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Comparing Sanitation Systems Using Sustainability Criteria

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PREFACE

This report presents how criteria-based comparison of sanitation systems can be used to guide decision-makers and planners to take strategic decisions based on sustainability when planning for sanitation. The report uses three examples from three different countries, from a municipal perspective, to illustrate the use of the criteria. Due to the fact that sustainability is a context-specific matter, no sanitation system can be considered universally sustainable; therefore each needs to be assessed in a specific context.The report has benefited from constructive comments from Professor Ralf Otterpohl and Björn Lindner at the Technical University Hamburg Harburg, as well as from Dr Klas Sandström, Akkadia.

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

Stockholm and Tepoztlàn April, 2006

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1 INTRODUCTION

Most recent estimates state that worldwide at least 2.6 billion people lack access to basic sanitation (WHO/JMP, 2004). This global sanitation crisis has been recognised by the international community and the UN has identified a concrete target of halving the number of people without access to basic sanitation by 2015, under target 10 of goal 7 in the Millennium Development Goals (MDGs—see box 1.1).

Box 1.1: The Millennium Development Goals

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Provision of water and sanitation systems and services is a complex issue. The lack thereof inhibits progress towards all the Millennium Development Goals and robs the poorest—particularly women and girls—of their health, time and dignity (UN Millennium Project, 2005). Health, livelihood and vulnerability are three points of connection between poor people and their water environment (UN Millennium Project, 2005), where the first two are closely related to sanitation. With 6,000 deaths per day related to different contamination routes, mostly children under the age of five (UN-HABITAT, 2003), the connection between poor sanitary conditions and poor health is obvious. In fact, the lack of access to safe water, basic sanitation, and good hygiene practices is the third most significant risk factor for poor health in developing countries with high mortality rates (WHO, 2002). The connection between livelihood in a broader sense and sanitation has several different aspects:

- **Environment.** Contamination of common property resources, such as lakes, rivers and coastal areas, directly translates into less food, income and time for the people dependent on the resource (UN Millennium Project, 2005). Different sanitation systems stress the natural resource base differently. Environmental protection, especially with respect to water, is not a luxury but a prerequisite for a well-functioning society.

- **Poverty.** Poor people are more likely to live in areas subject to environmental hazards of all kinds. Poverty also results in lesser quality and quantity of food intake, which in itself is contributing to a poor health status. Ill health related to poor water and sanitation lead to further impoverishment that has severe financial and personal costs (UN Millennium Project, 2005).

- **Dignity and gender equality**. Privacy while defecating is one important element of dignity, as well as not having to fear physical abuse as a possible risk during the visit to the sanitation facility. In many South African townships women and children never leave the house after dark due to the risk of being abused (Holden, 2004), which means that the use of any toilet facility outside the house is impossible at night for women and children. Lack of proper school sanitation might make girls drop out of school prematurely (Snel and Shordt, 2005). Similar issues from several cultures around the world, including strong taboos, highlight the prime importance of adequate sanitation, especially for girls and women.

Figure 1 represents another way to illustrate the complexity of water and sanitation systems. The diagram describes the relationships between different societal subsystems in housing areas in Dar es Salaam, Tanzania, and the society's water and sanitation system.

Due to these complex ways in which water and sanitation are interlinked with other systems in society, access to water and sanitation will not only contribute to the fulfilment of target 10 of goal 7 of the MDGs but, due to strong interlinkages, it will also contribute to the fulfilment of the full set of MDGs (UN Millennium Project, 2005). Monitoring of progress has, however, shown that the world will miss the sanitation target by half a billion people unless a sharp acceleration in the rate of progress is made (WHO/JMP, 2004).

With this pressing need for action to meet the MDG sanitation target, there is a great risk of actors focusing simply on sanitation coverage (i.e. the provision of latrines and toilets), thus overlooking what is needed for the sanitation system and related services to be

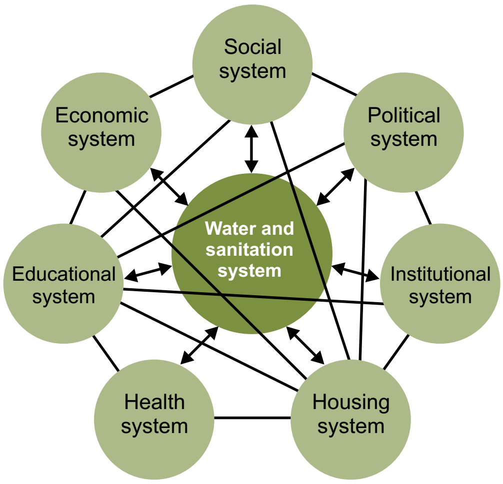

Figure 1.1: System interaction - Water and sanitation in housing areas in Dar es Salaam, Tanzania (Mwaiselage, 2003)

sustainable from a broader perspective. There is therefore a need for an approach, when planning for sanitation systems, which allows an assessment of the sustainability of sanitation systems and services from a broader perspective. One way of achieving this sustainability assessment is to evaluate the ability of different sanitation alternatives to comply with criteria identified as important for the sanitation system and services to be sustainable in the actual context. This criteria approach, coupled with a participatory planning method, could be very useful for sanitation planning on municipal level. However, identification and use of sanitation sustainability criteria could also be useful for decision-making on a macro level, where the criteria approach could inspire decision-makers to look beyond sanitation coverage only and aim for sustainable sanitation systems and services, and thus to a wiser allocation of resources to meet the MDG sanitation target.

This report illustrates how a sustainable sanitation criteria assessment of sanitation systems could be carried out in municipal settings, using a simple, relative comparison to a 0 sanitation alternative. Our hope is that this report could inspire a more impartial and less technology-fixated decision-making process for sanitation interventions on the municipal level.

1.1 WHAT IS SUSTAINABLE SANITATION?

The term 'sustainable sanitation' is sometimes used without identifying what the author or speaker means by the phrase. However, there are several researchers that have been working with conceptualisations of sustainable sanitation and more broadly in sustainable urban water management systems.

Larsen and Gujer (1997) underlined the need to focus on functions that the urban water management system should provide in order to be sustainable. The functions proposed by Larsen and Gujer (1997) are:

- to guarantee urban hygiene;
- to assure drinking water of good quality and in sufficient quantities to allow use for personal hygiene;
- to prevent flooding and allow drainage of urban areas;
- to integrate urban agriculture into urban water management; and
- to provide water for pleasure and for recreational aspects of urban culture.

Van der Vleuten-Balkema (2003) identified sustainable technology as technology that does not threaten the quantity and quality of resources, and has the lowest costs with respect to the physical, socio-cultural and economic environments. Moreover, she underlined that implementing sustainability means seeking solutions that balance the costs with respect to the different resources in such a way that the contribution to local and global problems is minimised, or at least known and accounted for by being sustainable (van der Vleuten-Balkema, 2003). It is, however, important to recognise the importance of sustainability of services provided by the sanitation technology, and not only sustainability of the technology itself. Inadequate focus on sustainability of services (operation and maintenance, clear division of responsibility between household and service provider) may render any sanitation technology, however well-designed and environmentally sustainable, a health hazard.

In this report we consider a sanitation system, and services provided by the system, as sustainable if they protect and promote human health, do not contribute to environmental degradation or depletion of the resource base, and are technically and institutionally appropriate, economically viable and socially acceptable.

1.2 ASSESSING SUSTAINABILITY OF SANITATION SYSTEMS

Sustainability assessment of sanitation systems is no easy task. Factors influencing sustainability vary between communities, influence and interact with each other and change over time, which renders measurements of sustainability a complex issue (Mukherjee, 1999).

Even so, attempts have been made to assess the sustainability of wastewater structures. One methodology used is system analysis, using a multidisciplinary set of sustainability criteria (Balkema *et al.*, 2002). This approach has been used extensively among researchers in order to compare different wastewater systems from different perspectives.

The Swedish research team Urban Water has generated computer models to represent situations such as the environmental impact of urban wastewater systems through material flow analysis (Balmér *et al.*, 2002; Hellström *et al.*, 2000). Urban Water has also developed models for microbiological risk assessment (Ashbolt *et al.*, 2005), chemical risk assessment (Malmqvist and Palmquist, 2005), and economic assessments (Hjerpe, 2005). The tools have been tested in different Swedish settings and are considered appropriate for countries with a similar infrastructure to that of Sweden (Malmqvist *et al.*, 2006). Van der Vleuten-Balkema (2003) presented a decision support tool for the selection of sustainable domestic water systems through a computer model that included life cycle assessment, cost–benefit analysis and social inventories. A multi-criterion approach for decision-making in water management is proposed by Acreman (2003), taking into account not only economic but also social and ethical values.

System analysis approaches have also been used for assessment of sanitation systems in developing countries. A method to estimate nitrogen flows for different sanitation systems in a Vietnamese context, through a material flow analysis, has been proposed by Montangero *et al.,* (2004). Loetscher and Keller (1999) have developed a computer tool for the estimation of financial costs of sanitation systems in developing countries.

1.3 SUSTAINABILITY CRITERIA

The sustainability of sanitation systems is, as already mentioned, a complex matter to assess due to its dependency on the actual context. Criteria for sustainability need to be developed in close cooperation with all relevant stakeholders and take into consideration institutional matters, such as the existing legal framework and institutional capacity, preferences among future users, environmental conditions in the actual area and so on. What may be judged as sustainable in one context might not be the same for another setting. Thus, it is impossible to identify a complete list of factors that will affect the sustainability of a sanitation system without knowing the specific context.

Attempts have been made to propose categories important to consider when assessing sustainability of sanitation systems. Balkema *et al.* (2002) made an overview concerning the use of criteria in the assessment of water and sanitation systems and proposed that the criteria be divided into four different groups: economic, environmental, technical and socio-cultural. Mukherjee (1999) identified five categories of factors in order to measure the sustainability of rural water supply and sanitation in the Indonesian context: social, organisational, technical, environmental and financial. Zinn (2000) proposed and evaluated sustainable development indicators for urban water systems for King William's Town (Buffalo City Municipality) in South Africa. Kvarnström *et al*. (2004a) proposed five categories for the sustainability assessment; health, environment, economy, technical and socio-cultural. All of these authors have expanded on the triple-bottom line identification of sustainability of environmental, economic and social sustainability with one or more additional categories.

Kvarnström *et al.* (2004a) presented an extensive range of criteria that could be considered for a sanitation system sustainability assessment. The list would need to be expanded or reduced for each specific case, and should be seen as an inspiration to start assessing sanitation systems from a wider perspective than costs only, to help narrow down discussions, and to make the decision-making process more transparent. This list is presented in Appendix 1. Moreover, a process of giving weight to each criterion is also necessary, in order to identify the most important criteria to consider in each situation.

1.4 THE CONNECTION OF SUSTAINABILITY CRITERIA TO A PLANNING METHOD

Criteria for sustainable sanitation systems alone will not suffice to allow planning and implementation of sustainable sanitation systems and services. The use of sustainability criteria, without a process-oriented approach, will be a tool of only academic use. Starkl and Brunner (2004) underline the trade-off between sustainability and feasibility when theory meets practice in urban water management and emphasise the need to change the decision-making process to be more transparent.

A combination of a product- and process-oriented approach has been shown to benefit more sustainable decisions within urban water management (Söderberg and Kärrman, 2003). In this case criteria are used to keep many sustainability aspects in mind (the product orientation) and negotiation among stakeholders is used for the weighting of criteria (the process orientation). Using process-guided multi-criterion analysis in decision-making provides a structured way of articulating strategies and preferences and a transparent way of showing the success and the robustness of the strategies (Refsgaard, 2005).

The use of sustainability-oriented criteria will also need to be connected to a planning method relevant for the size of intervention. For municipal sanitation planning the Household-Centred Environmental Sanitation planning guidelines could be a useful planning tool to use, which allows an integrated approach in the planning of water, sanitation, storm water and solid waste management (SANDEC/WSSCC, 2004).

2 OBJECTIVE OF THE STUDY

The objective of this study is to illustrate how the sustainability of sanitation systems, in three different contexts, can be assessed using an integrated comparative approach. The perspective used for all examples is that of the municipality. The comparative approach outlined in this report could further be used as one integrated part in decision-making for future sanitation investments in the municipal setting.

3 METHOD

3.1 USE OF ILLUSTRATIVE EXAMPLES

Since sustainability only can be assessed when the context is known we have chosen to work with one illustrative example each from three different countries; Sweden, South Africa, and Mexico. The examples were chosen to illustrate different sanitation planning situations. The illustrative examples used are, however, not real case studies, since neither of the comparisons has actually been executed the way suggested here. The aim is to show how a criteria-based comparison of sustainability of sanitation systems using a 0 alternative could look in three different settings:

- planning for upgrading of on-site sanitation outside municipal wastewater treatment jurisdiction, induced by increased pressure on existing on-site sanitation systems (Swedish case);
- planning for sanitation in new low-cost housing areas (South African case);
- strategic decision-making concerning connection to and the dimensioning of future municipal wastewater treatment plant (Mexican case).

3.2 CRITERIA USED

The list of criteria used within this report is presented in Table 3.1. When these kinds of comparison are to be made in actual situations, the sustainability assessment criteria should be identified through a participatory approach with all relevant stakeholders, and properly weighted as described above. The criteria in Table 3.1 have not been developed through that model but are an excerpt of the criteria presented in Appendix 1. Thus, the same criteria are used in all illustrative examples. The main reason behind this is that context-relevant criteria have not been identified and weighed through participative approaches for all three examples used. For the Swedish illustrative example this process had been carried through using the MIKA tool referred to in section 4.1, and is reported in Lundberg and Wijkmark (2005). However, for illustrative purposes we chose to expand those criteria somewhat for the context of this report. The use of the same criteria for all examples will facilitate the illustration that somewhat similar sanitation systems might perform differently depending on context, and also highlight that different criteria might be weighed differently depending on the context.

