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Urine Diversion: One Step Towards Sustainable Sanitation

Elisabeth Kvarnström, Karin Emilsson, Anna Richert Stintzing, Mats Johansson, Håkan Jönsson, Ebba af Petersens, Caroline Schönning, Jonas Christensen, Daniel Hellström, Lennart Qvarnström, Peter Ridderstolpe and Jan-Olof Drangert

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Foreword

Sweden has a strong position among countries working with development of sustainable sanitation system alternatives. The past 15 years have seen an evolution of techniques, methods and organizational structures that are far-reaching in environmental protection and sustainability. It is of great importance to collect and disseminate the knowledge that has been generated during this period. This report presents the current state-of-the-art of urine-diverting systems, focusing on Swedish experience. The report is an important statement and a contribution to the work for global sustainability and the achievement of the Millennium Development Goals.

In 1995, Stockholm Water Company initiated a research and development project on urine diversion that ran until 2000. The results are presented in the report "Urine separation – Closing the Nutrient Cycle", available at www.stockholmvatten.se. At that time, urine diversion was a new phenomenon, mainly implemented in areas with high environmental ambition and in eco-villages. The project generated valuable information on health, agricultural reuse, social and technical aspects. Now we are seeing a shift in development, and the next step is mainstreaming and large-scale implementation. The experiences in Sweden since then have been focused mainly on organizational aspects, planning and implementation.

Although we have well-functioning large-scale sanitation systems in Sweden there is a need to develop alternatives. There are situations where a traditional, large-scale system solution cannot meet sustainability goals. One example is areas where there is no sanitation coverage at all in combination with an ongoing population growth, another where there is a need for high ambition in environmental protection and resource management. Development of alternatives drives evolution, and in the case of urine-diverting systems we are forerunners.

Some aspects are of specific importance when introducing new sanitation systems. Appropriate planning and early interventions, the involvement of stakeholders at an early stage and the access to technical instructions are vital for successful implementation, as is shown in the report.

Urine diversion is a system solution of great potential. Closing the loop through nutrient recycling is a key sustainability challenge and this technique makes it possible without expensive treatment processes. Given the proper attention to remaining questions, such as residual pharmaceuticals and hormones, urine diversion has a large potential for sustainability.

Stockholm, 2006-02-09

Gunilla Brattberg, Deputy Managing Director, Technical Director Water Supply and Water Consevation, Stockholm Water Company

Preface

This report presents the current state of the art of urine-diverting systems, with focus on Swedish experiences of urine diversion. The intention is to inspire decision- and policy-makers to consider urine diversion for sanitation interventions aimed at meeting the sanitation target of the Millennium Development Goals. Section 1 describes how urine diversion can help meet multiple Millennium Development Goals. Going to scale with urine diversion is also discussed in this section.

Another target group for this report is municipal engineers worldwide, whom we want to enthuse to consider urine diversion as an alternative/complement to currently used sanitation options. Section 2 gives examples of urine diversion in different Swedish settings, both from a technical and organizational point of view. Moreover, different aspects of urine diversion from user to field are described in this section.

This report has profited from invaluable input from several persons. Many thanks are due to Arno Rosemarin and Xiao Jun (both Stockholm Environment Institute), Amah Klutse (CREPA, Burkina Faso), Teddy Gounden (eThekwini Municipality, South Africa), Ricardo Izurieta (University of South Florida, USA), Christine Moe (Rollins School of Public Health at Emory University, USA), Lana Corrales (National Centre for Environmental Health, USA), Ron Sawyer (TepozEco, Mexico) and Larry Warnberg (oyster farmer, USA) for their important knowledge contributions to this report.

Kristina Nyström helped out through in-depth investigations of the Swedish urine diversion market, work for which she is gratefully thanked.

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If, in spite of the good input we have had from all mentioned above, there are still errors in the report, the responsibility is solely the authors.

Stockholm and Uppsala 2006-02-08

Elisabeth Kvarnström, Karin Emilsson, Anna Richert Stintzing, Mats Johansson (all VERNA Ecology, Inc.), Håkan Jönsson (Swedish University of Agricultural Sciences), Ebba af Petersens (WRS), Caroline Schönning (Swedish Institute of Infectious Disease Control), Jonas Christensen (Ekolagen), Daniel Hellström (Stockholm Water Company), Lennart Qvarnström (Stockholm Water Company), Peter Ridderstolpe (WRS), Jan-Olof Drangert (Linköping University)

Definitions

Blackwater	Domestic wastewater containing human waste, usually a definition of wastewater from the toilet, if water is used for conveyance of human waste
Dual-flush urine diversion	Dual-flush urine diversion toilets have separate collection of urine and faeces. The faecal fraction is flushed with water, as is the urine fraction.
EPA	Environmental Protection Agency
Exergy	Exergy is the maximum amount of work that can be extracted from a physical system by exchanging matter and energy with large reservoirs in a reference state. This work potential is due to either a potential due to a force, temperature, or the degree of physical disorder. While energy is conserved, exergy can be destroyed. While there is a constant amount of energy in the universe, the amount of exergy is constantly decreasing with every physical process.
EU	European Union
Eutrophication	Eutrophication is over-enrichment of a water body with nutrients, resulting in excessive growth of algae and plants and depletion of oxygen concentration by its decomposition.
Greywater	Greywater is domestic wastewater from kitchens, personal hygiene, and laundry
IEC	Information, Education and Communication
K	Potassium, one of the macronutrients vital for crop development
MDGs	Millennium Development Goals
N	Nitrogen, one of the macronutrients vital for crop development
O&M	Operation and Maintenance
Outhouse	Simple, dry sanitation, with combined collection of urine and faeces in a facility detached from the house – a latrine. Outhouses are common sanitation alternatives in summer houses in Sweden.
P	Phosphorus, one of the macronutrients vital for crop development
Primary, secondary and tertiary wastewater treatment	Primary wastewater treatment is applied to remove solids from wastewater. This is mainly accomplished through sedimentation. Secondary wastewater treatment is often preceded by primary treatment and involves the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment. Activated sludge and trickling filters are two of the most common means of secondary treatment. Tertiary treatment encompasses unit processes following on secondary treatment. Examples of tertiary treatment processes are phosphorus and nitrogen removal.
Pathogens	Disease-causing micro-organisms
pe	Person equivalent
Sida	Swedish International Cooperation and Development Agency
Sludge	Sewage sludge is formed through different unit processes in the wastewater treatment plant. Primary sludge is formed through pre-sedimentation. The biological unit process will also result in sludge as will precipitates in tertiary treatment.
SMI	Swedish Institute for Infectious Disease Control
Swedish EPA	Swedish Environmental Protection Agency
UN	United Nations
Urine-diverting dry toilet	Urine diversion in dry systems have separate collection of urine and faeces. The faecal fraction is collected dry, without water-flushing. The urine bowl can be flushed with a small volume of water, either automatically through a flush mechanism or by hand.
VIP latrine	Ventilated Improved Pit latrine
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

Section 1 – Urine Diversion and the MDG Challenge

Chapter 1: Background

This chapter provides an overview of what makes urine diversion a sustainable sanitation alternative to be considered by decision makers around the world as an option to help reach the Millennium Development Goals (the MDGs). It also gives examples of urine diversion from around the world.

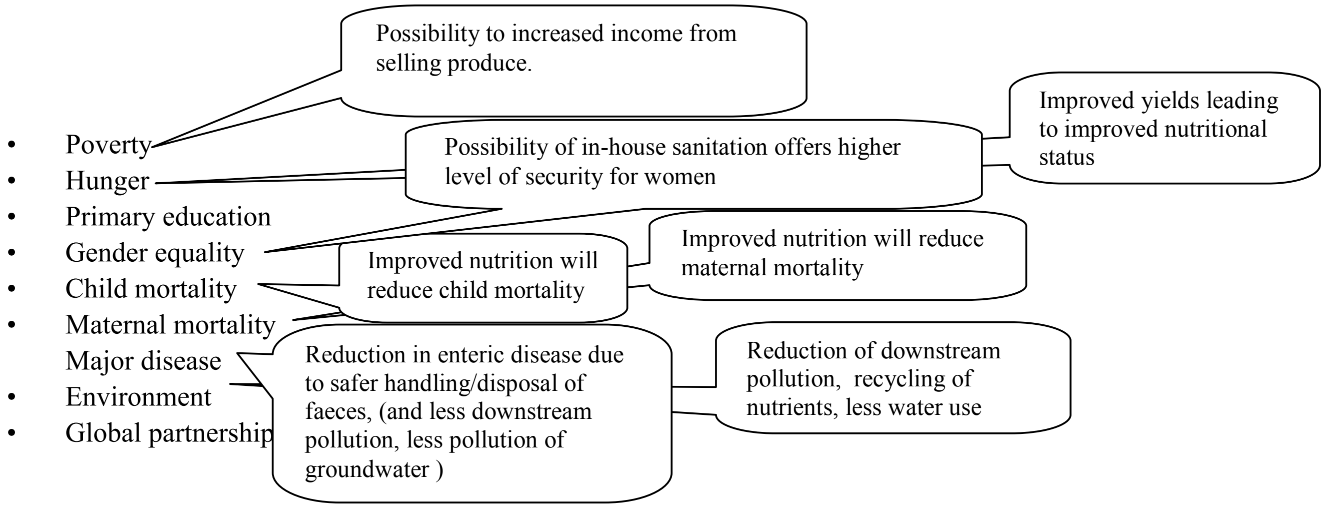
The expansion of centralized, waterborne wastewater treatment plants accelerated during the latter half of the nineteenth century in Sweden, and today approximately 90% of the Swedish population is connected to centralized wastewater treatment plants. The remaining 10% rely on on-site sanitation. The connection of sewers to functioning wastewater treatment plants has led to improved health and environment.

Even if centralized wastewater treatment still dominates for large infrastructural investments, a shift can be noted in the sanitation discourse during the past 15 years, as a result of an increased environmental awareness. This has, in the Swedish context, led to the development of so-called alternative sanitation treatment methods, both for on-site treatment as well as for centralized wastewater treatment. Urine diversion is an alternative, or rather a complementary, sanitation technology which has been implemented in many places in several different countries worldwide (see Chapter 2 for international examples and Chapter 3 for Swedish examples).

Technical and organizational experiences concerning urine diversion have been generated both in Sweden and internationally through piloting and some larger scale interventions. The intention of this report is to communicate experiences generated to date about how urine diversion systems can be constructed and organized in order to function properly, with a focus on experiences gained in the Swedish context.

1.1 URINE DIVERSION AS ONE POSSIBILITY TO MEET THE MILLENNIUM DEVELOPMENT GOALS

The UN Task Force 7 on Water and Sanitation has shown that meeting the water and sanitation target will influence, positively, the meeting of all Millennium Development Goals (see Appendix 1 for a full account of the Millennium Development Goals). Water supply and sanitation services were recognized as being critical to sustainable development — contributing to increased food security, supporting environmental protection, empowering women, and reducing productivity losses due to morbidity and malnutrition. The significance of water supply and sanitation can therefore not be overemphasized, and decision-makers, both in the South and the North, must take the water and sanitation task extremely seriously. If sanitation is provided using urine diversion with subsequent nutrient cycling, further benefits can be reaped by meeting the sanitation target. Urine diversion can provide hygienic fertilizer for “free”, which can be used for cultivation purposes. Thus, urine diversion can provide additional positive impacts for meeting the MDGs.



Malnutrition is estimated to have a significant role in the deaths of 50% of all children in developing countries (10.4 million children under the age of five die every year)[1]. In this light, urine diversion and subsequent use of urine as a fertilizer appear as a promising technology to consider for MDG sanitation interventions, see Box 1.

Box 1. Effects of urine diversion from an MDG perspective

As a sanitation technology in the MDG perspective urine diversion is of importance in many ways.

- It improves dry sanitation facilities by:
  - reducing odours
  - facilitating maintenance of the system
- It contributes to improved health:
  - easier and more hygienic handling of the faeces
  - reduced risk of pathogen transport to groundwater
- It can provide more permanent interventions compared to, e.g., VIPs:
  - simplified emptying increases the toilet lifetime
- It facilitates nutrient cycling and creates possibilities to increase food security:
  - urine contains the majority of nutrients found in excreta
  - urine is an excellent fertilizer, suitable for all crops needing quick-acting nitrogen
  - urine has an extremely low content of micro-pollutants such as, e.g., heavy metals
  - urine leaving the bladder has a high microbial quality (i.e. low content of pathogens)
- Urine diversion systems need not be more expensive than similar conventional technologies:
  - dry urine diversion was shown to be cheaper to install than VIPs in West Africa
  - dry urine diversion was shown to be the cheapest alternative for on-site sanitation in the Swedish context
  - one example has shown that over a ten-year period the full toilet investment can be paid for solely by the value of nitrogen and phosphorus in the urine for an Indian family of six (see Chapter 2 for details)
- Urine diversion systems contribute less to environmental contamination than conventional sanitation systems:
  - reduced risk of groundwater pollution for dry urine diversion systems
  - reduced risk of surface water pollution for water-flushed urine diversion systems

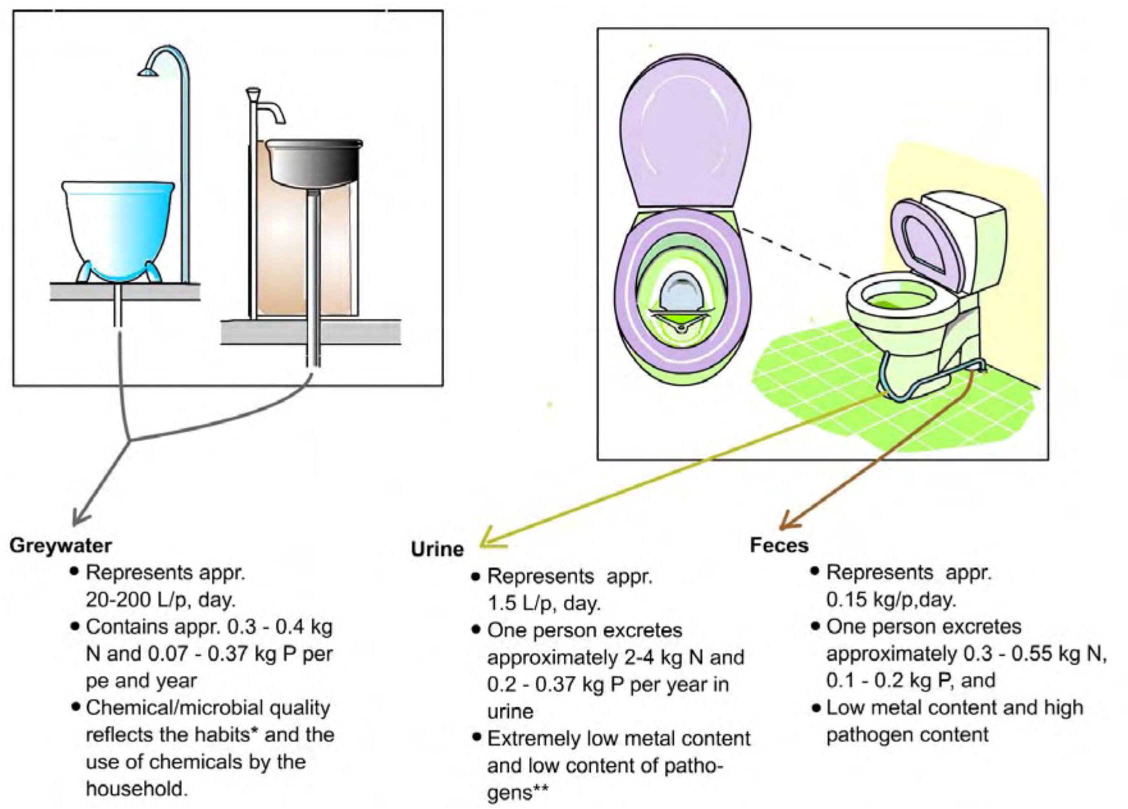
[1] WHO. 2000. Turning the tide of malnutrition: responding to the challenge of the 21^{st} century. World Health Organization.

1.2 WHAT IS URINE DIVERSION?

The major difference of urine diversion compared to other sanitation systems is that a urine-diverting toilet has two outlets and two collection systems: one for urine and one for the faeces, in order to keep these excreta fractions separate. Other than that, the system contains only conventional technical construction material/devices, even if they might be used in completely or partly new ways. The urine-diverting toilets can be either water- or dry-flushed, they come in pedestal as well as squatter models with models suitable both for those using water as well as tissue or other solid objects for anal cleansing. There are ways of achieving urine diversion both in rural settings as well as in urban areas. Research and experience show that the systems function in all these different settings, provided that they are properly installed, operated and maintained.

Urine diversion in itself shall be seen as a complementary technology since the other wastewater flows (faeces fraction, greywater and stormwater) also need to be handled and treated, Figure 1. The faecal fraction will, due to its possible high content of pathogens constitute the main hygienic risk. This aspect needs to be accounted for when designing/planning a sanitation system, especially if the faeces are also intended for reuse as a fertilizer. An effective treatment to reduce the pathogen content and safe handling procedures is of importance to manage health risks.

Urine diversion can be considered a component that can improve the sustainability[2] of sanitation systems in several different kinds of sanitation infrastructural contexts:



* dependent on habits, e.g. washing of diapers

** few diseases transmitted through urine, risk dependent on faecal cross-contamination

Figure 1. Urine diversion – flows and content of different wastewater fractions. Picture by Palmcrantz & Co.

2 The implementation of the concept of sustainable development is symbolized rather by a direction indicator than a specific state. It is our belief that sanitation systems, including related services, which protect and promote human health, do not contribute to environmental degradation or depletion of the resource base, are technically and institutionally appropriate, economically viable and socially acceptable will take us in the direction of sustainable development.

Context 1. On-site water and sanitation (or no sanitation at all) with low population density (rural to urban edge)

Improved sanitation and nutrient recycling are drivers for urine diversion in this context. Since urine diversion places different demands on infrastructure compared to conventional technologies, it is easier to introduce in situations where there is less existing conventional infrastructure, as is usually the case in this context. This is also one of the contexts for which the Millennium Development Goal efforts will have to be concentrated when it comes to meeting the sanitation target. In this context one major driving force for urine diversion is the possibility of obtaining a high quality, quick-acting fertilizer for free.

Figure 2. Urine diversion in the on-site low population density context. a) South Africa, photo: Aussie Austin b). Sweden, Separett is a dry urine diverting toilet for indoor use. Photo: Mats Johansson.

Context 2. On-site water and sanitation (or no sanitation at all), with a high population density (urban to peri-urban)

This situation is extremely prevalent in any peri-urban setting, for example in Africa, Asia or Central America. One example is Jakarta (population density of 1,200 people/ha in slum areas), where 70–90% of the population relies on on-site sanitation, and only 40–50% of these are in working condition[3]. Improved sanitation is the obvious driver in this context – as urine diversion improves the functioning of dry sanitation both from a household as well as from a municipal O&M perspective, compared to a conventional VIP (see Box 3). This context is also one within which much effort will be invested for meeting the sanitation target for the Millennium Development Goals as urban populations around the world continue to increase dramatically. The possibility of obtaining a high-quality, quick-acting nitrogen fertilizer for free (urine is well suited for increased efficiency in urban agriculture) is also an important driver for urine diversion in this context. The high population density would allow for micro enterprises to develop to handle the urine.

[3] Presentation made by Richard Pollard (WSP Jakarta) at World Water Week 2005.

Figure 3. Urban agriculture in Kampala, Uganda, supplies the city with a substantial percentage of the food intake. Photo: Margaret Azuba.

Context 3. A piped water distribution system and wastewater collection system exists but with no or inadequate wastewater treatment

Only 2% of cities in sub-Saharan Africa have sewage treatment, and only 30% of these are operating satisfactorily[4]. Median percentage of wastewater treated by efficient treatment plants per continent are shown in Figure 4. The main benefit of urine diversion in this context is reduced environmental load on the recipient of the untreated wastewater. The discharge of untreated wastewater into coastal waters causes economic losses for fishermen and aquaculture as well as for the tourism industry. Nutrient cycling for improved urban agriculture is another driver in this context, where the high population density would allow for commercial handling of the urine.

Box 2. Impacts of sanitation on surface waters

Hood Canal in Washington State (USA) is renowned for its commercial and sports fishing and shellfish harvesting. However, Hood Canal is suffering from fish and shellfish death due to eutrophication. The major eutrophication source is nitrates from untreated wastewater from on-site systems[5]. Washington State Department of Health has made a calculation of the prohibited acreage in shellfish growing areas, due to elevated faecal coliform levels, and found that 74% of the acreage closed was due to potential impact from wastewater treatment plants and 20% from non-point sources (including impact from on-site sanitation)[6]. It has been estimated[7] that the impact of bathing in, and eating shellfish from, polluted seas is approx. US$12–24 billion per year.

