Summary

Rapid urbanisation in the developing world has increased the demand for housing, infrastructure and services. In the past, efforts to improve sanitation have tended to focus on ambitious master plans requiring large investments in trunk sewerage and stormwater drainage systems. These master plans have not paid enough attention to financial and institutional constraints and have tended to ignore what sanitation users actually want and are willing and able to pay (GHK 2002, pp. 28). The limited infrastructure provided is often inadequate, thus leading to a poor, deteriorating environment (Parkinson and Taylor 2003). This is especially true in informal areas built outside a formal regulatory boundary where most poor communities live and work. “Official” facilities and services often extend only to the rich, leaving the underprivileged to provide for their own sanitation needs in a piecemeal and generally unsatisfactory manner (GHK 2002, pp. 28).

Furthermore, access to a latrine or connection to a septic tank does not necessarily indicate adequate sanitation if faecal sludge management is not ensured or if the liquid effluent flows untreated into open drains, adjacent surface water or groundwater. A system approach to environmental sanitation, which extends from the point of generation to the point of disposal/discharge or reuse – from cradle to grave – is urgently needed, both at the planning and implementation level. (Sandec News No. 8, 2007, pp. 2)

This module aims to define the main issues related to the lack of adequate sanitation in developing countries, to compare different technological approaches of sanitation management and to identify new strategies for reaching unserved communities. The main focus is placed on wastewater and excreta management, i.e. from their source to their final disposal or reuse (Figure 1). Faecal sludge management will be dealt with in a separate module. Due to rapid urbanisation and the urgent need for adequate sanitation solutions in urban areas, this module is centred mainly on urban sanitation management.

Not included in Module 4

- Industrial and hospital wastewater treatment
- Details on Faecal Sludge Management (see Module 5)
- Details on all sanitation technologies (see Sanitation Compendium Sandec 2008)
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1.1 How is “sanitation” defined and what are its objectives?

- **Sanitation** is an intervention involving behaviour and facilities aiming at interrupting the disease cycle.
- **Sanitation should provide a safe and hygienic environment.**
- **“Access to improved sanitation” is a measurable monitoring parameter based on the hygienic quality of sanitation technologies.**

There are numerous definitions of sanitation. In this document, the word sanitation alone is taken to mean the safe management of human excreta. It therefore includes both the hardware (e.g. latrines and sewers) and the software (regulation, hygiene promotion) needed to reduce faecal-oral disease transmission. It also encompasses the reuse and ultimate disposal of human excreta. (DFID 1998, pp. 4)

The term “environmental sanitation” is used to cover the wider concept of controlling all the factors in the physical environment, which may have deleterious impacts on human health and well-being. In developing countries, it normally includes drainage, solid waste management and vector control, in addition to the activities covered by the definition of sanitation. (DFID 1998, Ch. 1, pp. 4)

**Objectives of sanitation systems**

The first question is: Why do we need any sanitation facilities such as latrines, flush toilets, septic tanks etc? What conditions must be fulfilled by a sanitation system?

A sanitation system must:
- **Protect and promote health** – it should keep disease-carrying waste and insects away from people, both at the site of the toilet, in nearby homes and in the neighbouring environment.
- **Protect the environment** – avoid air, soil, water pollution, return nutrients/resources to the soil, and conserve water and energy.
- **Be simple** – the system must be operational with locally available resources (human and material). Where technical skills are limited, simple technologies should be favoured.
- **Be affordable** – total costs (including capital, operational, maintenance costs) must be within the users’ ability to pay.
- **Be culturally acceptable** – it should be adapted to local customs, beliefs and desires.
- **Work for everyone** – it should address the health needs of children, adults, men, and women.

"Access to basic" vs "access to improved" sanitation

The term “basic sanitation” includes the critical components of sanitation services: privacy, dignity, cleanliness, and a healthy environment. From a monitoring viewpoint, however, such characteristics are difficult to measure. To resolve these issues, the Joint Monitoring Program (JMP) of Unicef and WHO classifies sanitation facilities as either “improved” or “unimproved”, as shown in Table 1. (Unicef, www)

It is important to bear in mind that the question is not whether urban dwellers have access to sanitation, but whether the quality of sanitation provided is appropriate for all household members, affordable and prevents contact to human excreta and wastewater within the home and wider neighbourhood. (UN-HABITAT 2003)

**Improved technologies:**
- Connection to a public sewer
- Connection to a septic system
- Pour-flush latrine
- Simple pit latrine
- Ventilated improved pit latrine (VIP)

**Unimproved technologies:**
- Bucket latrines
- Public latrines
- Open latrines

| Table 1: Classification of improved and unimproved sanitation options. Access to adequate sanitation facilities is based on the number of inhabitants using „improved sanitation”. (JMP, www) |

**Further questions**
- What is the difference between sanitation and environmental sanitation?
- Against what environmental health threats can sanitation protect us?
- What other indicators could measure progress in global sanitation?

**Additional info**
- DFID Guidance Manual on Water Supply and Sanitation Programmes (1998); London School of Hygiene & Tropical Medicine (LSHTM) and Water, Engineering and Development Centre (WEDC), Loughborough University, UK. www.lboro.ac.uk/well/resources/Publications/guidance-manual/ (last accessed 01.04.08)
- Downloads available from the Internet and/or on the CD of Sandec’s Training Tool.
2.1 What is the current state-of-the-art of global sanitation progress?

Despite great efforts, global sanitation coverage is not increasing.

In September 2000, 189 UN Member States adopted the Millennium Development Goals (MDGs), setting clear, time-bound targets towards achieving real progress in the most pressing development needs. Meeting these targets will directly affect the lives and future prospects of billions of people around the globe. It will also set the world on a positive course at the start of the 21st century.

Goal 7 aims at ensuring environmental sustainability: halve the number of people without sustainable access to safe drinking water and basic sanitation by 2015. (WHO/UNICEF 2004, pp. 5)

Global sanitation coverage rose from 49 per cent in 1990 to 58 per cent in 2002. Still, some 2.6 billion people – half of the developing world – live without improved sanitation. Sanitation coverage in developing countries (49%) amounts to only half of that of the developed world (98%). Though major progress was made in South Asia from 1990 to 2002, little more than a third of its population is currently using improved sanitation. In sub-Saharan Africa, coverage totals a mere 36%. Over half of those without improved sanitation, i.e. almost 1.5 billion people, live in China and India. (WHO&UNICEF 2004, pp. 12)

Based on current trends, the world will miss the sanitation target by more than half a billion people. To reach the sanitation target means providing services to an additional 450,000 people a day until 2015 or almost doubling the current efforts. (WaterAid, <www>, based on UNDP 2006)

The population without coverage will need to be reduced from 2.6 billion people in 2002 to 1.9 billion in 2015, or a total decline of over 700 million people. Meeting this target and reducing rural and urban disparities means providing sanitation services to one billion new urban dwellers and almost 900 million people in rural areas where progress has been slower. (WHO&UNICEF 2004, pp. 17)

Interrupt the negative cycle
Access to water and sanitation infrastructure helps interrupt the cycle of poverty and disease. In the UK, provision of sanitation infrastructure in the 1880s contributed to a 15-year increase in life expectancy over the following four decades. (WaterAid, <www>)

Minimal water and sanitation funds
India’s military budget is eight times and Pakistan’s 47 times greater than their funds allocated to water and sanitation. Diarrhoea claims some 450,000 lives every year in India – more than in any other country – and in Pakistan 118,000 lives a year are claimed. (WaterAid, <www>, based on UNDP 2006)

Further questions
- Where has sanitation coverage increased? Are there regional differences and why?
- Can the Millennium Development Goals still be met?

Additional info

Downloads available from the Internet and/or on the CD of Sandec’s Training Tool.
2.2 Why is sanitation coverage not increasing?