The sanitation systems alternatives are scored in comparison to the 0 alternative with either ++, +, 0, –, ––. The + sign always indicates higher performance compared to the 0 alternative and the – sign always indicates lower performance compared to the 0 alternative.

Criteria that are difficult to analyse in matrix form, such as legal issues and institutional aspects, were discussed in the text for each illustrative example.

3.3 RELATIVE COMPARISON OF DIFFERENT SYSTEMS TO A 0 ALTERNATIVE

The functional unit for the comparison is the total wastewater fractions generated by one person during one year. The wastewater fraction flows vary for each country and setting.

The 0 alternative, to which the other systems are compared in a relative manner, is a connection to a wastewater treatment plant and subsequent treatment. In the countries of investigation this choice is made since the waterborne flush and discharge is usually preferred. The 0 alternative was assessed according to the list of criteria (either qualitatively or quantitatively depending

Table 3.1: Criteria matrix

(a + sign always indicates higher performance compared to the 0 alternative)

Criteria Each rated as ++, +, 0, – or –– compared to the 0 alternative	**0 alternative: Connection to waste-water treatment plant**	**Sanitation system 1**	**Sanitation system 2**	**Sanitation system 3**	**Sanitation system 4**
Health					
Risk of infection: household	Qualitative				
Risk of infection: immediate environment	Qualitative				
Risk of infection: downstream	Qualitative				
Environment					
Discharge: BOD, mg/L	Quantitative				
Discharge : N,P, mg/L	Quantitative				
Potential for reuse of water	Quantitative				
Potential for reuse of nutrients	Qualitative				
Water use	Qualitative				
Quality of recycled product	Qualitative				
Economy					
Investment costs (individual & societal)	Quantitative				
O&M costs (individual & societal)	Quantitative				
Socio-cultural					
Convenience	Qualitative				
Safety	Qualitative				
Appropriateness to local context	Qualitative				
Technical function					
System robustness	Qualitative				
Odour	Qualitative				
Complexity of construction and O&M (individual & societal)	Qualitative				

on criteria). A choice of at least three different country-relevant sanitation alternatives was identified for each country. The different alternatives were compared, in a relative manner, to the 0 alternative. The relative comparison was based on real data from the country when available and otherwise was based on qualified estimates from local consultants.

All wastewater fractions generated at the household level were included in the comparison: blackwater (or urine and faeces), greywater, or combined wastewater. Treatment and management of all wastewater fractions were included in the comparison. Solid waste, storm water, and industrial wastewater were not considered for this comparison. For responsibility issues the boundary of the system, from a household perspective, is the plot.

METHOD ADAPTATIONS FOR REAL CASES

The assessment of sanitation systems based on criteria alone, as presented in this report, does not suffice for the planning and implementation of sustainable sanitation systems and services. The use of sanitation sustainability criteria is one important component of the planning and implementation of sanitation systems. It is of utmost importance that the use of sustainability criteria is connected to an integrated planning tool, taking into consideration all relevant sanitation flows (water, wastewater, storm water, solid waste, industrial wastewater) and responsibility issues across all the different domains of a city, to avoid sub-optimisation. Moreover, what is sustainable in the actual context needs to be agreed upon, taking into consideration the context (need for comprehensive site assessment) and the views of all relevant stakeholders, including everything from legal to household aspects. The criteria identified as important to fulfil sustainability will also need to be weighted through negotiations with the stakeholder group.

4 COMPARISON OF SANITATION SYSTEMS IN THREE DIFFERENT COUNTRIES

In this chapter three different illustrative examples of the use of criteria in sanitation planning (as described in chapter 3) are explained. The first case, from Sweden, illustrates how criteria could be used for the upgrading of on-site sanitation outside municipal wastewater treatment jurisdiction. The second, from South Africa, illustrates how the use of criteria could guide decisions on sanitation alternatives in low-cost housing projects. The third example is from Mexico and highlights how the use of criteria could support strategic decision-making processes around whether to connect or not to connect to a future wastewater treatment plant.

4.1 SANDVIKEN, SWEDEN

Background

In Sweden the municipalities are legally responsible for carrying out various services including sanitation and waste disposal. They also a have monopoly on spatial planning within the municipality. The municipalities are self-governed and an example of where decentralisation of responsibilities, down to local level, functions relatively well. Hence, the decentralisation of responsibilities has been connected to an equal decentralisation of powers, financial means and competence. The technical division of the municipality is responsible for water supply and wastewater treatment within the municipal water and wastewater jurisdiction as well as collection, treatment and disposal of solid waste. The environmental division of the municipality is a decentralised authority responsible for issuing permits for on-site sanitation outside the municipal water and wastewater jurisdiction, as well as follow-up of these systems.

The Swedish illustrative example shows a typical sanitation planning situation for the Swedish context: the fast development of a summerhouse area with old, under-dimensioned and under-performing on-site sanitation systems into a permanent residential area with higher water use and higher demands on treatment performance of sanitation systems. This illustrative example is based on the work performed by Lundberg and Wijkmark (2005), in cooperation with researchers from Chalmers University of Technology and the research program Urban Water (Henriette Söderberg and Jaan-Henrik Kain) where the knowledge integration tool MIKA was used (Söderberg and Kärrman, 2003). The work has been somewhat adapted in order to fit the presentation format of this report.

The illustrative example used is Sandviken, situated by Lake Mälaren roughly 50 km from Stockholm. Sandviken comprises about 200 households (approximately 500 persons) out of which just about 100 are permanently inhabited and the remaining 100 are summer houses with a high degree of utilisation. The area is interesting from a development perspective due to its natural beauty and proximity to Stockholm and other cities.

The area is similar to many other residential areas in the region. There are about 200 identified residential areas within the Stockholm region with a high settlement rate and increasing sanitation problems (Stockholm County Administrative Board, 1995). Most sanitation systems in these areas are old and too simple for year-round use. This leads to increased release of inadequately treated wastewater into recipients.

The current and expected increase in pressure on the infrastructure in Sandviken has induced preliminary investigations into possibilities to extend the municipal water and sanitation services to Sandviken, thus adding it to the municipal water and wastewater jurisdiction. These preliminary investigations showed that extension of municipal water and sanitation services to the area would be too costly for the municipality, and ultimately the house-owners, due to the guiding principle of full cost recovery within the municipal water and wastewater jurisdiction. This was one factor contributing to the investigation of different water and sanitation alternatives and was used to guide the decision-making process in the municipality.

Environmental description

Geology

The area consists of several long valleys perpendicular to the waterfront. Almost all housing in the area is located either in these valleys or at the waterfront. The soil in the valley consists of sand, gravel, moraine and, in some cases, clay. The upland areas are covered with thin layers of washed moraine containing rocks and boulders, or do not have a soil cover at all.

The beachfront is narrow and characterised by steep slopes going down to the lake.

Natural and cultural environment

The varying geological conditions contribute to a variety of flora, from pine forest on the uplands to agricultural land or spruce-dominated mixed forests in the soil-rich valleys. The forests are used for local outdoor recreation.

Sandviken is located in a typical countryside area where the houses are located at the forest fringe or around the agricultural land. The roads in the area are gravel and of low standard.

Sandviken belongs to the Lake Mälaren catchment area. The infiltration capacity varies throughout the area due to its varying soil conditions.

Current water and sanitation facilities

The inhabitants in Sandviken are supplied with water mainly through groundwater extraction from drilled or dug wells. The water quantity provided through the wells is considered sufficient. However, little is known of the water quality. A few households extract water from Lake Mälaren for consumption, something considered completely inappropriate by the local authorities from a health perspective. Almost all houses have in-house water taps, providing in-house water during at least the summer season.

All households use varying types of on-site sanitation systems. The most common system is a holding tank which is emptied by a municipal contractor. The house owner pays a fee for this service to cover the municipality's costs for the contractor. The sanitation waste is transported and released into the municipal system which leads to Himmerfjärden WWTP. Other systems include composting toilets (the most frequent solution in the summerhouse-dominated parts of Sandviken) with infiltration for greywater treatment, and infiltration of mixed wastewater.

The under-dimensioned, old and heavily loaded on-site systems raise questions about the eventual risk for health and environment. So far there has been no report of contamination of wells or in Lake Mälaren. According to the municipal health and environmental authority, it is just a matter of time before these problems occur.

Comparison: sanitation systems for Sandviken

The functional unit for the comparison is the treatment and management of wastewater fractions generated from one person during one year. For the Swedish context the composition of the wastewater fractions is shown in Box 4.1.

Box 4.1: Content of wastewater fractions per person and year

- Weight: 40,590 – 58,590 kg (550 kg urine, 40 kg faeces, 40,000 kg greywater, 0 to 18,000 kg flush water, depending on toilet system).
- N: 5,010 g/yr/person (4,000 g in urine, 550 g in faeces, 460 g in greywater).
- P: 658 g/yr/person (365 g in urine, 183 g in faeces, 110 g in greywater).
- BOD_7: 17,520 g/yr/person (7,300 in black-water and 10,220 in greywater).

(NV, 1995; Jönsson and Vinnerås, 2004, Balmér et al 2002)

0 alternative: Himmerfjärden wastewater treatment plant

The Himmerfjärden wastewater treatment plant (WWTP) is located by the Baltic Sea 50 km south of Stockholm. The nearest point for connection to the municipal main sewer system is about 4 km from Sandviken. The WWTP receives wastewater, complete or partial flows, from six different municipalities located within the southern greater Stockholm area. Approximately 250,000 household users are connected to the plant and an additional 35,000 industry-related person equivalents (p. e.) are connected to the plant. The average flow is 110,000 m^3/day. The WWTP is designed to reduce the effluent wastewater content of organic matter, nitrogen and phosphorus. The unit processes applied are:

- pre-precipitation of P with iron phosphate;
- active sludge process with nitrification;
- post-denitrification with ethanol and methanol additions;
- sand filtration.

The sludge treatment consists of:

- thickening;
- thermophilic anaerobic digestion;
- dewatering by centrifugation;
- drying.

The treatment results for the Himmerfjärden WWTP, compared to issued permits, are shown in Table 4.1 .

Table 4.1: Himmerfjärden WWTP average yearly performance values, compared to issued permits

Parameter	Average yearly effluent values	Issued permits allowing average yearly effluent value
Incoming wastewater	101 000 m^3/d	130 000 m^3/d
BOD_7	6.7 mg/L	15 mg/L
Total P	0.31 mg/L	0.5 mg/L
Total N	4.1 mg/L	15 mg/L
COD_{Cr}	36 mg/L	70 mg/L
NO_x	0.017 g NO_x/MJ	0.1 g NO_x/MJ
Dust	0.0015 g/Nm^3 gas	0.05 g/Nm^3 gas

(Anonymous, 2004)

The treated wastewater is discharged into the Baltic Sea, through two 1600-metre wooded pipes (Ø1600). The treated wastewater is released through 20 sprinkler nozzles. During summertime the thermocline will prohibit transport of effluent to the surface. During all other seasons, the effluent will, due to temperature difference between effluent and the ambient sea water, be conveyed to the surface.

The dewatered sludge (DM content of 85–95 per cent after drying) is for the most part used for construction purposes.

The biogas produced is mostly used to cover energy demands within the treatment plant.

The demand for a connection from Sandviken to Himmerfjärden WWTP is met through piping to the closest Himmerfjärden sewer, which is 4 km from Sandviken, and also a local sewer network within Sandviken.

Treatment of mixed wastewater in semi-collective filter beds

Mixed wastewater is conveyed to a septic tank and further transported to a filter bed constructed according to a Norwegian concept, with both vertical and horizontal flow (see figure 4.1). The wastewater is evenly spread by spray nozzles over the vertical filter surface in an unsaturated flow, where organic matter and micro organisms are reduced biologically. Conversion of ammonium to nitrate through nitrification also occurs throughout the unsaturated flow. The wastewater continues through a saturated horizontal flow where phosphorous is sorbed onto the filter substrate and denitrification of nitrate into N_2 occurs. The filter substrate is a P-sorbing light-weight clay aggregate 'leca', which will need replacement whenever the P-sorbing capacity of the filter substrate has been exhausted. The replacement rate can be on the order of decades.

The treated wastewater is either infiltrated into the soil or conveyed to an appropriate surface water recipient. The used filter substrate could possibly be used on agricultural land. This reuse of filter substrate will require the identification of responsible actors for collection, transport, storage and spreading on arable land. Sludge from the septic tank is pumped out at an interval dependent on the size of the sludge tank and transported by tank truck to the municipal WWTP. An uncommon but possible local solution is local treatment of sludge by dehydration and composting for use as a soil improver.

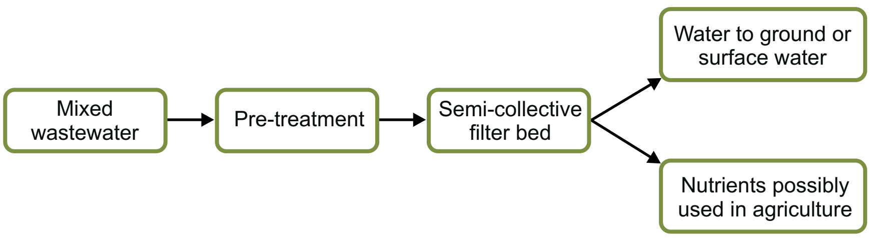

Figure 4.1: Treatment of mixed wastewater in semi-collective filter bed

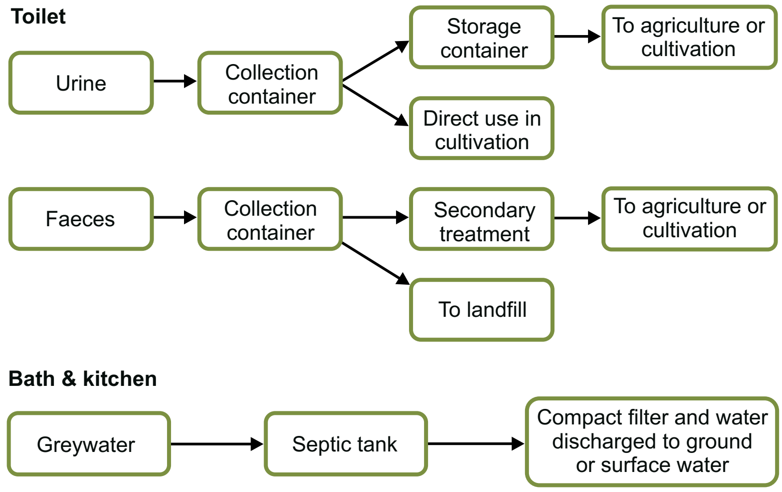

Figure 4.2: Dry urine-diversion with greywater treatment in compact filter

This system is mainly appropriate for groups of households and is considered to be too expensive for single households.