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4 UNEP. 2004. International Source Book on Environmentally Sound Technologies for Wastewater and Stormwater Management. (www.unep.or.jp/ietc/Publications/TechPublications/TechPub-15/3-1Africa/1-3-1.asp)

5 http://www.psat.wa.gov/Publications/hood_canal/HC_PACA.pdf

6 Washington State Health Department, communication with Scott Berbells.

7 GESAMP (2001). A Sea of Troubles. Rep. Stud. GESAMP No.70. 35

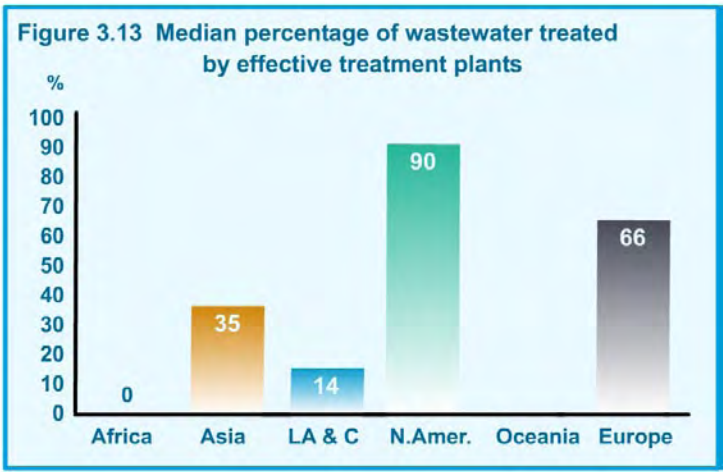

Figure 4. Median percentage of wastewater treated by efficient treatment plants per continent. (Source: UNEP 2004. International Source Book on Environmentally Sound Technologies for Wastewater and Stormwater Management. (http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-15/3-1Africa/1-3-1.asp))

Context 4. A piped water distribution system and wastewater collection system and adequate wastewater treatment exists

In this sanitation context it is generally more difficult to promote urine diversion as it is not immediately obvious that the cost/benefit ratio is advantageous. A possible driver could be increased demand on nutrient removal, since more than 50% of the N can be instantly removed from the wastewater by urine diversion. It has been shown in systems analyses that urine diversion is a resource-efficient way to achieve N removal from the wastewater. Urine diversion can decrease the exergy use in the wastewater treatment plant while simultaneously increasing its nitrogen removal performance[8]. Water-flushed urine diversion toilets have also been shown to be competitive through cost analysis, if nitrogen removal and nutrient recovery is required[9].

Figure 5. Urine-diverting toilet system at Kullön, Sweden. Photo: Ron Sawyer.

[8] Hellström, D. (1998). "Exergy Analysis: A Comparison of various treatment alternatives for nutrient removal". 8th International Gothenburg Symposium on Chemical Treatment in Prague, 7-9 September 1998, pp 313-324. and Hedström, A., Hellström D., Ericson L. (2000). A comparison of human urine, commercial fertilizer and green manure crops as nitrogen fertilizers – an exergy analysis. In: "Adsorption and reclamation of wastewater nitrogen and the value of human urine as a nitrogen fertilizer". Licentiate thesis LTU 2000:17.

[9] Hellström D. (ed), 2005. Final report from the model city Hammarby Sjöstad, Urban Water Report 2005:4, Chalmers University of Technology, Gothenburg, Sweden (in Swedish)

1.3 URINE DIVERSION AND DRIVERS FOR SANITATION

Figure 6. Urine diversion toilet in Burkina Faso. Photo: Karin Ahlgren.

The identification of sanitation drivers is crucial in order to ensure the acceptance of any sanitation intervention directed towards a population previously not served and to gain the intended health benefits for the population at large. Urine diversion has been researched and implemented in seven different West African countries for the past three years by the CREPA[10] organization. They have been conducting a three-year multidisciplinary applied research programme on ecological sanitation in seven of the 17 countries they are covering. The research encompassed sanitation technology, sociological aspects, hygiene and agriculture. The research results show that urine diversion is feasible in West Africa, since the concept was accepted and appreciated by the users in all countries. The urine diversion toilets could also be constructed at less of a cost of a VIP in all countries. CREPA also found, by working in peri-urban and rural areas, for example, demonstrating the fertilizing value of sanitized urine and faeces in cultivation, that the fertilizing value of the sanitized excreta worked as a factor raising the sanitation demand within the populations see Box 3.

Box 3. Urine utilization in West Africa

- CREPA conducts urine fertilization research and demonstration in seven different West African countries. After two years of demonstration users in all seven countries use urine as a fertilizing agent on different types of crops (e.g. cassava, cotton, lettuce, tomatoes, cabbage, and gombo). The appreciation of urine as a fertilizer was marked, e.g. in Anagbo in Bénin, by stored urine-filled jerry cans being stolen and then returned… empty!
- Another example is Saaba in Burkina Faso where the CREPA agricultural research team had a hard time obtaining enough urine for their research site, when the population realized the fertilizing power of urine, and a strong demand for urine-diverting toilets is present in the population not covered today.
- In Burkina Faso, the villagers in Sabtenga call the urine diversion toilet “Yiyandin” which means “come out from shame” or “our shame is finished”. The reason for giving the toilet this name is the dignity experienced from having a toilet to offer visitors instead of open defecation and also because of the possibility to produce crops with this type of toilet.
- In Côte d’Ivoire, a farmer said when he visited the cassava experimental field of CREPA “*we know the quality of this type of soil, we never yield cassava on it. When CREPA started this project we did not believe that they will gain something from this soil, but when they harvest the cassava and invited us to come and see, we agreed with them that urine has a great value as fertilizer. The Atieké made by this cassava is delicious so there is no change on the taste. We are now convinced and next year we will start our own experience*”.
- In Togo and Benin, in polygamist families, there was an issue of who had the right to use the collected urine. Usually in polygamist families, each wife has her own field, and if children of the second or third wife contribute to the collection of urine they also need to share the collected urine to benefit everyone.

The village chief in Sabtenga, Burkina Faso, shows with pride his production of green peppers using urine as fertilizer. Photo: Anna Richert Stintzing.

[10] Centre Régional d’Eau Potable et Assainissement, an international network organization encompassing French-speaking countries in West and Central Africa.

The monetary value of the nutrients in the urine is an incentive for urine diversion, both at household level as well as for the development of micro-enterprises around urine-diverting sanitation systems and services. A simple calculation of the monetary value in NPK content in urine shows that a urine-diverting toilet will pay for itself within ten years or less, depending on choice of urine-diverting toilet, for a family of six persons in, for example, India, Box 4.

Box 4. Ecosan – both economic and eco-sane (published in the June issue of Water21)

In the April issue of Water21 (p28–30), Prof Duncan Mara, using an example from India, argues that ecological sanitation* (ecosan) is more expensive than conventional sanitation. However, he is misled by a faulty calculation. When this is corrected, his example convincingly shows that ecosan is economical and thus eco-sane, using Prof Mara's criteria and terminology.

The following data from India was given by Prof Mara. The cost of a pour-flush toilet is 1,900 rupees and the cost quoted by Duncan Mara of an ecosan* toilet is 4,200 rupees**. The family in the example consists of two adults and four children and their total excretion is assumed to be the same as from four adults. The excretion of one adult is given as 4.55 kg N, 0.58 kg P and 1.27 kg K and the cost of NPK fertilizer as 10 rupees per kg.

The yearly excretion of this Indian family of six is approximately 18.2 kg N, 2.3 kg P and 5.1 kg K, which adds up to 25.6 kg of the nutrients N, P and K. However, chemical fertilizers do not only contain N, P, and K but also oxygen and hydrogen etc. Therefore, the amount of nutrients in the excreta corresponds to around 75 kg of NPK 25-2-6 fertilizer, which according to the data above costs approximately 750 rupees in India. The present value of 750 rupees over years two to ten at 10% interest rate is about 4,300 rupees. Thus, over a ten-year period the ecosan toilet not only pays for the extra investment compared to a pour-flush toilet, but for the whole toilet investment! Furthermore, the excreta fertilizers are of even higher value to the poor, as they can normally not afford any fertilizers. Thus, ecosan is advantageous from the perspectives of poverty alleviation and gender, as most poor are women and children.

Excerpt of debate article in the June Issue of Water21, written by Håkan Jönsson, Christine Werner, Ralf Otterpohl, Arno Rosemarin, Paul Calvert, Björn Vinnerås

* ecological sanitation = systems allowing the safe use of human excreta in cultivation, with minimum resource use.
** cheaper ecological sanitation systems than the one quoted by Duncan Mara exist on the Indian market, one of which is a plastic chamber with a urine diversion squat pan for approximately 2,400 INR.

A driver for dry urine diversion on municipal level is facilitated maintenance compared to the services demanded for VIP or even traditional simple pit latrines. What should be remembered here is the fact that service systems for VIP emptying can be anything from extremely expensive to non-existent, see Box 5. Whilst for simple pit latrines, rather than emptying the pit, households often resort to building an entirely new latrine. However, with time and / or increasing population density this becomes almost impossible. Moreover, it is important to remember that the urine represents a fertilizer around which there are excellent possibilities for micro-enterprises to develop.

Box 5. Urine diversion in Durban, South Africa (unpublished data, eThekwini Municipality)

140,193 households lack sanitation facilities in the eThekwini Municipality (Durban, South Africa). The goal of the Water and Sanitation Unit of the municipality is to clear this sanitation backlog by 2010. The unserved areas are mainly rural communities of the municipality, on the urban edge. EThekwini Municipality has taken a strategic decision to use (i) urine diversion toilets together with (ii) health and hygiene education and (iii) a provision of 200 L water/household/day as the sanitation alternative to fight the sanitation backlog within the unserved areas. From the municipal perspective one reason for going for urine diversion toilets rather than VIPs is that VIPs demand mechanical desludging. The mechanical desludging equipment is expensive, vulnerable to failure, often cannot access the site and frequently cannot cope with the heavy sludge and solid matter found in the pit. The alternative is manual emptying, where people dig excreta and solid waste out of the pit, using shovels, buckets and other implements. This work can be deeply unpleasant, and poses a number of health risks if not managed carefully. For those pits that can be accessed by tanker the average costs for emptying one pit is in the region of the equivalent of €77–128, the householders contribution for emptying the pit is €10. The rest of the costs are subsidized by the municipality (applicable to Durban), which puts the municipality in an unsustainable situation in the long term. Moreover, South Africa in general runs a risk of loosing previous investments in VIPs to address the sanitation backlog in peri-urban areas since previously installed VIPs are now filling up and many municipalities do not have emptying mechanisms put in place. Urine diversion toilets can, on the other hand, be maintained by the users themselves, after vigorous community participation and education in order to gain adherence to the system. To date 30,000 urine diversion toilets have been installed within the municipality and it appears to be on track for achieving the sanitation target of the MDGs.

Double-vault urine-diverting toilet with hand washing facility nearby. Photo: Teddy Gounden.

Read more

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Chapter 2: Urine Diversion – Going to Scale

This chapter gives an overview of issues critical for urine diversion up-scaling both within and outside municipal wastewater jurisdiction. This is illustrated with examples of urine diversion from around the world.

2.1 PRINCIPLES FOR LARGE-SCALE SANITATION INTERVENTIONS

There is a growing awareness among decision-makers, policy-makers and professionals within the water and sanitation sector that the wide variation in geographical, demographic, cultural, climatic, financial and other conditions makes any attempt at direct sanitation technology transfer or uniform sanitation approaches subject to large risks of failure, both considering function and organization. These risks can be reduced substantially if some principles for water and sanitation management are followed. One is to raise political will, and secure financial resources for the intervention. Another is to involve all relevant stakeholders throughout the planning and implementation to the greatest possible extent, to ensure that the sanitation system is appropriate to the context and to not restrict sanitation to simply being the supply of toilets. These principles, and others, are described in detail in Box 6. As stated in the report "Securing Sanitation – the Compelling Case to Address the Crisis" (2005), we need to think about what we mean by sanitation; think again about how to do it right, and think again about how we are going to find the money.

BOX 6. 10 keys for local and national action on municipal wastewater (UNEP/WHO/HABITAT/WSSCC, 2004)

1. **Secure political commitment and domestic financial resources**
   A political climate has to be created in which high priority is assigned to all the aspects of sustainable municipal wastewater management, including the allocation of sufficient domestic resources.
2. **Create an enabling environment at national AND local levels**
   Public authorities remain responsible for water and wastewater services. The 'subsidiarity principle', i.e. the delegation of responsibilities to the appropriate level of governance, applies to the entire water sector. National authorities should create the policy, legal, regulatory, institutional and financial frameworks to support the delivery of services at the municipal level in a transparent, participatory and decentralized manner.
3. **Do not restrict water supply and sanitation to taps and toilets**
   A holistic approach to water supply and sanitation should be adopted. This incorporates not only the provision of household services, but various other components of water resource management, including protection of the resource that provides the water, wastewater collection, treatment, reuse and reallocation to the natural environment. Addressing the environmental dimensions mitigates direct and indirect impacts on human and ecosystem health.
4. **Develop integrated urban water supply and sanitation management systems also addressing environmental impacts**
   Municipal wastewater management is part of a wider set of urban water services. The wastewater component is usually positioned at the end of a water resource management chain. Integration of relevant institutional, technical, sectoral, and costing issues of all major components of the chain is required. Consideration should be given to the joint development, management, and/or delivery of drinking water supply and sanitation services.
5. **Adopt a long-term perspective, taking action step-by-step, starting now**
   The high costs of wastewater systems necessitate a long-term, step-by-step approach, minimizing current and future environmental and human health damage as much as possible within existing budgetary limits. Non-action imposes great costs on current and future generations and misses out on the potential of re-using valuable resources. A step-by-step approach allows for the implementation of feasible, tailor-made and cost-effective measures that will help to reach long-term management objectives.

BOX 6, continued: 10 keys for local and national action on municipal wastewater (UNEP/WHO/HABITAT/WSSCC, 2004).

6. **Use well-defined time-lines, and time-bound targets and indicators**
   Properly quantified thresholds, time-bound targets and indicators are indispensable instruments for priority setting, resource allocation, progress reporting and evaluation.

7. **Select appropriate technology for efficient and cost-effective use of water resources and consider ecological sanitation alternatives**
   Sound water management relies on the preservation and efficient utilization of water resources. Pollution prevention at the source, efficient use and re-use of water, and application of appropriate low-cost treatment technologies will result in a reduction in wastewater quantity and in investment savings related to construction, operation and maintenance of sewerage systems and treatment facilities. Depending on the local physical and socio-economic situation, different technologies will be appropriate. Ecotechnology is a valid alternative to traditional engineering and technical solutions.

8. **Apply demand-driven approaches**
   In selecting appropriate technology and management options attention must be given to users' preferences and their ability and willingness to pay. Comprehensive analyses of present and future societal demands are required, and strong support and acceptance from local communities should be secured. With such analyses realistic choices can be made from a wide range of technological, financial and management options. Different systems can be selected for different zones in urban areas.

9. **Involve all stakeholders from the beginning and ensure transparency in management and decision-making processes**
   Efforts and actions on domestic sewage issues must involve pro-active participation and contributions of both governmental and non-governmental stakeholders. Actors stem from household and neighbourhood levels to regional, national and even international levels, and possibly the private sector. Early, continuous, targeted and transparent communication between all parties is required to establish firm partnerships. The private sector can act as a partner in building and improving infrastructure, in operating and maintaining of facilities, or in providing administrative services.

10. **Ensure financial stability and sustainability**
    10.1 Link the municipal wastewater sector to other economic sectors
    Sound and appropriate wastewater management may require substantial construction and operational investments in wastewater infrastructure and treatment facilities. Relative to the water supply sector, cost recovery in the wastewater sector is traditionally a long process. Developments in other (socio-) economic sectors, for instance water supply or tourism, may create opportunities to address sanitation at the same time. Linking wastewater management with other sectors can ensure faster cost-recovery, risk-reduction, financial stability and sustainable implementation.
    10.2 Introduce innovative financial mechanisms, including private sector involvement and public-public partnerships.
    Traditionally, sanitation services have been provided by public authorities. Costs for investments, operation and maintenance, however, often outstrip their capacities, as do present and future requirements for serving the un-served. Therefore, innovative, more flexible and effective financial management mechanisms have to be considered, e.g. micro-financing, revolving funds, risk-sharing alternatives, municipal bonds. Public-private partnerships, and also public-public partnerships, are important tools to assist local governments in initial financing and operating the infrastructure for wastewater management.
    10.3 Consider social equity and solidarity to reach cost-recovery
    The employment of principles like 'the water user pays' and 'the polluter pays' is required to achieve stable and sustainable wastewater management with efficient cost-recovery systems. These principles should be applied in a socially acceptable way, considering solidarity and equitable sharing of costs by all citizens and facilities. Various user groups should be made aware of – and be able to identify with – concepts such as "water-" and "catchment solidarity". All users will benefit from environmental improvement.

2.2 EXAMPLES OF LARGE-SCALE URINE DIVERSION

There are only few examples of large-scale urine diversion and nutrient recycling in the world today. The main reason for this is the inertia associated to shifts in technological systems, reflected through institutions, municipalities, education systems etc. China, Box 7 and 10, is one example of large-scale implementation of urine diversion. Another example where urine diversion has been somewhat mainstreamed is El Salvador, Box 8. Swedish examples are referred to in Chapter 3.

Below we discuss some particularities for going to scale with urine diversion in different sanitation contexts, assuming that fundamental principles such as applying a demand driven approach, gender-sensitive stakeholder processes, and appropriate technology adaptation have been put to use.

Context 1. On-site water and sanitation (or no sanitation at all) with low population density (rural to urban edge)

The example in Box 7 illustrates going to scale in a rural sanitation context. Most important factors here, according to the Chinese experience, is to provide appropriate technology allowing for in-house sanitation, demonstrated on-site in order to raise awareness in the population that dry sanitation featuring urine diversion is a technology appropriate for in-house sanitation. Another important issue is training of trainers and cooperation with other bulk infrastructure and service providers.

This underlines the need for proper training when introducing new sanitation concepts. The knowledge of possibilities of safe nutrient cycling from urine is unknown to most stakeholders (including decision-makers). The effect of this is that neither decision-makers nor other stakeholders are in the position to make informed choices in strategic planning for meeting MDGs. Suitable information and awareness-raising is therefore needed. Further there is also a need for appropriate Information, Education and Communication (IEC) programmes for execution within the users of the urine-diverting systems. The size of the IEC intervention strongly depends on the future user's previous sanitation habits as well as how much of the system maintenance is supposed to be carried out by the users themselves. Examples of different IEC approaches are shown in Box 9.

None of this can be done unless there is an enabling environment, including e.g. political support, appropriate policies and legislation and strong institutional frameworks. Supporting policy such as the China Western Region Development Strategy (CWRDS) is thus, for the Western China case, of great significance. If policies and institutions are adverse to urine diversion there are a number of steps to take, described in the forthcoming WHO Guidelines on Agricultural Use of Excreta and Greywater (currently in a draft version).

Context 2. On-site water and sanitation (or no sanitation at all), with a high population density (urban to peri-urban)

Box 10 shows another case of Chinese dry toilets with urine diversion: the construction of an eco-suburb in the city of Dong Sheng. An enabling environment is of course also extremely important for the peri-urban and urban contexts as is training. Moreover, since there is a need to develop collection services for the different fractions, it will demand institutions with sufficient capacity and clear mandates to carry out the task, either through the existing organization or through contracting. It is most important to ensure financial stability by planning services consistent with available financial resources (expected revenues and considering planned cost sharing mechanisms).

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[11] The Bellagio Principles have been used as the base for a guideline for decision-makers in urban environmental sanitation services. Read more in the document "Implementing the Bellagio Principles in Urban Environmental Sanitation Services: Provisional Guideline for Decision-Makers" published by WSSCC in 2004.
They are popular complements to e.g. facilitate cleaning.

For resource efficiency it is important that the urine is used close to the source of generation. This implies that sound sanitation planning[11] must be coupled with sound urban planning if possibilities for urine use within city limits are desired for sanitation contexts 2, 3 and 4. These possibilities could encompass, for example, support to urban agriculture, use of urine in parks and soccer fields, the provision of space for small-scale providers of sanitization of urine within the city limits etc.