- There are many factors preventing people’s access to adequate sanitation.
- Developing countries often lack political will, a supportive institutional framework, know-how, and capacity.

Inadequate institutional framework
The institutional framework in place is often monopolistic, lacks transparency, neglects the needs of the most vulnerable segments of the population, and ignores the powerful role of NGOs and the private sector (Simpson-Hébert and Wood 1998). Emerging alternatives involving greater participation of users and other stakeholders in planning and implementation of sanitation projects and, thus, broadening the institutional framework, have led to developing realistic and sustainable programmes. Adequately supported communities are capable of introducing, sustaining and expanding effective sanitation improvements.

Inadequate legislation and policy
Existing policies are often counterproductive to creating a supportive environment for sanitation (Simpson-Hébert and Wood 1998). The policies focus too much on water supply at the expense of wastewater management, and the subsidies favour centralised systems in middle and high-income communities. Although most countries have recognised the need to implement improved systems for wastewater management and have developed a basic wastewater management policy together with supporting legislation governing water-resource protection, these policies are generally not well defined and difficult to implement due to an overall lack of resources and management skills (Parkinson and Taylor 2003).

Another major issue is the illegal status of many settlements. In African, Asian and Latin American cities, between quarter and half of the populations live in informal or illegal settlements (UN-HABITAT 2003). This is of key importance for liquid waste management, since public or private sanitation providers are often not legally allowed to operate in such settlements. The risk of eviction in illegal settlements prevents the household from improving sanitation, since no household will invest its limited resources in a sanitation system if chances of eviction are high.

The Orangi Pilot Project in Karachi, Pakistan
The Orangi Pilot Project (OPP) is a good example of empowerment. With the assistance of an innovative community organis- er, Akhtar Hameed Khan, the OPP has built up local organisations capable of planning and financing their own latrines and house drains, and also exerting pressure on Karachi’s municipality to provide funds for secondary and primary sewers. The OPP has led to the provision of sanitation facilities and sewerage for over 90% of the households in Orangi – the largest squatter settlement (900,000 people) in Karachi. It is a good example of how people’s demands for improvements grow incrementally with increasing benefits after the implementation of each step. (Wright 1997)

Inappropriate financing schemes
How is sanitation financed? In the past and in numerous countries today, investments in liquid waste management programmes are financed largely by tax revenues and government borrowing. However, public funds fall far short of the required level of investment to cover the rapidly growing demand in many urban areas. The economic problems faced by most countries in Africa, Asia and Latin America have further reduced the availability of these funds. Financing investments with bilateral funds have also created many problems in the past. Tying these funds to goods and services from specific countries has often led to higher costs and to the import of unfamiliar and inappropriate technologies (UN-HABITAT 1996). Mobilisation of private capital for liquid waste management systems has always been extremely difficult, as private capital is limited and liquid waste management has to compete with sectors yielding a higher return on investments. To date, only limited amounts of private capital have been used to finance sanitation infrastructure in urban areas.

The assumption that users of sanitation facilities do not have the means to pay for the service has led to strongly subsidised unsustainable sanitation projects achieving only a minimum in-
crease in coverage. Many examples reveal that users’ willingness and readiness to pay is underestimated.

**Capacity and expertise**

The power of local governments to develop strategies and plans for urban environmental infrastructure is very often restricted by central governments (UN-HABITAT 1996). Such a situation may have been acceptable when the urban sector was rather small; however, the increasing demands of rapid urban growth make such a centralised approach less and less relevant. Experience shows that centralised approaches to liquid waste management have been particularly poor at reaching peri-urban areas (especially those that fall outside municipal boundaries) and have not been responsive to local needs and resources. (Parkinson and Taylor 2003)

**Further questions**

- What are the major stumbling blocks? What priority should they be given?
- How have some regions overcome obstacles to increasing their sanitation coverage?

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### 2.3 What principles could improve environmental sanitation?

- **The Bellagio Principles** put the individual needs in the centre of the planning process and try to involve all stakeholders.
- **The Bellagio Principles** promote decentralised solutions with a closed nutrient cycle.

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During a meeting in Bellagio, Italy, from 1–4 February 2000, an expert group brought together by the Environmental Sanitation Working Group of the Water Supply and Sanitation Collaborative Council agreed that current waste management policies and practices are abusive to human well-being, economically unaffordable and environmentally unsustainable. They therefore called for a radical overhaul of conventional policies and practices worldwide, and of the assumptions on which they are based in order to accelerate progress towards the objective of universal access to safe environmental sanitation, within a framework of water and environmental security and respect for the economic value of waste.

**The principles governing the new approach are the following:**

1. **Human dignity, quality of life and environmental security at household level** should be at the centre of the new approach, which should be responsive and accountable to the needs and demands within the local and national setting. (WSSCC/Eawag 2000, pp. 12)
   - Solutions should be tailored to the full spectrum of social, economic, health, and environmental concerns.
   - The household and community environment should be protected.
   - The economic opportunities of waste recovery and use should be harnessed.

2. **In line with good governance principles**, decision-making should involve participation of all stakeholders, especially the consumers and service providers.
   - Decision-making at all levels should be based on informed choices.
   - Incentives for provision and consumption of services and facilities should be consistent with the overall goal and objective.
   - Rights of consumers and providers should be balanced by responsibilities to the wider human community and environment.

3. **Waste should be considered a resource and its management should be holistic and form part of integrated water resources, nutrient flows and waste management processes.**
   - Inputs should be reduced so as to promote efficiency as well as water and environmental security.
   - Exports of waste should be minimised to promote efficiency and reduce the spread of pollution.
   - Wastewater should be recycled and added to the water budget.

4. **The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, community, town, district, catchment, city) and waste diluted as little as possible.**
   - Waste should be managed as close as possible to its source.
   - Water should be minimally used to transport waste.
   - Additional technologies for waste sanitisation and reuse should be developed.

**Further questions**

- What are the main differences between former sanitation models and the new approach (HCES) based on the Bellagio Principles?
- Could the Bellagio Principles also be applied to sanitation in industrialised countries?
- What does “resolve environmental problems in a minimal domain” mean?

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**Additional info**

- WSSCC/Eawag (2000); Summary Report of Bellagio Expert Consultation on Environmental Sanitation in the 21st Century. 1–4 February 2000, Water Supply and Sanitation Collaborative Council (WSSCC) and Swiss Federal Institute for Environmental Science and Technology (Eawag), Duebendorf, Switzerland. Download available on the CD of Sandec’s Training Tool and from the Internet: www.sandec.ch
2.4 What waste products are generated?

- Households produce different waste products.
- A sanitation system must deal with all products generated.

The different sanitation systems generate the following products:

**Blackwater** is the mixture of urine, faeces and flushing water along with anal cleansing water (if anal cleansing is practised) or dry cleansing material (e.g. toilet paper).

**Greywater** is used water generated through bathing, hand-washing, cooking or laundry. It is sometimes mixed or treated along with blackwater.

**Urine** is the liquid not mixed with any faeces or water.

**Brownwater** is blackwater without urine.

**Beigewater** is anal cleansing water. It is generated by those who use water rather than dry material for anal cleansing.

**Faeces** refer to (semi-) solid excrement without any urine or water.

**Excreta** is the mixture of urine and faeces not mixed with any flushing water (although small amounts of anal cleansing water may be included).

**Faecal sludge** is the general term for the undigested or partially digested slurry or solid resulting from the storage or treatment of blackwater or excreta.

**Domestic wastewater** comprises all sources of liquid household waste: blackwater and greywater. However, it generally does not include stormwater.

**Stormwater** in a community settlement is runoff from house roofs, paved areas and roads during rainfall events. It also includes water from the catchment of a stream or river upstream of a community settlement.