Dry urine-diversion with greywater treatment in compact filters

The system is based on urine-diversion (UD) with dry collection of faeces (see figure 4.2). The urine is collected in a watertight tank and the faeces fraction is collected in barrels. The greywater is gravity-fed to a septic tank and further on to a compact filter bed. The compact filter consists of a bearer material, such as perforated plastics wrapped in folded geotextile fabric, thus creating a large specific area for microbial biofilm growth. The compact filter could either be enclosed in a tray with one outlet or open with direct contact to the underlying soil. Thus, treated greywater is either infiltrated directly into the ground or conveyed to an open ditch and/or a surface water recipient. The urine is either transported to a farmer and sanitised for at least six months before used as fertiliser or can be used as a fertiliser in the garden, if the plots have enough space. A plot of about 150–200 m^2/person is needed to make reasonable use of the nutrients in the urine, if an average need of 150 kg N/ha is assumed, estimating that the concentrated urine contains 5 g N/L and that 550 L of urine is produced per person per year (Vinnerås, 2002). The faeces are preferably composted locally in a faecal compost and also used locally as soil conditioner.

Double-flush UD with treatment of greywater and faeces fraction in a filter bed—single home solution

The system is based on diversion of urine, where the urine is collected in a watertight tank located within the premises of the household (see figure 4.3). The collected urine is either transported to a farmer and sanitised for at least six months before use as fertiliser or used as a nitrogen fertiliser in the garden, if the plots have enough space. Even here about 150–200 m^2/person is needed to make reasonable use of the nutrients in the urine, if an average need of 150 kg N/ha is assumed, estimating that the concentrated urine contain 5 g N/L and that 550 L of urine is produced per person per year (Vinnerås, 2002).

The remaining wastewater, containing the faeces and its associated flush water along with the greywater is

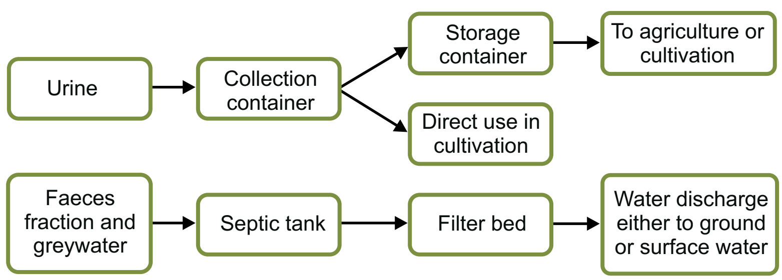

Figure 4.3: Double-flush urine diversion with treatment of greywater and faeces fraction in a filter bed

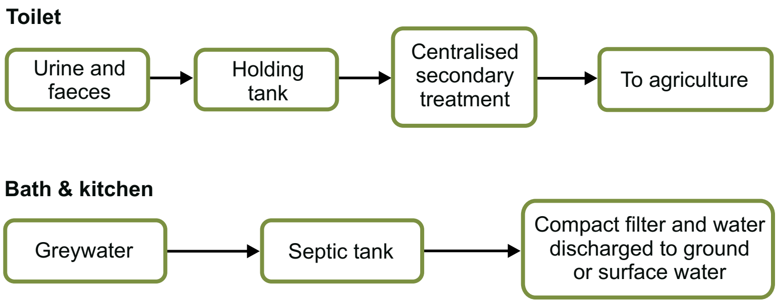

Figure 4.4: Blackwater collection with centralised sanitisation and treatment of greywater in compact filter

conveyed to a septic tank and further to a filter bed, constructed according to the description in the preceding section on 'treatment of mixed wastewater in semi-collective filter beds'.

The treated wastewater is either infiltrated into the soil or conveyed to an appropriate surface water recipient. Treatment and use of used filter substrate can also be done as described earlier.

Blackwater collection with centralised sanitisation and treatment of greywater in a compact filter

This system is based on the separate collection of the blackwater, which includes the flush water (see figure 4.4). For collection, storage and treatment reasons, it is important that the WCs used are extremely low in their water consumption (about 1 L per flush). The blackwater is gravity-fed to a watertight tank that is emptied about once a year. The greywater is also gravity-fed to a septic tank followed by a compact filter. The compact filter consists of a bearer material, such as perforated plastic wrapped in folded geotextile fabric and thus creating a large specific area for microbial biofilm growth. The compact filter could either be enclosed in a tray with an outlet or open with direct contact to the underlying soil. The treated greywater is either infiltrated directly into the ground or conveyed to an open ditch and/or a surface water recipient. The blackwater is handled by a contractor for centralised sanitisation, either by a wet composting process or through anaerobic digestion. Organic household waste may be part of the sanitisation process in order to increase the dry matter content. This sanitisation is a precondition for recycling the nutrients contained in the blackwater.

Comparison matrix

See table 4.2 for the comparison matrix. The 0 alternative contains either quantitative or qualitative estimates of compliance to identified criteria, whereas the alternatives are assessed relative to the 0 alternative. These are all filled in by either ++, +, 0, –, ––, compared to the 0 alternative. A + signifies higher performance and a – signifies lower performance compared to the 0 alternative.

Health

The 'dry urine-diversion with greywater treatment in a compact filter' system has a slightly higher risk of infection on a household level compared to the 0 alternative, which is due to local handling of the faecal matter (removal from toilet to latrine compost). Since the faecal matter is kept out of the wastewater, the risk for health is lower in the immediate environment and seen as non-existent downstream. To minimise risks with the dry system proper guidelines regarding handling, sanitisation and use need to be followed. The blackwater system also has lower health risks downstream compared to the 0 alternative for the same reason. All other systems are seen as equal to the 0 alternative regarding health aspects.

Environment

'Filter bed for mixed wastewater' is equivalent to the 0 alternative concerning the reduction of BOD_7 and P. However, the filter bed may reduce about 50 per cent of N which is lower than for the 0 alternative. Reduction rate of BOD_7 from dry urine-diversion with greywater treatment in compact filter is estimated as higher than 90 per cent, since 60 per cent is removed by diverting urine and faeces from the greywater (NV, 1995) and another 80–90 per cent reduction of the remaining BOD can be expected in the compact filter. More than 90 per cent of the N is found in the urine and faeces; therefore the N reduction is higher for the dry urine-diversion alternative compared to the 0 alternative. About 10–20 per cent of the remaining N in the effluent greywater

Table 4.2: Comparison matrix for the Swedish setting

Criteria Each rated as ++, +, 0, – or –– compared to the 0 alternative	**0 alternative: Connection to Himmer-fjärden wastewater treatment plant**	**Filter bed for mixed wastewater: Semi-collective**	**Dry urine-diversion with greywater treatment in compact filter**	**Double-flush urine diversion with treatment of faeces and greywater in filter bed: Single home**	**Blackwater collection with centralized sanitization and treatment of greywater in a compact filter**
Health					
Risk of infection: household	Low	0	–	0	0
Risk of infection: immediate environment	Low	0	++	0	0
Risk of infection: downstream	Low to Medium	0	++	0	+
Environment					
Discharge: BOD, mg/L	6.7	0	+	0	+
Discharge : N,P, mg/L	4.1; 0.31	0	+ (N), - (P)	+	+ (N),– (P)
Potential for reuse of water	Low[1]	+	++	+	+
Potential for reuse of nutrients	Low[2]	0	++	+	+
Water use	High	0	++	+	+
Quality of recycled product	Medium to low	+	++	+	+
Economy					
Investment costs Individual (I) and Societal (S)	$26,000/0	0 (I) 0 (S)	++ (I) 0 (S)	–(+) (I) 0 (S)	++(0) (I) –(0) (S)
O&M costs Individual (I) and Societal (S)	$550 per year/0	++ (I) 0 (S)	+ (I) 0 (S)	+ (I) 0 (S)	+(0) (I) –(0) (S)
Socio-cultural					
Convenience	High	0	––	–	0
Safety	High	0	0	0	0
Appropriateness to local context	High	+	–	0	0
Technical function					
System robustness	Medium	+	++	+	0
Odour	Low	0	0	0	0
Complexity of construction and O&M Individual (I) and Societal (S)	Low (I) High (S)	– (I) 0 (S)	– (I) – (S)	– (I) – (S)	0(–) (I) – (S)

(1) The water used within the area is mainly groundwater. This will be conveyed to Himmerfjärden WWTP, which is located south-east of Sandviken and discharged into the Baltic Sea.

(2) Currently the sludge from Himmerfjärden wastewater treatment plant is used for construction purposes. In general 12% of the sludge is reused in agriculture today. Therefore, we consider the potential for use of sludge from Himmerfjärden to be low.

can be expected to be reduced through the septic tank and compact filter.

Urine and faeces contain about 80 per cent of total P in wastewater, depending on the choice of detergents in the household. If P-free detergents are used within the household, the reduction of P for the dry urine-diversion system is expected to be at least 90 per cent. The blackwater collection system is equal to the dry system in every aspect concerning the P reduction. All on-site systems return treated wastewater and greywater locally, either to the groundwater or to nearby surface waters. They all rank higher in that respect compared to the 0 alternative, since conveyance there would mean discharge of water into the Baltic Sea which cannot be seen as local reuse of water. The dry system uses extremely little water (approximately 0.2 L/flush of the urine bowl). The blackwater concept needs about 1L of water per flush. A double flush toilet uses less water than an ordinary water closet, making this system slightly better than the 0 alternative in this respect.

Average heavy metal content in sludge from Himmerfjärden wastewater treatment plant complies with existing regulations concerning reuse of sludge in agriculture (SNFS, 1998:4). However, sludge in general has low acceptance among farmers, and presently the Farmers' Association recommends that their members not use sludge on agricultural land due to the fear of negative consumer reactions. At present, the acceptance of sludge reuse is also low from the food industry for the same reason. In fact only about 12 per cent of the sludge from WWTP in Sweden is distributed to farmland (Statistics Sweden, 2004). The *Leca* filter substrate has potential as a P source, complementing other fertilisers (Kvarnström *et al.* 2004b), but more information is needed before general recommendations can be made concerning agricultural use of filter substrates. Human urine is an efficient nitrogen fertiliser with very low heavy metal content. There is an interest for using urine as a fertiliser in Sweden, as long as no additional costs are associated with the use from the farmer's perspective. Faecal matter may, after composting, be used locally in gardens as a soil improver. The environmental quality of the faecal matter is higher than that of sludge due to its dependency on the quality of food intake. The blackwater collecting system is mixing both urine and faecal matter and has a high content of both N and P. The blackwater may be of interest for farmers after sanitisation through anaerobic digestion or wet composting, preferably together with organic household waste.

Economy

Sweden actively uses the principle of cost recovery for water and wastewater supply and treatment within the municipal water and wastewater jurisdiction. 'Filter bed for mixed wastewater' is, for an individual household, a high cost alternative exceeding the 0 alternative. However, for the Sandviken case the investment cost was calculated for 20 households, which yields investment costs comparative to those for the 0 alternative. The investment cost for the filter bed per household is reduced for every household connected to the filter bed. A substantial part of the investment is the extension of the sewage pipes, which is largely affected by the distance between the semi-collective filter bed and the houses. The operation and maintenance costs in the semi-collective system are estimated to be lower than for the 0 alternative.

The dry urine-diversion system is a low budget alternative both regarding investment and operation, including the purchase and installation of the urine tank, toilet and the faecal composting unit, but also in regard to convenience and status. However, the investment cost is not as low as one might expect due to the need for double piping (urine and greywater) and excavation needed for the compact filter and the urine holding tank. There is also an operational cost for transportation of urine and faeces, if not used locally. However, this system gives the house owner the greatest possibility to reduce the investment cost, compared to all the other alternatives. The 0 alternative provides very few opportunities for the house owner to reduce their own costs.

The double flush urine-diversion system has a rather high investment cost. Compared to the dry urine-diversion system, this system requires a larger and more advanced filter bed for treatment of faeces and greywater. As described earlier, a filter bed for a single household is a high cost alternative compared to the 0 alternative. On top of this there is a cost for double piping, toilet, holding tank and so forth. If the house owner has an existing sand filter bed or soil filter they may convert to urine diversion at a low cost, if this is approved by the authorities. Operation and maintenance costs may be a little lower than for the 0 alternative but are still a little higher than for the dry urine-diversion system. The blackwater system consists of a holding tank, piping and an extremely low flush toilet and is therefore a low investment alternative, but with slightly higher maintenance costs compared to the other on-site alternatives due to a higher emptying frequency. If any semi-collective facilities such as wet composting or anaerobic digestion are included, the collective cost will be increased compared to the 0 alternative.