If possible one should draw on experiences existing within the solid waste management sector. This sector has the necessary market experience of the handling and logistics of organic waste, very useful for the organization of urine handling and use. One can also imagine that urine collection, sanitization and use could be contracted to a farmer close to the town/city in question, which is planned for in the example shown in Box 10.

Context 3 and 4. A piped water distribution and wastewater collection system exists, *with* or *without* functioning wastewater treatment

The same reasoning as for context 2 is valid also for these contexts. It could be cheaper to achieve the desired reduced recipient load through urine diversion rather than construction of a wastewater treatment plant or upgrade/expansion of an existing treatment plant. Relining technology, used for e.g. fast internet connection installation in existing sewers, can also be carried out for centralized collection of urine. The Swiss research programme NOVAQUATIS (www.novaquatis.ch) at EAWAG are doing research on the implementation of urine diversion within centralized wastewater treatment systems. The possibility of cost recovery of system investments and services offered is higher in an area being served with wastewater collection compared to an un-served peri-urban area, with the assumption that sewer served areas are more affluent than non-sewer served areas. Thus, it is possible that higher levels of services can be offered within this context and still have cost recovery on the services. Box 11 shows a German experience of urine diversion within the municipal wastewater jurisdiction. Box 12 describes important issues for a municipality to address while organizing urine use.

Box 7. Rural urine diversion in China

The improvement of rural sanitation is one of the key issues in China's current 5-year plans. One sanitation technology used for increase in rural sanitation coverage is urine diversion using double-vault dry toilets.

A Sida-funded dry toilet urine diversion pilot project, in cooperation with NPHCCO and UNICEF-Beijing, started in 1998. The original project covered 70 households, and it was enlarged to cover 2,000 households the following year. By the end of 2003, 685,000 urine-diverting toilets had been installed in 17 provinces according to official statistics.

Key issues in the original pilot project were (i) providing indoor sanitation, which is possible through dry toilet urine diversion, (ii) training of core teams at both village and county level, and (iii) comprehensive approach with cooperation with other bulk infrastructure and service providers at the village level.

Double vault urine diverting toilet Nanning, Guangxi,China.
Photo: Arno Rosemarin.

Box 8. Urine diversion in El Salvador

The Salvadorian Government has assumed the responsibility of providing support for nutrition, sanitation, and health education for the most vulnerable population sectors. The sanitation activities have been delegated to the National Sanitation Program which is the Ministry of Health Division in charge of these activities.

In 1990 the Government Fund for Social Investment (GFSI) decided to rehabilitate those communities affected by the Salvadorian Civil War of the 1980s. The first pilot urine diversion latrines were constructed while the last combats were carried out in the Chalatenango zone. However, the GFSI implemented a latrine prototype which was not functional for the needs of the community. Consequently, the Ministry of Health (MOH) assumed the responsibility of the latrine programme with the support of UNICEF. The latrines initially constructed were modified urine-diverting pit latrines and the double-vault urine-diverting toilets (DVUDs). For more than 10 years the MOH has been improving the systems and is currently testing the prototype IV Solar urine-diverting toilet.

Since 1990, the MOH in El Salvador has constructed an approximate of 120,000 of urine-diverting pit latrines, double-vault urine-diverting toilets and solar urine-diverting toilets. At least 30% of the 120,000 units are double-vault urine-diverting toilets and solar urine-diverting toilets. MOH works in close cooperation with a number of NGOs.

Different models for financing have been used. In some communities the NGO provided both the materials and labour, whereas in others, the NGO only provided materials and information on how to build the toilet and labour was provided by the future users of the toilets. Certain overlap in activities has been noted in programmes as well as lack of regular follow-up on installations made. Urine use has not been promoted in El Salvador, and the collected urine is usually only led to a soakaway pit. It may require the participation of the Agriculture Programme in order to promote the use as fertilizer. Sanitation education interventions could, in the future, also include elements on the use of urine as a fertilizer.

The Ministry of Health has established the regulations for the construction and maintenance of each of the urine-diverting systems used. These regulations are updated according to the improvements and development done in the new urine diversion sanitation systems. General information about the MOH goals are included in its web page: www.mspas.gob.sv/p_salud_ambiental6.asp

Solar IV latrine from El Salvador. Photo: Ministry of Public Health and Social Wellbeing, El Salvador.

Box 9. Information Education Communication (IEC) tools for urine diversion

There are different successful examples of how to raise awareness around urine diversion. One is the use of an adapted PHAST/SARAR tool from West Africa, which also include the use of urine and composted faeces for productive purposes in the original sanitation concept.

Another is the sanitation exhibit in Nacka municipality outside Stockholm where five different types of toilets and two different types of waterless urinals are installed and thus can be tested in real life. A demonstration centre for urine diversion as well as simpler sanitation approaches (using composting within pit such as the arborloo and fossa alterna) has been established in Tepoztlàn, Mexico. There, faecal composting, local greywater treatment and urine use are also successfully demonstrated.

Street theatre and door to door visits have been used for education purposes in communities where dry urine diversion has been installed in peri-urban Durban.

How efficient information campaigns geared towards children can be is illustrated by the result achieved by the Swedish science TV show for children, Hjärnkontoret ("The Brain Office"). They ran a campaign during September 2005 named "Proper Crap", with the intention to reduce the amount of non-proper crap flushed down the WCs, causing malfunctioning of the wastewater treatment plants. Twelve wastewater treatment plants participated in the experiment and they had a reported influx of solids, such as pieces of plaster, hair from hair brushes, sanitary pads and tampons, dental floss, of over 128 tons weekly at the start of the experiment. For three weeks, children in the participating cities were informed about what constitutes "proper crap" (urine, poop, and toilet tissue) and the message was repeated on the programme's weekly show. Every week, a number of "Proper Crap" t-shirts were given to a few of the children reporting "Proper Crap" actions, among other things. "I myself picked up all toys that my little brother was about to flush down the toilet, then I told him that he can only flush down poop, urine and toilet tissue," says Alfred Lind, one of the children awarded a t-shirt for his "Proper Crap" action, on the children's show's home page. William Öberg-Löfstedt says that he tells everyone he knows what "proper crap" is and that he often sings "The Proper Crap song". At the end of the three-week period the amount of incoming non-proper crap to the participating wastewater treatment plants had been reduced by more than 14 tons weekly compared to the onset of the experiment. Ljusdal municipality even reported a reduction of 50% in solids into the wastewater treatment plant after the experiment and that no operational disturbances have occurred in the plant after the onset of the "Proper Crap" campaign.

Information Education and Communication material. a) Street theatre in Durban, photo: Teddy Gounden. b) t-shirt from the "Proper Crap" actions, photo: Sveriges Television ©

Box 10. Large-scale ecosan services in Dong Sheng, Inner Mongolia, China

Dong Sheng has a population of 400,000 and is located in Inner Mongolia, in the Yellow River Basin. A new suburb (Hao Zhao Kui, HZK for short) is currently under construction a few kilometres from the city centre. In all, the plan is for 2,000 households in one- and two-storey houses and four- and five-storey buildings. The first phase will be completed by 2007. The first 600 have already been completed and purchased and people started moving in at the end of 2005.

The efforts in HZK represent an attempt to apply a sustainable approach to water and sanitation systems and services, including:

- urine collection, sanitization and recycling;
- dry fecal collection, sanitization/composting and recycling;
- kitchen organics collection, composting and recycling;
- greywater collection, advanced treatment and reuse.

The city of Dong Sheng is responsible for the infrastructure of HZK – roads, water, gas, electricity, telephone, TV cable. The local government will be responsible for the operations and maintenance of the ecostations within the area, and the collection service will be included in a monthly fee paid by each household. A training programme has been set up for a team to instruct households in the use of the ecosan toilet, the dry urinal, and the source separation of solid waste. The trained ecostation personnel will be carrying out collection of fecal material and kitchen wastes and carry out the composting and eventual packaging for transfer for reuse. Local farmers are being trained for reuse of urine and composted materials. The urine storage capacity in the area allows for one month storage. Further storage, to ensure sanitization, is organized at the final urine use site. The urine will be used in local farms and greenhouses. The treated greywater will be stored in a pond and reused locally for irrigation during the non-winter seasons and discharged during the winter via underground pipe.

(left) Bins in basement containing dry faeces mixed with dry cellulose fibre – drying & bulking agent & carbon source for later composting

(right) View of pond to contain treated greywater (bathroom and kitchen) for reuse. Houses in background.
Photos: Arno Rosemarin.

Box 11. Urine diversion where existing piped facilities exist

In Eschborn, near Frankfurt, the head offices of the German technical co-operation, GTZ, are situated. During the current renovation of these offices, a modern, ecologically sustainable concept for the management of the wastewater from toilets is being installed. The main building will be equipped with waterless urinals and water-flushed urine diversion toilets, enabling the separate collection of urine and faeces. Through the separate, undiluted collection of urine, the water demand for flushing toilets will be significantly reduced. With this concept, the GTZ not only saves 900 m³ of water per year, but the load of nutrients on the wastewater treatment facilities is also reduced.

After treatment the urine will be used in agricultural tests carried out as part of a research project. The information collected from the project will also help to improve agricultural production with fertilizer originating from urine. When finished, the system will serve as a model for similar facilities, not only in Germany, but also in countries where water is scarce and fertilizer is needed in local agriculture. As the building receives thousands of overseas visitors per year from developing countries, a large public relations impact is expected.

For the treatment and reuse of the brown-water originating from the UD-toilets an additional research component is foreseen. Treatment with an activated sludge reactor, followed by membrane filtration, is currently being discussed as one possible technological option.

Urine diversion to be installed in GTZ head office. Photos: GTZ.

Box 12. Experience gained from organization of municipal systems for agricultural use of urine in Sweden.

- Start small and with the easy fractions. This can be done by the municipality collecting e.g. urine for treatment and use on their own land, to create internal experience and external awareness before going to scale with excreta and greywater use.
- Clear division of responsibility between the body responsible for control (usually the municipality) and the body executing the excreta and greywater use (could be a local farmer, contractor, farming cooperative etc).
- Long-term approach with clear agreements between the body responsible for control and the use executing body, so that the municipality can be confident in having a safe excreta and greywater use scheme. The executing body, on the other hand, also needs to know that the excreta or greywater will be available in appropriate quantities and at appropriate times, especially if they need to invest more cash or to change to crops that take longer to mature.
- Flexibility in the system, providing as many degrees of freedom as possible (e.g. allowing for use of urine at the household level for those interested, in parallel with more large-scale approaches).
- Functioning quality control of excreta and greywater, which is necessary for protection of public health, for maximizing the use of nutrients, and for creation of confidence in the system.
- Strong and continuous information flows between involved parties. This is important to build trust between the involved parties and to react to and mitigate problems that might develop.

2.3 KNOWLEDGE GAPS

Urine diversion, at least in the Swedish setting, stemmed from a grass roots development (see Section 2 for details), with the implication that the full potential of the system is not yet achieved. In order to do so there is a need to have the conventional sanitary engineers on board, which is happening only very slowly. With a technological mainstreaming of urine diversion we will see a system with more efficient diversion of the fractions, and more reliable and robust technological components. Mainstreaming will also lead to an increased availability of parts for urine diversion systems, and increased financing and attention in research and development. It is anticipated that current difficulties, such as logistical challenges of transporting large volumes of urine to fields, will eventually be addressed in this context, through for example appropriate technologies to concentrate the nutrients. Other currently unresolved issues, such as hormones (see more below), will also benefit from this increased attention

Even if it has been shown that urine-diverting toilets can be constructed more cheaply than VIPs, for example the West African context, there is a general need for cost minimization for all sanitation systems and services, including the urine collection and handling system, in order to increase the possibility of coverage and sustainable services. Effective financing mechanisms need to be developed, as for all sanitation interventions.

Fully functioning centralized sanitization of the faecal fraction from urine-diverting dry systems remains to be implemented and mainstreamed.

A large proportion of the hormones produced by our bodies and the pharmaceuticals that we consume are excreted with the urine. The question whether the use of urine as a fertilizer can have any negative effect on the quantity or quality of crops is posed. It is reasonable to believe that these risks are negligible due to the fact that all mammals, including domestic animals (which are larger consumers of antibiotics by the way), produce hormones which are constantly excreted/ used as fertilizer in terrestrial environments. These supposed negligible risks need, however, to be confirmed with field experiments.

Read more

- Proceedings of 1st International Conference on Ecological Sanitation, Nov 5 – 8, 2001. www.ecosanres.org/Nanning%20Conf%20Proceedings.htm
- SIWI 2005. Securing Sanitation – the Compelling Case to Address the Crisis. www.siwi.org/downloads/Reports/CSD_Sanitation.pdf
- UNEP/WHO/HABITAT/WSSCC. 2004. Guidelines on Municipal Wastewater Management. UNEP/GPA Coordination Office, The Hague, The Netherlands.
- Forthcoming WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume 4 – Excreta and Greywater use in Agriculture (currently in final draft).
- WSSCC. 2004. Implementing the Bellagio Principles in Urban Environmental Sanitation Services: Provisional Guideline for Decision-Makers, Geneva, Switzerland.

Section 2 – Urine Diversion: the Swedish Experience

Chapter 3: Planning for Urine Diversion – Examples from Swedish Municipalities

This chapter focuses on the possibilities of implementation of urine diversion based on Swedish experiences. System organization is presented for cases of varying complexity, from the individual house owner to a municipal system encompassing collection, treatment and use for cultivation purposes.

3.1 URINE DIVERSION IN SWEDISH SANITATION HISTORY

Industrialization caused an increased population density in towns and cities in Sweden during the 19th century. Stockholm had an approximate size of 300,000 inhabitants by the beginning of 1900. Towns in general were served with poorly maintained latrines and the sanitary state was usually very poor both concerning faecal sludge and solid waste management, as well as management of excrement from animals living within the city limit (horses, pigs etc.). As a mean to reduce the filling speed of latrine buckets and to achieve less smell, 20,000 urine-diverting Marino closets were in use in Stockholm by the end of the 19th century. This development of urine diversion did not continue when the city decided to go with waterborne sewerage during the first half of the 20th century. By 1927 the number of WCs in Stockholm exceeded 100,000. Degradation of the water quality subsequently followed, and the first wastewater treatment plant (dimensioned for 5,000 pe) was inaugurated by 1934.

National grants were used to construct wastewater treatment plants nationwide to mitigate the environmental degradation caused by waterborne sewerage. The use of commercial fertilizers was increasing during the latter half of the 20th century in Sweden. Some nutrient cycling was at that time achieved through the use of sewage sludge in agriculture, a use that has dropped to near zero today, due to sewage sludge being a complex product, always reflecting chemical use in society. Thus, the sustainability, from a resource perspective, of conventional sanitation was beginning to be questioned in Sweden by the late 20th century.

The choice of sanitation system was one of the cornerstones in the eco-village movements during the 1990s. The first phase of modern urine-diverting toilets took off in the early 1990s targeting single households and summer houses and a few eco villages. In the mid-nineties a few multi-storey

Figure 7. Dass-Isak, an addition to a urine-diverting toilet for Swedish summer houses. Photo: Örnplast AB.

Figure 8. Thwo urine-diverting toilet models on the Swedish market. a) Gustavsberg Nordic 393U and b) WM-Ekologen DS.

buildings and residential areas in urban settings were built with urine diversion. Systems for urine use were established and municipal actors involved in some cases, e.g. in Stockholm. Research and development has been undertaken on these systems from household to reuse in industrial agriculture and technical, sanitary as well as socio-economic aspects have been investigated. Many of these findings were published in the report *Urine Separation – Closing the nutrient cycle* available for downloading at the Stockholm Water Company website (www.stockholmvatten.se), Box 13.

Since the middle of the 1990s at least 135,000 urine-diverting toilets have been installed in different settings in Sweden. The bulk part of the installations are urine-diverting liners made of plastic for outhouses at summerhouses or plastic urine diversion with dry collection of faeces, but at least 15,000 are made of porcelain and have either dry- or water-flushed collection of faeces. There are a number of different models available in Sweden, from several different manufacturers.

Box 13. The first large-scale urine collection system with urine diversion in Stockholm

The system was established in 1997 and urine from the Understenshöjden, Palsternackan and Gebers residential areas and the Bommersvik conference centre is transported to the Lake Bornsjön area where it is stored and replaces chemical fertilizer in agriculture. This system is an outcome from a research project on urine diversion in the Swedish context, which is described in the report *Urine separation – closing the nutrient cycle* (www.stockholmvatten.se/pdf_arkiv/english/Urinsep.eng.pdf). The research project involved researchers from different research institutions, the Stockholm Water Company, and two housing organizations.

- The condominium organizations at household level are responsible for the collection tanks in the residential areas. They contract an entrepreneur to transport the urine to the centralized storage. Tanker lorries are used for transportation and the distance is appr 30 km.

- The Stockholm Water Company is responsible for storage (in “balloon tanks”) and the spreading on farmland.

- The tenant farmer is involved in all decisions concerning spreading and application of urine.

<u>Short facts:</u>

Connected households: 130 + 1 conference centre.
Type of toilets: 50% Dubbletten, 25% Gustavsberg and 25% Wost Man Ecology single flush.
Glass-fibre tanks in each housing area – 15 – 40 m^3 each.
Yearly volume of collected urine: 150 -170 m^3.
Storage tanks: 3 PVC balloon tanks of 150 m^3 each.

– As an environmental manager at a housing organization, and a user of a nice, modern water-flushed urine diversion toilet myself, I’m convinced that urine diversion will be considerably more common in Sweden ten years from now. It simply is such a simple and beautiful way of capturing nutrients and returning them to the farmland where they belong, says Mia Torpe, Environmental Manager at HSB and also resident in Understenshöjden.

Storage takes place at Bornsjön, and the urine is used on fields in the background owned by the Stockholm Water Company. Photo: VERNA.

Swedish map with Urine diverting toilets for more than 10 households or equivalent:

Municipality	Site	Site characteristics
Alingsås	Östlyckans residential area	Year around living
Eksjö	Juventum	Culture school and cooperation activities
Eskilstuna		Holiday camp for children
Göteborg	Kyrkbyn	Permanent living
Göteborg	Universeum	Science and discovery park (see chapter 3.2)
Göteborg	One buiding at Chalmers University of Technology	Office building and showrooms
Göteborg	The Ecological house, Lindholmen	Permanent living
Götene		More than 10 on-site installations
Hallsberg	Miljöhuset	Permanent living
Halmstad	Frösakullaskolan	School for children
Hudiksvall		Permanent living and boat club
Hylte	Elias Fries skola	School for children
Hörby		More than 10 on-site installations
Hörby	Ekerödsrasten	Highway facility
Jönköping	Smedens Eco-village	Permanent living
Kalmar	One building at the University of Kalmar	University building
Karlstad	Mjölnartorpets Eco-village	Permanent living
Kungsbacka	Frillesåsskolan	School for children
Linköping	Liljan 2	Permanent living
Linköping	Hulta Eco-village	Permanent living
Luleå	Björsbyns Eco-village	Permanent living
Lund	Östra Tornskolan	School for children
Mark		More than 10 on-site installations
Mellerud		More than 10 on-site installations
Mölndal	Eklandskolan	School for children (see chapter 3.2)
Mölndal	Glasbergsskolan	School for children
Nacka	Nyckelviken	Nature school, restaurant and show-garden
Norrköping		More than 100 on-site installations
Norrköping	Ekoportens eco-village	Permanent living in block of flats
Norrtälje	Campingplats	
Rättvik	Naturbruksgymnasiet	High school
Simrishamn		More than 30 on-site installations in permanent living and summerhouses
Stockholm	Palsternackan	Permanent living in block of flats
Stockholm	Understenshöjden	Permanent living (see Box 11)
Stockholm	Gebers	Permanent living in block of flats (see chapter 3.2)
Sundsvall	Vallens skola	School for children
Sundsvall	Rumpans Eco-village	Summer houses
Tanum		Several hundred installations in permanent living and summer houses (see chapter 3.2)
Timrå	Laggarbergsskolan	School for children
Tjörn	Södra Valsängens Eco-village	Permanent living
Trollhättan		More than 10 on-site installations
Uppsala	Hågaby Eco-village	Permanent living
Uppsala	Hällen Eco-village	Permanent living
Vaxholm	Kullön	Permanent living (see chapter 3.2)
Värmdö		More than 500 installations
Västervik	Gamlebyviken	(see chapter 3.2)
Österåker		50 installations

Figure 9. A selection of places in Sweden where urine diversion is installed for ten households or more. Picture by Johan Palmcrantz & Co.

