.g. comfort value, increased security for women or social impacts of improved sanitation) and thus need to be ascertained through proxy pricing or contingent valuation techniques. Hence, the analyst must compare the methods available, justify selection of a single method; and conduct sensitivity analysis to assess how uncertainty in price assumptions affects the overall benefit estimation.

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Authors and contributors

Main authors:

- Jonathan Parkinson, IWA, UK (jonathan.parkinson@iwahq.org)
- Guy Hutton, consultant (guy.hutton@bluewin.ch)
- Verena Pfeiffer, formerly KfW, Germany (verena.pfeiffer@volvendo.de)
- Steffen Blume, GIZ, Zambia (steffen.blume@giz.de)
- Philipp Feiereisen, GIZ, Germany (philipp.feiereisen@giz.de)

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For questions or comments please contact the SuSanA secretariat at info@susana.org or susana@giz.de. We invite you to join the SuSanA discussion forum: www.forum.susana.org. This document is available at www.susana.org.

sustainable sanitation alliance

SuSanA factsheet

Links between sanitation, climate change and renewable energies

April 2012

1 Summary

Sustainable sanitation projects can contribute to both climate change mitigation (through energy or nutrient recovery) and to climate change adaptation (through innovative sanitation systems and wastewater management).

Measures of renewable energy production consist basically of either biogas production from waste water or biomass production through the use of waste water to grow short rotation plantations for firewood. Biogas can also be used for heat generation while heat exchangers can recover heat energy from wastewater in sewers. Measures of nutrient recovery are primarily based on nitrogen reuse. Adaptation measures in the area of sanitation aim at coping with increasing water scarcity or flooding.

By using reuse-oriented sanitation systems with energy, nutrient or wastewater recovery and reuse, anthropogenic greenhouse gas emissions can be reduced (mitigation) as well as people's capacity to cope with climate change impacts can be increased (adaptation).

In cases where these measures for reduction of greenhouse gases are achieved in developing countries, the emission allowances can be sold on the international emissions trading market and thus can contribute additional financial benefits. In order to be financially viable, there is a minimum project scale due to fixed transaction costs, with project bundling the minimum scale can be achieved.

This factsheet emphasises the need for climate change mitigation and adaptation measures in the area of sanitation. In addition, it provides an overview of the possibilities of using sanitation systems for renewable energy production, nutrient recovery and it explains the financial benefits that emission trading can bring.

2 Introduction

2.1 Overview

UNFCCC[1] defines 'Climate change' as a "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Some of the major climate change effects that have been predicted are the significant rise in temperature due to greenhouse gases, rising sea level and shifts in precipitation and evapotranspiration patterns (IPCC, 2007a). By 2050, the number of countries facing water stress or scarcity could rise from 48 to 54, with a combined population of four billion people i.e. about 40% of the projected global population of 9.4 billion[2].

Increasing water scarcity combined with increased food demand and water use for irrigation as a result of less precipitation are likely to be a driving force leading to water reuse. Areas with low sanitation coverage might be found to be practising more uncontrolled water reuse i.e. reuse performed using polluted water or even wastewater (Bates et al. 2008).

Sustainable sanitation has a strong link to climate change and renewable energy production. For example, sanitation systems can be designed in a way to produce renewable energy sources (biogas or biomass) which in turn may mitigate climate change by reducing greenhouse gas emissions. Sanitation systems may also serve to help people adapt to climate change by reusing energy, nutrients and treated wastewater and thus substituting the use of primary resources.

Figure 1: Urine Diversion Dehydration Toilets (UDDT) withstood the flood waters that resulted from a cyclone that struck southern Bangladesh in 2009 (source: A. Delepiere). More photos from this project: www.flickr.com/photos/gtzecosan/sets/72157626407064863/

Another example is dry toilets such as Urine Diversion Dehydrating Toilets (UDDT) with a raised platform and safe containment of excreta and which use no water for flushing (suitable for areas with increasing water scarcity) or which

[1] UNFCCC – United Nations Framework Convention on Climate Change, www.unfccc.int

[2] See: www.maps.grida.no/go/graphic/increased-global-water-stress

can still function during flooding events. UDDTs are potentially resilient to all expected negative climate change impacts while water born systems (flush toilets and sewers) are more vulnerable to different climate change scenarios (WHO and DFID 2009)[3].

2.2 Greenhouse effect and contributing gases

The greenhouse effect is the phenomenon where the presence of so-called greenhouse gases (GHG) cause warming of the earth's surface: GHG allow solar radiation to enter the earth's atmosphere but prevent heat from escaping back out to space. They absorb infrared radiation and reflect it back to the earth's surface leading to its warming.

Many human activities cause GHG emissions which drive the anthropogenic greenhouse effect. According to the Intergovernmental Panel on Climate Change (IPCC) the anthropogenic greenhouse effect will cause a rise in the mean global temperature of between 1.1 and 6.4℃ by the end of the 21st century (IPCC, 2007a). Changes in rainfall patterns, rising sea level and weakening of sea currents will also have additional impacts on the global temperature distribution. In order to limit climate change to tolerable levels, global temperature rise should be limited to 2℃ (IPCC, 2007b). To achieve this, GHG emissions would have to be reduced by 50% by 2050 compared to the level in 1990 (IPCC, 2007c).

2.3 Relevant greenhouse gases

In the field of sanitation, the following GHG are climate relevant:

- *Methane* (CH_4) is a potent greenhouse gas with a global warming potential 25 times higher than that of carbon dioxide (CO_2) in a 100 year perspective (IPCC/TEAP, 2005). In anaerobic processes, organic matter contained in domestic waste and wastewater is decomposed and biogas is formed which contains 60-70% methane.
  In soak pits, anaerobic ponds, septic tanks and other anaerobic treatment systems or even at the discharge of untreated wastewater into water bodies, anaerobic processes take place to different extents and methane is released to the atmosphere.
  While combustion of biogas produces CO_2, a greenhouse gas (see below), the carbon in biogas comes from solid or liquid biomass that has fixed carbon from atmospheric CO_2. Thus, biogas usage is carbon-neutral and does not add to greenhouse gas emissions.
- *Carbon dioxide* (CO_2) is produced as a result of combustion of any fossil or biomass fuel. However, CO_2 from biomass combustion does not contribute to global warming as it originates from the atmosphere; it is a step in the organic carbon cycle. In sanitation, CO_2 emissions occur whenever fossil energy is used, as fossil fuel-based electricity. The treatment of wastewater for removal of organic matter and nutrients in wastewater treatment plants requires energy. The same holds true for the production of mineral fertilisers which is a very energy intensive process.
- *Nitrous oxide* (N_2O) is a strong greenhouse gas with a global warming potential 298 times higher than that of CO_2 in a 100 year perspective (IPCC/TEAP, 2005). Nitrous oxide emissions occur during the denitrification process in wastewater treatment, at the disposal of nitrogenous wastewater into aquatic systems and also during mineral nitrogen fertiliser production. For climate protection, nitrogen in excreta or wastewater can be recovered and reused as a fertiliser to save energy.