Socio-cultural aspects

The 0 alternative represents high convenience, safety, accessibility and appropriateness to the local context for the households. The semi-collective filter bed also represents high convenience, safety and accessibility. The semi-collective filter bed system ranks higher than the 0 alternative according to appropriateness, since a local system is more easily adapted to the local context. The dry urine-diversion system ranks lower in the Swedish social-cultural context since flushing toilets are considered normal standard. Above this, the handling of barrels or sacks of faeces may not be seen as appropriate by some individuals. The double-flush urine-diversion system also ranks somewhat lower on convenience, as the toilet may need more frequent maintenance and cleaning. The blackwater system is equal to the 0 alternative in all aspects. The safety aspect is high for all systems since all toilets are located indoors.

Technical function

From the household perspective the 0 alternative has a high robustness and a low complexity. However, from a societal perspective the 0 alternative has a medium robustness and high complexity in comparison to the local alternatives. The dry urine-diversion system can be seen as very robust in its simplicity but more complex to operate and manage from the household perspective. The dry urine-diverting toilet smells less than a flushing toilet due to the fan which evacuates all odours through the toilet, as long as the ventilation is in operation. The local systems need more management from the household perspective. From the municipality perspective, the local diverting systems need a new commitment from the municipality in the form of new systems for collecting, transporting and possibly treating the sorted wastewater fractions and could therefore be seen as more operationally intensive compared to the 0 alternative (for which the operation and maintenance is well established and known). However, it is most probable that it is easier to find cultivation and agricultural outlets for the sorted wastewater fractions compared to the sludge, which also should be taken into consideration in a favourable way for the wastewater fraction sorting systems.

Discussion: Swedish case study

It is obvious that the on-site treatment systems can offer N, P and organic matter reductions results well in line with, or even higher than, what can be achieved with conventional tertiary wastewater treatment plants. This has been shown in a project where the performance of 15 different types of on-site wastewater treatment units was examined over three years (Hellström *et al.*, 2003). The on-site systems chosen in this study are generally less costly for the household compared to the cost for connection to the wastewater treatment plant, which is a strong incentive towards decentralisation of sanitation systems.

The Swedish Environmental Code has boosted the issue of nutrient recycling, since both recycling and efficient use of natural resources are integral objectives of the Code. Moreover, diverted urine can legally be interpreted to be a source-diverted waste fraction rather than a 'conventional' wastewater fraction, and therefore the responsibility of the municipal waste departments to handle. It is therefore reasonable to believe that urine is increasingly seen as a natural part of the municipality's source-diverted waste collection systems. Already today there are some municipalities that take this task seriously and offer different levels of system for collection and use of urine, and also take actions to inspire the citizens to install urine-diverting systems both within and outside the municipal water and wastewater jurisdiction.

As noted above, it is likely to be easier for the municipalities to find agricultural and cultivation outlets for the source-diverting systems compared to the 0 alternative producing sludge. This is an important question to consider on municipal level due to the existing ban on land filling of organic waste and since the demand for sludge from the farmers is very low in the Swedish setting.

The less conventional systems, such as the dry urine-diversion system and the double flush urine-diversion system, rank lower than the 0 alternative on the socio-cultural criteria. This is expected since conventional systems are known and recognised both by the general public and institutions. Formal institutional recognition of conventional sanitation systems occurs through legislation and regulation. Informal institutional recognition of conventional sanitation systems occurs through attitudes and norms concerning sanitation systems. Both formal and informal institutional recognition can be achieved for new sanitation systems through legal and regulatory reform, generation of knowledge around new sanitation systems, and information, education and communication.

A parallel can be drawn with the introduction of source diversion of solid waste fractions in Sweden. Since 1994 there has been producer responsibility to organise collection of a number of waste types such as packaging material (SFS 1994:1235), waste paper (SFS 1994:1205), and tyres (SFS 1994:1236). The household's responsibility is to transport these waste fractions to recycling stations or other outlets. The recycling of paper and cardboard has increased from 10 per cent in 1994 to 41 per cent in 2001 (Hage, 2005). The same figure for glass was 56 per cent in 1994 and 84 per cent in 2001 (Hage, 2005). This increase in recycling of solid waste has not been for free but has entailed commitment from both formal and informal institutions. However, it also shows that something similar could be achievable for source-diverted wastewater fractions, provided that there is institutional support.

4.2 BUFFALO CITY, SOUTH AFRICA

Background

The South African case study is from Buffalo City Municipality, a coastal municipality with both urban and rural areas located on the south coast. Buffalo City Municipality was created through a merger of the former East London and King William's Town municipalities and the integration of rural areas that fell under the Amatole District Municipality. It consists of three urban centres—East London, Mdantsane and King William's Town—and surrounding rural settlements.

The case study illustrates a municipal sanitation situation in South Africa where increased sanitation coverage has been one of the important targets for service delivery over the past ten years. Yet the municipality has not been able to deliver at the rate originally intended for the national targets (Anonymous, 2003). There is a lot of pressure on the municipality to eradicate the sanitation backlog by 2010.

The Strategic Framework is somewhat conflicting in its formulation around technology versus function for sanitation systems and services. Definition-wise, the Strategic Framework is function-oriented, which implies an opening up towards a wide range of alternative sanitation systems and services. On the other hand the Strategic Framework has a section prescribing preferred technology options for urban, rural and intermediate zones. The Strategic Framework indicates that waterborne sanitation should be the target for urban areas. It thus implies that it is always possible to provide waterborne sewerage within the urban zone. In fact, this puts an enormous pressure on local authorities to provide these services both in regards to human and financial resources, especially in a municipality such as Buffalo City Municipality, which only has a low to intermediate revenue collection base.

The sanitation situation in Buffalo City Municipality still is being investigated; therefore little documentation is available, and the information used in this study is to a large extent based on personal information from various departments in the municipality. Figures mentioned in the Integrated Development Plan indicate that approximately 39 per cent of the population do not have access to proper sanitation (formal and informal settlements) (Buffalo City Municipality, 2002) and housing delivery programs have identified the need for services for some 70,000 new houses (Buffalo City Municipality, 2003).

The environmental impacts of the sanitation situation have been covered in recent work being carried out under the Integrated Environment Management Plan (Carter, 2005). This report indicates that the sanitation situation is one of the core environmental and health problems in the municipality, not only due to the backlog but also due to under-performing, under-dimensioned and inappropriately maintained systems. The water reservoirs show signs of eutrophication, the treatment facilities are overloaded, the bulk infrastructure is outdated and untreated sewage is discharged into water bodies. Outbreaks of Hepatitis A, cholera and other sanitation-related diseases have brought sanitation higher up the political agenda. A recent report to the Mayor from the Engineering Directorate estimates that about ZAR 518 million (USD 86 million) is needed to get the existing centralised system up to standard. This does not include the extension of services to eradicate the backlog (The Daily Dispatch, 27th January 2005).

The sustainability of the sanitation systems has therefore become an issue for discussion, not only in terms of the environmental and health aspects but also the financial implications of extending services to all. As previously mentioned, the Strategic Framework indicates that waterborne sanitation should be the target for urban areas. However, even if the initial investments are subsidised extensively by national government, the question remains of how to cover the costs for future operation and maintenance of the system. According to the latest census (2001), 56 per cent of the Buffalo City population has no income. As such, the majority of the population is unemployed, earns little or no money and would be unable to pay for the services.

Mdantsane, one of the three urban centres in Buffalo City Municipality, has some 400,000 inhabitants and is the second largest township after Soweto. Most of Mdantsane is serviced with municipal water and sanitation and connected to two nearby wastewater treatment plants. The focus community, Manyano, is an informal settlement at the border of existing formal areas. The settlement is planned for upgrading but cannot be fully serviced in the near future due to the insufficient capacity of the bulk infrastructure. The case study used in this report is based on work carried out by Fergus and Lennartsson in the Manyano community as a test case for a pilot project using urine-diversion systems. As a means of creating awareness, various systems were suggested, described and compared.

Environmental description

Geology

Mdantsane is a densely populated suburban area about 40 km inland from the coast. It is located in the catchment area of the Bridaldrift Dam, which is one of the main municipal water reservoirs, and the Buffalo River. The area is hilly with several valleys perpendicular to the river crossing the area. The settlements are located on the ridges and slopes of the hills.

The soil consists of a layer of clay on top of sandstone. Due to the clay it is expected that the infiltration capacity is minimal.

Natural and cultural environment

The Manyano community is located along the railway line on one of the ridges forming a transportation corridor through the municipality. Housing is planned as detached housing on plots of about 300 m^2. Housing is mixed with communal open land that could be used for farming.

Due to high unemployment, the majority of the households in Manyano rely on subsistence farming, producing maize, spinach and cabbage. The vegetation is predominantly grass where gardening does not take place, and few trees grow in the area.

Current water and sanitation facilities

The informal settlement is provided with municipal water through standpipes within 200 metres. Some of the houses have individual toilets (pit latrines) but most households rely on communal pit latrines.

Neither the private nor the communal toilet facilities are appropriate. From a social aspect an improvement in safety, specifically for women and children, is essential. The toilets are never used at night due to the risk of abuse. The toilets fill up and flood during rains, creating a health hazard.

Comparison - sanitation systems for Manyano

0 alternative: Mdantsane wastewater treatment plant

One of the challenges in providing waterborne sanitation for this particular community is that there is limited capacity in the bulk sewers. The area has not been prioritised for upgrading within the next few years, but could be serviced within the next five to ten years. As waterborne sanitation is the preferred solution for most people it has been used as the 0 alternative in this comparison.

Water and sanitation for low cost housing is provided through a detached toilet unit with a tap and wash basin outdoors. This solution has been chosen to keep the costs to a minimum.

The Mdantsane wastewater treatment plant (WWTP) is located below the residential areas at the banks of the Buffalo River. The WWTP receives complete flows from the Mdantsane area. Approximately 150,000 people are connected to the plant system. There is no formal industry in the area. The plant is designed for 18,000 m^3/day but the average flow is 20,000 m^3/day. On rainy days the average flow is 26,000 m^3/day. The unit processes applied are:

- screening;
- active sludge process with nitrification;
- chlorination.

Table 4.3: Mdantsane WWTP average yearly performance values, compared to South African Water Quality Guidelines (State of Sanitation Report, May 2005)

Parameter	Average reduction percentages	Average yearly value (2004)	Water Quality Guidelines
Incoming wastewater		20,000 m^3/d	18,000 m^3/d
COD	90%	40 mg/L	75 mg/L
Total P		Not monitored	0.5 mg/L
Total N	40%	11 mg/L	10 mg/L
Bacteria		Not monitored	2,000 cells/mL

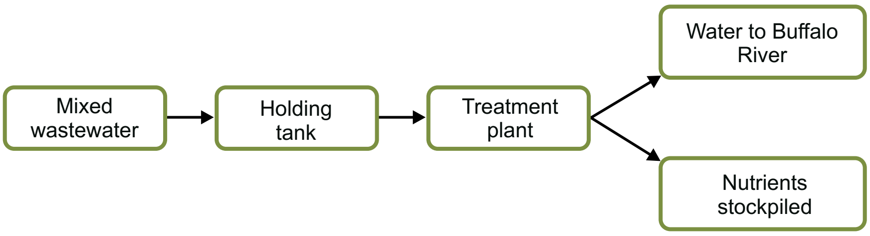

Figure 4.5: Schematic of a conservancy tank system

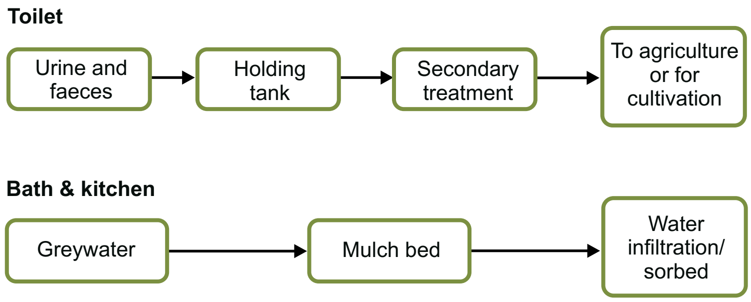

Figure 4.6: Schematic of the Enviro Loo system

The sludge treatment consists of:

- drying;
- stockpiling.

The treatment results for the Mdantsane WWTP, compared to the South African Water Quality Guidelines, are shown in table 4.3.

The treated wastewater is discharged into the Buffalo River.

The dewatered sludge is stockpiled on-site. The management of the sludge is not appropriate, and there is a risk of leachate from the sludge as well as the sludge itself being washed into the river with surface runoff. The current sludge management guidelines require that sludge is either used or disposed of on landfills.

There is no information available on the quality of the sludge but there is apparently no demand for it.

Conservancy tank with subsequent off-site treatment of wastewater

The mixed wastewater is gravity-fed to a holding tank and emptied by the municipal vacuum tankers on a regular basis (see figure 4.5). The contents are taken to a wastewater treatment plant for treatment.

The maintenance of the system is the responsibility of the owner. The system requires regular monitoring to ensure that the content is removed and treated appropriately.

Enviro Loo with treatment of greywater in a mulch bed

Enviro Loo is a composting toilet that collects and treats human waste in a single or multiple chamber system. The Enviro Loo System (see figure 4.6) separates the solids and liquids upon entering the holding tank. The liquids make their way to the bottom of the container, and the solids are captured on a specially designed drying tray that is suspended at an angle approximately half way down the holding tank. The liquids evaporate and dehydrate or dry out the solids, via an accelerated ventilation process. Under higher usage and colder and humid climates, an overflow needs to be installed.