3.2 FROM ECO-VILLAGES TO URINE DIVERSION WITHIN MUNICIPAL WATER AND WASTEWATER JURISDICTIONS

There has been a shift in the sanitation discourse in Sweden during the past ten years. Urine diversion was originally considered an “alternative” sanitation component, mostly eco village-oriented. Today the Swedish EPA is considering urine diversion as a possible option when planning for future investments to meet new legislation and environmental goals. Urine diversion has also been used as one measure to mitigate eutrophication problems along the Swedish coastline, see Box 14. However, the existing water and wastewater institutions/infrastructure form a real “super tanker”, therefore re-routing just slightly is a major task and will take resources and time. The lack of investments leading to necessary product development, lack of good engineering and organizational practices, as well as cheap commercial fertilizers are other reasons for the slow development.

Tanum – urine diversion mainstreaming through municipal policy work

There are a number of examples of urine diversion mainstreaming through the establishment of pro-urine diversion policies on municipal level, both within and outside the municipal wastewater jurisdiction. Tanum municipality, with its 12,300 inhabitants, is one example, which is described below. Another is Norrköping municipality, with 150,000 inhabitants.

Tanum is located on the west coast of Sweden. In the summer the number of inhabitants multiplies about five times which results in extreme wastewater flow variations over the year. Furthermore, in Tanum municipality, a large part of the inhabitants live in single houses in the countryside built on rocky terrain which makes connections to the centralized wastewater treatment plant difficult and expensive. Thus, sanitation has high priority on the political agenda. This, together with a political will to strive towards sustainable development, has led to a new municipal sanitation policy that encourages both dry- and dual-flush urine diversion.

Today there are about 400–500 private households (both dry- and dual-flush urine diversion systems), one museum and three camping grounds which have installed urine-diverting toilets. Moreover, conventional dry sanitation in the form of outhouses is common in the municipality due to its character of a summer paradise.

Box 14. Gamlebyviken, Västervik

Gamlebyviken is a bay connected with the Baltic Sea in the south east of Sweden that has had large problems with eutrophication. After an inventory, the municipality of Västervik realized that measures regarding the wastewater systems of single households around the bay were needed in order to improve the situation. The municipality has worked together with the inhabitants and farmers in the area and large efforts regarding information have been included in the Project *Future Gamlebyviken* with a holistic perspective on supply, health and environment.

By presenting criteria for the wastewater systems on reduction and possibilities for recycling of nutrients and a model for subsidies, the project has resulted in a large number of installations of both dry- and water-flushed urine-diverting toilets. Of approximately 1100 evaluated systems (of which half were classified as “bad”), around 200 are now adapted for recycling through urine-diversion. In 2004, 80 m^3 of urine was collected and reused by a farmer.

During a five-year period the situation has improved significantly. The municipality has evaluated the project with questionnaires to the inhabitants and entrepreneurs, and satisfying results have been achieved. A majority (89%) of the households are satisfied with their diverting toilet of which around 30% had had some kind of practical (usually smaller) problem. Environmental concern is high and 95% of users see their contribution through a urine-diverting system as being of importance for improving the situation. 23% of households with a flush-type of toilet and 83% of households with a dry toilet say that they would have installed the system without having the subsidies (which corresponded to 50% of the installation cost).

Technical System Design

Toilets	WM-ekologen most common, Gustavsberg
Pipes (indoor)	The municipality recommends Ø110-piping after the water seal
Pipes (outdoor)	Likewise
Tanks	At least 3 m^3 per household is recommended by the municipality. The municipality encourages households to arrange for joint tank solutions for several households.
Emptying/use	Urine is collected once a year by entrepreneurs (on contract) or is emptied by the house owner.
Storage – sanitization	Storage in a separate tank for at least 6 months
Other wastewater fractions	Households with dry sanitation use the faecal fraction in their own garden after composting. Faecal flush water from water flush urine-diverting toilets is treated conventionally

Organization – local use and cooperation with farmers

To meet the increasing demand for urine-diverting toilets that followed a ban on water toilets in rural settings the municipality started a dialogue with local farmers. Informal recommendations were developed which in 2002 were turned to a municipal sanitation policy. This policy is one of the most innovative and future-oriented in Sweden today as it requires urine diversion and/or dry sanitation and that this requirement be applied both for rural settings and within the municipal wastewater jurisdiction. There are a number of newly developed areas in Tanum where conventional, tertiary wastewater treatment will be combined with urine diversion.

Roles and responsibilities

The municipality has declared its responsibility for emptying, storage, and use of urine on arable land and it has signed agreements with farmers or contractors who are approved for these activities. The sanitation policy states different ways by which agricultural/horticultural urine use can be achieved:

- For houses located within the municipal wastewater jurisdiction, the urine pipes and tanks are owned by the municipality and the municipality arranges for collection of urine and reuse on arable land.
- House-owners outside the municipal wastewater jurisdiction can either arrange for the emptying and use of urine through a municipally contracted farmer or arrange for a private contractor/farmer to empty their tanks. In the latter case the fee is stipulated separate to the municipal contract. The entrepreneurs/farmers report back to the municipality on their activities once a year.
- House-owners, both within and outside the municipal wastewater jurisdiction, can use urine on their property according to given requirements. However, the municipality must give its approval to each household.

Economy

Households connected to the municipal urine diversion system within the municipal wastewater jurisdiction (where the municipality is in charge of tanks etc) pay the same connection and user fee as households connected to the regular sewer system. Households which have their own urine tanks are charged a reduced connection and user fee. Tanum municipality also works with hardware subsidies for those installing urine-diverting toilets, paying half the investment cost for the households.

Information activities and monitoring

To establish robust urine use contracts the importance of communication between stakeholders has been recognized by the municipality. Farmers using human urine and representatives from the municipality meet twice a year to exchange experiences and to agree on improvements.

In the sanitation policy there are specific requirements for storage and use of urine. There is also general information available both for the householder and the entrepreneurs/farmers.

Lessons learned: Tanum

One of the most interesting things about Tanum is that the municipality has clarified its role and its responsibilities in the sanitation question and defined itself as a central actor in the system. The municipality of Tanum foresees that different options and strategies may be needed to secure the collection and the use of urine in agriculture. This gives the system flexibility over time and also opens up for individual choices for the households. Of course this is based on a strong political support and the assumption that resources are allocated for communication between stakeholders and for good information dissemination.

Figure 10. Tanum, situated in a rocky environment bordering on the sea. Photo: Kjell Holmner.

"Since we used to have cattle, we already had storage tanks and the machines for spreading urine. Our household got an exception from the municipal collection of sewage sludge as we could handle it on the farm, and then the neighbours asked us to collect their urine. In the vicinity there is a summer house area with many urine-diverting toilets, which needed collection. It has ended up to around 100 households from which we collect urine, black water or sludge.

Today, the urine is diluted with sludge from septic tanks and closed tanks. Therefore the nutrient content is rather low and varies a lot. If there were bigger volumes of urine, we could treat the urine separately and would get a much better fertilizer, with a more exact and stable nutrient content."

Flemming Arvidsson, Farmer, Grebbestad

Kullön – urine diversion in an attractive and modern residential area

Kullön is located on an island in the municipality of Vaxholm, not far from Stockholm. The residential area is comprised of 250 houses. The first inhabitants moved in during 2000. The area is very beautiful and has attracted mainly young, well-educated families with children.

Kullön is an area of Vaxholm with high environmental ambitions. The most thorough and attention-drawing environmental venture is the water and sanitation system. One interesting aspect of Kullön's sanitation system is the combination of urine diversion and tertiary treatment for the remaining wastewater fractions.

Technical System Design

Toilets	Gustavsberg or Dubbletten
Pipes	Plastic pipes drawn in the same pipeline trench as the other pipes. Urine has to be pumped from some parts of the area.
Tanks	Urine is collected at neighbourhood level. It is possible to transport urine straight or via overflow to the local wastewater treatment plant if needed.
Emptying/use	The tanks will be emptied by tanker trucks, through a contractor. First agricultural use of collected urine will take place during spring 2006.
Storage – sanitization	Urine storage will be arranged at the farm where the urine will be used.
Other wastewater fractions	Remaining wastewater (faeces, flush water and greywater) is treated tertially in a local wastewater treatment plant.

Organization

Kullön is not only interesting due to its size, it is also interesting from an institutional point of view. In contrast to Tanum the municipality of Vaxholm initially did not want to get involved in the system for transport, storage and use of urine from the households. Their point of view was that the households themselves should solve this and contract a farmer or contractor. This led to a situation where the urine was not collected at all between 2001 and 2005, but overflowed into the wastewater treatment plant. The municipality has thereafter been forced to engage itself in stages in the organization of a urine use system.

Roles and responsibilities
The municipal water and wastewater company will be responsible for contracting a farmer during 2006.

Economy
For the Swedish context it is estimated that the monetary value of the nutrients in urine corresponds to the extra costs of spreading urine compared to spreading commercial fertilizer (see Chapter 4 for more details). For large-scale systems there are also costs for storage and transport of the urine. In the Kullön case these additional costs will, at least initially, most probably be charged to the households. This means that the households at Kullön have to pay more for their water and wastewater services even though they contribute less to environmental degradation compared to other inhabitants in the municipality.

Information activities and monitoring
During 2004/2005 all new inhabitants of Kullön were trained on environmental aspects of the full technical system. Special attention was paid to the sanitation system. A detailed manual for the operation and maintenance of the urine system has been produced and distributed to the households.

Lessons learned: Kullön

The Kullön case shows that urine diversion is well-suited for modern, attractive residential areas and compatible with tertiary treatment of the other wastewater fractions. This case also underlines the absolute necessity, for a residential area of this size, of clear division of responsibilities between actors in order to achieve agricultural use of the collected urine.

"We were really excited to move into a residential area where so much effort had been made to use functioning environmental technology, both regarding sanitation, solid waste and energy. We also saw that the discharge of nutrients etc would be lower from our sanitation system compared to a conventional sanitation system. The sanitation system works well for us, but the responsibility question regarding cost sharing between the municipality and the household should have been clearer from the beginning." Rolf Svedberg, Environmental Adviser at the Environmental Court of Appeal and resident at Kullön.

"We, as developers, had expected this project to be easier than it turned out to be. The largest challenges have been organizational aspects and lack of political will at national level. A lot of responsibilities and costs have been charged to the households. Technical challenges have been easier to solve". Ulf Jonsson, Project Manager for the developer SMÅA Hus.

Figure 11. Kullön is situated in the sensitive environment near the Baltic sea. Photo: Anna Richert Stintzing.

Universeum – science and discovery museum with urine diversion

Universeum is a science discovery centre in downtown Gothenburg. It was inaugurated in the summer of 2001. With its 0.5 million visitors yearly it is the largest example of public urine diversion in Sweden.

Technical System Design

Toilets	25 urine-diverting Dubbletten dual-flush toilets
Pipes	Plastic pipes drawn in the same pipeline trench as the other pipes. Urine has to be pumped from some parts of the area.
Tanks	Two 6 m^3 underground tanks connected in a parallel fashion, which increases the flexibility of the system. The tanks are filled from the base. If necessary the tanks can be disconnected and the urine conveyed into the centralized sewage system.
Emptying/use	The tanks are quite small, considering that the presumed yearly collection volume is 180 m^3. This means that the tanks must be emptied about 15 times yearly when the collection system is up and running.
Storage – sanitization	Storage site on municipal land, total volume of 600m^3, see details below.
Other wastewater fractions	Remaining wastewater (faeces flush water and greywater) is treated tertially in a local wastewater treatment plant.

Organization

The City of Gothenburg is currently in the process of establishing a system for urine collection, storage and use. The storage site is constructed on municipal land and has been constructed to receive approximately 300 m^3 a year for filling, while 300 m^3 is used for undisturbed storage to allow for sanitization of the urine. The tanks used are called balloon tanks. The storage facility and urine use will be operational from the spring of 2006. The City of Gothenburg is in the process of signing a five-year agreement with a farmer who will use the urine to replace commercial fertilizer in his farming activities. The farmer will use the urine on fodder crops for his own bovine stock.

With the reuse system the City of Gothenburg will incur a cost of approximately 1,500 € yearly, a figure calculated on the assumption that the farmer pays for the nutrients in the urine minus extra costs incurred in spreading the urine, as compared to costs that he would have incurred had he used mineral fertilizers. However, this cost is considered reasonable from the City of Gothenburg's perspective, considering other equal costs for wastewater management.

Roles and responsibilities
The Department of Sustainable Water and Waste Management at the City of Gothenburg is the central stakeholder for establishing the use of urine in agriculture. This is seen as a pilot for future development of the sanitation systems of the region. The City of Gothenburg also has a parallel R&D-project focusing on blackwater treatment with subsequent agricultural use.

The households/facilities are responsible for collection of urine in tanks after which the municipality takes responsibility for the urine. The contracted farmer is responsible for storing the urine according to the current recommendations and for the use of urine as a fertilizer.

Economy
The fees/cost recovery for urine-diverting systems within the municipal wastewater jurisdiction are not all set yet. In general the idea is that facilities/houses with urine diversion will get a reduction of the municipal wastewater fee, since the nutrient load on the centralized wastewater treatment plant is reduced, and the water consumption is lowered.

This approach functions quite well for a single household within the municipal wastewater jurisdiction or a residential housing where everybody has urine diversion. However, for a case such as Universeum, where huge amounts of water are used for the aquariums and rain forest etc. it is more difficult to motivate a smaller reduction of the wastewater fee. This is thus not solved as of yet. There is also a cost connected to the emptying of the urine tanks. The City of Gothenburg will probably propose that each household/facility will pay for emptying the urine tanks themselves. This fee will, however, be reduced, compared to what is charged for emptying septic tanks. The main reason for the fee on the emptying service is to motivate household/facilities to avoid dilution of the urine, and thus immediately care for ground water intrusion in tanks etc.

"Resource efficiency and recycling are cornerstones of a modern approach, and the urine-diverting system thereby is an important component of the message Universeum wants to transmit to its visitors". Lasse Forsberg, Attendant in charge at Universeum.

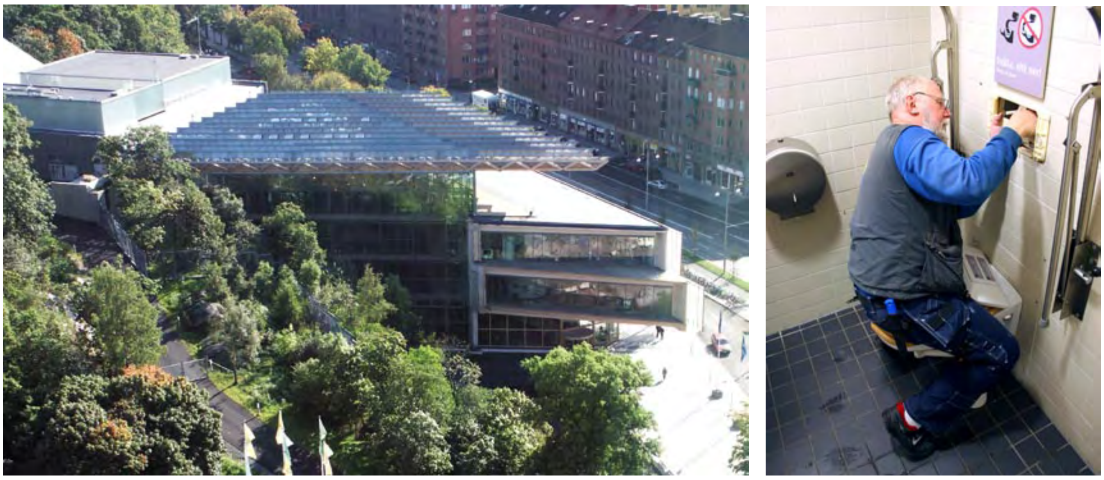

Figure 12. (left) Universeum, one of Gothenburg's larger tourist attractions.
(right) Fixing the pipes in Universeum, Lasse Forsberg.

Lessons learned: Universeum case

One important lesson learned from Universeum is the importance of choosing a toilet model with care for use in a public setting (see further in Appendix 1) to minimize the need for maintenance and cleaning. Universeum technical staff has been forced to reconstruct the toilets several times (e.g. adjusting U-bends and changing toilet seats). The type of diverting toilet that Universeum has installed is one of the best when it comes to percentage urine-diverted, which is good from an environmental point of view. However, it is also less forgiving for misuse, since the urine bowl needs to be cleaned manually at faeces misplacing events. This is not the case for other dual-flush urine diversion toilets.

An important aspect is the need for clear and proper information especially about the recycling issue, so that the visitors understand why the urine is diverted. At Universeum the rate of misplaced faeces was reduced when the staff changed the information signs to include "why" they used urine-diverting toilets and not only information on how the toilets function.

By installing urine diversion in public buildings of this size it is possible to kick-start agricultural urine use in a municipality, both generating public awareness and interest and at the same time organizing a robust system for transport, storage and use. Another relevant lesson learned is that it takes time to organize an agricultural use system of this size.

There have been technical problems to solve with water intrusion into the tanks, both through the manholes and through groundwater intrusion. This causes the tanks to fill faster and it also dilutes the urine, which is undesirable from a transportation, storage and fertilizing perspective. This underlines the necessity to ensure that underground urine collection tanks are watertight.

As mentioned, Universeum is located in downtown Gothenburg. Even so, there have been no complaints about the smell of urine at the two or three emptying events that have so far taken place.

Gebers – Changing from water toilets to urine-diverted dry toilets in a two-storey building

Gebers housing area is situated by the lake Drevviken about 15 kilometres from Stockholm city. It was built in 1936 and has been used as a convalescent home and later as a refugee camp. In 1998, it was reconstructed and turned into ecological and condominium housing for about 80 inhabitants in 32 apartments in a two-storey building. Gebers is unique in Sweden due to its sanitation system: a urine-diverting system with dry collection of faeces in a two-storey building.

Technical System Design

Toilets	Wost Man Ecology dry toilet porcelain model in all apartments.
Pipes	The piping system for urine has a dimension of Ø50 and both pipes and tanks are made of polypropylene.
Tanks	The three collecting tanks are located in the basement.
Emptying/use	Tanks are emptied from outside the house by an entrepreneur 2–3 times a year and used in agriculture after storage for hygiene reasons.
Storage – hygienization	
Other wastewater fractions	Faeces is transported in vertical "Spiro" pipes with a dimension of Ø200 and collected in common plastic bins used for garbage. Each bin is located in a fire-proof metal box. The dried faeces can easily catch fire if someone for example throws a match into the toilet. All pipes are constructed to be completely air- and liquid-tight. Each household is responsible for maintenance of their proper faeces bin. If the faeces gets too wet, e.g. by misplaced urine, drying material such as sawdust is added. The plastic bins are emptied, by each household, and added together with carbon rich material in layers in a compost box with a water tight concrete floor and a lid, in order to minimize the possibility of environmental contamination and exposure to the faecal matter. The faecal matter is stored for years before being removed and used as soil conditioner. The greywater is conveyed to the municipal wastewater treatment plant for the area.

User aspects

The user aspects at Gebers have been thoroughly investigated through a research project carried out by Linköping University. Some of the findings are presented here, and others in Chapter 4. See the 'Read more' box at the end of this chapter for the full reference of the report.

The research project revealed both positive and negative attitudes among the users in Gebers towards the sanitation system. The low water use is one positive factor and is mentioned by most respondents as one important factor behind the toilet system selection. One of the users says: *[...] my feeling is that every time I use a conventional toilet I'm wasting something we use as drinking water in this country ... it feels completely idiotic to pee a few decilitres and then flush ten litres to get rid of it [...]*. As long as the ventilation works there is no smell at all in the bathroom, not even right after defecation, which is perceived as very positive. In this respect the urine diversion dry toilet is superior to a water closet. The ventilation is dependent on a functioning power supply. Thus, if there is a power cut there is consequently a bad smell from the toilet.

The most important negative aspect on the sanitation system in Gebers seems to be occasional fly breeding in the faecal bins, a problem that might be the main reason to why some residents in Gebers are not happy with the sanitation system. However, the fly breeding is less of a problem today, than in the beginning, due to the establishment of some simple practices. The one most crucial practice, both in order to prevent flies from multiplying and for getting rid of the problem once it has occurred, is to empty the bin more often. One resident says: *[...] so when you spot* *small, small, small, small flies … then you know that there's a hotbed down there and then it is time to go down and remove the sack and you may have to take it often* … […]. Other measures which can be taken are to keep the faeces dry by adding ash or lime/ash mixtures or other drying agents. Insect repellents have also been used.