3 Climate change mitigation and adaption potential of sanitation

3.1 Mitigation measures

3.1.1 Energy recovery

Sanitation systems can be designed and operated to produce renewable energy in the forms of either biogas or biomass and thus reduce primary energy consumption (see Section 4 for details). Small scale biogas systems can generate enough biogas to cook main family meals and thus replace part of the traditional used cooking fuels. It should, however, be kept in mind that particularly in small systems the organic load from human excreta alone is in most cases not high enough for the economical usage of biogas for cooking, lighting or heating but still beneficial. Much more biogas is produced if animal excreta, organic solid waste (e.g. from kitchens and/or markets), or agricultural waste is co-digested as well.

Figure 2: Biogas stove at Cachoire Girls High school, Kiambu, Kagwe District, Kenya (source: S. Blume, 2009). More photos about this project: www.flickr.com/photos/gtzecosan/collections/72157616752316076

Biogas can also be used for combined heat and electricity generation by means of a combined heat and power (CHP) plant. This can substitute the use of fossil or non-renewable energy sources.

Another possible energy recovery method is the recovery of heat from wastewater especially in cold countries where the wastewater temperature is higher than the ambient temperature. Warm greywater from showers, wash basins and sinks (with temperatures of up to 35℃) usually flows directly into the sewage system. The energy contained in the greywater can however be effectively recovered by means of heat exchangers installed inside or close to the house. Conversely, most of the thermal energy in the wastewater is lost in the sewer. Depending on climate,

[3] WSSCC working group on WASH and climate change www.wsscc.org/topics/hot-topics/climate-change-and-wash

region and season wastewater temperature can go down below 12℃ making it much more difficult and insufficient for energy recovering. Similarly, a large amount of warm wastewater is also produced in industries, hospitals, swimming pools etc., which could also be harvested and used efficiently for preheating cold water.

3.1.2 Nutrient recovery

The macronutrients nitrogen (N), phosphorus (P) and potassium (K) contained in human and animal excreta can be locally recovered and safely used as fertiliser in agriculture. Hence, a substitution to the manufactured mineral fertilisers with their associated energy intensive production and transport over long distances. Further information on the safe use of excreta in agriculture can be found in WHO (2006) and Gensch et al. (2012).

Figure 3: Urine application in agriculture, in Ouagadougou, Burkina Faso (source: S. Tapsoba, 2009). For more information on this project see the SuSanA case study: www.susana.org/lang-en/case-studies?view=ccbktypei tem&type=2&id=84

Nitrogen fertilisers require more energy (Remy and Ruhland, 2006) and are consumed in larger amounts than P- and K-fertilisers (Gellings and Parmenter, 2004). Since 87% of the excreted nitrogen is contained in urine, concentrating on the recovery and reuse of the nitrogen contained in urine represents a possible means of emission reduction through nutrient recovery.

A life cycle analysis study comparing the energy demands for nutrient removal and mineral fertiliser production versus nutrient recovery identified a considerable energy saving potential with urine diversion nutrient recovery (Maurer et al., 2003). Compared to a conventional wastewater treatment system, the use of reuse-oriented sanitation systems can lead to energy savings (e.g. due to smaller sewer networks and treatment plants). However, when reuse-oriented sanitation systems are dependent on road-based transportation of excreta or sludge, they are also associated with energy consumption. Thus, while comparing reuse-oriented with conventional sanitation systems, a careful analysis of the different systems from an energy perspective is necessary.

The emission reduction potential through energy recovery (biogas) and nutrient recovery (urine) was analysed for a case study in India (Olt, 2008). For nutrient recovery it was calculated as 23 kg CO_2/person/year resulting mainly from savings in energy consumption for the production and transportation of mineral fertiliser, savings in field emissions during fertilisation and avoided disposal of nitrogenous wastewater into aquatic systems. From an emission reduction point of view, this case study however faced unfavourable conditions in view of nutrient recovery as pumps were used to pump flush water to overhead storage tanks from the wells. Therefore, the above indicated value of emission reduction through nutrient recovery can be regarded as a lower value.

Source separation of urine and subsequent use of urine as fertiliser reduced the climate impact by 33 kg CO_2/person/year in a scenario study evaluated with life cycle assessment methodology, where wheat production in Sweden with urine as fertiliser was compared to conventional mineral fertiliser use and wastewater treatment (Tidåker et al., 2007). The benefits originated mainly from an avoided need for the production of mineral fertilisers and from avoided field emissions.

Therefore, artificial mineral fertilisers should be replaced by safe application of excreta-based fertilisers (urine, faecal or wastewater sludge, dried faeces) as far as possible.

3.2 Adaptation measures in the area of sanitation

Adaptation to climate change ensures that sanitation systems can in the future - with a potentially different climate - still deliver services and maintain safe hygiene practices to prevent the spread of diseases.

Figure 4: Tanker supplying water to low-income areas in Lima, Peru (source: H. Hoffmann, 2010). Climate change will aggravate the existing water scarcity problems in Lima due to melting and disappearing of glaciers in the Andes – which is currently the source of water supply for Lima. More photos showing water scarcity in Lima: www.flickr.com/photos/gtzecosan/sets/72157629511631340/

Adaptation measures include the planning for preparedness, prevention, protection, and response (relief and rehabilitation). Risk management and adaptation planning aims to develop different strategies based on the different scenarios, by choosing technologies that are resilient to the expected scenarios, by adapting operation and management of existing services, and by taking into consideration socio-economic factors. Furthermore, it is also advisable to separate the preparedness for extreme events and adaptation measurements from expected perpetual challenges.