The generation of liquid waste from human activities is unavoidable. However, not all humans produce the same amount of liquid waste. The type and amount of liquid waste produced in households is influenced by behaviour, lifestyle and standard of living of the population as well as by the governing technical and juridical framework. (Henze and Ledin 2001, pp. 57–72)

The following section describes the different liquid waste fractions produced by the households. Industrial wastewater is not included, although it makes up an important fraction of wastewater in some environments. (Tilley 2008, pp. 2)

Further questions
- Why distinguish between so many products?
2.5 What are the main parameters used to describe wastewater?

- A series of physical, chemical and biological parameters are used to describe wastewater characteristics.
- Parameters are used for designing and monitoring sanitation systems.

Wastewater is characterised in terms of its physical, chemical and biological composition. Several relevant parameters, which are used to describe the specific wastewater characteristics, shall be briefly presented here. These parameters are useful when designing wastewater treatment facilities, monitoring performance and determining compliance with wastewater discharge standards. It should be noted that many of the physical properties and chemical or biological characteristics listed hereafter are interrelated. (Metcalf and Eddy 2003, pp. 30–81)

**Solids**
- TS  Total solids
- TSS  Total suspended solids

Suspended solids are those solids that do not pass through a 0.2-um filter. About 70 % of those solids are organic and 30 % are inorganic. The inorganic fraction is mostly sand and grit that settles to form an inorganic sludge layer. Total suspended solids comprise both settleable solids and colloidal solids. Settleable solids will settle in an Imhoff cone within one hour, while colloidal solids (which are not dissolved) will not settle in this period. Suspended solids are easily removed through settling and/or filtration. However, if untreated wastewater with a high suspended solids content is discharged into the environment, turbidity and the organic content of the solids can deplete oxygen from the receiving water body and prevent light from penetrating.

**Organic constituents**
- BOD  Biochemical oxygen demand
- COD  Chemical oxygen demand

Biodegradable organics are composed mainly of proteins, carbohydrates and fats. If discharged untreated into the environment, their biological stabilisation can lead to the depletion of natural oxygen and development of septic conditions. BOD test results can be used to assess the approximate quantity of oxygen required for biological stabilisation of the organic matter present, which in turn, can be used to determine the size of wastewater treatment facilities, to measure the efficiency of some treatment processes and to evaluate compliance with wastewater discharge permits.

**Nutrients**
- TN  Total nitrogen
- TP  Total phosphorus

Nitrogen and phosphorus, also known as nutrients or biostimulants, are essential for the growth of microorganisms, plants and animals. When discharged into the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life, which rob the water of dissolved oxygen. When discharged in excessive amounts on land, they can also lead to groundwater pollution.

**Heavy metals**

Heavy metals are usually added to wastewater by commercial and industrial activities and may have to be removed if the wastewater is to be reused. Cadmium, chromates, lead, and mercury are, for example, often present in industrial waste.

**Pathogens**
- TC (MPN) Total coliforms, most probable number
- FC (MPN) Faecal coliforms, most probable number

Communicable diseases can be transmitted by pathogenic organisms present in wastewater. The presence of specific monitoring organisms is tested to gauge plant operation and the potential for reuse.

**Acidity/Basicity**
- pH  \(-\log_{10}[H^+]\)

The concentration range suitable for the existence of most biological life is quite narrow (typically 6 to 9). Wastewater with an extreme concentration of hydrogen ions is difficult to treat biologically. If the concentration is not altered prior to discharge, the wastewater effluent may alter the concentration in natural waters, which could have negative effects on the ecosystem.

**Alkalinity**
- Ca\([HCO_3^-])_2\)  Calcium bicarbonate
- Mg\([HCO_3^-])_2\)  Magnesium bicarbonate

Alkalinity in wastewater results from the presence of calcium, magnesium, sodium, potassium, carbonates and bicarbonates, and ammonia hydroxides. Alkalinity in wastewater buffers (controls) changes in pH caused by the addition of acids. Wastewater is normally alkaline due to the presence of groundwater (which has high concentrations of naturally occurring minerals) and domestic chemicals. The alkalinity of wastewater is important where chemical and biological treatment is practised, in biological nutrient removal and where ammonia is removed by air stripping.

**Electric conductivity**
- EC  Electric conductivity

The measured EC value is used as a surrogate measure of total dissolved solids (TDS) concentration. The salinity (i.e. ‘saltiness’) of treated wastewater used for irrigation is also determined by measuring its electric conductivity.

**Temperature**

The wastewater temperature is commonly higher than that of local water supplies. Temperature has an effect on chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water.

Further questions:
- Which listed parameters can be monitored in the field or in rural areas?
- Which listed parameters need to be measured in a laboratory?
- What other parameters could be important? Where are they relevant?

Additional info:
2.6 What are the characteristics of the main “waste” products and how can they be of value?

- Greywater, urine and faeces have distinct characteristics.
- When dealing with waste products, it is important to account for their value and potential risks.

Greywater
Since greywater is a reflection of household activities, its main characteristics strongly depend on factors such as cultural habits, living standard, household demography, type of household chemicals used etc. (Morel and Diener 2006, pp. 5–8, 85, 86)

Water consumption in low-income areas with water scarcity and rudimentary forms of water supply can be as low as 20–30 litres per person and day. Greywater volumes are even lower in regions where rivers or lakes are used for personal hygiene and for washing clothes and kitchen utensils. Households in richer areas with piped water may, however, generate several hundred litres per day.

In urban and peri-urban areas of low and middle-income countries, greywater is most often discharged untreated into stormwater drains or sewers – provided they exist – from where it normally flows into aquatic systems. This practice may lead to oxygen depletion, increased turbidity, eutrophication, as well as microbial and chemical contamination of aquatic systems.

Reuse of greywater for irrigation of home gardens or agricultural land is widespread, especially in regions with water scarcity or high water prices, such as in the Middle East, parts of Africa and Latin America. Untreated greywater, though less contaminated than other wastewater sources, contains pathogens, salts, solid particles, fat, oil, and chemicals. If reuse practices are inappropriate, these substances may potentially have a negative effect on human health, soil and groundwater quality. Pathogen ingestion through consumption of raw vegetables, which have been irrigated with untreated greywater, is an important disease transmission route. Inadequate reuse of greywater can also have detrimental effects on soil. Suspended solids, colloids and surfactants can clog soil pores and change the hydro-chemical soil characteristics. Furthermore, the improper discharge of greywater can also lead to irreversible salinisation and deterioration of the topsoil, especially in arid regions with high evaporation rates.

Direct irrigation of untreated greywater is not recommended. Irrigated greywater should undergo at least primary treatment to prevent clogging and the build-up of solids. Appropriate greywater treatment systems range from very simple and low-cost disposal options (e.g. local infiltration) to complex treatment units for neighbourhoods (e.g. a series of vertical and horizontal-flow planted soil filters). Primary treatment is required to lower the risk of clogging in secondary treatment steps. Septic tank systems and simple sedimentation tanks have proven to be efficient and robust. Anaerobic filters as well as planted and unplanted aerobic filters are best suited for secondary greywater treatment.

Urine
The concentration of nutrients in the excreted urine depends on the nutrient and liquid intake, the level of personal activity and climatic conditions.