Another issue is the cleaning of the toilet. Although all toilets need cleaning it seems like the residents in Gebers find the cleaning of their dry toilet more difficult than with a water closet, due to the need to avoid too much water into the faecal bin while still arrive at having a clean faecal bowl. One resident says: *[…] with an ordinary toilet you can just put the brush down into the water that's there ... but here it's somewhat more complicated as … we have the shower right next to it so you sort of have to shower on the brush and then put it into the toilet and try to clean and after that try to make it (the brush; author's remark) clean and shower it … it's a bit trickier […]*

Figure 13. Gebers, once a convalescent home, is today a modern apartment house close to lake Drevviken. Photo: Mats Johansson.

Figure 14. (left) The sanitation system is unique: a urine-diverting system with dry collection of faeces in a 2-storey building. Photo: Mats Johansson.

Figure 15. (right) The faeces are composted in a closed bin together with grass and leaves. Photo: Ebba af Petersens.

Lessons learned: Gebers

The Gebers experience shows that it is possible to have urine diversion dry toilets (i.e. dry collection of faeces) in high standard, two-storey residential housing. Moreover, it shows that it is possible to retrofit buildings from waterborne sewage to dry sanitation. It also shows that when motivation is high among the inhabitants, handling and sanitization of the faecal fraction can be solved locally, even though there is still potential for improvement of especially the faecal handling in Gebers.

Eklandaskolan in Mölndal – one of several schools in Sweden with urine diversion

Since the middle of 1990s several schools in Sweden have been constructed with urine-diverting systems, often a result of political decisions. These school sanitation interventions were one component of an ecological switch-over, including other components such as, for example, energy. Eklandaskolan in Mölndal was constructed in 1999 via an initiative by local politicians and municipal desk officers. The school is owned by the municipality of Mölndal and it has about 450 students of 6–15 years of age. Municipal investment money was used to finance the school.

At Eklandaskolan a urine-diverting water flushed system combined with a faecal separating system (called Aquatron system) is installed.

Technical System Design

Toilets	65 Dubbletten water flushed toilets by gravity and collected in tanks with a total size of about 50 m^3.
Emptying/use	The tanks are emptied once a year by a farmer after storage in-situ. The municipality is responsible for the transport of urine to a farmer for use on farmland.
Other waste water fractions	Faeces are separated from the main part of the flush water by the use of a separator and collected in a separate tank in the basement. Collected faeces is stored in the tank for at least 9 months and then used as fertilizer by people in the neighbourhood. Separated flush water from the Aquatron-system is treated locally together with greywater in reed beds.
Maintenance	Daily management of the system is run by a janitor. The janitor uses citric acid, boiling water and pipe cleaners once yearly in all toilets to prevent blockages.

Figure 16. The Dubletten toilet at Eklandaskolan. Photo: Karin Emilsson.

Lessons learned: Eklandaskolan

Oral information about the system to system's users, in this case students and personnel, is very important in order to reduce amounts of misplaced faeces and paper etc. From the beginning of the process it is also very important to inform and motivate the operating personnel, especially janitors and cleaners who will run the system. The need for information and clearly defined roles and responsibilities cannot be over-stressed in a school or other public environment.

Read more:

- Degaardt, S. 2004. Human Urine to Fields and Green Areas – Market Potential and Implementation Issues in the Gothenburg Area. MSc Thesis (2004:04), Swedish University of Agricultural Sciences, Uppsala, Sweden (in Swedish with English summary).
- Krantz, H. 2005. Matter that Matters – A study of household routines in a process of changing water and sanitation arrangements. Dissertation – Linköping Studies in Arts and Science, # 316, Linköping University, Sweden. www.ep.liu.se/diss/arts_science/2005/316/digest.pdf
- Water and sanitation policy for Tanum municipality available in English at www.tanum.se/vanstermenykommun/miljo/toaletterochavlopp/waterandsanitationpolicy.4.8fc7a7104a93e5f2e8000636.html
- For pdf file on Gebers in English, check www.ccb.se (www.gebers.se, www.ekbo.se in Swedish).

Chapter 4: Urine Diversion – From Toilet to Field

Of the technical components in a urine diversion system, it is only the urine diversion toilet that is a new gadget on the engineering scene. All other technical components (pipes, tanks, pumps, trucks, spreading equipment etc.) used in urine-diverting systems have been used for a long time in other construction works, although not previously for urine diversion. One can conclude that the same basic planning/engineering rules apply to urine diversion as to any other sanitation system: (i) proper engineering is paramount, (ii) competent O&M personnel indispensable and (iii) good information to the users necessary to ensure proper use of the system.

An overview of recommendations for urine diversion systems, from toilet to field, is given below. The recommendations are based on the practical experience from these installations in single housing and multi-storey apartment buildings, supplemented with international experiences as well as research within the area. The technical recommendations are further developed in Appendix 2.

4.1 SWEDISH URINE-DIVERTING TOILETS AND URINALS

There are mainly three different kinds of urine-diverting toilets/systems in use in Sweden: urine-diverting water toilets, urine-diverting dry toilets and outhouse toilets with a urine-diverting liner. There are a number of different toilet models with urine diversion on the market, from dual-flushed water toilets made of porcelain for permanent housing to more summerhouse toilets made of plastic, see figures 2, 5, 7, 8, 14 and 17.

In water flushed toilets both bowls are flushed with water, while in a dry toilet faeces and paper are collected dry in a bin beneath the toilet. Some urine diversion dry toilets have a flushing system for the urine bowl, while others can be flushed with a cup of water when needed. Outhouse toilets with urine-diverting liners represent the simplest way to achieve urine diversion and also the by far most common in Sweden, see figures 17 and 18. The liner consists of a funnel which is located in the front section of the hole. Faeces and tissue are collected in a latrine bin as in a common dry outhouse toilet while the urine fraction is collected in the front and conveyed to a collecting vessel/container.

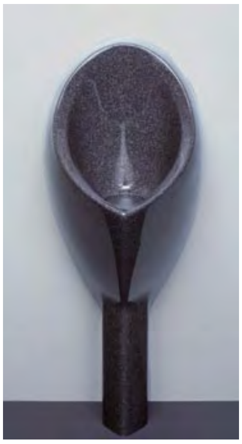

Figure 17. (left) Urinal Uridan available on the Swedish market

Figure 18. (right) Urine-diverting liner for outhouses. Picture by Palmcrantz and Co.

Urinals, which are common as a complement[12] to conventional toilets in public settings in Sweden, also constitute a good complement to urine-diverting toilets. Urinals have widespread acceptance among users. Urinals can either be water flushed or "water free". By using urinals as a complement to urine-diverting toilets the amount of urine ending up in the faecal compartment decreases and the total amount of collected urine increases, especially in public settings. Urinals for women exist but have not yet reached the Swedish market.

Box 15. Voices of some urine-diverting toilet inventors

Mats Wolgast – Inventor of WM Classic, a urine diversion toilet with dry collection of feces

How did you get the idea to develop a urine-diverting toilet?

- In the development of compost toilets the question arose as to the nutrient content of urine compared with faeces. Moreover, the compost toilets often had difficulties with ammonia odours and we worked a lot with precipitation of ammonia with phosphoric acid, formic acid, acetic acid, etc. However, when I figured out how much nutrients there is in urine (the nutrients we find in one year's production of excreta, mainly urine, can basically fertilize the area needed to cover one person's need of food yearly) I started developing a toilet diverting the urine.

What were your strongest driving forces?

- The environmental aspects were the strongest driving forces, but the fact to have a dry, odour-free feces fraction was also of importance.

Describe the process from idea to developed product.

- The time from initial idea to a prototype was about a year. We did not have any financial or capacity support in our development. On the other hand we have the feeling that we did not really encounter any defeats along the way either. We don't have any patent of our product. The company producing the toilet is Wostman Ecology.

Lennart Lindvall, Gustavsberg – Designer of Nordic 393U, a dual-flush urine diversion toilet

How did you get the idea to develop a urine-diverting toilet?

- Through a cooperation between Gustavsberg and a consulting company (Verna) and, to some extent, with Mia Torpe, Environmental Manager at HSB (a cooperative housing organization). The first Gustavsberg urine-diverting toilet was installed in Bommersvik, a conference center.

What were your strongest driving forces?

- The environmental advantages were obvious and Gustavsberg wanted to be in the lead and check the market development. The Gustavsberg urine diversion toilet is designed around optimal hygiene rather than optimal source diversion. One way to increase the fraction or urine collected is to use urinals. Gustavsberg has developed a waterless urinal with an oil seal.

Describe the process from idea to developed product

- Half a year passed between idea to prototype. We did not have any financial support. Nor do we have any patent. Production-wise it is challenging to manufacture a product in small volumes. It slows down the manufacturing of other products.

[12] They are popular complements to e.g. facilitate cleaning.

Holger Isaksson – Inventor of plastic urine-diverting liner for dry sanitation, Dass-Isak

How did you get the idea to develop a urine-diverting toilet?

- I've had the idea of reducing odours and decreasing the amount of faecal sludge to handle through urine diversion by the attachment of a funnel in the chute of the outhouse ever since being a teenager. However, it was not until later I developed the first prototype, a development provoked by an accident in my summerhouse. As many summerhouses in Sweden, my summerhouse was equipped with an outhouse, where the faecal sludge was collected in a cardboard container lined with a latrine bag. The municipality usually offers collection services but the place where the truck passed by my summerhouse was some distance from the outhouse. Thus, the container needed to be carried some distance at each emptying occasion. At one of these occasions, the latrine bag burst and so did the cardboard container and its content gushed down into my boots. Immediately thereafter, I produced the first prototype of a funnel to divert the urine. First I experimented in stainless steel, after which I went with polyethylene.

What were your strongest driving forces?

- The most important driving forces were to reduce odours and allow for easier emptying of the faecal sludge bin. Another driving force, however of less immediate importance compared to the other drivers, was reduced need for transportation and thus reduced environmental impact.

Describe the process from idea to developed product.

One year and two months passed between idea to first prototype. I did get financial support from three different sources to develop the first tool for injection moulding. The financial partners were Almi*, the trade and industry executive of Haparanada municipality and the plastic company that later produced the urine-diverting liner. The product is not patented but has a registered design, and it is produced by Örnplast since 2004. Challenges faced were first of all the production of the first tool for injection moulding, and then to assert myself on the market as a small entrepreneur. The marketing costs are relatively high for a small company.

*: The ALMI-group was founded in 1994 and consists of a parent company, owned by the government, and 21 regional ALMI offices. ALMI's mission is to stimulate growth and development for small and medium-sized companies and innovators. ALMI offers financing and business development consultation.

Blockages can occur in the piping from the urine-diverting toilets and in urinals. How to remove these types of blockages is quite easy and is described in Appendix 2.

4.2 PIPES AND TANKS

Neither pipes nor tanks should be made out of metal due to the corrosive nature of urine. Metal details should be avoided altogether in the system. The pipe dimensions depends on choice of toilet and of which type the system is, see Appendix 2 for further details.

Tanks buried in the soil and their connections must be completely impermeable to surrounding water and attention must be paid to the lifting force of groundwater where the groundwater level is high. Consider the possibility of using a pump well and a holding tank located at the surface or above ground. Figure 19 shows a well anchored urine collection tank at Kullön in Sweden during the construction phase. More on tank dimensions and other important information is described in Appendix 2.

Figure 19. This picture shows the urine tanks at Kullön during the construction process. The tanks will be covered with soil. Photo: Mats Johansson.

Box 16. Other wastewater fractions from urine-diverting systems

The main focus of this publication is urine from urine-diverting systems. However, since wastewater flows other than urine are generated from urine-diverting systems they merit some further attention.

Faeces

The faecal fraction will, due to its possible high content of pathogens, constitute the main hygienic risk in a urine-diverting system. This aspect needs to be accounted for when designing/planning a sanitation system, especially if the faeces are also intended for reuse as a fertilizer. In this case it is highly recommended to provide safe sanitation through secondary treatment of the faeces in order to achieve an acceptable microbial quality. To avoid smell and flies it is important to provide good ventilation of the faeces collection bin and to keep the faecal surface dry by the addition of one cup of ash/lime/soil/organic material after each defecation. Addition of ash and lime also have an additional pathogen-killing effect due to them increasing the pH and can be seen as a primary treatment of the faeces.

Options for secondary treatment of faeces includes composting, incineration, urea treatment, and warm storage. For details, see the forthcoming WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume 4 – Excreta and Greywater use in Agriculture.

Safe handling procedures are very important to manage health risks. Points of risks in handling a dry faecal fraction include:

- Emptying of the toilet/vault:
  - If available, use gloves etc for personal protection
  - When finished: wash hands, clean surfaces of the vault outside and equipment used or use special equipment used only for non-sanitized material
- Transportation and handling before sanitization:
  - If available, use gloves etc. for personal protection
  - When finished: wash hands, clean surfaces outside and equipment used
- Recontamination after sanitization:
  - Bacteria can regrow after sanitization, while protozoa, viruses etc. cannot
  - Well-cleaned tools and equipment should be used for the sanitized product

Greywater

Greywater is water originating from laundry, kitchen and showers. Its quantity varies, in an international context between 20–200 L per person per day depending on habits and water availability. Greywater usually contains quite low quantities of pathogens (depending on e.g. washing habits, if diapers are washed greywater can contain higher levels of pathogens), and also relatively low levels of phosphorus and nitrogen, whereas its organic matter content can be quite high. To avoid foul smells, waterlogging and other nuisances, greywater needs to be treated. In rural settings the treatment can be organized quite easily, for example, by using compact filters, mulch beds or similar. In dense peri-urban or urban areas semi-centralized units for greywater treatment could be imagined. For more information on greywater, please see the ‘Read more’ box at the end of the chapter.

From dual-flushed urine diversion systems the greywater will usually be mixed with the water-flushed faecal fraction and will need subsequent treatment. With the addition that this fraction the same approaches apply as for greywater (see above), but the mixture will need a higher degree of treatment than just greywater in order to ensure an effluent of high enough hygiene standard.

Stormwater

Urban planning entails also planning for stormwater management. Filter strips and swales, filter drains and permeable surfaces, infiltration devices, basins and ponds are examples of stormwater management options available.

4.3 SANITIZATION OF URINE

Even if from a hygiene point of view urine is a “safe” fertilizer, concern regarding risk for disease transmission when handling and using human urine has been raised and research on the topic has been conducted. Urine by itself is uncommon as a transmission route for disease, and this is true for most settings around the world. The scenario involving risks occurs if faeces, possibly containing pathogens, contaminate the urine by misplacement in the urine bowl. If so, a reduction in pathogen numbers can be obtained by storing the urine. The elevated pH (around 9), ammonia content and temperature will affect the die-off of pathogens. Recommendations for use of urine in large-scale systems are based on combinations of storage and restrictions on use[13], whereas at household level it is considered acceptable to use urine without storage as long as one month passes between fertilization and harvest of crops that are consumed raw. These recommendations, developed by the Swedish Institute for Infectious Disease Control, are about to be adopted by WHO (Appendix 3) and as legally binding by the Swedish EPA (Appendix 4).

In terms of health and hygiene it is important to remember that the faecal fraction is of most concern. Precaution need to be taken when handling the faeces (or blackwater) and if they are to be used as fertilizer sufficient treatment is needed and application to crops that are to be consumed raw should be avoided.

4.4 STORAGE AND USE OF URINE

Reuse of urine in Sweden today is carried out both on a small scale basis at home and allotment gardens and in agriculture, where it is spread with regular farm equipment for slurry. Both cases are presented below. The practice of fertilizing with urine is carried out during the early part of the growing season, which in Sweden lasts from April-May to September-October. This means that in a system with urine-diverting toilets installed, urine collected during winter must be stored until the growing season. A research project was carried out from 1996 to 2000 to investigate the use of urine as fertilizer in agriculture. Extensive field trials were carried out and the results are reported in Johansson et al, 2000. Results show that urine can replace mineral nitrogen fertilizers in production of spring sown grain crops. Another finding showed that the ammonia losses when spreading the urine were small, usually around 5% and they were never higher than 10% of the nitrogen content.

[13] (Höglund 2001; Swedish EPA 2002; Schönning and Stenström 2004)

Home gardens

Storage

According to Swedish recommendations, urine does not need to be stored for hygiene reasons when it is used in the garden of the home where it is collected. However, as mentioned above, the cropping season is short and urine collected outside that period needs to be stored. In a summer house setting, jerry cans may be sufficient but in an all year round home, larger tanks must be provided. Care should then be taken to make the emptying of the tank simple, for example by a hand-operated pump, figure 20.

Figure 20. Hand pumping of urine from household tank for subsequent use in garden. Photo: Mats Johansson.

Use

There is an awakening awareness among household gardeners, and especially allotment gardeners, of the fertilizing advantages of urine. This has had the result that even people who do not have urine-diverting toilets installed are using urine collected in plastic bottles as fertilizer for flowers etc. The Swedish University of Agricultural Sciences has carried out several research projects, one of which was fertilization of leek. The gardening associations have produced fact sheets on the use of urine in home gardens, and the daily papers in Sweden have covered the use of urine as fertilizer. This may result in a demystification of use of urine as fertilizer, which could support the development of urine-diverting toilet systems.

From a legal perspective, the use of urine in the home garden is allowed, but the local environmental authority may pose conditions to the urine use, e.g. on size of the "productive" surface in the garden available for urine spreading. This is to ensure that the urine use does not jeopardize the precautionary principles stated in the Environmental Code which could possibly apply if too much urine is spread on too small a surface. However, a too conservative approach has been noted in Swedish municipalities concerning this, when in fact use of urine on cultivated land is a significant environmental improvement compared to any soak-away or infiltration system. See Box 17 for an example of calculations showing the necessary surface, in order to maximize the use of the nutrient in urine.

Urine used as fertilizer does not need to be diluted, but many gardeners do dilute before spreading even though this increases the handling needed. Usually spreading of undiluted urine followed by irrigation is simpler and generates less odour. In the small scale, urine is spread with a watering can. Care should be taken not to use equipment with metal components, and if this is done, the equipment should be carefully washed afterwards since urine is very corrosive.

Urine is best used as fertilizer to nitrogen demanding crops, but most garden crops respond well to urine as a fertilizer. Urine has been used with good results on lawns, roses, berry bushes, vegetables as well as annual and perennial flowers. A one month holding period is recommended between last application of urine and harvest of food crops consumed raw, for safety reasons.

Box 17. Calculation of necessary "productive" area in garden to maximize nutrient use in urine.

The necessary productive area (e.g. turf, flower beds, vegetable garden, trees) necessary per person for use at household level depends on three things:

- the nitrogen demand of the productive area
- the concentration of nitrogen in the collected urine
- how many "harvests" are made per year (in Sweden we only have one harvest a year, whereas in other climates two or three harvests are made)

Rules of thumb are useful to get-ball park numbers, if the exact figures for the above factors are unknown. The nitrogen demand for vegetables, turfs, etc. varies between 100–200 kg/ha, depending on type of crop and the yield. The concentration of nitrogen in urine depends on the diet. Undiluted urine will usually contain between 3–7 g N/L. A person excretes about 550 L urine per year, depending on liquid intake, climate etc. Thus, the excreted amount of N per person and year will be between 1.65 kg–3.85 kg, using the figures above. If the nitrogen demand of the crop/turf etc is 100 kg/ha and the N concentration in the urine is 7 g/L the urine from one person can fertilize 385 m^2 (1.5 L of urine per m^2), if one single crop is harvested per year. If there is a restriction in plot size, it is usually possible to increase the fertilization up to three to four times (thus using up to 6 L per m^2) without any negative effects on crop or environment.

Calculation example:

A family of five has a plot size of 300 m^2 on which they want to use the urine they collect in their urine diversion toilet. The family lives in a climate allowing for two yearly crops. If we assume that they can apply 6 L per m^2 per cropping season, how many m^2 do they need to use their urine in their garden?

Answer:

Since they live in an area where two crops can be taken per year and 6 L/m^2 can be used per cropping season it means that 12 L/m^2 can be applied yearly. Each person excretes about 550 L (assuming that all urination takes place at home and that all urination is made into the toilet, which might not be the case), giving that a family of five will excrete 2750 L of urine yearly. This will fertilize 229 m^2 since each m^2 will receive 12 L on a yearly basis. Thus, the plot size would be able to productively use the collected urine. In cases where the plot size is too small to use the urine productively, one has to either find other ways of more or less disposing of the urine (could be done as an N supplement to composts for example) or construct a urine collection system.