Climate change proofing measures involve households, communities, service providers and governments alike, and some examples are given below.

3.2.1 Adaptation to increased occurrence of droughts and increasing water scarcity

In order to adapt sanitation systems to water scarcity, the measures that can be taken include for example:

- Wastewater especially greywater, treated to the appropriate degree for the intended use can be reused for the irrigation of food crops, energy crops, parks, lawns and other public spaces, for groundwater recharge or as service water. In cases where potable water is used for irrigation, the use of treated wastewater would substitute the extraction, processing and distribution of potable water and thus may lead to energy savings. The nutrient content of the wastewater also reduces the need for mineral fertiliser input. Further information on wastewater reuse in agriculture can be found in WHO (2006).
- Dry toilet systems can be an alternative, especially in water scarce areas, to water-flushed toilets. Toilets which do not require water for flushing, but can nevertheless be indoors (such as urine diversion dehydration toilets (UDDTs) or composting toilets), save about 40L/person/day in comparison to conventional flush toilets.
- Water or wastewater irrigation methods should minimise water losses through evaporation. Therefore, subsurface drip irrigation is generally preferable although possible nozzle clogging should be considered (Palada et al, 2011).

3.2.2 Adaptation to increasing amounts and periods of rainfall and flooding

In order to adapt sanitation systems to flooding, one effective measure is building sanitation structures in a way that they are above ground and either not affected by flooding such as UDDTs built high enough above ground, or to use mobile toilet systems (Johannessen et al., 2012)[4]. Another measure is building sanitation systems where flood water can drain quickly, such as elevated sludge drying beds, or constructed wetlands.

3.3 Emission trading as an additional financial benefit

The first phase of the Kyoto Protocol – the internationally binding contract on climate protection measures valid until the end of 2012 – assigns each participating country which has emission reduction commitments, an allowed amount of greenhouse gas emissions. In order to reach this emission target at the least macroeconomic costs, the Kyoto Protocol offers three market-based flexible mechanisms. One of them, the Clean Development Mechanism (CDM), is designed for trading emission reductions which have been achieved in developing countries.

[4] See publications of SuSanA library dealing with the issue of flooding: www.susana.org/lang-en/library?search=flood

The CDM can be used for emission reductions achieved through sustainable sanitation systems. It can contribute to an additional financial benefit but also generates CDM-related costs which are mostly fixed and which negate achieved credits to some extent.

Hence, for sustainable sanitation systems a minimum project scale is required to make CDM economically attractive. This is dependent on the baseline and the project scenario, the energy demand of the fertiliser production plants, the different available sources of energy of the country being considered, the transaction costs and the price of carbon credits which fluctuates.

The minimum project scale for an economic use of CDM for energy recovery (biogas use) and nutrient recovery (urine use) was analysed for a case study in India (Olt, 2008). Assuming average transaction costs and a long-term price of 20 EUR/CER[5], the minimum viable project scale was found to be around 25,000 PE[6] for energy recovery, and 37,000 PE for nutrient recovery.

From an emission reduction point of view, this project had favourable conditions regarding energy recovery but unfavourable conditions regarding nutrient recovery. Therefore the above indicated project scale for energy recovery represents an absolute minimum value, while the value for nutrient recovery can also be lower.

In order to reach this project size, similar CDM projects may be bundled together to a "Programme of Activities" (PoA). A manual for biogas plants at household level is given in GFA (2009). Further information on PoA is available at the website of UNFCCC[7].

4 Renewable energy production from sanitation

4.1 Biogas production

4.1.1 Overview

Biogas is a renewable energy that can be used for cooking, lighting, heating and for generating electrical power. It is produced by bacteria that decompose organic matter under anaerobic conditions (i.e. in the absence of oxygen). The technology of anaerobic digestion has been applied to human and animal excreta for over 150 years. The anaerobic bacteria grow slowly, and higher temperatures result in faster decomposition rates[8].

[5] 1 CER (Certified Emissions Reduction) is considered equivalent to one metric ton of CO_2 emissions

[6] PE = population equivalent, equalling approximately the organic biodegradable load of one person.

[7] http://cdm.unfccc.int/ProgrammeOfActivities/index.html

[8] For further information on anaerobic digestion and biogas production, please see the SuSanA library and filter for biogas systems. Also photos of biogas systems are available in the Sustainable Sanitation photo collection: www.flickr.com/photos/gtzecosan/collections/72157 626218224122/

For biogas generation various substrates can be used (also in combination with each other):

- organic waste from households or agricultural farms
- animal manure
- sewage sludge originating from domestic wastewater treatment
- blackwater, i.e. mixture of excreta and flushing water (best from low-flush or vacuum toilets)
- fresh faecal sludge from public toilets and septic tanks and pit latrines

Figure 5: Construction of a fixed dome biogas plant, Lesotho (source: M. Lebofa, 2006).

In many Asian countries, e.g. in China, India and Nepal, human excreta are treated in this way together with animal manure and other organic waste. As a result of a Chinese national programme in the 1970s ("Biogas for every household"), addressing increasing energy demand and wood cutting, there is an on-going interest in China in biogas which is supported by the Ministry of Agriculture. For example, there are now approx. 5 million family-sized biogas plants of 6, 8 and 10 m^3 in operation, mainly built as fixed dome plants (Balasubramaniyam et al., 2008).

Due to the two benefits of energy production and fertiliser production, anaerobic digestion (AD) is receiving interest as an option in sustainable sanitation concepts.

For a sanitation system, maximising the stabilisation and hygienisation of the wastewater is more important than maximising the biogas production. The pathogens contained in the raw wastewater are reduced somewhat during anaerobic treatment but not to a high degree. In general the pathogen reduction during anaerobic digestion is higher the longer the retention time.