Urine, rich in nitrogen and phosphorus, can be used as fertiliser for most non-nitrogen-fixing crops after appropriate treatment to reduce potential microbial contamination. Since spinach, cauliflower and maize are crops with a high nitrogen content, they respond well to nitrogen fertilisation. The nutrients in urine are present in ionic form, and their plant availability and fertilising effect compare well with those of chemical (ammonium and urea-based) fertilisers (Kirchmann and Pettersson 1995, pp. 149–154; Johansson et al. 2001). If the nitrogen content of collected urine is unknown, a concentration of 3–7 g of nitrogen per litre at excretion can be used as a default value (Jönsson and Vinnerås 2004, pp. 623–626). On an annual basis, the amount of nitrogen produced per person equals 30–70 kg, which can satisfy the demand of one crop on 300–400 m². However, up to 3–4 times this level may be an optimal application strategy. (WHO 2006, Vol. 4, pp. 10)

Microcontaminants
Fifty to ninety per cent of the pharmaceutical drugs consumed may be excreted and discharged into waterways in their original or biologically active form. Furthermore, partially degraded drugs can be reconverted into their original active form by environmental chemical reactions. Pharmaceutical drugs, such as chemotherapeutic drugs, antibiotics, hormones, analgesics, cholesterol-lowering drugs etc., have turned up in tap water, groundwater beneath sewage treatment plants, lake water, rivers, and in drinking water aquifers. (Joseph Jenkins 1999, pp. 37)

Urine can be applied either undiluted or diluted with water, preferably just before sowing or during initial plant growth. The best fertilising effect is obtained if the urine is directly incorporated into the soil; shallow ploughing is sufficient (Rodhe et al. 2004, pp. 191–198.). Direct ploughing also minimises ammonia losses to the air. Surface application generally results in over 70% nitrogen loss due to ammonia volatilisation. Therefore, soil incorporation is very important. (Morken 1998, pp. 4–7; WHO 2006, Vol. 4, pp. 10, 11)

Environmental transmission of urine-excreted pathogens is of minor concern in temperate climates. However, faecal cross-contamination may create a health risk. In tropical climates, faecal contamination of collected urine poses the main health risk. However, some (rare) urine-excreted pathogens should also be taken into account.

In a healthy individual, urine in the bladder is sterile. Nevertheless, different types of bacteria are picked up in the urinary tract. Freshly excreted urine normally contains <10,000 bacteria per ml. In urinary tract infections, significantly higher amounts of bacteria are excreted. These are normally not transmitted to other individuals through the environment.

Most of the pathogens transmitted through urine are rare enough that they
do not pose a significant public health risk if human urine is reused in agriculture. Schistosoma haematobium presents an exception in tropical areas. However, due to its life cycle, the risk of transmission is low. (WHO 2006, Vol. 4, pp. 34, 36)

**Faeces**

From a risk perspective, exposure to untreated faeces is always considered unsafe on account of the high levels of pathogens whose prevalence is dependent on the given population. Enteric infections can be transmitted by pathogenic species of bacteria, viruses, parasitic protozoa, and helminths. (WHO 2006, Vol. 4, pp. 31)

Faecal compost can be applied as a complete phosphorus-potassium fertiliser or as a soil improver. About 40–70% of the organic matter and slightly lower nitrogen content are lost through biological activity and volatilisation. Most of the remaining nitrogen will become available to plants during degradation. The content of organic matter in faeces also increases the water-holding and ion-buffering capacity of soils, an important aspect to improving soil structure and stimulating microbial activity. (WHO 2006, Vol. 4, pp. 11,12)

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**Eutrophication**

Nitrogen is normally a soil nutrient and an agricultural resource, however, depending on the concentration and environment, it can be regarded as a pollutant. Long Island Sound (New England, USA) receives over one billion gallons of treated sewage every day; the waste of eight million people. So much nitrogen was discharged into the Sound from the treated wastewater that it caused the aquatic oxygen to disappear, rendering the marine environment unsuitable for the local fish population. (EPA, [www])

Eutrophication is frequently a result of nutrient pollution caused by the release of sewage effluent into natural waters (rivers or coasts), although it may also occur naturally in situations where nutrients accumulate (e.g. depositional environments) or where they flow into systems on an ephemeral basis (e.g. intermittent upwelling in coastal systems). Eutrophication generally promotes excessive plant growth and decay, favours certain weedy species over others and is likely to cause severe reductions in water quality. In aquatic environments, enhanced growth of choking aquatic vegetation or phytoplankton (i.e. an algal bloom) disrupts the normal functioning of the ecosystem, thus causing a variety of problems such as a lack of oxygen in the water required for the survival of fish and shellfish. The water may turn murky and and/or a shade of green, yellow, brown or red. Human society is impacted as well: eutrophication decreases the resource value of rivers, lakes and estuaries and impairs recreation, fishing, hunting, and aesthetics. Health-related problems may occur where eutrophic conditions interfere with drinking water treatment. (Bartram et al. 1999)

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**Phosphate crisis**

Phosphate is an essential component of DNA, RNA, ATP and other biologically active compounds. Microbes, plants and animals – including humans – cannot exist without phosphorus (Abelson 1999, [www]). However, the global reserves of “cheap” phosphorus will be depleted within 60–80 years at present rates of extraction. The highly skewed geographic distribution of the reserves will further complicate access and global shortages, and increased prices may become commonplace within the next few decades. Future generations will ultimately face problems in obtaining enough to survive. (Moberg 2007)

Fertilisers are currently the main consumers of mined phosphate. Growing crops remove phosphate and other soil nutrients. Even the best land loses fertility unless nutrients are replenished. There is a threefold (or greater) difference in crop yield between fertilised and unfertilised areas. Most of the world’s farms do not have or do not receive adequate amounts of phosphate. Feeding the world’s increasing population will accelerate the depletion rate of phosphate reserves. (Abelson, 1999, [www])
Further questions

- Which constituents cannot be removed from waste products by most treatment technologies? How can that problem be solved?
- Why is the volume an important parameter for describing waste products?
- Are the nutrients in faeces readily available?
- How can eutrophication of a lake be reversed?
- How can future generations meet their phosphorus demand?

Additional info

- Morel, A. and Dienes, S. (2006); Greywater Management in low and middle-income countries. Review of different treatment systems for households or neighbourhoods. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland.
- WHO (2006); WHO guidelines for the safe use of wastewater, excreta and greywater; Geneva, Switzerland: www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html (last accessed 01.04.08)

Downloads available from the Internet and/or on the CD of Sandec’s Training Tool.

---

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Greywater***</th>
<th>Urine</th>
<th>Faeces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume [l/cap·yr]</strong></td>
<td>25’000−100’000</td>
<td>25’000−100’000</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td><strong>Nutrients</strong></td>
<td>2−4 kg/cap·yr</td>
<td>5%</td>
<td>85%</td>
<td>10%</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>0.3−0.8 kg/cap·yr</td>
<td>10%**</td>
<td>60%</td>
<td>30%</td>
</tr>
<tr>
<td>Potassium</td>
<td>1.4−2.0 kg/cap·yr</td>
<td>34%</td>
<td>54%</td>
<td>12%</td>
</tr>
<tr>
<td>COD</td>
<td>30 kg/cap·yr</td>
<td>41%</td>
<td>12%</td>
<td>47%</td>
</tr>
<tr>
<td>Faecal coliforms</td>
<td>–</td>
<td>$10^2−10^5$/100ml</td>
<td>$10^2−10^3$/100ml</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Characteristic comparison for greywater, urine and faeces. (Source unknown)

<table>
<thead>
<tr>
<th></th>
<th>Greywater</th>
<th>Urine</th>
<th>Faeces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical contamination</strong></td>
<td>Fats, oils and toxic substances (org. compounds, chlorides, metals)</td>
<td>Micro-contaminants (e.g. hormones &amp; antibiotics)</td>
<td>Micro-contaminants (e.g. Heavy metals)</td>
</tr>
<tr>
<td><strong>Biological contamination</strong></td>
<td>Pathogens (bacteria, viruses, helminths, protozoa)</td>
<td>Almost sterile (i.e. cross-contamination from faeces)</td>
<td>Pathogens (bacteria, viruses, helminths, protozoa)</td>
</tr>
<tr>
<td><strong>Value</strong></td>
<td>Reuse potential (for irrigation or municipal and non-potable domestic use)</td>
<td>Nutrients (N, K and P etc.) =&gt; ideal fertilizer</td>
<td>Good soil conditioner, but only little nutrients</td>
</tr>
</tbody>
</table>

Table 3: Potential risk factors and benefits of greywater, urine and faeces.
3 – Systems and Technologies

The technologies presented in the following chapters were selected for their relevance or particular suitability in the context of developing countries. The reader should keep in mind that there are far more technology options, which cannot all be presented here. A wider selection is presented in the “Compendium of environmental sanitation systems and technologies”. (Tilley 2008)

3.1 What are the Functional Groups through which the products flow?

- A sanitation system is a combination of technologies through which the products flow.
- Technologies which perform the same, or similar function are grouped into “Functional Groups”
- Only selected combinations of technologies will lead to functional systems.