The maintenance of the Enviro Loo toilets is based on periodic raking of material after installation. The dry material is removed to a drying bag for six months for stabilisation, after which it is removed. The number of users of the toilet will determine the rate of this process. The solids can thereafter be used as a soil conditioner (based on information provided by the manufacturer, Enviro Options Australia). To ensure the hygienic quality of the product it is recommended that the solids

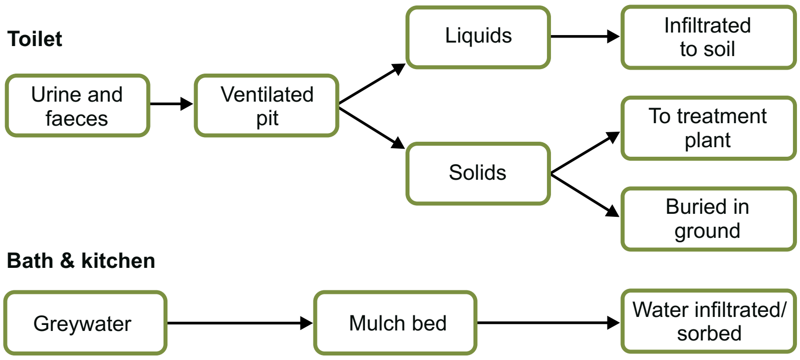

Figure 4.7: Schematic of a VIP system

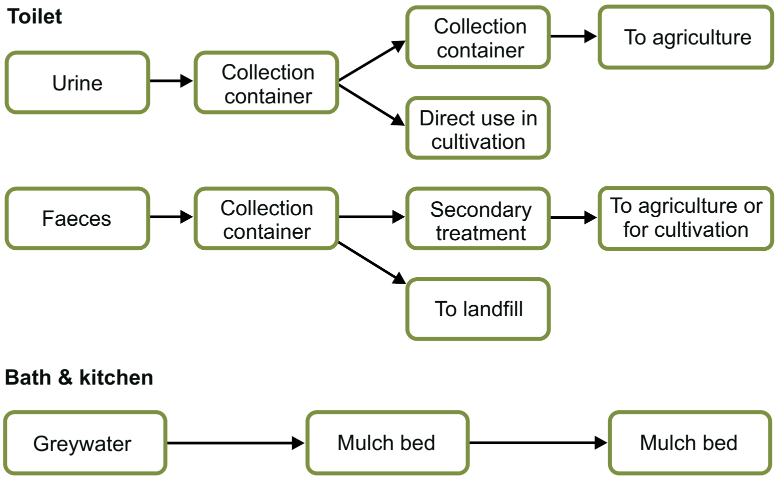

Figure 4.8: Schematic of a dry urine-diversion system

are composted before being used in agriculture. This can be carried out by the municipality or on contract.

The level of water services normally provided with Enviro Loos is a standpipe at a maximum distance of 200 m. In this example we have included greywater treatment in mulch beds on-site followed by disposal through infiltration and resorption.

VIP with treatment of greywater in a mulch bed

VIPs in Buffalo City Municipality are regular pit latrines with improved superstructure (bricks or concrete blocks) and ventilation (see figure 4.7). If the soil conditions are difficult or the water table is high, the pits are lined. The liquid infiltrates into the ground and the solids accumulate in the pit.

The maintenance of the VIPs is based on evacuation of the pits by tankers. The contents are either buried in the ground or taken to a treatment plant. Optionally the superstructure is moved to a new pit.

The level of water services provided with VIPs is a standpipe at a maximum distance of 200 m. In this example we have included greywater treatment in mulch beds on-site and thereafter disposed of through infiltration and sorption.

The system requires an organised maintenance system to ensure proper handling of the sludge. This can be carried out by the municipality or on contract.

Dry urine-diversion with treatment of greywater in a mulch bed

The system is based on urine diversion with dry collection of faeces (see figure 4.8). The urine is collected in a container, whereas the faeces are collected in a bin. The greywater is treated in a mulch bed and thereafter disposed of through infiltration and sorption.

The urine is used in agricultural activities on individual plots or in communal gardens in the area. If the amount of urine exceeds the need on the local level it is collected and taken to commercial farmers. The faeces are collected by the municipality and taken to a waste disposal site for treatment.

The system requires an organised management system, where user management is optional. It requires informed and trained users who appreciate the benefits of the products. To increase the flexibility in case the users are not interested in managing and using their own waste, a communal system (or a contract based system) for collection and reuse will be set up. If reuse is difficult to achieve, the faeces will be taken to the communal landfill site.

Comparison matrix

The 0 alternative contains either quantitative or qualitative estimates of compliance to identified criteria, whereas the alternatives are assessed relative to the 0 alternative. These are all filled in by either ++, +, 0, –, ––, compared to the 0 alternative. A + signifies higher performance and a – signifies lower performance compared to the 0 alternative. See table 4.4 for the comparison matrix.

Health

Health risks downstream for the waterborne systems are extremely high if no wastewater treatment is provided. Vandalism and outdated infrastructure result

Table 4.4: Comparison matrix for the South African setting

Criteria	0 alternative: connection to Mdantsane WWTP	Conservancy tank with off-site treatment	Enviro Loo with treatment of greywater	VIP with treatment of greywater	Dry UD with treatment of greywater
Health					
Risk of infection: household	Low	0	--	--	-
Risk of infection: immediate environment	High	+	0	0	++
Risk of infection: downstream	High	0	0	0	+
Environment					
Discharge: COD	40 mg/l	0	-	-	++
Discharge : N,P	N: 11 mg/l P: not monitored	-	--	--	++
Potential for reuse of water	High	0	NA	NA	NA
Potential for reuse of nutrients	N: Low P: Medium	0	0	0	++
Water use	30-60 l/pe & day	0	++	++	++
Quality of recycled product	Not monitored	+	+	+	++
Economy					
Investment costs (individual & societal)	$2,000 25% (I) - 75 (S)	- 40% (I) 60% (S)	+ 40% (I) 60% (S)	++ 100% (I)	++ 100% (I)
O&M costs (individual (I) & societal (S))	$15/month 10% (I) - 90 (S)	-- 10% (I) - 90 (S)	++ 50% (I) - 50 (S)	+ 50% (I) - 50 (S)	++ 50% (I) - 50 (S)
Socio-cultural					
Convenience	Medium	++	0	0	+
Safety	Low	++	0	0	++
Appropriateness to local context	Medium	0	-	+	- (+)
Technical function					
System robustness	Low	0		++	
Odour	Low	0	--	--	0 (-)
Complexity of construction and O&M	High	0	+	++	++

in numerous incidents of uncontrolled discharge into the environment. This is also the case in Mdantsane, where manholes are blocked on purpose to divert the wastewater to gardening activities and outdated infrastructure results in burst pipes (Carter, 2005). Untreated water is discharged into streams that are used for both domestic and recreational purposes, creating serious health risks.

The current set-up for management of VIPs and Enviro Loos in Buffalo City Municipality does not include organised disposal or use of sludge. Current practices involve health risks both during emptying and in the inappropriate disposal of sludge. However, in the set-up described above an organised system is planned to reduce the risks, yet the personal contact during emptying of pits and chambers is considered a health risk at the household level.

The urine-diversion system will require some handling by the user and therefore the risk of infections at household level is considered to be higher than for the waterborne system. Proper guidelines regarding collection, sanitisation and usage need to be followed in order to minimise risks on a household level for dry systems.

Environment

The reality in Buffalo City Municipality is that raw sewage is discharged into the environment due to vandalism, outdated infrastructure and lack of capacity in the system (Carter, 2005). This is not reflected in the discharge data above as it only reflects the efficiency of the treatment plant. The volume of untreated wastewater is difficult to estimate but is substantial. This is in line with the findings of Lundin and Morrison (2002) who reported that the environmental sustainability of the King William's Town wastewater treatment plant was low, with an infrastructure characterised by (*a*) not meeting water supply demand and protection of human health; (*b*) uncertainty of supply on a day-to-day basis; and, (*c*) minimal environmental monitoring. Its organisation was characterised by (*a*) inadequate operation and maintenance; (*b*) inadequate cost recovery; and, (*c*) high rate of expansion.

The impact of the VIPs in terms of nutrient leakage to ground water has been raised as a concern in the State of Environment Report. According to Montangero *et al*. (2004), up to 50 per cent of the nitrogen leaches into the ground, potentially ending up in surrounding watercourses. There is also a considerable amount of ammonia released into the air.

The current management of Enviro Loos involves disposing of the untreated sludge in the nearby environment. The nutrients and pathogens are washed into watercourses during rains. The operation of the toilet also results in a considerable ammonia release to the air. The improved management system proposed in the case of Manyano would reduce the environmental impacts through the productive use of nutrients.

Water is a scarce resource in Buffalo City Municipality and therefore is an important aspect in sanitation planning. The currently available water is not sufficient to provide a full level of service to all. In the planning process there are various scenarios that are being explored that would use less water and reuse treated wastewater. The reuse of treated wastewater in industrial production is being considered and the potential for reuse has therefore been assessed as high.

Conservancy tanks are predominantly used in environmentally sensitive areas without centralised systems. The high costs involved in emptying the conservancy tanks and the lack of monitoring capacity at a municipal level makes it difficult to rely on the performance of the system. An investigation carried out by Department of Water Affairs in one of the Buffalo City Municipality coastal resorts indicated that less than 10 per cent of the tanks were emptied on a regular basis.

The quality of the recyclable products from the wastewater treatment plant is not monitored. However, there are small- and medium-scale household-based industries connected to the centralised system. The quality of the sludge and products coming out of the on-site systems is therefore expected to be of a higher quality.

Economy

The costs for sanitation used in this comparison are obtained from the Buffalo City Municipality Sanitation Branch at the Directorate of Engineering.

The investment cost of the waterborne system is currently subsidised through two national sources. The bulk infrastructure is partly covered by national grants from the Department of Water Affairs and Forestry as counter-funding to municipal funds, while household installation and local sewage pipes are covered by housing subsidies. With the current system, subsidies will be provided for any type of sanitation solutions but the question remains on how to utilise these funds as efficiently as possible. A system that increases or reduces the overall investment costs has therefore been ranked accordingly.

The operation and maintenance of the waterborne system is currently to a large extent subsidised by the society. It is either done through flat subsidised rates for water and sewerage that does not take the used and discharged volumes into account, or through free services to poor people. Even with these subsidies it is difficult to collect the rates and the arrears for municipal services, which in December 2004 were about ZAR 400 million. Whether this reflects a limited willingness to pay for services or that the services are unaffordable to a large proportion of the population, even with the current subsidies, has not been investigated. But as previously mentioned, if 56 per cent of the population claims to have no income at all, the affordability of the various systems is an important aspect that needs to be taken into account. Boydell (1999) points out that if water is not managed as an economic good the sustainability of the systems is endangered. The Strategic Framework states very clearly that the municipal responsibility for service delivery also gives the right to monitor, control and collect revenue to cover the costs for the same. The selection of a service needs to be planned and provided based on the community's willingness to pay for it. The Strategic Framework also supports this approach, but points out that impoverished groups need to be provided with free basic services.

The issue of affordability is also relevant at the societal level. If a minority of the population is expected to subsidise the services to the entire population, the question of sustainability, especially related to operation and maintenance, will be an issue. This is to some extent reflected in the current state of the centralised system, which is a pressing issue for Buffalo City Municipality. Due to lack of funds for maintenance the system has now reached a stage where about ZAR 500 million is required for upgrading the existing system to a maintainable standard. The sustainability of a system is questionable if the revenue collected from the users of the system does not cover regular operation and maintenance costs.

With the introduction of dry, on-site systems the intention was to provide a service that could be operated and maintained by the owner. It was also expected that the owner would cover the costs. However, in the case of VIPs this has become a subject for discussion as the toilets are difficult to maintain for the user. The evacuation of pits needs proper equipment and the sludge has to be disposed of in an appropriate location. The cost of maintaining VIPs distributed on a monthly basis is low and affordable, but collected over a 4–6 year period it becomes unaffordable to most users. As the responsibility for providing adequate sanitation falls on the local authority, the cost of maintaining the VIPs has subsequently been fully subsidised by the society.

In the comparison matrix, a system that increases or decreases the overall maintenance costs has been ranked accordingly.

Socio-cultural aspects

The systems that locate the toilet outdoors have been ranked low. The location of conservancy tanks and the urine dispersal system are more flexible as no adjustment to bulk infrastructure is required. It has been assumed that the toilets are located in the house, thereby receiving a higher ranking.

From an acceptability point of view the flush toilet is considered the best. However, the fact that people are using inappropriate materials for anal cleansing makes waterborne systems not always appropriate in the local context. The dry systems have received a low ranking due to the current acceptability level. The urine dispersal system has the potential to be fully accepted as it is an indoor system, and the use of urine is culturally accepted which makes it an additional benefit to the system.

Technical function

As described above, the waterborne system faces severe problems of vandalism and misuse and has therefore been ranked low on robustness.

The Enviro Loos in Buffalo City Municipality have not performed very well. The contents of the holding tank are not drying out and have to be removed more frequently than intended as a liquid sludge. Whether the toilets are under-performing due to inappropriate use or installation is not known. However, to provide an appropriate service the Enviro Loo has to be used and maintained by users who understand the system. The Enviro Loo is supposed to be odourless; the toilet itself is, but due to the non-functioning process the odour covers the area.

The maintenance of VIPs, which is the responsibility of the owner, has proved to be complicated. As the contents of the pits are relatively dry and the pits in many cases are also used for solid waste disposal, the emptying of the pits becomes costly and difficult. 600–800 litres of water have to be mixed into the contents of the pits before being emptied. The emptied pits also seem to be clogged and fill up much faster. The improved superstructure that is required by national guidelines also makes it difficult to move the pits to a new location.

The VIPs do not have adequate ventilation, and suffer from strong odours both inside and outside the toilet. If not operated appropriately, the urine dispersal (UD) system could also have strong odours. However, it is easier to rectify this issue for a UD system than in the case of the other toilets as the UD toilets are easier to maintain on a user level.