Biogas from anaerobic wastewater treatment contains 60-70% methane. The biogas production depends on the amount of organic matter removed by anaerobic treatment. 1 m^3/d of biogas is enough to cook three meals for a family of 5-6 members. According to Balasubramaniyam et al. (2008), as an indicative value, this can be produced from excreta of either, 50 - 90 humans, 2 - 3 cows or 7 - 8 pigs over a 24 hour-period. This means that the excreta from approximately 10 people is needed to produce biogas for the cooking needs of one person. Hence, the available energy potential in human excreta should not be overestimated. An advantage is that, there is no human health risk at all caused by pathogenic contamination in biogas itself (Vinnerås et al., 2006).

If the biogas cannot be used, then it should at least be flared (this converts methane to carbon dioxide which has a 25 times lower GHG potential than methane, see Section 3.2). However, as described in Hoffmann et al. (2011), when biogas needs to be burnt, there are additional costs for equipment. The flare for a household plant has nearly the same costs as a flare for a large plant of 20,000 inhabitants – thus the specific costs per person are relatively high for flares implemented in small systems.

If neither biogas use nor flare can be realised, uncontrolled biogas production should be avoided. There are various possibilities to reduce unintended biogas leakage:

- Replace existing anaerobic ponds and septic tanks by a controlled anaerobic treatment system such as biogas plant, UASB reactor or anaerobic baffled reactor.
- Design and build any new anaerobic treatment systems as a closed gastight construction with biogas capture.
- Make existing open UASB reactors as well as leaky biogas plants gastight and avoid biogas emissions by installing or restoring the flares.

Where septic tanks are too small for a controlled anaerobic treatment (i.e. generally or household level), consider replacing septic tanks by appropriate, low-energy, composting toilets or aerobic treatment methods such as dry toilets, or constructed wetland systems.

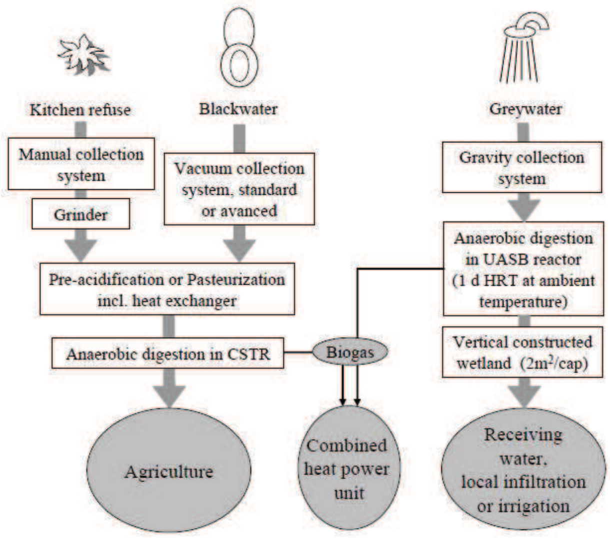

Figure 6: Schematic of the proposed AD system for household wastewater which includes a Decentralised Wastewater Treatment System (DEWATS) for greywater (source: C. Wendland, 2009).

4.1.2 Use of the biogas

Biogas can either be burnt in a gas stove or used within a combined heat and power unit (CHP) for electricity generation. For use in a CHP, the biogas must be filtered to remove aggressive sulphur compounds. The CHP is equipped with a gas engine for producing electricity and heat. The efficiency is 30% for electricity generation and

60% for heat production which may sum up to a total energy efficiency of 90% in case the excess heat is used on-site. This high efficiency represents the main advantage of a CHP compared to a biogas plant.

4.1.3 Use of the digestate

After the generation of biogas, the residue of anaerobic digestion (called "slurry or digestate") still contains all the nutrients and some organic matter. This residue is therefore suitable for application in agriculture as a fertiliser and soil conditioner. The macronutrients (N, P and K) which are contained in the substrates remain in the digestate and are easily available to plants.

Organic matter is reduced by the digestion process but is still available in the digestate, and can contribute to raising the soil organic matter content. The digestate is "stabilised" with reduced odour emissions, pathogens and weed seeds compared to undigested manure (pathogens are not removed to a significant extent). The use of the digestate as a fertiliser reduces the need for mineral fertilisers, which reduces costs as well as greenhouse gas emissions. However, safety measures in the application of digestate should be applied, especially when the substrate sources contain human and animal excreta.

4.2 Biomass production

4.2.1 Overview

Biomass is a non-fossil energy source which can substitute fossil fuels. However, it is neither always harmless nor always neutral to the climate. According to the UNFCCC definition (UNFCCC, 2006), renewable biomass is understood as:

- wood (provided that wood harvest does not exceed wood growth)
- other wooden biomass (provided that the cultivated area remains constant)
- animal or human manure
- solid organic waste (domestic or industrial)

Both food and biomass or energy production are essential for people's livelihoods, and often compete with each other for available land, water and nutrient resources. Food and biomass production might be seen as equally important in economically rich countries with a safe food supply. But in many developing countries food production takes priority, whilst at the same time people are dependent on biomass (particularly on wood) for their energy supply, primarily to cook their food.

Conducting a national food balance, which takes into account food production versus consumption is one way to establish whether priorities should tend towards either food or biomass production[9]. This can then be used as a basis for making decisions regarding the cultivation of more food or more energy crops. The use of sanitation-derived fertilisers in agriculture may increase the productivity of the land and thus decrease the conflict between food and biomass production at the local level.

If the decision has been made in favour of the cultivation of energy crops, the reuse of domestic wastewater to irrigate and fertilise energy crops in so-called Short-Rotation-Plantations (SRP) is a new approach which aims at using the nutrients contained in wastewater for an enhanced biomass growth.

The term SRP refers to plant species which are harvested after short periods, usually between 2-8 years, but also annually in the case of herbaceous plants or grasses. Their cultivation intensity, their high nutrient uptake and the frequent harvests require irrigation and fertilisation. By irrigating with wastewater rich in plant-available nutrients, fertiliser costs are zero, plant growth is enhanced, and wastewater is subjected to a more sustainable treatment[10].