A sanitation system should consider all the products generated and all the Functional Groups these products are subjected to prior to being suitably disposed of. Domestic products mainly run through five different Functional Groups, which form together a system. Note: depending on the system, not every Functional Group is required.

User interface describes the type of toilet, pedestal, pan or urinal the user comes in contact with. User interface also determines the final composition of the product, as it is the place where water is introduced in the system. Thus, the choice of user interface is often dependent on the availability of water.

Collection and storage/treatment describes the ways of collecting and storing products generated at the user interface; storage often also performs some level of treatment.

Conveyance describes the way in which products are moved from one process to another. Although products may need to be moved in various ways to reach the required process, the longest and most important gap lies between on-site storage and (semi-) centralised treatment. For the sake of simplicity, conveyance is thus limited to moving products at this point.

(Semi-) centralised treatment refers to the treatment systems which, unlike those used on-site, are larger, require a greater inflow (that can usually not be met by just one family) and often more skilled operation.

Use and/or disposal refers to the ways in which products are ultimately returned to the soil, either as harmless substances or useful resources. Furthermore, products can also be re-introduced into the system as new products. A typical example is the use of partially treated greywater used for toilet flushing.

Technologies are the specific infrastructural configurations, methods or services designed specifically to contain, transform or transport products to another process, point of use or disposal. (Tilley 2008)

Figure 3: Main processing steps and links in a sanitation system. (Sandec Training Tool, ppt)

Further questions
- Which processes are not required in certain sanitation systems?

Additional info
  Can be ordered: info@sandec.ch
3.2 How can sanitation systems be classified?

- Sanitation systems can be mainly classified as waterless and water-based systems.
- Here we define eight technically feasible system templates, each with several alternative configurations.
- The eight system templates are mostly defined by user interface and collection technology.

Several attempts have been made to classify sanitation systems. Some classifications differentiate between earth-based and water-based treatment systems, while others characterise size and placement of the treatment unit (on-site and off-site technologies). In this document we refer to the classification presented in the "Compendium of Sanitation Systems and Technologies". (Tilley 2008)

The Compendium defines eight different system templates comprising only technologies that can be logically linked together to form an appropriate system. Most system templates have several alternative configurations with different technology options. The eight system templates range from simple (with few technological choices and products) to complex (with many technological choices and products). As shown in Table 4, four are water-based, the other four waterless. Most of the eight system templates have several alternative configurations. Selection of the most appropriate system is given later in this chapter along with a detailed description of the system templates.

### Table 4: Classification of sanitation systems as defined by Tilley (2008).

<table>
<thead>
<tr>
<th>Waterless systems</th>
<th>Water based systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1: Single Pit System</td>
<td>System 3: Pour Flush with Urine Diversion</td>
</tr>
<tr>
<td>System 2: Waterless Alternating Double Pits</td>
<td>System 5: Decentralised Blackwater Treatment</td>
</tr>
<tr>
<td>System 4: Waterless Urine Diversion</td>
<td>System 6: (Semi-) Centralised Blackwater Treatment</td>
</tr>
<tr>
<td></td>
<td>System 7: Sewerage with (semi-) Centralised Treatment</td>
</tr>
<tr>
<td></td>
<td>System 8: Sewerage with (semi-) centralized treatment</td>
</tr>
</tbody>
</table>

**Further questions**
- What other sanitation systems are available aside from the described eight system templates?
- What are the other possibilities to classify sanitation systems?
- What are the advantages and disadvantages of these system designs?

**Additional info**
- Can be ordered: info@sandec.ch
3.3 What are the major technology options for the functional group “user interface”?

This section describes the user-interactive technologies. The user interface is the way in which the sanitation system is accessed. Choice of the user interface has a great impact on the entire system design, as it defines the products or product mixtures fed into the system. Therefore, the user interface strongly influences the technological choices of subsequent processes.

Dry toilet

- Dry toilets are easy to use and can be built almost everywhere.
- Despite an available lid or cover, odours and flies can become a nuisance.

Description

A ‘dry’ toilet is a toilet that operates without water. As shown in Figure 4, the dry toilet may be a raised pedestal for users to sit on or a squat pan for users to squat over. In both cases, excreta (both urine and faeces) falls through a drop hole. The dry toilet is usually placed over a pit. If two pits are used, the pedestal or slab should be designed so that it can be lifted and moved to the next location. The slab or pedestal base should fit the pit well to ensure both safety and prevent stormwater from infiltrating the pit (which may cause it to overflow). (Tilley 2008)

Suitability

Pedestals and squatting platforms can be made locally with only concrete (provided sand, water and cement are available). Wooden or metal moulds can be used to produce several units quickly and efficiently. Fibreglass and even stainless steel versions are available but more expensive and not always available.

Health Aspects/Acceptance

Since dry toilets do not have a water seal, odours are a constant nuisance. A cover or lid can be used to limit flies from entering the dry toilet, though when the lid is removed, the trapped flies may escape: an unpleasant experience for the user. Since squatting is a natural position for many users, a well-kept squatting slab may be the most acceptable option.

Advantages

- No need for flushing water
- Can be made on site with locally available materials
- Very low cost

Disadvantages/Concerns

- Since dry toilets do not have a water seal, odours are normally noticeable even if the vault or pit used to collect excreta is equipped with a vent pipe
- The excreta pile is visible except where a very deep pit is used
- Safety concerns for children, disabled, elderly

Maintenance

The sitting or standing surface should be kept clean and dry to prevent pathogen/disease transmission and limit odours. For lack of mechanical parts, the dry toilet should not need repair except if it cracks.

Costs

Dry toilets are the least expensive toilet options as they can be made on site and require no special parts or materials. Depending on the availability of materials, costs range from about $2 for a concrete squatting platform to $30 for a polished concrete pedestal.