The conservancy tank system relies on the capacity of the treatment plant. The inadequate capacity of the existing plants limits the possibility of installing conservancy tanks in the area.

Other relevant criteria

Some of the criteria that have not been included in the matrix above but are of importance are further discussed below.

Responsibility requirements and legal aspects

The Municipal Act and the Strategic Framework for Water Services clearly state that the provision of basic sanitation, including operation and maintenance, is ultimately a municipal responsibility. The responsibility also gives the right to monitor, control and collect revenue to cover the costs for the service.

From a legal perspective, the products from sanitation systems are considered waste or pollutants. This aspect will have to be taken into consideration if reuse is being proposed as part of the management system. In the current update of the sludge management guidelines the potential of reuse in agriculture is seen as the preferred way to go. Source separated urine is considered a liquid waste, and will have to be addressed differently through obtaining a permit from the Department of Water Affairs and Forestry.

The discrepancy between the existing legal framework and the reality on the ground is very clear. The legal framework is stringent and proactive, while the capacity and resources at municipal level to comply with regulation is very limited. In the case of Buffalo City it has been recognised that striving towards complying is very important, and that improvements will lead to long-term sustainability.

Institutional arrangements

Institutional arrangements have to be taken into consideration when designing the systems, as even the on-site and dry systems need some sort of institutional capacity to function. Even if the responsibility of maintaining the on-site system is placed on the user, the municipality needs monitoring capacity to ensure the overall sustainability of the system.

Attitudes towards recycled product and other important attitudes for the context

Culturally, urine is used for medical purposes. When discussing the use of urine in agriculture the initial response is negative, but when explained and related to cultural use there seems to be an acceptance. Fertilisers are needed and few can afford to buy them. The message that free fertilisers are readily available seems to get through to the farming community.

Other important attitudes relate to the historical use of bucket toilets. Any system that resembles a bucket toilet is seen as unacceptable. Dry toilet systems have therefore been stigmatised as inferior systems. These aspects are important to recognise and take account of in the design of toilets as well as in the development of management.

Discussion: South African case study

The example of Buffalo City shows that what from a political point of view has been considered the only acceptable form of sanitation—that is, waterborne—is not necessarily the best from a sustainability point of view. It is socially well accepted but it requires ample availability of water. In the case of Buffalo City Municipality, the currently available volume in reservoirs and dams is not sufficient to extend the service to all. Furthermore, it also requires good management, sufficient funding, clean technologies and efficient resource use to operate at an acceptable level. The current state of the system and the estimated need of funds for upgrading reveal that sufficient resources have not been allocated to keep the system in a sustainable condition. In the case of King William's Town, one of Buffalo City Municipality's urban centres, Lundin and Morrison (2002) conclude that the indications are that the centralised system diverges from environmental sustainability and is not meeting the basic objective of ensuring human and environmental health.

The comparison also shows the importance of using similar system boundaries, including the same criteria for the system. The boundaries need to include issues such as user awareness and the maintenance and treatment systems for all flows and fractions. The use of similar system boundaries, including the management of waste fractions, has not been included in the planning process. The maintenance of on-site systems has been expected to be the responsibility of the owner, while little effort has been placed on monitoring to ensure that they are operated in a sustainable way. The State of the Environment Report has also highlighted some of the environmental impacts of this approach.

In the comparison, the dry urine-diversion system came out as a more sustainable alternative. However, with the introduction of new concepts, such as the dry urine-diversion toilets, the acceptance at the user level is and will continue to be an issue until the concept has been mainstreamed. This can only happen when an appropriate system has been developed and demonstrated on a large scale in urban environments. The system needs to be marketed not only for low-income communities but also in affluent areas, such as holiday homes and developments in areas not serviced by the centralised system to show that this is not only a 'poor man's solution'. The management systems that go with this system and possible use of products in agriculture could provide an extra benefit as job creation and improved food production are priority issues in Buffalo City. The challenge is to find management and reuse systems that are acceptable and safe to people. As the social and cultural context varies from one person to another, and from one community to the next, the handling and reuse approach needs a more flexible and open-minded planning process.

4.3 SANTIAGO TEPETLAPA (TEPOZTLÁN MUNICIPALITY) - MEXICO

Background

Mexico's Congress has recently passed a new Law of National Waters (*Ley de Aguas Nacionales*), where municipalities have a certain number of years (5–10) to install sanitation systems or face fines imposed by the National Water Commission (CNA). Municipalities are thus faced with the task of making appropriate decisions in a short amount of time and finding the necessary funding for the construction of such systems. The terms for municipal presidents are three years, with no possibility of re-election. As most of the municipal staff is also replaced at the end of the term, there is a chronic lack of professionalism, foresight and long-term planning in public service.

The only sanitation systems that are currently being promoted by government authorities are waterborne. Local officials usually lack the technical capacity to make informed and appropriate decisions about possible options. As a consequence, the majority of municipal wastewater treatment plants built so far in the country are non-functional. Indeed, approximately 90 per cent of treatment plants are abandoned due to lack of maintenance, insupportable operational costs, inappropriate choice of technology, and the community's lack of involvement and understanding of the sanitation system. As a result, the untreated wastewater simply bypasses the system.

In rural areas as well as urban and peri-urban neighbourhoods without sewer systems, the prevailing sanitation practice usually consists of self-constructed, badly-designed household 'septic' tanks that are neither adequately maintained nor properly regulated. Such is the case in Tepoztlán, State of Morelos.

Tepoztlán is ethnically and culturally diverse. On the one hand it still maintains many of the characteristics that had defined it as the prototypical Mexican village. In recent decades, though, it has also become very much a tourist town attracting many different people, from some of Mexico's most wealthy, who have mansions in the valley, to pro-environment foreigners who have been evolving communities based on sustainable living concepts ('eco-villages'). Tepoztlán's mystique of the quiet town with cobblestone streets, the beauty of the surrounding mountains, and its proximity to Mexico City have also made it a favourite weekend tourist destination. Through a programme called Pueblos Mágicos, sponsored by the Ministry of Tourism since 2002, Tepoztlán has been receiving federal and state funds to upgrade its current infrastructure.

With funds from the Pueblos Mágicos program, the preceding municipal government initiated the construction of a sewage network for the town's four main downtown blocks, which was finished by the current government. However, since there is still no wastewater treatment plant, the sewage is currently stored in a holding tank before it is trucked daily to the open-air municipal dump. Establishing a centralised sewage network for the whole town is almost impossible because of topography, soil characteristics, and the excavation costs involved. Therefore, the system that is already in place can only be expanded to serve a few more blocks of the town's centre and possibly three settlements located along the sewage line's ten-kilometre path to the treatment plant site. These towns are named Colonia Ixcatepec, Colonia Huilotepec, and Santiago Tepetlapa.

We will consider Santiago Tepetlapa as a sample study area with relatively clear boundaries to evaluate what sanitation system alternatives might exist for comparison with the more conventional wastewater treatment plant option.

Environmental description

Geology

Tepoztlán is located at the top of its watershed, at about 1,700 metres in altitude. The town is built on steep slopes and extends through a valley. There is a difference of 700 m from the uppermost neighbourhood to the valley. A chain of mountains that belong to the Chichinautzin Biological Corridor Natural Protected Area surrounds the town and most of the municipality is located within the Tepozteco National Park. The area sits on volcanic substrate but the valley has quite fertile soil, appropriate for flower cultivation. The porous volcanic rock soils make the entire area an aquifer recharge zone. Most of the water captured in the mountains drains to the aquifer down gradient and some feeds seasonal creeks and ravines.

Natural and cultural environment

Tepoztlán is an ecotone, a transition zone between two climates. While the upper regions of the mountains are covered by pinewood forests and have a mild to cool climate, the lower areas of the valley are warmer and dryer. Precipitation is, however, quite abundant during the monsoon months (June to August) with approximately 1,300 mm of rainfall. Thus, tropical vegetation is found at the foot of the mountains.

Culturally, Tepoztlán is quite a mixture as well. At the top of the Tepozteco mountain lays a pre-Hispanic pyramid and a few hundred metres below, on the main street, stands a sixteenth-century Spanish convent. Tepoztlán has received a variety of migrants from different parts of Mexico and many foreign countries. Indigenous and migrant populations commingle to sell art, handicrafts and other goods at the weekend market. The local population that used to rely on agriculture has now become more service- and tourist-oriented. Population has expanded rapidly due to high birth rates and immigration. Family plots have been consistently subdivided, creating quite a concentrated population in the eight neighbourhoods or 'barrios' of the main town. Santiago Tepetlapa is a somewhat recent settlement that has also seen its population expand rapidly in the past 20 years, to approximately 2,500 residents at the present time.

Current water and sanitation facilities

Water

The main town of Tepoztlán has a water supply network, furnished by 4 boreholes in the valley. The water is at times pumped more than one hundred metres to the surface, and then further pumped to reservoirs from where it is distributed by gravity. Consequently, most of the expenditures made by the water management office consist of payments for electricity. Monthly fees are approximately USD 3 for local residents and USD 12 for immigrants, regardless of water use. The system is very old, with estimated leaks at 50 per cent and hardly any budget or planning towards maintenance, repair or expansion.

Many neighbourhoods also have independent distribution networks that rely on piped springs in the mountains. This water is highly valued, since it is considered cleaner and purer, but it is usually only available to the families of those who helped or paid a fee at the time when each system was constructed.

Most of the homes in the valley, especially those from wealthy people from Mexico City, have private or shared wells. The number of total wells in the valley is unknown. In a report that is still unofficial the CNA suggests that water table levels are "stable", but with serious risks of over-pumping if current extraction rates continue to rise due to increasing demand for irrigation and domestic uses.

The situation in the surrounding towns and settlements is quite different. Most do not have access to a reliable source of water. People therefore depend on rain harvesting during the four-month wet season to supplement their yearly needs. More often than not, the amount of water collected is insufficient to last the whole year, so they must pay comparatively exorbitant amounts of money (USD 30–100 for 3 m^3 of water) for tank-trucks to distribute water to their homes.

The town of Santiago Tepetlapa is more fortunate than most of the other towns in that it relies on a well located upstream, at the Atongo valley, and has recently received assistance from the Morelos State Government to perforate another borehole and upgrade the distribution network. Local residents pay USD 300 for a connection to the network whereas immigrants pay USD 1,500 USD; monthly tariffs are USD 1.5 and 6, respectively.

Sanitation

Most households in the main town have flush toilets with either a septic tank or an infiltration pit for treatment and disposal (a detailed description is provided in the next section). As mentioned earlier, up to this day no community wastewater treatment facility exists, so the collected sewage from the town's four main blocks is disposed of, untreated, at the municipal garbage dump (which lies on porous, volcanic rock).

In the surrounding towns and *'colonias'* the situation is slightly different. Those that are more distant from the municipal centre, with lower socio-economic status, have a prevalence of unventilated pit latrines. The settlements closer to Tepoztlán town and with a more reliable water supply, such as Santiago Tepetlapa, usually have water flush toilets and household septic tanks as their sanitation system. Indeed, the ratio in Santiago Tepetlapa between septic tanks with infiltration pits and unventilated pit latrines is approximately nine to one. There are fewer than ten dry toilets in the town.

The number of dry eco-toilets in the municipality of Tepoztlán is estimated at more than 100. San Juan Tlacotenco, another town of Tepoztlàn, with a building materials subsidy from the State Government and facilitation of TepozEco (an ecological sanitation project, partly financed by Sida), currently is facilitating the construction of thirty dry urine-dispersal eco-toilets systems with greywater treatment in the town of San Juan Tlacotenco, higher in the mountains. If the program is successful, there is a strong likelihood that the experience will be repeated in San Juan as well as other communities, including Santiago Tepetlapa.

Since it is hoped that the comparison of sanitation systems will serve as a practical tool to assist local officials in the process of selecting an appropriate sanitation system for the towns of Huilotepec, Ixcatepec and Santiago Tepetlapa, we will focus our comparison and discussion on the systems that currently exist or may exist in the future: wastewater treatment plant (a constructed wetland), properly designed septic tanks, currently installed septic tanks, and dry urine-dispersal toilets plus greywater treatment. We will not discuss pit latrines as a sanitation system because they will neither be well accepted by the population nor promoted as a feasible alternative.

Comparison: sanitation systems for Santiago Tepetlapa, Municipality of Tepoztlán

0 alternative: Wastewater treatment by a constructed wetland in Tepoztlán

There is already a certain degree of interest and tentative commitment from the local authorities to choosing a constructed wetland (or a hybrid) as the treatment technology for the municipal wastewater treatment plant (see figure 4.9). Progress on this issue has, so far, been on the lobbying and political level, as the technical aspects still need to be developed. However, installation of the approximately ten-kilometre sewage main collector pipe has already begun and, in exchange for treated water, the local farmers' association has conceded to the municipality a three-hectare area to

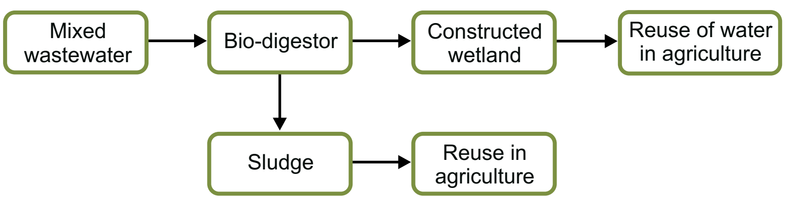

Figure 4.9: Schematic of wastewater treatment by a constructed wetland

construct the facility. Since the area is fixed and costs for constructing sewage networks are overwhelming, the municipality has a strong interest in not significantly expanding the existing network and, therefore, in seeking other sanitation alternatives. It has, however, promised connection access to the towns where the collector pipe passes through.