While constructed wetlands focus on wastewater treatment only and are sealed at their base for groundwater protection, the advantage of SRPs over constructed wetlands lies in the combined wastewater treatment and the production of wooden biomass. An SRP is not lined at the base and has a filter height of between 1.0 and 1.5 m resulting in an effective reduction of pathogens. Wastewater is usually applied on SRPs by means of sub-surface irrigation in order to avoid aerosol formation and spread of pathogens by air.

Figure 7: A two year old short-rotation-plantation (SRP) in Braunschweig, Germany, (source: TTZ, 2006).

In order to avoid nutrient overload, wastewater application has to follow a dosing recommendation depending on the site and plant species and – if built within the European Union – comply with the EU Nitrates directive. In addition, the nitrate content has to be monitored by soil samples or by sampling from drainage channels.

The following substrates can be applied on SRPs:

- domestic wastewater which contains nutrients in ratios that are close to the nutrient needs of SRP plants,
- sewage sludge originating from domestic wastewater,
- industrial wastewater from food processing or beverage industries.

[9] A useful online resource by OECD for agricultural food production by country and commodity is: http://stats.oecd.org/Index.aspx.

[10] Further information is available on the website of TTZ, Germany. www.ttz-bremerhaven.de/

Besides the above-mentioned benefits there are also some drawbacks to consider:

- Groundwater pollution could occur and needs to be prevented (from nitrate, pathogens and toxic substances especially if industrial wastewater is applied).
- The increase in soil salinity resulting from the irrigation with wastewater containing salts such as sodium chloride and hydrocarbonates might be a problem.

Figure 8: Short-rotation-plantation (SRP), Spain (source: TTZ)

4.2.2 Treatment performance of SRP

With a 10 hectare SRP, the wastewater of approximately 6,500 people with a daily discharge of 100 L/person may be treated, corresponding to an area of 15 m^2/person. The actual wastewater treatment takes place in the root system of the trees where bacteria are active. When the soil freezes, biological activity slows down considerably and there is a need for storage ponds to retain the wastewater during cold periods. Note that the area requirement per person is much higher for SRPs than for constructed wetlands. SRPs cannot be used when there is a space limitation.

4.2.3 Use of the biomass

The biomass produced in SRPs is most commonly used in European countries as wood chips for direct combustion in district heating plants or processed further into wood pellets or briquettes to be used in private households, smaller enterprises or hotels. However, the biomass can also be used for a variety of biomass conversion products and processes (i.e. combustion, gasification, hydrolysis, and fermentation) which can produce heat, electrical power, combined heat and power, ethanol or syngas (mixture of carbon monoxide and hydrogen).

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6 Authors and contributors

Main authors:

- Rahul Ingle, GIZ, Germany (Rahul.ingle@giz.de)
- Cecilia Sundberg, SLU, Sweden (cecilia.sundberg@slu.se)
- Claudia Wendland, WECF, Germany (claudia.wendland@wecf.eu)
- Stefan Reuter, BORDA, Germany (reuter@borda.de)
- Ina Jurga, WSSCC, Switzerland (ina.jurga@wsscc.org)
- Christian Olt, formerly GIZ, Germany (christian.olt@web.de)

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For questions or comments please contact the SuSanA secretariat at info@susana.org or susana@giz.de. We invite you to join the SuSanA discussion forum: www.forum.susana.org. This document is available at www.susana.org.

sustainable sanitation alliance

SuSanA factsheet

Sanitation systems and technology options

April 2012

1 Summary

To address the great sanitation challenge in developing countries, numerous technological innovations have been developed. But with so many innovations and a wide range of existing technologies for different settings, difficulties with knowledge dissemination hinder informed decision making and the integration of all sanitation elements.

This factsheet makes a plea for a sanitation system approach where technologies are categorised based on their "product-process" characteristics and then linked into logical systems using a "Flowstream" concept. Technologies are grouped and used to construct seven logical systems. This method for organising and defining sanitation systems helps facilitate informed decision making and consideration of an integrated approach.

By using the sanitation system and its technology configurations from user interface to reuse and disposal, other aspects can now be further highlighted such as the inherent implications for operation and management (O&M), business and management models, service and supply chains, possible involved stakeholders, and finally the associated health risks by exposure of different groups of people to waste products. Such a health risk assessment for different sanitation systems has recently been published by Stenström et al. (2011).

2 Introduction: the need for a systems approach

Technology choice should be based on determining the best possible and most sustainable solution within an urban or rural context. There is often a prevailing assumption that centralised water-based sewer system can be the solution in all urban and peri-urban contexts. Site specific considerations such as the scarcity of fresh water, farmers' demand for treated wastewater or excreta-based fertiliser, or lack of technical skill and institutional or socio-economic barriers to such centralised sewer systems are often neglected (Luethi et al., 2011).

Sanitation programmes and projects often ignore the impacts of different waste inputs on the treatment processes, and on the quality of the final products (sludge and final effluents). A typical example is the implementation of waterborne sanitation with sewer systems without consideration of water availability and reliability or an appropriate wastewater treatment technology of adequate size to accept the additional raw sewage inputs. Consequently, subsequent poor operation of the system has potentially severe impacts on the environment, resulting in health risks to those served as well as of downstream populations.

On the other hand, on-site sanitation, like in the South Asian rural context, consists of the widespread promotion of pour flush latrines with on-site disposal pits which in many cases are not able to cope with the hydraulic or organic loads due to certain geological, groundwater and climatic conditions.

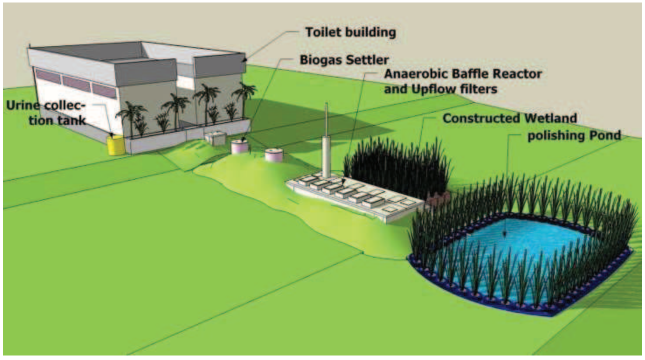

Figure 1: Schematic of school toilets connected to biogas settler and anaerobic baffled reactor at Adarsh College, in Badlapur, India (source: N. Zimmermann, 2009)[1].