Figure 4: Two dry toilet models: a pedestal seat unit (left) and a squatting platform unit (right). (Left: Servant Ministries 2007, <www>; right: Carter Center 2007, <www>)
Urine diverting dry toilet (UDDT)

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A urine diverting dry toilet (UDDT) is a toilet operating without water and separating the liquid (urine) from the solid (faeces) fraction. In a UDDT toilet, urine is collected and drained from the front area of the toilet, while faeces fall through a large chute (hole) in the back of the toilet (Figure 5). It is important for the two sections of the toilet to be well separated so that a) urine does not splash down into the ‘dry’ area of the toilet and b) faeces do not fall into and clog the urine collection area in the front. As shown in Figure 5 and depending on user preference, either a pedestal or a squat slab can be built/used to separate urine from faeces. (Tilley 2008)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>The dry toilet is quite simple to design and build and can be altered to suit the needs of specific populations (i.e. small children, people who prefer to squat etc.).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health Aspects/Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>The UDDT is not intuitive or immediately obvious to all users. Users may at first be hesitant to use it, and mistakes (e.g. faeces in the urine bowl) may also deter others from accepting this type of toilet. Education and demonstration projects are essential in achieving good acceptance among users.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A UDDT is slightly more difficult to keep clean than other toilets due to its lack of water and need to separate the solid from the liquid fraction. Since it forms part of a dry system, water should not be poured down the toilet, although the seat and the inner bowls should be wiped with a damp cloth. Metals should be avoided, as they tend to rust in the presence of urine.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages/Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Its use may be difficult for some people (heavy, old and young)</td>
</tr>
<tr>
<td>Faeces can be accidentally deposited in the urine section and lead to clogging and cleaning problems</td>
</tr>
<tr>
<td>Urine pipes/fittings can become blocked with time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDDTs come in a variety of shapes and sizes. A concrete and chicken wire pedestal could be made for as little as $5–10. Plastic squatting pans can sometimes be bought for as little as $2–3. More elaborate injection moulded fibre-glass or stainless steel squat slabs can be much pricier.</td>
</tr>
</tbody>
</table>

Figure 5: Two types of urine diverting toilets. The left photo shows a pedestal type, the illustration on the right a squatting version. (Left: Morgan 2003, Zimbabwe; right: source unknown)
Pour-flush toilet

- Pour-flush toilets have a water trap which reduce fly and odour nuisance.
- No constant water supply is required. Stored water can be used for flushing instead.

Description
A pour-flush toilet is or can be a regular flush toilet except that water does not come from the cistern above but is poured by the user. If running water is unavailable or infrequent, any cistern-flush toilet can become a pour-flush toilet. As in a traditional flush toilet, a water seal prevents odours and flies from coming back up the pipe. (Tilley 2008)

Both pedestal (sitting) and squatting pans can be used in the pour-flush version (Figure 6). Pour-flush pans are in fact becoming increasingly popular and easy to obtain at low cost.

To ‘flush’ the toilet, water is poured into the bowl; about 2–3L are usually sufficient. The water and the force of water (pouring from a height often helps) must be sufficient to move the excreta up and over the curved water seal (illustration in Figure 6). The S-shape of the water seal determines how much water is needed for flushing. It may be advisable to collect toilet paper in a separate container to reduce the amount of water used.

For pour-flush bowls or pans, a 25–30° inclination is necessary towards the back of the pan connected to the water seal. Water seals should be made of plastic or ceramic to prevent clogging and facilitate cleaning. About 2 cm is the optimum depth of the water seal; otherwise more flush water is required. The trap should be about 7 cm in diameter.

Suitability
The water seal is effective against odours and appropriate for those who sit or squat (pedestal or slab) or who practice anal cleansing with water.

Health Aspects/Acceptance
Since the pour-flush toilet (or squatting pan) prevents users from seeing and smelling the excreta of previous users, it is generally well accepted. Provided the water seal is working well, the pour-flush toilet should not emit any odours and should be clean and comfortable to use.

Maintenance
Due to its limited number of mechanical parts, pour-flush toilets are quite robust and rarely require repair.

Advantages
- The water seal effectively prevents odours
- Requires no water connection (i.e. can be used with stored water, rainwater etc.)
- The excreta of one user is flushed away before the next user arrives
- Can be used by sitters, squatters and anal cleansers using water

Disadvantages/Concerns
- 2–3L of water are required per flush, as the toilet will not work without water
- Dry cleansing materials should be discarded separately to prevent clogging

Costs
A pour-flush pan costs between $2–8, whereas a conventional flush toilet (that can be operated in pour-flush mode) can cost upwards of $40. Operating costs should also take the water costs into account.

Figure 6: A pedestal toilet (photo) and a cross-section (illustration) of a squatting pan with water seal. (Left: Anderson 2001, Mexico; right: WEDC 1998)
Cistern-flush toilet (CFT)

- Cistern-flush toilets are comfortable but expensive and not always available.
- CFTs use a lot of water and thus require a regular water supply.

**Description**

The flush toilet is mass-produced and usually made of porcelain. The attractive feature of the flush toilet is that a water seal prevents odours from coming back up through the plumbing. Depending on the age of the toilet, between 8 and 25 L of water may be used per flush. Water stored in the cistern behind the toilet is released by pushing the handle for it to run into the bowl, mixing with the excreta and carrying it away (Figure 7). (Tilley 2008)

There are different ‘low-volume’ flush toilets currently available that use as little as 3 L of water per flush. In some cases, however, the volume of water used per flush is not sufficient to empty the bowl, and the user is thus forced to use more flushes to adequately clean the bowl – a fact not favouring water saving.

The flush toilet must be installed by a plumber to prevent leaks and ensure that all valves are connected and sealed properly.

**Suitability**

When purchasing a flush toilet, care should be taken that connections and hardware accessories are available in the area/country concerned. The cistern-flush toilet requires a connection to a water line and must be connected to an on-site collection or transport technology. Due to the volume of water used and sewage generated, care should be taken to ensure that the system can accommodate the water volume.

**Health Aspects/Acceptance**

It is a safe and comfortable toilet.

**Maintenance**

Although flushing water rinses the bowl, the toilet should be scrubbed clean regularly. Maintenance may be required occasionally for replacement or repair of mechanical parts or fittings.

**Costs**

A flush toilet can cost anywhere from $20–200. Depending on the location and type of toilet, water can become a significant operational cost factor.

![Figure 7: Cross-section (left) and photo (right) of a classical cistern-flush toilet design. (Left: source not know; right: Oldtub 2007)](image)

**Advantages**

- Users never see the excreta of the previous users
- The toilet is comfortable and easy to use

**Disadvantages/Concerns**

- The toilet uses a lot of water and will not function without it
- It cannot always be purchased or locally produced
- Generates a large volume of sewage to be discharged

**Further questions: technology options for the process “user interface”**

- What are the criteria for a good latrine superstructure?
- How does the user interface influence the rest of the sanitation system?

**Additional info**


**Downloads** available on the CD of Sandec’s Training Tool.
3.4 What are the major technology options for the functional group “collection and storage / treatment”?

This section describes the technologies for the collection and storage of the products generated at the user interface. In the case of extended storage, some treatment may be provided, though it is generally minimal and dependent on storage time.

Single, double and ventilated improved pits

- Lined, or unlined pits can, in some cases, be the least expensive Collection and Storage/Treatment option
- Odour and fly nuisance can be reduced by a ventilation pipe (VIP toilet).
- Double pits can be filled and emptied in a continuous cycle, removing the need to dig new pits

Description

The single pit is one of the most widely used sanitation technologies. Excreta, along with anal cleansing materials (water and/or solids) are deposited into a pit. Lining the pit prevents it from collapsing and provides support to the superstructure.

A ventilated improved pit (VIP) is similar to a single pit with addition of a vertical vent pipe. The vertical pipe is ideally at least 150 mm in diameter; alternatively a brick or ferrocement pipe can be constructed. Wind blowing across the top of the vent pipe sucks air out of the pit while fresh air flows into the pit through the squat hole. This flow of air can be increased the pipe is painted black: the air in the vent heats up, rises, and creates and updraft which helps to pull air, moisture and smells out of the pit. The top of the pipe should be covered with mesh to stop flies from entering or leaving the pit through the vent. The VIP design can be used for both single and double pits. When double pits are used, one side is used at a time. One side is used until full, the second side is then used. The material is emptied from the first pit once the second pit is full, and the cycle is started again. In this way, no new pits need to be constructed.

Health Aspects/Acceptance

Even single pits are a significant improvement over open defecation, and well-built VIPs can be more comfortable to use than some water-based systems. However, pits are not perfect and may contaminate groundwater if they are improperly located. As well, stagnant water in pits may cause insect breeding and pits may be susceptible to failure or overflowing during floods or heavy rain events.