Odour

The smell when using the urine may be an issue in the home garden. Experience shows that if the urine is spread close to and directly onto the soil and watered down there is little smell and urine is currently used in densely inhabited housing areas without complaints from neighbours. However, handling of urine is naturally a smelly activity and thus wise procedures minimizing air exposure, e.g. by using closed containers, application close to soil and immediate incorporation or irrigation, are strongly recommended.

Box 18. Municipal demonstration garden in Nacka

The municipal gardens and greenhouses in Nacka outside Stockholm demonstrate the use of urine as fertilizer in the garden. The urine is collected from the staff toilets and is stored in two tanks, 1 m^3 each. The urine is spread with a hose that can be connected to a water stand, enabling subsequent flushing of the hose and irrigation of crops. A small trial has been set up, and the experiences after two years of fertilization are that urine compares well with poultry manure and compost. The garden has numerous visitors from within and outside the municipality, thus the outreach is very good.

Eva works in the municipal gardens in Nyckelviken, Nacka. Urine is applied several times during the summer season. Photo: Anna Richert Stintzing.

Large-scale agricultural production

Storage

When urine is collected from many households, the urine should be stored for a specified time in order to minimize risk of transmission of disease.

For small amounts of urine, a number of jerry cans or 1 m^3 plastic tanks can be used. This is a flexible solution, since the vessels can easily be moved, and subsequent use in municipal parks, gardens is simple. In addition, investment costs are low.

For larger amounts of urine, permanent tanks are recommended. Concrete or plastic tanks can be found on the market. Important aspects to be considered are the site where the storage is set up and ownership. In cases where the farmer provides the storage, the urine will be stored close to the land where it is used. Proper contracts should be arranged, regulating storage length, quality control, etc. Another alternative is to set up storage on municipal land, for example where the park department is in charge.

Suitable storage for urine can often be found on farms which have once had livestock. Empty slurry tanks can constitute cost-efficient storage for the urine. However, air exposure should be minimized and thus covers must be provided as the urine should be stored in covered containers. Existing containers may need modification.

Use

The use of urine as a fertilizer in agriculture has not met with any difficult practical problems[14], mainly due to the fact that the use of animal urine in agriculture is common practice. Mechanical equipment for application of the urine already exists and the farm routines do not need to be changed substantially. The main aspects that Swedish farmers have had to deal with are the storage of urine as well as quality control, certification, and also acceptance by the buyers of the grain, Box 19.

[14] Compared to spreading of mineral fertilizers the agricultural use of urine, as of animal slurry, has a few disadvantages, such as e.g. the risk of soil compaction. This risk can be mitigated by spreading the urine when the soil contains low amounts of soil moisture, or by using specially designed spreading equipment. It is also more time consuming.

Urine is a suitable fertilizer for agriculture, with levels of N, P and K well matching the needs of grain crops. The nutrients in urine are best utilized when the urine is spread on grain crops in the spring, or as a supplementary fertilizer when the crop is 15–30 cm high. The farmers using urine in Sweden today spread it either in the spring to summer or winter grain, or to leys.

In large-scale agriculture, there is a need to have sufficient volumes of urine for the farmer to even consider using it as a fertilizer. One hectare of grain is normally fertilized with around 100 kg N per year. This means that the urine from at least 25 people is needed to supply one hectare with nitrogen fertilizer, if all the urine is collected. Therefore, agricultural use of urine requires introduction of urine diversion on a large scale.

The urine is spread by conventional liquid manure spreaders using trailing hoses, Figure 21. If the urine is spread on bare soil, it should be incorporated by harrowing as soon as possible in order to avoid ammonia losses. If the farmer does not have access to the equipment, it can easily be rented and frequently groups of farmers cooperate using one spreader on many farms. In these cases, it is important to wash the spreader between different fertilizers to avoid contamination.

Figure 21. Large scale application of urine using a slurry spreader with trailing hoses. Photo: Mats Johansson.

Since urine is rich in ammonia, nitrogen may be lost as ammonia if the urine is not properly handled. Proper handling includes storing the urine in covered containers, and choosing spreading techniques that minimize the risk of ammonia losses. Trailing hoses, or broad spreading with subsequent harrowing may be used. New techniques are being developed for spreading liquid manures, where the fertilizer is injected into the ground directly.

Odours

There have been no problems with smell when urine is used as fertilizer in agriculture. Urine does smell, but so do most organic fertilizers. During the application, a strong smell may be noticed, but this is no more offensive than slurry, and only a short time after application, no smell can be detected at all. Notably, urine has been applied on fields close to Stockholm, in a recreational area, and no complaints have been received from house owners nearby.

Box 19. Quality control and certification

The farmer will only be interested in using the urine as fertilizer if the possibilities for marketing of the produce are not impaired. This could be the case if buyers set up restrictions for use of human waste on crops. Recent development has seen quality control systems for crop production evolving, and this is applicable for the fertilizers as well. There is currently a certification system for digested or composted household waste, enabling the use of this waste fraction in agriculture. A similar setup for urine would simplify its use in Swedish agriculture.

The role of municipalities in quality control and certification of urine has not been well explored in Sweden as of now, but an increasing number of municipalities have seen the need and are beginning to become aware of their responsibilities.

Transportation

Important aspects to consider when planning transportation of urine are choice of entrepreneur, hygiene and documentation. Regarding entrepreneurs, Swedish municipalities usually have one or a few companies that are contracted to transport the waste fractions generated within the municipality. Another interesting alternative is to contract the farmer who will be using the urine for transportation services. This way the farmer can generate some additional income from handling the urine. The hygiene aspect must be considered. All transports should be documented as a part of a quality control system.

4.5 USER ASPECTS

Many people are involved in handling urine during the chain from household to field. The users of the system include the households, municipalities, entrepreneurs, wastewater companies, farmers and others. If users are not motivated and/or do not fully understand the reasons why the urine-diverting system is installed, the system is more likely to fail. Therefore, it is important to establish good communication and robust routines.

Attitudes towards dual-flush urine diversion in Sweden

The attitudes among users of *dual-flush* urine diversion toilets in Sweden were investigated during a research project, resulting in the report entitled Urine Separation – Closing the Nutrient Loop. Through this project it was found that:

- Dual-flush urine-diverting toilets do not smell noticeably more than other toilets, although several households had an odour problem at the start. This was mainly because of inferior or faulty installation.
- Dual-flush urine-diverting toilets are not more difficult to keep clean than conventional toilets. Compared with a conventional toilet, respondents found that the Dubbletten toilet required more work, while the Wost Man Ecology DS toilet was somewhat easier to keep clean.
- There were complaints that the Dubbletten toilet did not flush the bowl clean and that it splashed. The flushing function has since been improved.
- There was a difference in nutrient concentration in the urine collected from the different estates participating in the research project, probably due to differing levels of motivation to conserve water at the estates.
- It was concluded that making available regular information to the residents increases their motivation for using the toilet as intended and that when the system works properly the residents accept it.

Attitudes on urine-diverted dry toilets in one housing area

The attitudes among users of urine-diverted dry toilets have been thoroughly investigated in the Gebers housing area in Stockholm (see Chapter 3 for both a description of Gebers and more on the attitudes among the users), through a Linköping university research project (see the Read more box for full reference of the report). Through this research project it was shown that the residents had both positive and negative attitudes towards their sanitation system. One respondent underlined that the absence of smell is especially nice while having guests. Another positive aspect is that the system is comparatively silent, since there is no flushing involved. One respondent says: *[…] I'm really happy that we don't flush. I've lived in apartment buildings and I've heard it, that is, in a flat where you can hear every sound, where I've not only heard the flushing but even the urinating […].*

Some residents, mostly women, are not satisfied with the toilet design from a user point of view and have expressed concerns about too much urine ending up in the faecal drop hole. One respondent says: *[…] the toilet isn't really designed for girls […] you easily pee into the drop-hole and then urine ends up where it shouldn't be ... […] perhaps the urine-bowl should be more ... arched or extended like a triangle maybe […].*

A WC is to some extent, unfortunately, used as a waste bin and the receptor of solid waste, medicine residues, tampons, food waste etc, a behaviour which is not possible to maintain with a urine diversion dry toilet system, where the faecal matter is to be composted and used as a soil conditioner. A dry toilet both encourages and requires an increased awareness of what is acceptable to discard into the toilet. Even though the Gebers residents can be said to have been environmentally concerned even before installing their dry sanitation system, their choice of toilet has made them gain a different view of what is acceptable to throw into a toilet. One conclusion from the research project is that *the change in technical arrangements secured environmentally friendly toilet disposal routines that reach beyond the "good" routines evolving from environmental concern.*

The dual-flush toilets are more forgiving towards misuse than urine-diverted dry toilet systems, for which the faecal collection chamber will overflow quickly if the urine is misplaced.

4.6 LEGAL ASPECTS

The Swedish legislation is quite modern and includes sustainability and protection of the environment. Both the Environmental Code and the revised Planning and Building Act embrace the ideas of sustainability, focusing on reuse and recycling of natural resources. For this reason, physical planning can be used as a tool to achieve implementation of urine diversion in Sweden.

The Environmental Code contains several opportunities for the implementation of urine diversion and other closed-loop oriented techniques in rural areas in Sweden. One is the fact that recycling and efficient use of natural resources are integral objectives of the Code. Others are the precautionary principle; the polluter pays principle and the concept of "Best Available Technology". Both Tanum and Norrköping have used this legislation as a basis for requiring urine diversion and other municipalities are now following.

While the Wastewater Act forces mainly the municipalities to build sewage systems and to supply their inhabitants with water, the Planning and Building Act gives the municipalities the faculty to single-handedly decide on the spatial planning and development of infrastructure in the local situation. The requirements within the Wastewater Act are only applicable in situations where there are more than 20-30 households, and within the Planning and Building Act, any decisions on sanitation are only imposed by binding force in rural areas. The Planning and Building authority may not issue building permits if there is no possibility of finding good quality drinking water and managing wastewater. However, the Planning and Building Act is seldom used by the planning sections of Swedish municipalities to decide how wastewater shall be treated in specific areas, or for strategic planning of sanitation. It specifies only that wastewater shall be taken care of in some way although it does have wider capacity for planning in rural areas. Strategic wastewater planning is usually performed by local and regional environmental authorities and cooperating organizations. The Planning and Building Act is, therefore, probably not used to its full potential in Sweden today, at least not in rural areas. The Planning and Building Act has recently (2005) been reviewed and it has been proposed that all new houses shall have enough space for source diversion of waste fractions. This would also be applicable to urine, since urine can be considered a waste fraction according to the Environmental Code, which is based on EU directives. Another example of this mainstreaming of urine diversion is the revision of the agricultural use of sludge statutes, issued by the Swedish Environmental Protection Agency, which also will regulate the use of human urine in agriculture as well as other wastewater fractions.

Sweden is a member of the European Union and is therefore governed by the EG Water Framework Directive, now being implemented throughout the EU. There are also many EU-related laws and regulations that are applicable to agricultural activities. Swedish organic agriculture is governed by the EU regulation (EEG) 2092/91 which applies to all certified European organic agriculture. The regulation is interpreted by the certification authorities in each member country. The EU regulation regulates all inputs allowed in organic agriculture. Human urine is at present not included in the EU regulation which makes it difficult for organic farmers to use human urine even if the Swedish organic farmers union and the Swedish organic agriculture certifying organization, KRAV, have nothing against it per se as a fertilizer.

IFOAM is the international organization for organic farming movements. The IFOAM norms state that in organic farming the use of human excreta is prohibited on crops for human consumption. However, exceptions may be made according to the same norms and an annex to the norms states that source-diverted human excreta may be used if it is monitored to avoid contamination, and not directly applied on edible parts of crops.

Box 20. Use of urine in organic farming – a small step towards acceptance

According to KRAV standards, septic tank sludge and urine originating from an organic farm can be used as a fertilizer on the farm in question.There is, however, a pilot project where urine collected from a number of households in the vicinity of an organic farm is used as a fertilizer on this farm. KRAV, consider the urine as originating from households with a close connection to the organic farm in question. This will help generate experience valuable for the development of proposals for new regulations for organic farming.

"In Hulta we have managed to close the nutrient loop on a local scale. The people in the village buy potatoes, flour and meat from our farm, and we use urine from their households on our fields. In a probable future, with more people on a vegetarian diet due to environmental reasons, health aspects or other things, it will become even more important to reuse of nutrients from human excreta, as animal rearing, and hence the amount of manure produced, will decrease." Börje Johansson, organic farmer in Hulta village.

4.7 ECONOMICS OF URINE DIVERSION SYSTEMS

The analysis of the economics of urine-diverting systems will necessarily depend on the context. For each of the four contexts given earlier in the report, the conditions will vary. In rural settings, the installation of a urine-diverting toilet may have a substantial cost if the alternative is no toilet at all. The economic gain from improved health is difficult to quantify. The generation of high quality fertilizers will, however, contribute to a return from the construction of the toilet.

Economic analysis

A Swedish study of the economy at the household level for on-site systems shows that the urine-diverting toilet with dry collection of faeces is the cheapest alternative when compared to urine-diverting dual-flush toilets, blackwater systems, composting toilets, filter boxes and small package treatment plants, see Figure 22.

The total yearly cost for investment and operation and maintenance of a dry urine-diverting system is estimated at a little more than 210 €; for a newly constructed system, with a urine-diverting dual-flush toilet and a sand filter bed for the greywater and faecal flows, it is estimated at approximately 640 € per year, which is only slightly more than the annual cost of a conventional on-site system in Sweden. These results are very interesting as it makes it possible for the environmental authorities to require urine diversion, for example, as a precautionary measure since it will not be substantially more expensive than a more conventional on-site system.

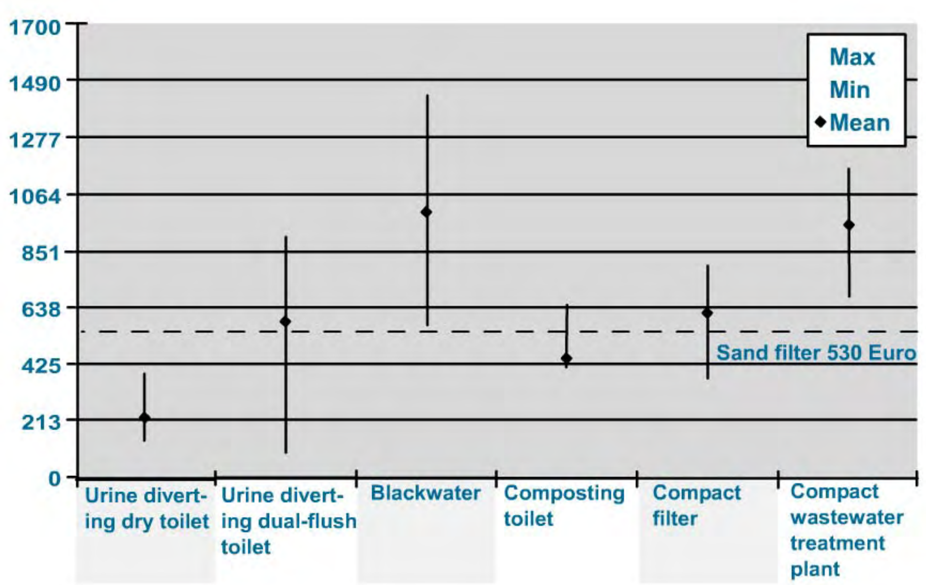

Figure 22. Results from a survey of house owners using alternatives to conventional sanitation[15]. (Source: Swedish EPA, 2004)

[15] Swedish EPA 2004. Avlopp i kretslopp. En utvärdering av LIP-finansierade enskilda avlopp, vassbäddar och bevattningssystem med avloppsvatten. Rapport 5406. Naturvårdsverket, Stockholm.

Box 21. Examples of investment and operation and maintenance cost comparisons

In Brandenburg near Berlin, Germany, cost comparisons have been made for three different sanitation concepts for a planned new housing estate, where the population is expected to increase from 672 to 5,000 inhabitants within 10 years. The three systems analysed were:

- Conventional, mixed, gravity sewerage system, consisting of: flush toilets, normal gravity sewerage system, pumping station with transport sewer to the existing sewerage network, system operated by the public supplier.

- Source separation concept I (gravity, composting of faeces) consisting of: Gravity urine diversion toilets, collection and storage of urine, with transport and agricultural use on a nearby farm, faeces transported in gravity sewer with aerobic treatment in a compost separator, utilization of compost in horticulture, transport of greywater in gravity sewerage system, treatment in a constructed wetland, transport to the receiving water.

- Source separation concept II (vacuum, digestion of faeces) consisting of: Vacuum urine diversion toilets, gravity urine transport, storage of the urine and agricultural use on a nearby farm, faeces transported by vacuum sewerage, common treatment with organic waste in a biogas plant, biogas used to produce energy, transport of the digested sludge to nearby farms and utilization in agriculture, transport of greywater in gravity sewerage system, treatment in a constructed wetland, transport to the receiving water.

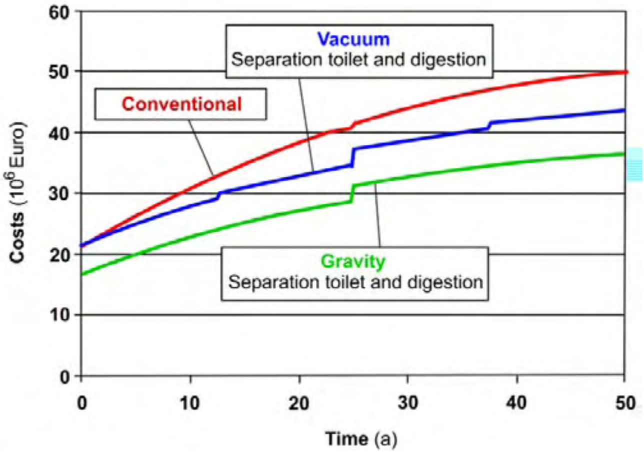

Figure 23. Cost comparison for the installation, operation and maintenance of three sanitation systems for a population of 5,000. The red line represents conventional sanitation, the blue urine diversion source separation concept II system and the green source separation concept I system.

The three systems were calculated over a lifetime of 50 years, with an annual interest rate of 3.5%. The results of this cost comparison can be clearly seen above, for the situation where 5,000 inhabitants are served and the local Berlin water company is responsible for the operation of the system. Other service scenarios have been calculated with different population numbers and operational models which also revealed a significant price advantage for the use-oriented systems over the system lifetime*.

*: Peter-Fröhlich, A., Kraume, I., Lesouëf, A., Gommery, L., Phan, L., and Oldenburg, M., (2004): *Sanitation concepts for separate treatment of urine, faeces and greywater." – Session G, p.675-683 - In: Werner et al. [eds.]. (2004): „Ecosan – closing the loop. Proceedings of the 2nd international symposium on ecological sanitation (…), 7th – 11th April 2003, Lübeck, Germany*, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn.

The cost for on-site systems consists of the investment and the costs for O&M. The municipalities can help by subsidizing the investment in special programmes. Another possibility for promoting urine-diverting systems is to reduce the costs for O&M such as costs for urine collection and other fees. This approach is used by some municipalities in Sweden, where urine is collected for free once or twice a year. Other approaches exist as well, where the municipality charges a lower annual fee if the household has a urine-diverting toilet, but the households need to pay for the collection of the urine. This is thought to work as an incentive for the households to make sure they keep the urine highly concentrated by ensuring that there are no leakages of water into the tank or malfunctioning flushing, as otherwise the tank will fill too quickly, causing unnecessary costs to the house owner.

Box 22. Investment costs for water and wastewater at Kullön, a newly constructed housing area with urine diversion toilets combined with conventional wastewater treatment.

More information about Kullön can be found in Chapter 3.

The urine-diverting toilet system at Kullön serves 775 people in 250 households. The toilets installed are urine-diverting dual-flush water toilets. The remaining wastewater is treated in a local wastewater treatment plant run by the municipal water company and includes tertiary treatment, a polishing pond and ditch system. There are 13 tanks for collection of urine in the area. The figure below shows an estimate of investment costs for the water and sanitation system at Kullön. The total investment cost for water and sanitation in Kullön is approximately 15,000–16,000 €/house.

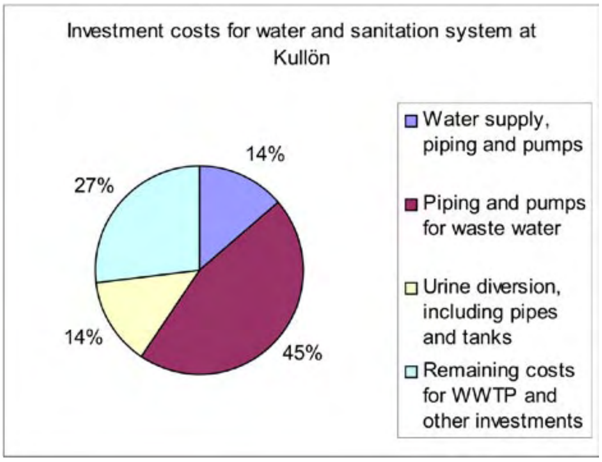

Figure 24 Urine diversion accounts for 14% of the total investments in water and sanitation at Kullön. Figures from 2005.