The options: to change the basic design or to consider alternative sanitation technologies to take into account the specific on site conditions are often overlooked or not investigated. As a result, in spite of significant investments, a number of latrines are found to be either dysfunctional or malfunctioning and the unsatisfied users have reverted to open defecation or the use of unsanitary pits latrines. In addition, the focus is often on the construction of *toilets* alone with little consideration given to the management of the generated *faecal sludge*, including its collection, transport, treatment and possible reuse or disposal.

There is a great need for sanitation practitioners to plan sanitation from a more holistic perspective, for example by considering the entire municipal area and the sanitation chain in order to come up with an overall sanitation concept. A holistic perspective includes components such as technical, (socio-) economic, institutional and financial feasibility studies, consultation with the users in which the whole life cycle of different sanitation options are presented and discussed, quality assurance during implementation, and ongoing institutional support during the O&M phases. Training is another very crucial aspect as even the most

[1] See SuSanA case study for details: www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=38

inexpensive or sophisticated technologies eventually fail if they are not accompanied by a trained service provider.

One of the challenges for improving sanitation in low and middle income countries involves acquiring a sound knowledge of the wide range of sanitation options to ensure informed decision making. The most feasible sanitation systems and technologies - for the different habitats in urban and rural areas, which can achieve the objectives of improved health, changed hygiene practices, minimal impact on the environment, improved quality of life, and are best suited to the site specific context - can be chosen when decision making is informed.

Commonly asked questions when faced with deciding on a sanitation option are: What are the available sanitation systems? Which sanitation systems are appropriate for which kind of faecal waste inputs? What kinds of waste products are produced from the technologies that transform waste inputs? This factsheet summarises and highlights previous work conducted by various authors who worked on the categorisation of sanitation systems (Cruz et al., 2005; IWA, 2005; Tilley and Zurbruegg, 2007; DWA, 2010; Tilley et al., 2008).

3 Systemising sanitation systems

The main objective of a sanitation system is to protect and promote human health by providing a clean environment and breaking the cycle of disease transmission, as well as to preserve the dignity of users - particularly women and girls. In order to be sustainable, a sanitation system has to be not only economically viable, socially acceptable, and technically and institutionally appropriate, it should also protect the environment and the natural resources (SuSanA, 2008).

A sanitation system - contrary to a sanitation technology - considers all components required for the adequate management of human excreta. Each system represents a configuration of different technologies that carry out different functions on specific waste inputs or waste products. The sequence of function-specific technologies through which a product passes is called a “Flowstream”. Each system is therefore a combination of inputs, function-specific technologies, and products designed to address each flowstream from origin to reuse or adequate disposal.

Technology components exist at different spatial levels, each with specific management, operation and maintenance conditions as well as potential implications for a range of stakeholders. A system can include waste generation, storage, treatment and reuse of all products such as urine, excreta, greywater, organic solid waste from the household and agricultural activities such as manure from cattle at or near the source of waste generation. However, the requirement to effectively contain the wastes and prevent the spread of diseases and the pollution of the environment can often not be solved at the household level alone.

Households “export” waste or environmental contaminants generated by the wastes to the neighbourhood, town, or downstream population. In such cases, it is crucial that the sanitation system is extended to include these larger spatial areas and take into account technology components for storage, collection, transport, treatment, and discharge or reuse at all levels.

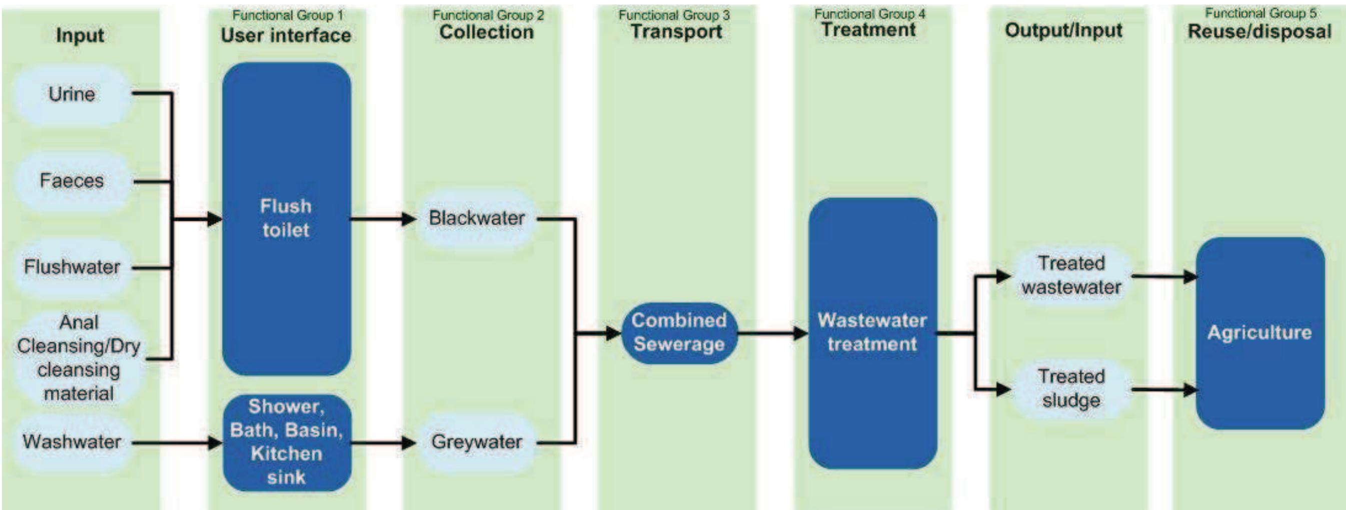

Figure 2: System template providing a schematic overview of the specific inputs of a sanitation system (left column), their transformation in the four functional groups “user interface”, “collection”, “transport” and “treatment“, the specification of two outputs for the fifth functional group “reuse/disposal” (in this example “nutrient reuse in agriculture”) (source: Luethi et al, 2011).

Sanitation systems can be distinguished by being water-reliant or non-water reliant for the transport of excreta and wastewater (Cruz et al., 2005; Tilley and Zurbruegg, 2007). Some manuals on technology options have used the type of anal cleansing (anal cleansing with water or dry anal cleansing material), water availability and affordability as distinguishing factors for on-site sanitation technologies.