Maintenance

There is no daily maintenance associated with a pit, however when the pit is full it must either be a) covered or b) emptied.

Costs

Depending on the soil type, the availability of labour and materials, a pit can be constructed for almost nothing (unlined) or can be quite costly (double lined VIP).

Advantages
- Flushing water is not required
- Can be made on site with locally available materials
- (Very) low cost
- Double pit latrines: since double pits are used alternately, their life is virtually unlimited
- VIP latrines: a ventilation pipe reduces odour nuisance

Disadvantages/Concerns
- Since dry toilets do not have a water seal, odours are normally noticeable even if the vault or pit used to collect excreta is equipped with a vent pipe
- The excreta pile is visible except where a very deep pit is used
- The rather large opening to the excreta pile might not suit children, the elderly, pregnant women etc.
Double dehydration vaults

- Urine and faeces are stored separately, thereby facilitating hygienisation and reuse.
- Vaults should be used with UDDTs and/or urinals

**Description**

Dehydration vaults are used to collect, store and dry (dehydrate) faeces. Faeces will only dehydrate when the vaults are water-tight to prevent external moisture from entering and when urine and anal cleansing water are diverted away from the vaults.

When urine is separated from faeces, the faeces dry quickly. In the absence of moisture, organisms cannot grow and as such, smells are minimized and pathogens are destroyed. Vaults used for drying faeces in the absence of urine have various local names. One of the most common names for this technology is the Vietnamese Double Vaults.

**Health Aspects/Acceptance**

Dehydration Vaults can be a clean, comfortable, and easy-to-use technology.

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**Pit sizing for latrines**

To size pits or tanks, it is important to determine the rate at which sludge (including faeces, urine and anal cleansing material) will accumulate, and the rate at which effluent will infiltrate in the surrounding ground. The top 0.5 m of a pit should not be filled to allow for safe backfilling and to prevent splashing, unpleasant sights and increased odour and fly nuisance.

The approximate m³ size of the pit can be calculated as a function of the following equation:

\[
V = \frac{(N \cdot S \cdot D)}{1000} \quad \text{and} \quad F = \frac{N \cdot W}{l}
\]

- **V**: Pit volume (m³)
- **N**: No. of users
- **S**: Sludge accumulation rate (litres/cap year) listed in the table below
- **D**: Pit life (years) >5 years for single pits, 1−2 years for double pits, 0.5−1 year for double pits with urine separation
- **F**: Infiltration area (m²); (water depth = F/pit circumference)
- **W**: Amount of water used for flushing (litres/cap day)
- **I**: Infiltration rates (liters/m² day)
  - Sand: 40
  - Sandy loam: 25
  - Silty loam: 20
  - Clay loam: 8
  - Clay: unsuitable

This method assumes that liquid waste is absorbed by the surrounding soil. If liquid remains in the pit it will fill far more rapidly. It should also be noted that soil pores become clogged with time, thus reducing or even stopping infiltration. Pits should therefore be oversized rather than undersized, especially where soil infiltration rates are relatively low.

Most single pits for household or family use are about 1 m wide and 3 m deep. It is difficult to excavate pits less than 0.9 m in diameter, as they do not provide enough room for a person to work. (Harvey et al. 2002, pp. 95−99)

In emergency situations (rapid accumulation), these rates should be multiplied by 150−200%.

**Table 5: List of sludge accumulation rates based on different scenarios.** (Franceys et al. 1992)

<table>
<thead>
<tr>
<th>Waste deposited and conditions</th>
<th>Sludge accumulation rate “S” (litres per capita per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste retained in wet environments where degradable anal cleaning materials are used</td>
<td>40</td>
</tr>
<tr>
<td>Waste retained in water where non-degradable anal cleaning materials are used</td>
<td>60</td>
</tr>
<tr>
<td>Waste retained in dry conditions where degradable anal cleaning materials are used</td>
<td>60</td>
</tr>
<tr>
<td>Waste retained in dry conditions where non-degradable anal cleaning materials are used</td>
<td>90</td>
</tr>
</tbody>
</table>

---

**Figure 9: Main parts of a Urine Diverting Dry Toilet.** (UNESCO-IHE 2007, <www>)
When users are well educated and understand how the technology works they may be more willing to accept it as a viable sanitation solution.

When the vaults are kept dry, there should be no problems with flies or odours. Faeces from the double vaults should be very dry and relatively safe to handle provided they were continuously covered with material and not allowed to get wet.

There is a low health risk for those who have to empty the urine container. Faeces that have been dried for over one year also pose a low health risk.

**Advantages**

- **No need for water**
- **Since faeces are relatively dry and the urine is separated, smells are minimised, though a lid should be used**
- **Can be built on site with locally available materials**

**Disadvantages/Concerns**

- **Its use may be difficult for some people (heavy, old and young)**
- **Faeces can be accidentally deposited in the urine section, causing blockages and cleaning problems**
- **Additional urinals should be provided for men**

**Maintenance**

To prevent flies, minimize odours and encourage drying, a small amount of ash, soil, or lime should be used to cover faeces after each use. Care should be taken to ensure that no water or urine gets into the Dehydration Vault. If this happens, extra soil, ash, lime, or sawdust can be added to help absorb the liquid.

Because the faeces are not actually degraded (just dried), dry cleansing materials must not be added to the Dehydration Vaults as they will not decompose. Occasionally, the mounded faeces beneath the toilet hole should be pushed to the sides of the pit for an even drying.

Where water is used for cleansing, an appropriate User Interface should be installed to divert and collect it separately.

**Costs**

Depending on the cost of materials and labour, dehydration vaults can be quite affordable to more expensive. The size and waterproofness of the vault will determine a large part of the cost.

**Twin pits for pour-flush**

- **The twin pits latrine can be operated uninterruptedly by using the pits alternatively.**
- **A water-seal requires water for flushing but reduces odour and fly nuisance.**

**Description**

This technology consists of two alternating pits connected to a pour flush toilet. The blackwater (and greywater) is collected in the pits and allowed to slowly infiltrate into the surrounding soil. With time, the solids are sufficiently dewatered and can be manually removed with a shovel.

The shelter can either cover one pit at a time or both at once. Alternatively, the pits can be built outside the shelter and connected to the user interface with short pipes. Only one pit is used at a time; a continuous cycle of alternating pits can thus be used. This is an effective solution in areas with limited space, since the pits can be used alternatively for several years. (Tilley 2008)

While one pit is being filled with excreta, anal cleansing water and/or flushing water, the other full pit is resting. At least 4L per person and day must be available to maintain the system, especially the water-seal. The pits should be designed to accommodate 1–2 years of filling. This will provide enough time for the content of the full pit to be transformed into an inoffensive, safe and soil-like material that can be excavated manually. The difference between this system and the alternating dry double pit system is that this system allows for water to be added but does not include addition of organic material. Due to these differences, the full pits require more time to degrade prior to their excavation (preferably two years).

Due to the characteristics of unsaturated soil, this technology is very effective in removing faecal organisms from sludge; however, it is not a failsafe treat-
ment option. Groundwater pollution is likely to occur with a high or variable groundwater table and/or if the bedrock is cracked. Since viruses and bacteria can travel hundreds of metres in saturated conditions and for several other complex reasons, it is difficult to estimate the distance between this sanitation technology and a water source. However, a minimum distance of 10 m should be maintained to limit exposure to chemical and biological contamination.

Also, the twin pits should be built at least 1 m apart from each other to minimise cross-contamination between the maturing pit and the one in use. Since leachate can also affect structural building support, pits should be built at least 1 m away from foundations.

Since far more water is used by this system than by a simple pit latrine, the walls have to be lined to prevent them from collapsing, and the top 30 cm should be fully mortared to keep the pit watertight and ensure support of the superstructure.