Costs for the spreading of urine in agriculture

In the Swedish context it has been estimated that the monetary value of the nutrients in urine usually approximately corresponds to the extra costs of spreading and soil compaction, Table 1.

Table 1. Costs for spreading of 41 m³ urine, corresponding to the nutrients in 375 kg of NPKS 24-2-5-3[16] on one hectare[17].

	Urine (costs in SEK for 41 m³/ha)	Commercial fertilizer (costs in SEK for 375 kg NPKS/ha)
Fertilizer purchase	0	1000[18]
Spreading	1000[19]	110
Soil compaction (spring fertilization on a medium clay)	300[20]	0
Total	1300	1110

[16] The figures corresponds to the percent of each of the nutrients nitrogen (N), Phosphorus (P), Potassium (K) and sulphur (S). Thus 24% of the 374 kg is nitrogen, 2% is phosphorus, 5% is potassium and 3% is sulphur.

[17] Degaardt (2004)

[18] According to figures from the Swedish Farmers Supply and Crop Marketing Association, 2004.

[19] Figures from a contractor in Southern Sweden for a tank wagon with an applicator fitted with trailing hoses

[20] Arvidsson (1998)

Thus, costs for storage and transportation of urine to field will have to be covered from elsewhere. However, in order to make a fair comparison, savings for the municipality due to urine diversion should also be included. These savings could mean cheaper processes in the wastewater treatment plant if urine is diverted from the wastewater flow, a cost that can be substantial if the existing treatment plant is insufficient in capacity.

4.8 URINE DIVERSION IN THE FUTURE IN SWEDEN – SOME VOICES

Some sanitation/agriculture professionals in Sweden were asked how they consider urine diversion within and outside municipal wastewater jurisdictions today and in ten years.

How do you consider the position of urine diversion today and in ten years within municipal wastewater jurisdictions?

- **Jan Eksvärd, Environmental Manager at Swedish Farmer's Association:** *"Today there are only few installations within municipal wastewater jurisdictions. This can change with time, when more experience is gained and costs are lowered. However, volumes collected within municipal wastewater jurisdictions will continue to be small, even if all new and renovated houses are equipped with urine diversion."*
- **Tor Borinder, Head of Industry Section, Implementation and Enforcement Department Swedish Environmental Protection Agency:** *"Urine diversion within municipal wastewater jurisdictions is one possibility for reaching the objective of phosphorus recycling, stated in the Swedish EPA's actionplan for recycling of phosphorus from wastewater. To achieve this there is an infrastructural need for collection, sanitization and transport to suitable areas for use. This entails an increase in transport unless the urine is concentrated, which might be questionable from several standpoints. Today, there are only few examples of urine diversion within municipal wastewater jurisdictions. The infrastructure necessary for the use of the plant nutrients also only exists in a few places. In ten years' time the situation will probably look differently, with more urine diversion. However, this is dependent on the development of certain things: the technology needs to be improved so that the urine is not diluted, or technology for concentration of the nutrients must be developed. A more positive attitude towards agricultural use of urine among the general public would also aid this development. It is most probable that urine diversion will be implemented in areas where the urine can be used quite locally".*
- **Eva Andersson, Municipal commissioner, Norrköping municipality:** "*Since source diversion is key to finding a market for wastewater fractions urine diversion is interesting also within municipal wastewater jurisdictions, even more so since agricultural use of sludge is complicated to achieve. Norrköping municipality has decided to develop guidelines for urine diversion within the municipal wastewater jurisdiction, something we already have for on-site systems. We have also, within our solid waste plan, especially underlined the use of urine diversion in urban areas. In ten years' time we will, in Norrköping, see that new houses are constructed with urine diversion, both within and outside the municipal wastewater jurisdiction. The fees will favour those source-diverting their urine, which will lead to the retrofitting of old houses to urine diversion. The sustainable society will use the plant nutrients available in the wastewater fraction. Urine, which can be considered a high quality nutrient solution, will be used more widely compared to sludge. The transports will be more efficient, due to higher concentration of the urine."*
- **Agneta Sander, Planning Manager of Department of Sustainable Water and Waste Management, City of Gothenburg:** "*The City of Gothenburg and the municipal wastewater company, GRYYAB are currently preparing a system's analysis, together with researchers from the Urban Water Research Programme. The aim is to produce a knowledge base, so*

that strategic decisions leading towards the most sustainable sanitation systems in the future can be made. With sustainable sanitation I mean sanitation systems with the smallest impact possible on the environment, allowing for nutrient recycling, while being economically and socially acceptable. The time frame for the study is 2050, with a requirement that most of the changes in the wastewater systems shall be achievable by 2020. The study looks into possibilities of refining today's wastewater systems as well as the potential of using other systems such as urine diversion and blackwater systems. The results of this study will give us a clearer picture of the future role of source diverting sanitation systems for the context of Gothenburg."

How do you consider the position of urine diversion today and in ten years outside municipal wastewater jurisdictions?

- **Jan Eksvärd, Environme•ntal Manager at Swedish Farmer's Association: "***The possibilities for urine diversion to establish itself as a conventional sanitation technology are more pronounced outside the municipal wastewater jurisdiction. It allows the possibility of low nutrient impact on surface and groundwater and of a high degree of nutrient cycling to agriculture. If one third of all on-site systems in Sweden are converted to urine diversion within a period of ten years, it will mean several hundred of thousands of urine-diverting households. The farmers are definitely interested in a commercial management of these kind of volumes of urine (and faecal composts) if connected to some kind of quality certification system."*

- **Tor Borinder, Head of Industry Section Implementation and Enforcement Department Swedish Environmental Protection Agency:**"*It is reasonable to believe that the foremost potential for implementation of urine diversion exists for on-site systems for several reasons. One is the proximity to farmland. It is most probable that the implementation of agricultural use of urine is implemented where farmland is available where the nutrients can be used. Today urine diversion exists to a higher extent outside rather than within municipal wastewater jurisdictions, even though the total number still is low. The driving force for this development has mainly been individual municipalities. Urine diversion is one way to achieve the requirements within the forthcoming national recommendations for on-site systems. Within ten years the situation for urine diversion will probably have changed in a positive direction."*

- **Eva Andersson, Municipal commissioner, Norrköping municipality: "***Norrköping municipality has had, since 2002, a requirement for on-site systems which implies that new systems shall be source diverting. In addition to a direct reduction in environmental impact, urine diversion gives our local farmers an attractive high quality nutrient solution. Norrköping municipality does not charge extra for emptying the household urine tanks. This is appreciated and is an important statement that the municipality is actively working for a reduction of emissions and for nutrient cycling. We also have a functioning system for urine collection and it is delivered to the farmers without any extra charge. We have noted a demand for urine from the farmers. Source diversion is foremost suitable for on-site systems, not having the same high removal efficiencies as in centralized treatment plants. In ten years' time urine diversion will be a matter of course and the collected urine will contain only small volumes of flushing water, which will give a high concentration of nutrients in the urine. The urine concentration question is thereby more or less solved and urine will be a commodity."*

- **Agneta Sander, Planning Manager of Department of Sustainable Water and Waste Management, City of Gothenburg: "***The reply from Swedish EPA basically covers, also outside the municipal wastewater jurisdiction, what we believe is the role of urine diversion for the Gothenburg context as well. Moreover, other legal and regulatory instruments, such as possible changes in EU directives, Swedish legislation etc., considering nutrient cycling and recipient protection will influence the development of urine diversion."*

Read more

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Chapter 5: Questions and Answers

PLANNING AND IMPLEMENTATION

Why should I consider urine diversion when planning for new sanitation/ sanitation upgrades?

Urine diversion, with subsequent collection and reuse of the urine, is one way to collect nutrients from the wastewater fraction for use in agriculture or the home garden. Urine diversion should be considered among different options. Urine diversion will emerge as the best solution when aspects such as protecting the environment, generating fertilizers and recycling on the small scale are prioritized. Cases where urine-diverted dry systems have been promoted are where the wastewater treatment plant has limited capacity, where the surface and ground waters need to be protected, and where there is a demand for urine and faeces as fertilizers.

Are there any risks involved that should be avoided when planning for urine-diverting systems?

Since urine diversion has not been considered mainstream, there is a risk regarding the quality and construction of the toilet and piping systems. Many of the existing places where urine diversion has been installed have had to develop systems as they went along, causing irritation and costs. As development progresses, this risk will diminish. Another risk relating to the mainstreaming of urine diversion is the risk of misuse/abuse of the system. Education of household owners, as well as simple manuals and instructions for temporary users will minimize this risk.

The risk of transmission of disease is minimal if proper hygiene guidelines are followed.

One risk that the planner/municipality needs to consider is the acceptance of the system by the users. In order to establish a sound and stable system, users need to accept, for example, changes in practice using the toilet. The users may also need to accept increased costs, or handling of the urine and faeces.

Does the system have high operation and maintenance (O&M) demands?

The answer to this question depends on the design of the system. In many cases, there will be two, or in some cases three fractions to handle instead of one or two, which in itself may entail more practical aspects since both the urine and faeces should be recirculated to agriculture. Regarding the toilets, the experience is that the piping for urine needs more maintenance than the conventional piping, in order to avoid blockages. However, with improved design this need may diminish.

If the urine and faeces are to be used locally, operation and maintenance will be geared towards the piping system and collection tanks. If the urine and faeces are to be used in agriculture, operation and maintenance include transportation, storage and use of the products.

What do construction companies need to consider when planning for a urine diversion system?

Since urine-diverting systems are seldom included in building codes, special care needs to be taken by the builders to ensure proper running of the system. The sizing and inclination of pipes, documentation and accessibility, are some of the aspects where mistakes can lead to failure of the system.

Household owners should be supplied with a simple manual that explains the concept, as well as operation and maintenance routines. If there is a choice between suppliers, take care to choose a supplier where spare parts and support can be given. If there is no municipal collection of urine, you must plan for an adequate space where the urine can be used for crop production, and establish routines in order to put the urine to use.

The construction should cater for appropriate collection and storage capacity for the urine.

SANITARY ASPECTS

Is urine hygienically safe to use in the home garden as well as in agriculture?

There is minimal risk of disease transmission when urine is used without prior storage in the home garden, provided that it is also collected in the home situation. If guidelines for storage of urine are followed, the urine can be used safely in any crop production. There is always a recommended waiting period of one month between last application of urine and harvest, in order to provide an extra barrier for additional safety.

ECONOMIC ASPECTS

Is urine diversion more expensive?

The cost of a urine-diverting system should be seen in a broad perspective. Advantages such as improved environment, food security for households, safer handling of a waste flow from the household should be weighed against costs. Introduction of new systems may entail additional initial costs, until the systems are up-scaled and mainstreamed. If the collection system includes transport to a farm, calculations of costs should include all costs right up to the use of the urine on the crops, and not just costs for installing toilets and pipes. In a municipality, costs should be seen in comparison with costs for wastewater treatment or solid waste treatment.

The cost to the household of urine-diverting toilet systems will of course vary with different conditions. Factors that may make urine diversion systems more expensive are small-scale production and the double piping systems. However, in a situation where houses are being newly built, the cost of installing urine diversion will often be marginal compared to the whole cost of the house. Retrofitting may prove a challenge.

RESOURCE MANAGEMENT/ENVIRONMENTAL ASPECTS

How and when do I apply urine to my plants?

Urine is a nitrogen rich all-round fertilizer with good effect on nitrogen-demanding crops. Apply the urine when the plants need fertilizer, and water down after spreading. The rate of application depends on the plants' needs and the soil conditions. A simple rule of thumb is to apply the urine from one person during one day to a square metre of soil. The urine does not need to be diluted.

What do I do with the rest of the "wastewater flows"?

When urine diversion is implemented, there will still be faeces and greywater to take care of. These fractions can be treated separately or jointly, locally or on large scale. In flush systems, removing urine from the other wastewater flows will naturally remove nutrients, lowering the agricultural quality of the remaining flows. Another result is that the need to remove nitrogen and phosphorous in the wastewater treatment plant is lowered when the urine is source diverted. In dry systems, the faeces will be easier to handle when the urine is removed since the faeces will be drier. There are examples of introduction of urine diversion in existing systems where the faeces and greywater are treated conventionally and the urine is collected for reuse.

Are there any harmful substances in the urine?

In excreta the content of heavy metals and other contaminating substances such as pesticide residues is generally low or very low, and depends on the amounts present in consumed products. Faeces contains a greater amount of these substances than does urine. Even so, the concentrations of contaminating substances in faeces are usually lower than in chemical fertilizers (e.g. cadmium) and farmyard manure (eg. chromium and lead).

A large proportion of the hormones produced by our bodies and the pharmaceuticals that we consume are excreted with the urine. It is reasonable to believe that the risk for negative effects on crop quality and quantity from hormones is negligible. All mammals produce hormones and the vegetation and soil microbes are adapted to, and can degrade, these hormones. Furthermore, the amount of hormones in manure from domestic animals is far larger than the amount found in human urine. Thus, both fertilizer experiments and evolutionary history strongly indicate that there is no real risk.

Is there any risk associated with pharmaceuticals from using the urine in crop production?

There are research projects going on to investigate the environmental effect of pharmaceuticals in urine. By far the majority of all pharmaceutical substances are derived from nature, even if many are synthetically produced, and they are thus found and degraded in natural environments with a diverse microbial activity. This has been verified in ordinary wastewater treatment plants, where the degradation of pharmaceutical substances improved when the retention time was prolonged from a number of hours to a number of days. Urine and faecal fertilizers are mixed into the active topsoil, which has a microbial community just as diverse and active as that in wastewater treatment plants, and the substances are retained for months in the topsoil. This means that there is plenty of time for the microbes to degrade any pharmaceutical substances and that risks associated with them are small.

Concerning both hormones and pharmaceutical substances, it thus seems far better to recycle urine and faeces to arable land than to flush them into recipient waters. Since the aquatic systems have never before been exposed to mammal hormones in large quantities, it is not surprising that the sex development of fish and reptiles is disturbed when they are exposed to wastewater effluent. Furthermore, the retention time of the wastewater in the treatment plants is far too short for many pharmaceutical substances to degrade and recipient waters are also usually connected to water sources.

There are many indications that the possible risk from pharmaceutical substances in the agricultural system is small and far smaller than the risks associated with the present system. One such indication is that in many countries the human consumption of pharmaceuticals is small compared to that by domestic animals, as in most countries most commercial feeds contain antibiotic substances, added as growth promoters. Furthermore, the human use of pharmaceutical substances is small compared to the amount of pesticides (insecticides, fungicides, bactericides and herbicides) used in agriculture, which are just as biologically active as pharmaceutical substances.

SOCIAL ASPECTS

How do I get different stakeholders to accept/adopt urine diversion?

The demonstration of good examples will facilitate the acceptance of new systems. If users are aware of the benefits the introduction of urine diversion will be easier. These good examples should be geared towards different levels of stakeholders. Farmers need to see the fertilizing effect of urine and faeces, toilet users need to see the toilet installed and in use, decision makers need information on financial aspects etc.

What features does a gender-appropriate UD toilet/urinal carry?

A gender-appropriate toilet should cater for the fact that men and women excrete urine in different ways. The bowls should be designed so that urine is collected in an appropriate way from both women and men using the toilet, and the question of which design promotes this aspect still needs attention and product development. It is likely that the urinals for men and women need to be designed in different ways.

Appendix 1: Millennium Development Goals

Goal 1: Eradicate extreme poverty and hunger

- Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day
- Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger

Goal 2: Achieve universal primary education

- Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling

Goal 3: Promote gender equality and empower women

- Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and to all levels of education no later than 2015

Goal 4: Reduce child mortality

- Target 5: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate

Goal 5: Improve maternal health

- Target 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio

Goal 6: Combat HIV/AIDS, malaria and other diseases

- Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS
- Target 8 Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases

Goal 7: Ensure environmental sustainability

- Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources
- Target 10 Halve, by 2015, the proportion of people without sustainable access to safe drinking water and sanitation
  Target 11: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers

Goal 8: Develop a Global Partnership for Development

- Target 12: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system [Includes a commitment to good governance, development, and poverty reduction – both nationally and internationally]
- Target 13: Address the Special Needs of the Least Developed Countries [Includes: tariff and quota free access for LDC exports; enhanced programme of debt relief for HIPC and cancellation of official bilateral debt; and more generous ODA for countries committed to poverty reduction]
- Target 14: Address the Special Needs of landlocked countries and small island developing States (through the Programme of Action for the Sustainable Development of Small Island Developing States and the outcome of the 22nd special session of the General Assembly)
- Target 15: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term
- Target 16: In co-operation with developing countries, develop and implement strategies for decent and productive work for youth
- Target 17: In co-operation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries

- Target 18: In co-operation with the private sector, make available the benefits of new technologies, especially information and communications

Source: www.unmillenniumproject.org

Appendix 2: Technical Recommendations

TOILETS, PIPES AND TANKS

This appendix focuses on how to build and maintain a well-functioning urine-diverting system, i.e. to avoid problems such as blockages, odour, intrusion of groundwater and nitrogen losses. It covers all parts of the system at household level from how to choose and install the toilet to the size of pipes and important aspects about the collecting tank. For information on other aspects such as sanitization of urine, storage and use of urine, transportation, user aspects, legal aspects and economical aspects, see Chapter 4 and Appendices 3 and 4.

The recommendations in Appendix 2 are based on Swedish and international experience and research. They build on current knowledge and we recommend that they are revised regularly incorporating the latest findings. The recommendations cover the most technically complicated of urine diversion cases, somewhat corresponding to sanitation context 4 in Chapter 1: "A piped water distribution system and wastewater collection system and adequate wastewater treatment exists", but recommendations pertaining to the other sanitation contexts are also given.

Urine-diverting toilets

Choice of toilet model

In most cases an inexpensive toilet model can meet the needs. It is important, however, that in the long run the user feels comfortable and is satisfied with it. It is therefore recommended that the prospective user, if possible, tries out the toilet before the choice is made. Other important aspects are that the toilet is easy to clean, that it is robust and easy to maintain. In terms of cleaning, the surface finish is important, and for maintenance, the technology, the availability of spare parts and labour skilled in their replacement etc. are important. Another important aspect is how easy it is to get at and access the urine pipe for cleaning and inspection. Furthermore, when a urine-diverting system is installed in a public place this imposes special requirements on the toilet design. Toilets which flush any misplaced material away from the urine compartment to the faecal compartment should be preferred. This aspect is less important in private households, where the toilets are used by people who soon become very experienced in their use.

Urine diversion in dry, non-complicated systems

The least complicated, but in many cases well-functioning, urine-diverting system has only one toilet per collecting vessel, short pipes and the urine is spread in the garden outside. The easiest way to have a urine-diverting toilet is by placing a liner consisting of a funnel in the front of a dry toilet. The urine can be collected in 10–25-litre containers or a larger tank placed beside the latrine bin. When needed the container is emptied and the urine used as fertilizer. It can be easily spread by pouring directly from the container, possibly equipped with a hose down to the ground or by use of a plastic watering-can or similar. Care should be taken to allow for proper withholding times when fertilizing food crops, see Appendix 3 and 4.

Design

When a urine-diverting flush toilet is being installed, connection to the fresh water system should be performed in the same way as for a common WC.

To avoid odours it is preferable that both dry and water-flushed toilets be equipped with a seal (this could be a water seal or other type of seal), even though small installations (one toilet or urinal on a short piping system preferably less than 10 metres long and with a good slope, preferably >4%) can be built without seal.

Outlet pipes for faeces can normally be connected to the existing wastewater pipes by the use of a transition socket.