Another common categorisation divides sanitation systems into on-site and off-site (i.e. whether treatment of the wastes occurs on-site or the wastes are transported off-site for treatment).

In addition to water-reliant or non-water reliant, or on-site or off-site, another distinction can be made in the various degrees of separation of incoming wastes. Urine diverting sanitation systems keep urine separate from faeces from the very beginning. On the other hand sewered sanitation systems mix faeces, urine, flushing water, greywater as well as wet or dry anal cleansing materials resulting in a waste product called wastewater. Depending on the degree of waste separation, various flowstreams can be distinguished, which must be accounted for in the subsequent functional components of the sanitation system.

It is also important to note the similarity in the naming convention between products and flowstreams. For example, blackwater is a product, but the entire process of collecting, treating and disposing of blackwater is referred to as the blackwater flowstream. Similarly, greywater can be managed separately as an independent product, but when it is combined and treated along with blackwater, the flowstream is referred to as the "blackwater mixed with greywater" flowstream (Tilley et al., 2008).

"Wet" and "dry" indicate the presence of flushing water for the transport of excreta or the use of water for facilitating the treatment of the wastes. This however only gives a certain indication of how wet or dry the collected waste materials will be. Although flushing water might not be used it would not necessarily qualify as a "dry system" as it may nevertheless contain anal cleansing water or even greywater. Also, it should be remembered that wet systems also contain solids, like faecal material and anal cleansing materials. In wet systems the solids flowstream must be taken into account and treated accordingly with its own set of specific technologies for reuse or disposal.

In this factsheet seven distinctly different sanitation systems are described based on the categorisation from the EU-funded NETSSAF project (Network for the development of Sustainable approaches of large-scale implementation of Sanitation in Africa[2]). They all have their place and application, and not one of them is per *se* better than the other.

[2]Information about NETSSAF and its outputs: www.susana.org/library?search=netssaf

a) Wet mixed blackwater and greywater system with offsite treatment

In this system, all wastewater which is created by households and institutions, also partly industries and commercial establishments is collected, transported through gravity sewers or pumping mains, and treated without stream separation. There are different user interface technologies available for the collection of blackwater. These can be cistern-flush toilets or pour-flush toilets.

After collection, the blackwater is mixed with household greywater as it leaves the house; the mixture (referred to as "wastewater") is transported to a centralised treatment plant. Then a wide array of technology options for wastewater treatment can be applied. These treatment processes are generally biological reactors that convert the organic matter into bacterial cells, CO_2, and other non-noxious carbonaceous products. Some of the nutrients such as nitrates and phosphates can also be removed in the treatment process. The treated effluent is then discharged into the environment while the sludge produced is dried and disposed of on land or used as a soil conditioner.

The most common transport technology for "system" is sewer pipes with gravity flow. This system is generally called conventional sewer system. Occasionally, non conventional vacuum systems are used as a transport technology.

For this system new approaches and technologies have also been developed to take into account the limited financial capacities of low and middle income countries. Simplified sewers, also called condominial sewers, have less stringent design criteria, are located in backyards or sidewalks rather than under the roads, and can be constructed together with the community, although operational challenges have to be considered. This is a type of technology for wastewater transport which is used for example in Brazil.

b) Wet mixed blackwater and greywater system with semi-centralised treatment

This system, like the previous one, is characterised by flush toilets (cistern flush, pour flush or vacuum toilets) at the user interface. Here however, the treatment technology is located closer to the source of wastewater generation. Depending on the plot size, the treatment technology will be appropriate for one house, one compound or a small cluster of homes or an entire settlement.

Transport to the treatment plant is limited to short distances mostly by gravity sewers. There are various technology options for on-site wastewater treatment, which differ from those typically used for centralised, off-site technologies. These may or may not treat the wastewater to the same effluent standard as a centralised treatment facility, but due to the smaller volumes this can still be acceptable in environmental terms. Examples include anaerobic baffled reactors, constructed wetlands, DEWATS[3] and biogas plants (Gutter et al., 2009). Although it is commonly practiced, pits

[3]DEWATS stands for Decentralised Wastewater Treatment Systems, see www.borda-net.org

should not be used as disposal sites for mixed wastewater systems.

Figure 3: Vertical flow constructed wetland in the "Olympic forest park" located north of the city centre of Beijing, Peoples Republic of China, 2008 (source: J. Germer, 2008)[4].

c) Wet blackwater system

In this system, urine, faeces and flushing water (together called blackwater) are collected, transported and treated together. However, greywater is kept separate. Since greywater accounts for approximately 60% of the wastewater produced in homes owning flush toilets, this separation simplifies blackwater management. A common example of this system is the double-pit pour flush toilet; this technology allows users to have the comfort of a pour-flush toilet and water seal. Another technology option is anaerobic treatment for blackwater with biogas production.

In this system, a separate process for greywater management must be implemented. Since separated greywater contains few pathogens, and usually low concentrations of nitrogen and phosphorus, it does not require the same level of treatment as blackwater or mixed wastewater. Greywater can be treated with soil filters and recycled for irrigation, toilet flushing, cleaning around the house etc.

d) Wet urine diversion system

In this system, faeces, flushing water and greywater are collected, transported and treated together but urine is kept separate. The diversion of urine from the other flowstreams requires a specific user interface, known as a urine diversion toilet. Urine can be either collected with or without flushing water (see von Muench and Winker, 2011, for a detailed description of this concept).

The objective of the urine separation is to keep the urine free of pathogens and to ultimately facilitate its reuse in agriculture. In wet urine diverting systems, the faeces are flushed with water to an off-site treatment facility. Sometimes the urine is mixed with a small amount of flushing water. Due to the novelty of the user interface and the complicated infrastructure required for this type of system, it is not widely used yet and exists only in some demonstration projects[5].

e) Dry excreta and greywater separate system

Here excreta, a mix of urine and faeces, are discharged at the user interface without using any flushing water. Greywater is collected separately. Consequently, although the mixture of urine and faeces is wet, the system is referred to as "dry" because there is no flushing water. Depending on the cultural habits, anal cleansing water may or may not be included although odour and flies are minimised if the mixture is kept as dry as possible. This is particularly true for the simple composting toilets (such as Arborloo, Fossa alterna) that can become smelly if too much water is added.