Even though the technical details have not been fully defined, it is expected that the system will consist of a combined process where, after screening, the water will be partially treated either in an Imhoff tank, a biodigester or a surface-flow wetland and further treatment will occur in a subsurface-flow wetland. The main concern is to lower the pathogen load to acceptable levels for water reuse, since nutrients will be valued by farmers who will apply the effluent on their crops. The low amounts of sludge produced should be manageable on-site (dried and applied on fields).

Another desirable aspect of the treatment wetland is to convert the municipal wastewater treatment plant into an eco-park, where tourists may be able to visit a diverse ecosystem, learn about nature's ability to recycle matter, have exposure to various alternative water conservation technologies, and thus help alleviate some of the operation and maintenance costs.

Upgrading of existing system

Actual situation of Tepoztlán

Although the majority of households have septic tanks, there is little information amongst the public regarding the proper design and maintenance of these systems. Indeed, most residents—and masons—are convinced that a well-built septic tank requires no maintenance and should last indefinitely without getting clogged. It is also assumed that greywater interferes with the treatment process so it should be routed away from the first two chambers and into the infiltration pit. Some tanks are purposely built without the bottom slab, and leach fields are virtually nonexistent. Most septic tanks either discharge into an infiltration pit or into natural soil 'sinkholes' or fissures in the bedrock, which allows water to flow continuously without clogging the system.

In practice, since the sediments are not periodically removed, the system may only function properly for the first year or so. Afterwards, short-circuiting occurs and basically untreated water is free to flow through volcanic fissures, presumably into groundwater. Even though physical evidence supports the notion that septic tanks may be polluting groundwater, wells have not yet been adequately tested to confirm it objectively. It should also be noted that those who do empty their systems regularly, generally because of impervious soil conditions, do not necessarily hire a licensed enterprise for the task, so their sludge may well end up at the municipal dump or a nearby ravine.

A variation of this disposal procedure consists of discharging mixed wastewater into an infiltration pit, even without the preceding pseudo-treatment of the septic tank. An infiltration pit is a large unsealed chamber that allows water to be absorbed directly into the subsoil. As the primary objective of this system is disposal—not treatment—it is considered highly desirable to discover a fault line where the wastewater can be drained completely. Although the wastewater that percolates through porous soil is somewhat treated physically and biologically, it is doubtful that this can, in fact, provide acceptable treatment for wastewater that is discharged from such a large town (>18,000 inhabitants). Furthermore, it seems very unlikely that similar natural filtering occurs when the discharge is directly into an underground fault.

Upgrading of existing system: treatment of mixed wastewater in septic tank plus leach field

Septic systems are based on conventional water flush

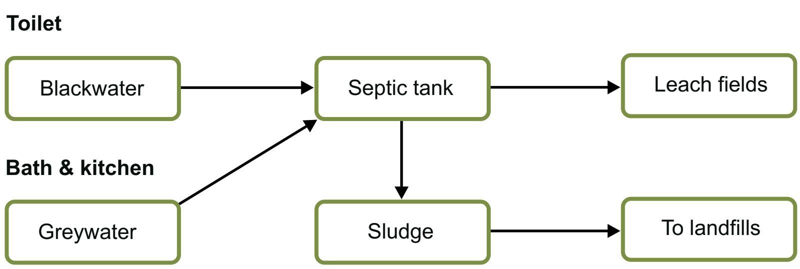

Figure 4.10: Schematic for the upgrade of an existing system: treatment of mixed wastewater in septic tank plus leach field

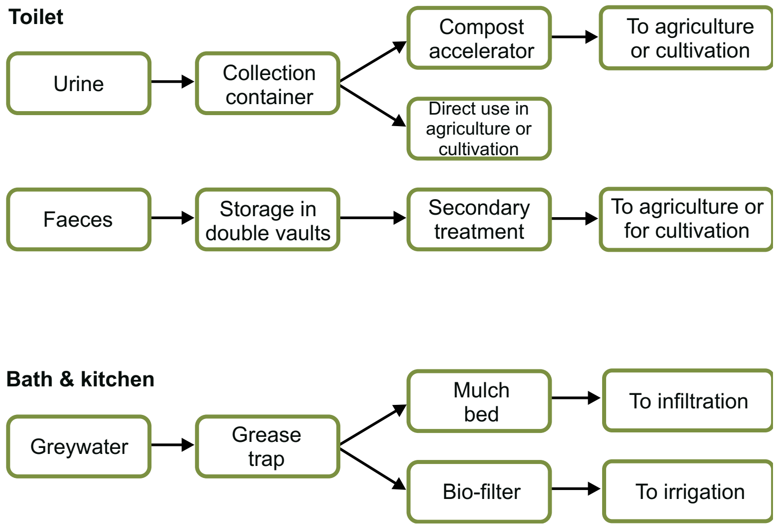

Figure 4.11: Schematic of a dry urine-diversion system with treatment of greywater

toilets (WC) (see figure 4.10). Properly designed systems consist of two or three impermeable interconnected tanks and either an infiltration pit or a leach field. They may be constructed on-site or a prefabricated model can be installed. However, Mexican legislation has developed standard parameters exclusively for prefabricated tanks, since only they are considered acceptable.

In principle, the system functions as follows. The sewage water from the WC is discharged into the first tank, where most of the pathogens are destroyed through an anaerobic fermentation process. From there, the wastewater, now almost entirely free of solids, flows into a second vented chamber where aerobic fermentation destroys the remaining anaerobic bacteria by oxidation. Finally, the treated water from the septic tank is discharged into either an infiltration pit or a leach field. The latter option is preferred because the oxidation process is allowed to proceed further and plants uptake nutrients. In general, raw greywater is connected directly to the third chamber or the leach field.

In order to assure adequate operation, the septic system should be inspected at least once every six months to determine the level in the tanks and whether there is any sort of obstruction in the pipes. Every year or two the accumulated sludge must be emptied from the first tank and transported to an appropriate treatment facility.

Dry urine-diversion toilet system with treatment for greywater

The Mexican urine-diversion ecological dry toilet is an adaptation of the Vietnamese double-vault UD system (see figure 4.11). The architect Cesar Añorve has been the principle proponent and designer of the urine-diversion pedestal. The pedestal is located on a raised platform above two chambers, where faeces are collected, dehydrated, and stored. The urine is collected in a separate container or drained into a soak-pit. After each use, a cupful of a mixture of soil and ash (or lime) is added to the chamber to absorb excess humidity, increase the pH, and eliminate unpleasant odours. When the first chamber is full it is sealed and let to sit, while the second chamber is in use. The systems that TepozEco has been designing have one large chamber, a permanent pedestal, and two interchangeable containers. They follow the same storage principle.

By allowing faeces to be stored from 6 months to a year, at a high pH and low humidity, most pathogens will be destroyed. (Indeed TepozEco tests have detected zero pathogens following the recommended storage time.) The dried faeces can then be added to a compost pile for secondary treatment or mixed with regular soil as a conditioner. The urine is either fermented and diluted with water for use as fertiliser or added to a kitchen or garden compost to provide valuable nutrients and accelerate the decomposition process. At this point in Tepoztlán, handling of the end products is generally done at the household level, although the municipal composting centre does receive urine for application on compost.

Greywater is treated either through a household biofilter (reed bed) or a mulch basin (original idea developed by Art Ludwig at Oasis Design). Both treatment mechanisms operate on the same principles: using soil-borne microorganisms to degrade organic matter, installing a substrate where water is distributed and microorganisms thrive, and having plants that benefit from the available water and nutrients.

In the biofilter, water passes through a grease-trap to separate large particles (oil and solids) and then to a bed filled with volcanic rock and sand, planted with hydrophilic plants. The effluent may be collected and used for irrigation of plants or trees. Mulch basins are appropriate when the flow may be split or directed from the source to specific trees. The water flows through the subsurface of mulch basins around the tree. A grease trap is usually not necessary, and there is no effluent or standing water since water is either absorbed by the tree or distributed around the mulch area.

Table 4.5: Comparison matrix for the Mexican setting

Criteria	0 alternative: Connection to constructed wetland WWTP	Upgrading of existing system: mixed wastewater to septic tank + leach field	Dry urine-diversion and treatment of greywater	Actual system: mixed wastewater to septic tank + infiltration pit
Health				
Risk of infection: household	Low	-	-	-
Risk of infection: immediate environment	Low	-	0	--
Risk of infection: downstream	Medium	-	++	--
Environment				
Discharge: BOD	<10 mg/L (1)	-	+	--
Discharge : N,P	N<10 mg/L (1) P<5 mg/L (1)	-	+	--
Potential for reuse of water	High	0	0	--
Potential for reuse of nutrients	High	0	0	--
Water use	120 – 150 L/pe/day	0	++	0
Quality of recycled product	Medium/High	-	+	--
Economy				
Investment costs Individual (I) and Societal (S)	100 – 150 (2) USD/ pe -100% (S)	- 100% (I)	+ 100% (I)	- 100% (I)
O&M costs Individual (I) and Societal (S)	20 USD/pe*yr (3) 90% (S), 10% (I)	- 100% (I)	++ 100% (I)	++ (no maintenance)
Socio-cultural				
Convenience	High	0	-	0
Safety	High	0	0	0
Appropriateness to local context	Medium/Low	-	+	++
Technical function				
System robustness	Medium	0	0	+
Odour	Medium/Low	-	0	-
Complexity of construction and O&M	Construction: High O&M: Medium	Construction: + O&M: 0	Construction: + O&M: -	Construction: + O&M: ++

(1) Values assumed from data of treatment wetlands designed by the Mexican Institute of Water Technology (IMTA).

(2) Construction cost calculated from actual budget. It does not include the cost of either the sewage network or the collector.

(3) Operation and maintenance cost extrapolated from systems designed by the Austrian-Nicaraguan ASTEC project.

Comparison matrix

See table 4.5 for the comparison matrix. The 0 alternative contains either quantitative or qualitative estimates of compliance to identified criteria, whereas the alternatives are assessed relative to the 0 alternative. These are all filled in by either ++, +, 0, –, ––, compared to the 0 alternative. A + signifies higher performance and a – signifies lower performance compared to the 0 alternative.

Health

It is assumed that connections to the sewer system do not leak or burst and that the treatment wetland will have high pathogen-removal efficiencies. If disinfection is not complete, however, there is a risk of downstream contamination. Sludge from septic tanks must be removed and this operation is a household risk. This demands that a licensed sludge-removal service be used, and that there exist a municipal scheme for treatment of sludge from septic tanks, otherwise the risk of infection in the immediate environment and downstream is quite high. Dry systems have higher risks of infection at the household level since products may need to be handled by family members. It is, however, a minimal one if appropriate guidelines are followed regarding the collection, sanitisation and use of end products. Tests performed on the processed faecal material show a pathogen-free product, so it can safely be applied on the immediate environment. Products in the dry system are contained in place, so there is no risk of downstream infection.

Although greywater may be discharged, it is assumed that, after treatment, the associated health risk is minimal. Even though the downstream effects of current septic tanks are not visible, the risk of polluting groundwater sources possesses a real threat to community health.

Environment

It is assumed that the treatment wetland will be adequately designed, operated and managed, with similar removal efficiencies to systems already designed and currently operating. The IMTA reports removal efficiencies for BOD, N, and P at 99 per cent, 93 per cent, and 84 per cent respectively in the Cucuchucho system, whereas the effluent from the Masaya pilot treatment plant—designed and operated by ASTEC—has averaged 5, 20, and 4.5 mg/l in those three parameters during six years of operation.

Septic systems usually provide only about 60 per cent treatment of BOD and still lower values for nutrients. Even the ideal system cannot perform to the expected capacity of the treatment wetland. Dry systems received a higher ranking because the only discharge is treated greywater. However, removal performances of greywater filtering systems have not yet been measured quantitatively. Nutrients and water may be reused in septic tank leach fields but not in infiltration pits, whereas most of these inputs may be recycled both in dry systems and the 0 alternative with high-quality end products. However, dry systems have a major advantage: water is conserved.

Economy

The treatment plant's budget is approximately USD 1.3 million and the system will serve a maximum of 9,000 pe so the investment cost may oscillate around USD 150 per pe. However, the cost of constructing a sewage network in Santiago Tepetlapa (or the collector, currently under construction) has not been included in this estimate. Given the generally rocky terrain of this town and considering a network length of three kilometres, we may roughly estimate the cost of the collection system at USD 240,000.

Operation and maintenance costs are estimated from constructed wetlands already functioning in Nicaragua and Mexico. Construction of a septic tank may cost up to USD 2,700, which, for a five-member family, represents approximately USD 550 per pe. The total cost varies depending on the type of tank (prefabricated or self-constructed) but excavation costs represent a significant share. Current systems avoid maintenance while those properly designed may need yearly removal of solids at an approximate cost of USD 200. A major contrast is that the treatment plant will be totally subsidised (maybe even its operation and maintenance), while individuals must pay the full cost of household systems. The Morelos State Water and Environmental Commission (CEAMA) is currently subsidising approximately 60 per cent of the construction cost of 30 dry systems in the municipality. A similar scheme may be feasible in Santiago Tepetlapa as an alternative to those who prefer the dry option. Dry toilet systems cost about USD 1,100, including self-help labour, and their maintenance is less than USD 30 per year. However, a micro-enterprise providing maintenance, collection, and secondary-treatment services may be envisioned. In this case, households may pay a monthly or yearly fee for the service, while the cost of secondary processing may be self-sustained if the potential value of recycled nutrients and compost is considered.