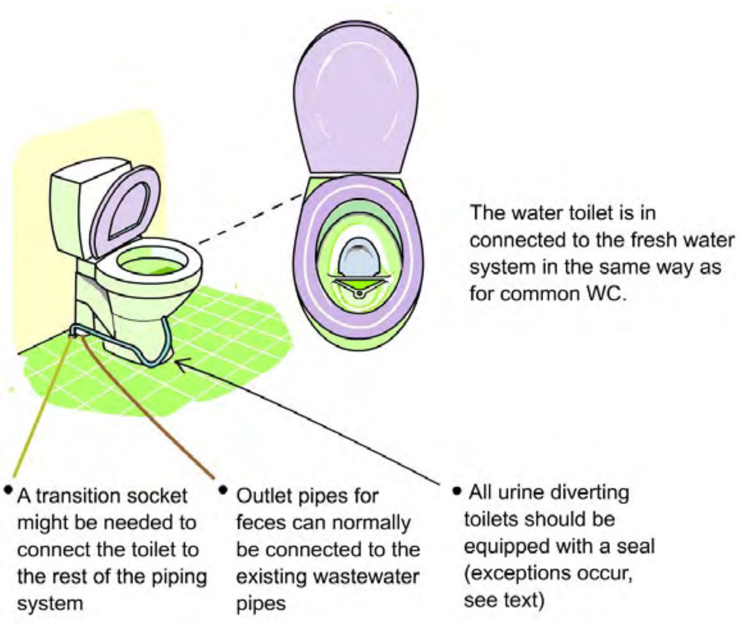

Figure 25. Detailed picture of a toilet pedestal. Picture by Johan Palmcrantz

Maintenance of urine-diverting toilets

In all installations there is a risk of blockages occurring mainly in the seal. It is a result of fibres and other particles entering the piping system and of chemical precipitation of struvite ($MgNH_4PO_4$) and calcium phosphates ($Ca_{10}(PO_4)_6(OH)_2$) from the urine caused by the increase in pH which occurs when its urea is degraded. The precipitation also forms a viscous sludge, which will slowly flow towards the tank provided that the slope of the pipes is correct. Another, but more costly way to solve the blockages, is to replace the water seal at regular intervals.

Degradation of urea to ammonia in water

$$CO(NH_2)_2 + 3\ H_2O \xrightarrow{\text{ureas}} 2\ NH_4^{\ +} + OH^- + HCO_3^-$$

$$NH_4^+ + OH^- \leftrightarrow NH_3(aq) + H_2O$$

Most blockages that occur in urine-diverting toilets are “soft” blockages caused by precipitation on hair and paper fibre. The other type is hard “blockages”, caused by precipitation directly on the on the pipe wall. The blockages are removed either mechanically by a drain auger or chemically by use of strong solutions of caustic soda (2 parts of water to 1 part of soda) or acetic acid (>24%). These methods can also be used also as prevention against blockages.

Figure 26. Cleansing tools for a urine-diverting toilet. Photo: Ebba af Petersens.

A suggested initial frequency for preventive cleaning is twice a year and then increasing the frequency if blockages still occur. Irrespective of the method used, it is important that the cleaning is followed by pouring 1–2 litres of water down the urine bowl as fast as possible, to flush away any material that might have come loose by the cleaning.

If chemical cleaning is preferred, it is suggested to alternate between caustic soda and acetic acid, as they supplement each other well. The caustic soda is very efficient in dissolving hair and organic residues and thus frees the mineral precipitates so that they can be flushed away as grains. Care should be taken, however, that the caustic soda is well dissolved in enough water (at least 2 volumes of water per volume of soda), before it is poured into the urine pipe, otherwise there is a risk of the soda itself forming a precipitate in the pipe. It is recommended that enough soda solution is used to also clear the pipe immediately behind the u-bend. A mixture of 5 dl of caustic soda and 1 litre of warm water will often be appropriate, as this will completely fill just over half a metre of a 50 mm pipe. Care should be taken and protective gloves and eyeglasses worn when handling the soda, as it is extremely caustic. The soda solution should be allowed to sit in the u-bend seal and the pipe over night and then it should be flushed away with at least 2 litres of water being poured down the urine bowl as fast as possible.

When acetic acid is used, it should be as strong as possible. The acetic acid does not dissolve hair and organic matter as efficiently as caustic soda, but it is more efficient in dissolving some of the mineral precipitates. Enough acid should be used to completely fill the u-bend and part of the pipe immediately behind it, normally at least 0.5 litres should be used. Also the acid should be allowed to sit over night and the pipe then flushed with at least 2 litres of water.

The caustic soda increases the pH of the urine and thus improves the sanitation of the urine. The acetic acid acts in the opposite direction. Therefore, if acetic acid is used, it is suggested that it is alternated with use of caustic soda.

Pipes

Material

Urine is, due to its content of ammonium, very corrosive. Therefore metals, for example copper, should be avoided anywhere in the system. Plastic pipes are preferred to metal ones. To maximize the flow rate of the urine and the sludge, the insides of the pipes should be smooth and flow restrictions, e.g. sharp 90º bends, should be minimized.

Dimensioning of pipes

Piping in the system should be minimized as much as possible. Based on the observations so far, the recommendations concerning urine pipes differ depending on whether the toilet has a u-bend or not. If the toilet does not have a u-bend, which is only recommended for small systems with one toilet on each urine pipe, the pipes can be thin, diameter at least 25 mm, and should have a good slope, a minimum slope of 4% is suggested, and obstacles slowing down the flow, e.g. sharp bends, should be avoided. The piping system should be short, preferably less than 10 metres, to limit the time the urine is in the piping system and thus the degradation of urea and risk of precipitation in the system.

If the toilet has a u-bend, all pipes should have a slope of at least 1%. The pipe diameter should be at least 75 mm, but where the pipes can be easily cleaned and/or disassembled 50 mm can be accepted, at the expense of regular maintenance e.g. flushing every few years. For underground pipes, a diameter of 110 mm is recommended. Ø110 mm pipes have thicker walls, are more stable and thus minimize the risk of pipe depressions. The possibility to inspect, flush and clean the pipes in both directions should be provided where there is a sharp bend in the piping, at all transitions, e.g. from vertical to horizontal piping and where the pipes leave the house. To prevent odours, the piping system should be only sparingly ventilated, pressure equalization is enough. Manholes outside the house shall be equipped with child safe lids that are water tight. When the collection container is outside of the toilet room, it is also important that the pipe ends close to the bottom of the collection container to avoid air flow through the pipe into the toilet room.

Care should be taken to prevent groundwater leaking into the pipe system. All connections in the ground must be completely tight (i.e. welded or glued, or if possible, avoided altogether) to minimize the risk for intrusion of groundwater. If possible, connections in the ground should be avoided all together.

It is essential to avoid sedimentation pockets and thus it is essential that negative slope is avoided in all parts of the pipe system.

The urine pipe is preferably located in the same piping trench as other wastewater pipes. It should be clearly marked, so that it is clearly distinguishable from the other pipes.

Maintenance of the pipe system

As a precaution against blockage in the piping system, it is recommended that 1 litre of water is flushed down the pipe once every 1–2 weeks.

If odours occur immediately when urine enters the pipe, minimizing the amount of water used can be tried. If the problem still persists, cleaning with 1–2 dl of strong acetic acid slowly poured down the pipe can be tried.

Tanks

Material

Collection tanks for urine can be fabricated in many different materials and designs. However, urine is very corrosive and if possible metals should be avoided altogether in the system. From an energy point of view tanks made of concrete or just a plastic liner in a dugout in the soil or a wooden frame are advantageous, but of greater importance for proper technical functioning is to ensure that the tanks used are water-tight and robust.

In Swedish schools with urine-diverting toilets no proper measurements have been made, but studies based on interviews about collecting intervals indicate that the amounts collected were 50–90 L per child per year when a dual-flushed system was used.

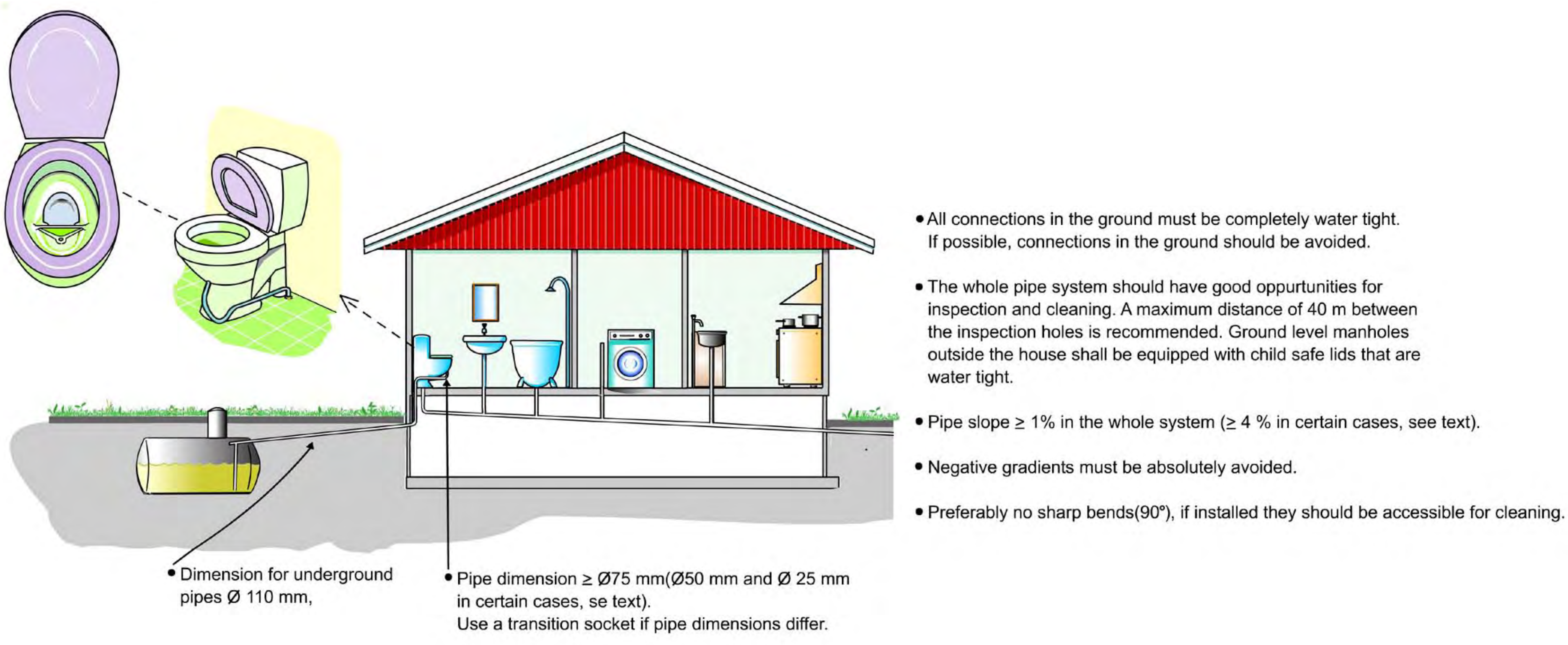

Figure 27. Urine diversion in the home; toilet and tank. Picture by J Palmcrantz & Co.

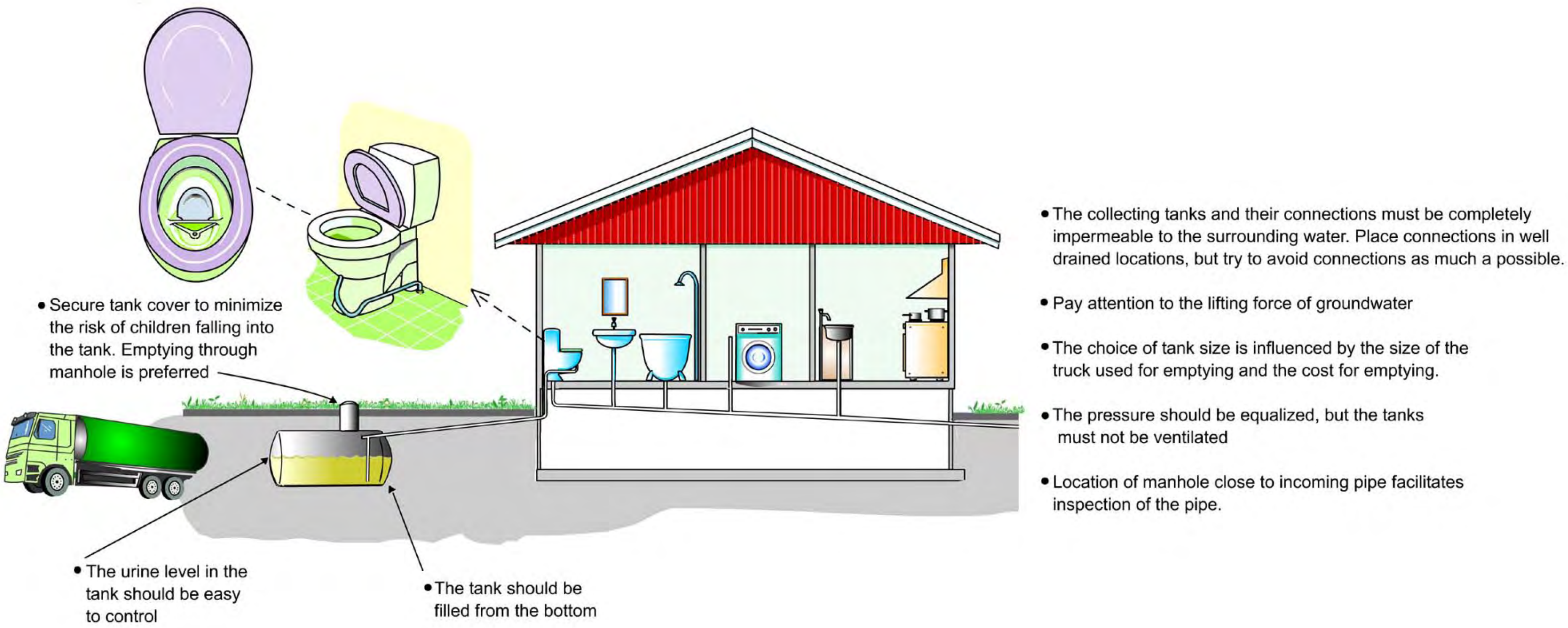

Figure 28. Instructions for filling and emptying of tanks. Picture by Palmcrantz & Co.

The amount collected depends on the kind of toilet model used, the motivation of the users and the time spent at home. The tank size should also be influenced by the size of the truck used for emptying and the cost for emptying. In a system for one household and spreading in their own garden, the collecting system is easy to design.

Maintenance of collecting tanks

Great care should be taken and the regulations issued by the proper authority on occupational safety and health should be followed if it is necessary to enter the urine tank, and this task should never be undertaken by one person alone.

Read more

- Af Petersens, E., Kvarnström, E. and Johansson, M. 2005. Helsingborg Interreg – Handbook in Urine Diversion (in Swedish) www.rent-vatten.com/download/Interreg_WRS_.pdf
- Emilsson, K., Jenssen, P.D.J., Flatlandsmo, A., Greatorex, J., Hellström, D., Magid, J., Malmén, L., Palm, O., Santala, E. 2006. Blackwater systems. Nordic inventory and proposals for research and development (in Swedish). Nordic Council of Minister's Serial: Tema Nord (in press).
- Lindgren, M. 1999. Urine separating toilets – clearing of blockages, collected volume and attitudes (Urinsorterande toaletter – rensning av stopp samt uppsamling och attityder; In Swedish English summary). Institutionsmeddelande 99:05, Institutionen för lantbruksteknik, SLU. Uppsala.
- Jönsson, H., Vinnerås, B., Höglund, C. Stenström, T.A., Dalhammar, G., Kirchmann, H. 2000. Source-diverted urine and recycling (in Swedish). VA-forsk report 2000–01. Svenskt Vatten, Stockholm, Sweden.
- Johansson, M., Jönsson, H., Höglund, C., Richert Stintzing, A., Rodhe, L. 2000. Urine separation – closing the nutrient cycle. Stockholm Vatten AB/FORMAS. www.stockholmvatten.se/pdf_arkiv/english/Urinsep_eng.pdf NMR-rapport
- Vinnerås, B., Jönsson, H., Niwagaba, C., Nordin, A. & Nalubega, M. 2006. Handling systems for reuse of faecal matter and urine. Ecosanres report, in press.

Appendix 3: Forthcoming WHO Recommendations for Sanitization of Urine (currently in final draft)

Table: Recommended guideline storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crop for larger systems[c]. (Adapted from Jönsson *et al.*, 2000 and Höglund, 2001)

Storage temperature	Storage time	Possible pathogens in the urine mixture after storage	Recommended crops
4°C	≥1 month	Viruses, protozoa	Food and fodder crops that are to be processed
4°C	≥6 months	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	≥1 month	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	≥6 months	Probably none	All crops[e]

[a] Urine or urine and water. When diluted it is assumed that the urine mixture has at least pH 8.8 and a nitrogen concentration of at least 1 g/l.

[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized for causing any of the infections of concern.

[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from which the urine was collected.

[d] Not grasslands for production of fodder.

[e] For food crops that are consumed raw it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

During storage the urine should be contained in a sealed tank or container. This prevents humans and animalst from coming into contact with the urine and hinders evaporation of ammonia decreasing the risk of odour and loss of nitrogen. The urine should preferably not be diluted.

- For vegetables, fruits and root crops consumed raw, a one-month holding period should always be applied.
- In areas where *Schistosoma haematobium* is endemic, urine should not be used near to freshwater sources.
- Urine should be applied close to the ground and preferably mixed with or watered into the soil.

The general recommendations for urine are:

- Direct use after collection or a short storage time is acceptable at a single household level. For larger systems, storage should be arranged.
- An interval of at least one month should be observed between fertilization and harvest.
- Additional stricter recommendations may apply at a local level in the case of frequent faecal cross-contamination. The recommendations for storage times is directly linked to agricultural use and choice of crop, see above.

Additional practices to minimize the risks include the following:

- When applying the urine precautions related to the handling of potentially infectious material should be taken. These precautions include wearing gloves and thorough hand washing.
- The urine should be applied using close-to-the-ground fertilizing techniques avoiding aerosol formation.
- The urine should be incorporated into the soil. In practice, this could be done mechanically or by subsequent irrigation with water.

Appendix 4: Proposed Swedish Legislation Regarding the Agricultural Use of Urine Collected from Multiple Households (Swedish EPA, 2002)

Table: Requirements for storage and allowed crops for urine-diverted human urine that is collected from larger systems[21]. The requirements presume a pH of at least 8.8 and a nitrogen content of at least 1 g/L. Temperatures and storage times are given as minimum values.

Storage temperature	Storage time	Allowed crops
4ºC	1 month	Food crops that are to be processed
4ºC	6 months	Food crops that are to be processed and fodder crops[22]
20ºC	1 month	Food crops that are to be processed and fodder crops
20ºC	6 months	All food crops[23] and fodder crops[24], park areas
-	1 year	All food crops[25] and fodder crops[26], park areas

[21] Recommendations on urine use on household level are currently under development.

[22] The spreading of urine on grasslands for fodder production is not allowed.

[23] For food crops consumed raw it is recommended that urine is spread at least one month before harvest and is harrowed down.

[24] The spreading of urine on grasslands for fodder production is not allowed

[25] For food crops consumed raw it is recommended that urine is spread at least one month before harvest and is harrowed down.

[26] The spreading of urine on grasslands for fodder production is not allowed

EcoSanRes is an international research and development programme sponsored by Sida (Swedish International Development Cooperation Agency). It involves a broad network of partners with knowledge/expertise in various aspects of ecological sanitation ranging from management and hygiene to technical and reuse issues. The partners represent universities, NGOs and consultants and they are involved in studies, promotion activities and implementation of projects in Asia, Africa and Latin America.

The network hub is Stockholm Environment Institute (SEI) which holds a formal contract with Sida. EcoSanRes has become an authoritative networking body within the field of ecological sanitation and also collaborates with other bilateral and multi-lateral organisations such as WHO, UNICEF, UNDP, UNEP, GTZ, WASTE, IWA, WSP, etc.

The EcoSanRes programme has three main components:

- outreach
- capacity
- implementation

The outreach work includes promotion, networking and dissemination through seminars, conferences, electronic discussion groups and publications.

Capacity building, is achieved through training courses in ecological sanitation and the production of studies and guidelines, with content ranging from eco-toilet design, greywater treatment, architectural aspects, agricultural reuse, health guidelines, planning tools, etc.

Implementation puts theory into practice with ecological sanitation pilot projects in diverse regions around the world. Because the most important factor to successfully implementing an ecosan system is local adaptation, EcoSanRes provides a logical framework for prospective pilot projects and insists the projects meet stringent criteria before approval.

EcoSanRes is running major pilot projects in China, South Africa, Mexico and India with plans for Bolivia. The new EcoSanRes Programme started in 2006 will help develop formal regional nodes in various parts of the developing world in order to further build capacity, general awareness and implement local projects.

For more information about the partner organisations and programme activities please consult

www.ecosanres.org