Generally, the system is characterised by "drop and store" latrines that are emptied or abandoned when full. The separate greywater should be treated close to where it is generated (on-site-treatment). The faecal sludge may be further treated off-site. Generally, off-site treatment of faecal sludge for pathogen removal is difficult to organise properly and unfortunately often neglected. Households who do not have sufficient space to move their latrine over a new pit once it is full will often revert to emptying the pits by hand and burying the sludge in shallow pits nearby. It is possible to either reuse the recovered resources (greywater or treated faecal sludge) or to dispose of them when interest in reuse is lacking.

Figure 4: Faecal sludge being discharged from trucks into treatment beds in Cotonou, Benin (source: S. Blume, 2010).

Certain innovations of this type of system have incorporated an enhanced drying process for the pit contents, producing dry compost that is simple to handle and dispose of. These latrines, also called desiccating latrines, generally use

[4] See SuSanA case study for details: www.susana.org/lang-en/case-studies?view=ccbktypeitem&type=2&id=36

[5] See SuSanA case studies with urine diversion flush toilets in Linz (Austria) www.susana.org/lang-en/case-studies?view=ccbktypeitem&type=2&id=66 and in Eschborn (Germany) - www.susana.org/lang-en/case-studies?view=ccbktypeitem&type =2&id=63

passive air flow enhancers and/or solar heat to speed up the drying process.

f) Dry urine, faeces and greywater diversion system

This system is characterised by the separation of urine, faeces and greywater into three different flowstreams, and, where anal cleansing water is used, a fourth flowstream. In this way, each flowstream can be separately managed in terms of its volumetric flow, nutrient and pathogen content and handling characteristics. This diversion can facilitate more targeted treatment and end use for the different fractions. This system requires a urine diversion dehydration toilet (UDDT) and a separate greywater treatment system.

In UDDTs, urine is collected through the front outlet and conveyed to a collection vessel (a tank in larger, more expensive systems or a jerrycan in smaller, simpler systems), or a soak pit if the urine is not reused. Through the second outlet the faeces are collected in a container located underneath the toilet pan or seat. The urine diversion squatting pan or seat can also be equipped with an additional outlet for anal cleansing water which is then treated in a separate flowstream. More information on UDDTs is available in Rieck et al. (2012).

g) Dry excreta and greywater mixed system

Urine, faeces and greywater are mixed in the same on-site collection, storage and treatment technology. Although this type of system with a simple soak pit for excreta and greywater together can be found in rural and peri-urban areas of many developing countries, it is not considered to be good practice in densely populated areas, or areas with high groundwater tables or unfavourable soil conditions. The difference between this system and the dry excreta and greywater separate system is the lack of separation of greywater. The performance of these systems has been enhanced through the incorporation of a sealed chamber into which all the wastes are disposed (a digester or type of septic tank system) with a filter at the outlet before the effluent enters a soak-away. The digester provides an environment for the partial treatment of the wastes.

Box 1: Note on reuse of sanitation sludge

Care should be taken in promoting the direct reuse of sanitation sludge for agricultural purposes. The digestion of wastes, even over long periods, may not render the compost-looking sludge completely free of pathogens. In particular the ova (eggs) of many protozoan parasites are not easily rendered non-viable even under good composting conditions. Users should always be informed on the safe use of the sludge including use of protective clothing (boots and gloves), and which crops it can be applied to.

4 Description and evaluation of technology components

In all the recent publications that have described sets of typical sanitation systems (Cruz et al., 2005; IWA, 2005; Tilley and Zurbruegg, 2007; Tilley et al., 2008; DWA, 2010) a certain procedure was applied to characterise technologies: along with the description of the sanitation system, each technology (or technological component) is discussed and described. The technology is grouped according to its role in the process (i.e. the function that it serves) while on the other hand it is also sub-divided according to the flowstreams that it deals with.

Table 1: List of sustainability criteria that can be used to evaluate and compare technological components and complete sanitation systems

Health issues	
reduces exposure (and thus health risks)	of users
	of waste workers
	of resource recoverers /reusers
	of “downstream” population
hygienisation rate	
increases health benefits	
Impact on environment / nature	
use of natural resources	needs low land requirements
	needs low energy requirements
	uses mostly local construction material
	low water amounts required
low emissions and impact on the environment	surface water and groundwater
	ground water
	soil / land
	air
	noise, smell, aesthetics
good possibilities for recovering resources	nutrients
	water
	organic matter
	energy
Technical Characteristics	
allows simple construction and low level of technical skills required for construction	
has high robustness and long lifetime/high durability	
enables simple operational procedures and maintenance; low level of skills required	
Economical and financial issues	
has low construction costs (unit cost per household) and low operation and maintenance costs	
provides benefits to the local economy (business opportunities, local employment, etc.)	
provides benefits or income generation from reuse	
Social, cultural and gender	
delivers high convenience and high level of privacy	
requires low level of awareness and information to assure success of technology	
requires low participation and little involvement by the users	
takes special consideration of issues for women, children, elderly and people with disabilities	

The technological components and the complete sanitation systems need to be discussed and evaluated with respect to specific sustainability criteria. Examples for such criteria are given in Table 1. This can lead to a comparison of the sustainability of different systems. Examples of such evaluations are given in Section 12 of each SuSanA case study (www.susana.org/case-studies).

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Authors and contributors

Main authors:

- Christian Zurbruegg, Eawag/Sandec, Switzerland (christian.zurbruegg@eawag.ch)
- Arne Panesar, GIZ, Germany (arne.panesar@giz.de)
- Soeren Rued, GIZ, Germany (soeren.rued@giz.de)

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For questions or comments please contact the SuSanA secretariat at info@susana.org or susana@giz.de. We invite you to join the SuSanA discussion forum: www.forum.susana.org. This document is available at www.susana.org.

More photos of sanitation systems and technology options are available here: http://www.flickr.com/photos/gtzecosan/collections/72157626218059440