Socio-cultural aspects

Convenience and safety are high for all systems because toilets are located inside the house or adjacent to it. Dry systems received a slightly lower ranking in convenience because they require more maintenance by household members, education for proper use, and acceptance of the technology. Although the treatment plant is being promoted as an alternative, it will not be accessible to the majority of the population unless the municipality spends huge sums to build the required sewage network. It is therefore not very appropriate to the local context. The same applies for the upgrading of the existing system: major retrofitting is required and most plots are not sufficiently large to install an adequate leach field. Because of this, it may be an even more difficult alternative to implement than constructing a sewage system. On the other hand, the current system is what people know and have used for many decades, however incomplete it may be when it comes to the health of the people and the ecosystem. Dry systems are both appropriate and accessible to all, provided that they are accepted by the community, but retrofitting is needed in most cases. This factor is particularly important regarding greywater, since the way water is distributed in the house greatly affects the possibility of implementing the system.

Technical function

The 0 alternative is expected to be quite robust since large and diverse ecosystems tend to respond well to fluctuations or peaks. However, natural systems are also susceptible to toxic substances flushed in the drainage network. The current disposal of wastewater in septic tanks and infiltration pits is ranked as more robust because it may operate for decades without any visual problem or need for maintenance. Emission of odours will depend on the type of wetland (surface or sub-surface flow) and the process to remove organic matter, but it will not be felt at the household level. Since septic systems are constructed inside the family plot, some local odours are created near the vent pipe.

Dry systems should have no odour problems if they are properly designed, used, and maintained.

The 0 alternative is quite difficult to construct, requiring engineers and heavy equipment. Its operation and maintenance, however, may be done by a well-trained gardener who is familiar with the system's functional aspects. All other systems are easier to construct. The dry alternative was ranked lower since most ongoing maintenance will generally be performed by members of the household who must have proper instruction in advance—although it is presumed that an external maintenance service might well evolve over time.

Other relevant criteria

Piloting new sanitation systems

Socio-cultural acceptability is a major issue regarding dry sanitation. Its adoption depends on two major fronts: community education and improvement of the regulatory framework. Indeed, most people are not familiar with dry eco-toilets and tend to associate them with pit latrines. There is therefore a need for more examples of appropriately designed systems that are well maintained and operated. Since flush toilets have a certain socio-economic status associated to them, dry sanitation must provide similar hygiene, design, and comfort standards as waterborne systems.

Education

Tepoztlán's residents generally do not acknowledge the consequences of current septic systems and seldom assume responsibility for their waste or discharges. Transferring individual problems or responsibilities to the commons (such as ravines, streets, and aquifers) is a frequent and culturally accepted practice, so a major behaviour shift is required if sanitation conditions are to be improved. For this reason, the education of the population concerning hygienic risks of these actions has to be undertaken. Scientific proof of groundwater pollution, if it is indeed occurring, could possibly raise awareness and result in the necessary change in sanitation practices.

Legislation

The adoption of waterborne systems throughout the country, regardless of local context, has been an official policy for decades. This is usually supported by legislation and local regulations that view these systems as the only alternative. In fact, until TepozEco assisted in the drafting of a new building code for Tepoztlán, local regulations did not even contemplate dry sanitation as an option. The new code still needs to be finalised and approved by the local council. However, citizens' non-compliance and officials' lack of enforcement of laws and regulations represent a major hurdle on the way to better water and sanitation management.

Discussion: Santiago Tepetlapa case study

According to population projections in the Municipal Development Plan furnished by the Morelos State Office of Urban Planning, the municipality of Tepoztlán will have 70,000 residents by the year 2015. Compared to the current population of approximately 34,000, this high number raises questions regarding the consequences of a densely populated area, such as the pressure that will be exerted on local resources. Sanitation systems that conserve resources and preserve human health must be established.

The WWTP is subsidised in its entirety and, since a scheme for recovering operation and maintenance costs has not yet been envisioned, it is quite likely that they will be subsidised also. However, incentives for construction of household systems are rarely available. Simple incentives such as waiving the cost of the construction license or lowering real estate taxes for households that implement resource-conserving systems should not be too difficult or costly to offer. In addition, construction incentives or subsidies for dry systems might be required, particularly during a transitional period. Other subsidies or legal regulations may be necessary for sludge collection from septic tanks and secondary processing support to assure compliance with appropriate maintenance.

The current waterborne disposal system based on non-maintained septic tanks and infiltration pits is not sustainable and poses a health risk. The envisioned wastewater treatment plant will solve only a fraction of the sanitation-related issues in the municipality. Santiago Tepetlapa, along with two other towns that lie on the path of the collector, is fortunate enough to have this system as an option. However, as for the rest of Tepoztlán, it is quite unlikely that all of its residents will have a connection to the treatment plant. A likely scenario is that a mixed system might evolve, where some residents might connect to the municipal WWTP and others will have alternative systems.

For dry sanitation to be considered as a viable alternative in an established town such as Santiago Tepetlapa, some sort of urine and faecal collection and secondary processing support would be advantageous. It would be a household-centred but not autonomous system that assured high-quality end products and attends the needs of those who do not wish to close the loop at the source. For this town and the rest of the municipality water and sanitation should be managed by an independent organisation that neither follows nor is affected by political whims. This would result in sounder decisions regarding water and sanitation as well as a more sustainable management of resources.

5 DISCUSSION

The three illustrative examples used in this report highlight how criteria for sustainable sanitation can provide insight into the pros and cons of different sanitation systems, depending on context. Multi-criteria analysis frameworks assist in learning about a problem and the alternative courses of action possible, by enabling people to think about their values and preferences from several points of view (Refsgaard, 2005). Multi-criteria analysis can thereby provide insight and structure into the nature of conflicts and the possible methods to produce political compromises in cases of divergent preferences (Munda *et al*., 1994). Of course this is very important in assessments such as those proposed in this report, since assessments *per se* will be coloured by the opinions of those conducting them. Additionally, in order for the assessment to be as useful as possible it needs to be undertaken with all relevant stakeholders. Thus, using a combination of product- and process-oriented approach, where criteria are used to keep many sustainability aspects in mind and negotiation among stakeholders is used for weighting of criteria, has been shown to benefit more sustainable decisions within urban water management (Söderberg and Kärrman, 2003).

There is a need for transparency in decision-making processes (Starkl and Brunner, 2004), which we strongly believe that multi-criteria analysis can support. Also, the assessment of the illustrative examples shows how important the local context and system boundaries are for the outcome of the assessment, an observation supported by Lundin *et al.* (2000).

The same 0 alternative was chosen for all three examples: connection to a centralised wastewater treatment plant. The difference in performance for wastewater treatment plants depends on the context, as the 0 alternatives represent different treatment results for the different countries. At the same time, since the wastewater is piped away from the households in all three examples, they all have the same low risk of infection in the household and in the immediate environment. Additionally, the quality of recycled products is ranked differently between the three different countries. In Mexico the quality of the recycled products is considered medium to high for the 0 alternative. In Sweden the same parameter is considered low for the 0 alternative, due to the strong resistance towards agricultural use of sludge by the Swedish food industry and the Farmers' Association.

The cost recovery approaches differ between the examples as well. Sweden requires full cost recovery for water and wastewater services for both on-site systems and for connections to wastewater treatment plant. This is not the case for the Mexican and South African examples, where the municipality would subsidise 100 per cent of the construction, and possibly also the operation and maintenance of the wastewater treatment plant, while costs for on-site systems are left to the household. This in itself is a strong economic driver for households to connect to the wastewater treatment plant, and the heavily subsidised water tariffs for those connected to the water system are a further incentive. Full cost recovery and strategic asset investment planning are vital for the sustainability of water and sanitation services, which is not done for both the Mexican and South African cases. Thus, the financial and economic sustainability of the 0 alternatives is highly questionable for these two cases.

The three illustrative examples show that there is no single sanitation system that is best when it comes to compliance to the given criteria. All systems have their pros and cons depending on context and type of criterion. However, all examples show that there are on-site systems that may have higher performance than the centralised connection to a treatment plant. This is the case for the dry urine-diversion systems in all three examples. Lower discharges for N, $BOD_{5,7}$, higher quality of recycled product, and lower water use are all parameters for which the dry urine-diversion systems have higher performance compared to the conventional system. Krebs and Larsen (1997) evaluated different strategies (source control, hardware, software, resilience) to increase performance of urban drainage systems. All suggested strategies that could be used to increase performance, but with different effects on the complexity of systems and use of resources. Source control was found to be the strategy that could provide increased performance with a decrease in the complexity of system and a decrease in the use of resources. The reduction in the use of resources is in accordance with the findings in the three examples presented in this report. The risk of infection downstream is another factor where, for all three cases, the dry urine-diversion systems have higher performance in common compared to the 0 alternative.

However, the dry urine-diversion systems also have negative scores in common throughout the illustrative examples in terms of health on household level (all three examples) and convenience and appropriateness to local context (two out of three for each of these). The increased health risk on the household level is due to the need to handle excreta by householders, which could possess a risk if not done with enough precautions or by a professional service. The non-diverting systems demand less change of behaviour and are therefore more readily accepted than the diverting systems, since centralised waterborne sanitation systems are the norm in all three countries. Conventional systems are known and recognised both by the general public by formal and informal institutions. High-performance dry urine-diverting sanitation can be considered a new concept in all three settings, and it has to be recognised that it takes both time and effort for mainstreaming new sanitation concepts. Both formal and informal institutional recognition can be achieved for new sanitation systems through legal and regulatory reform, the generation of knowledge around new sanitation systems, and through information, education and communication.

There is a need to underline the limitations of this kind of assessment. The selection of criteria for this report has been limited to a few examples under each heading and does not fully cover all aspects. Criteria that may be more relevant for a certain context may have been left out to simplify the comparison exercise in this example. Moreover, real data was used for the 0 alternatives only and qualitative deviations from the 0 alternative were used for the assessment of the on-site systems. It would have been desirable to make quantitative comparisons for all alternatives based on real data. However, if real data are not generated in a comparative manner using different systems tested under same conditions and context, it might be difficult to make an accurate comparison. Indeed, new sanitation systems will always suffer from a relative lack of real data compared to conventional sanitation systems.

6 CONCLUSIONS

The sustainability of sanitation systems and services can be assessed from a municipal perspective by using an integrated and comparative approach with criteria. The comparison shows that there are systems that rank high on many aspects. The comparison further describes the importance of similar system boundaries to include all sustainability aspects, as well as the affected parties—at the municipal level, at the user level, and downstream in the system.

The reports illustrated that the criteria approach could provide a tool for making informed decisions in sanitation planning and provision, including the pros and cons of various systems. An evaluation tool needs to be used, in parallel with the comparative approach shown in this report.

The three illustrative examples show that the different systems assessed have their pros and cons in their respective settings. It also shows that the assessment result is dependent on context, which is different in the three examples.

However, there are some similarities between the three examples that can be highlighted. In all three settings the dry urine-diversion systems ranked highly on environmental criteria, from discharge of nutrients and BOD to the quality of recycled product and water use. However, they also ranked lower than the 0 alternative on appropriateness to local context, due to the lack of mainstreaming of these kinds of system so far.

Full cost recovery is important for achieving financial sustainability of services. This is not achieved either in the Mexican or in the South African 0 alternatives, those being connection to wastewater treatment plants. This in itself should be a strong driver, from the municipal perspective, towards on-site systems where the cost is carried by the household. From the household perspective there are no financial incentives towards on-site systems, given the current subsidisation of centralised systems, and non-subsidisation of on-site systems.

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APPENDIX: FULL CRITERIA MATRIX FROM CSD WORK

Criterion	Indicator
Health	
Risk of infection of complete use of system	Risk assessment or qualitative
Risk of exposure to harmful substances: heavy metals, medical residues, organic compounds	Risk assessment or qualitative
Environment	
Use of natural resources, construction	
Land (investment)	m^2/pe
Energy	MJ/pe
Construction materials	Type and volume
Chemicals	Type and volume
Use of natural resources, O&M	
Land (investment)	m^2/pe/yr
Energy	MJ/pe/yr
Fresh water	m^3/pe/yr
Construction materials	Type and volume/pe/yr
Precipitation agents or other chemicals	Type and volume/pe/yr
Discharge to water bodies	
BOD / COD	g/pe/yr
Impact on eutrophication	g/pe/yr of NP
Hazardous substances: heavy metals, persistent organic compounds, antibiotics/medical residues, hormones	mg/pe/yr
Air emissions	
Contribution to global warming	kg of CO_2 equivalent/yr
Odour	Qualitative
Resources recovered (potential for approaches)	
Nutrients	% of incoming to system of NPKS
Energy	% of the consumption of the system
Organic material	% of incoming to the system
Water	% of incoming to the system
Quality of recycled products (released to soil)	
Hazardous substances: heavy metals, persistent organic compounds, antibiotics/medical residues, hormones	mg/unit
Economy	
Annual costs, including capital and maintenance costs	Cost/pe/yr
Capacity to pay – user (% of available income), municipality	Disposable income/pe
Local development	Qualitative
Socio-culture (institutional and user related)	
Willingness to pay (% of available income)	Reasonable % of income
Convenience (comfort, personal security, smell, noise, attractiveness, adapted to needs of different age, gender and income groups)	Qualitative
Institutional requirements	
Responsibility distribution	Definition of level of organisation
Current legal acceptability	Qualitative
Appropriateness to current local cultural context (acceptable to use and maintain)	Qualitative

Criterion	Indicator
System perception (complexity, compatibility, observability – including aspects of reuse)	Qualitative
Ability to address awareness and information needs	Qualitative
Technical function	
System robustness: risk of failure, effect of failure, structural stability	Qualitative
Robustness of use of system: shock loads, effects of abuse of system	Qualitative
Robustness against extreme conditions (e.g. drought, flooding, or earthquakes)	Qualitative
Possibility to use local competence for construction	Qualitative
Possibility to use local competence for O&M	Qualitative
Ease of system monitoring	Qualitative
Durability / lifetime	Yrs
Complexity of construction and O&M	Qualitative
Compatibility with existing system	Qualitative
Flexibility / adaptability (to user needs and to existing environmental conditions such as high groundwater level and geology)	Qualitative

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