Suitability
It is a permanent system suited for areas where continuous moving of a pit latrine is not an option. As this technology is water-based, it can provide a high level of comfort with hardly any odour or other nuisances. This technology is inappropriate in areas with a high groundwater table or where flooding is common.

Health Aspects/Acceptance
A VIP latrine can be a very clean, comfortable and well accepted sanitation option, however, some health concerns exist:
- Latrine leachate can contaminate groundwater.
- Stagnant water in pits may promote insect breeding.
- Pits are susceptible to failure/overflowing during floods.
- Health risks from flies are not completely eliminated by ventilation.

Upgrading
An alternating VIP latrine can be upgraded to include a water seal if flushing or washing water is used.

Maintenance
To keep a VIP latrine fly and odour free, regular cleaning and maintenance is required. Dead flies, dust and debris should be removed from the ventilation screen to ensure a good flow of air. The slab should be kept clean and dry to prevent odours and the spread of disease.

Costs
Depending on self-help input and choice of materials, starting capital is around $90. There are no operational costs except for possible replacements of damaged structures or slabs.

Advantages
+ Generally easy to build
+ Can be constructed by community members with local materials
+ Can be designed and built to be aesthetically pleasing and prestigious
+ Depending on design (e.g. by using a squatting pan with a water-seal), odours and other nuisances can be virtually eliminated
+ Can be used with anal cleansing water and/or dry material

Disadvantages/Concerns
- Excreta requires manual removal
- Clogging is frequent when bulky cleansing materials are used

Septic tank

- Septic tanks are one of the most widespread on-site treatment units worldwide.
- Construction is relatively costly, however, the technology requires little O&M.
- Both sludge and liquid effluent need further treatment.

Description
A septic tank is a watertight storage container (concrete or fibreglass) for storage as well as for physical and chemical treatment of liquid household waste. The septic tank should have at least two chambers. In the first chamber or ‘separation chamber’, most of the solids accumulate; in the second or ‘polishing chamber’, the effluent is further clarified. Liquid flows into the tank and heavy particles sink to the bottom, while scum (oils, fats, surfactants) floats to the top. With time, the solids settling to the bottom are degraded anaerobically. The clarified liquid passes out of the septic tank through an outlet-T to prevent the discharge of scum or sludge. The effluent must then be dispersed in some way, e.g. a leaching field or soak pit (see at-
Attched documents for details on these technologies). (Tilley 2008)

Suitability
A septic tank is an appropriate option where users show a moderate willingness to pay and where land is available for the septic tank and for dispersing the effluent (leaching field/soak pit, sewer etc.). Since the septic tank must be desludged regularly, a vacuum truck should be able to access the location; otherwise, desludging will have to be conducted manually. Septic tanks should not be used in very densely populated areas, as the limited land available may not accommodate all the effluent. Larger, multi-chamber septic tanks can be designed for groups of houses and/or public buildings (i.e. schools).

Health Aspects/Acceptance
Though pathogen removal is not significant, the entire system is below the surface and users do not come into contact with any of the wastewater. Users should be extremely careful when opening the tank, as noxious and explosive gases may be released. A vacuum truck should be used to desludge the tank. However, if this is not possible, the strict safety guidelines for ‘Manual Emptying’ should be followed.

Upgrading
A septic tank connected to a leaching field or soak pit can later be connected to a small-bore sewer if one is installed.

Maintenance
Septic tanks should be checked for watertightness, and the scum and sludge levels should be monitored to ensure that the tank is functioning well. On account of the delicate ecology of the system, care should be taken not to discharge strong chemicals into the septic tank. The sludge should be removed annually to ensure proper functioning.

Costs
Depending on the material used (concrete, fiberglass) and availability of spare parts, a septic tank is not a uniformly affordable option. Desludging and potential repair are not expensive but must be performed regularly for the system to function well.

Advantages
+ The tank is underground and does not require a lot of land
+ Minimum amount of O&M
+ Some semi-skilled or unskilled community labour is required

Disadvantages/Concerns
− Professional design and layout are required
− Not all parts and materials may be available locally
− Minimum removal of organics and pathogens
− Desludging is an added expense (or can be conducted manually, though unpleasant)
− Requires water for flushing
Anaerobic baffled reactor (baffled septic tank)

- An ABR is a highly reliable and robust (semi-) centralised treatment system.
- Both sludge and liquid effluent still need further treatment.
- High investment costs can be shared between many users.
- Requires expert design and skilled construction.

Description

An anaerobic baffled reactor (ABR) is mainly a small septic tank (settling compartment) followed by a series of anaerobic tanks (at least three). Most of the solids are removed in the first and largest tank. Effluent from the first tank then flows through baffles and is forced to flow up through activated sludge in the subsequent tanks. Each chamber provides increased removal and digestion of organics: BOD may be reduced by up to 90%. Increasing the number of chambers also improves performance. (Tilley 2008)

Suitability

This is a household centred or semi-centralised technology suitable for rural communities with a transport system in place, such as a simplified sewer. Since the tank is installed underground and has a fairly small footprint, the technology is appropriate for communities with limited land. The system can be efficiently designed for a daily inflow of up to 1000 m³. A good community organisation is required to ensure that the ABR is used and maintained properly. The effluent is not fully treated and must be disposed of or sent to secondary treatment.

Health Aspects/Acceptance

Though pathogen removal is not significant, the system is contained and users do not come in contact with any of the wastewater or disease-causing pathogens. The tank should be vented to prevent the release of potentially harmful gases. A vacuum truck should be used to desludge the tank.

Maintenance

Tanks should be checked for watertightness, and the scum and sludge levels should be monitored to ensure a well functioning tank. On account of the technology’s delicate ecology, care should also be taken not to discharge strong chemicals into the ABR. The sludge should be removed annually to ensure proper functioning.

Costs

The costs vary since they are dependent on the availability of materials and economy of scale; however, they are generally lower than more mechanical, centralised technology options.

Further questions: technology options for the functional group “collection and storage/treatment”

- When can collection & storage technologies be considered treatment units?
- What are the advantages and disadvantages of dry toilets vs water-based toilets?

Advantages

+ Low cost when divided among members of a housing cluster or small community
+ Minimum operation and maintenance
+ Resistant to organic and hydraulic shock loads
+ Reliable and consistent treatment

Disadvantages/Concerns

- Requires expert design and skilled construction; partial construction work by unskilled labourers
- Requires secondary treatment and discharge

Figure 12: Cross-section of a baffled reactor. Blackwater first enters the settling compartment on the left and is forced to flow through activated sludge in the subsequent tanks. (Modified from: Sasse 1998, pp. 81)

Additional info

- UNEP/GPA – UNESCO-IHE – UN/DOALOS (2004); A training manual on wastewater, Published by Train-Sea-Coast GPA, The Hague, Netherland. www.gpa.unep.org/training (last accessed 01.04.08)
- Tilley, E. et al (2008); Compendium of Sanitation Systems and Technologies (pre-print), Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland.

Downloads available on the CD of Sandec’s Training Tool and/or from the Internet.
3.5 What are the main technology options for conveyance of waste products to (semi-)centralised treatment technologies?

If waste products cannot be safely disposed of or even suitably reused on site, they have to be transported elsewhere. Faecal sludge emptying and haulage technologies are discussed in detail in Module 5, “Faecal Sludge Management (FSM)”. This chapter focuses on wastewater conveyance.

Classically, a sewerage system transports wastewater (i.e. blackwater separated from or mixed with greywater). The principle of using gravity as the driving force for conveying wastewater in a sewerage system is applied whenever possible to minimise pumping costs. (UNEP-IETC 2002)

Sewer technologies can be classified into three major types:
- Conventional sewerage
- Simplified sewerage
- Settled sewerage

Conventional sewer

- Conventional sewers require little effort on the part of the homeowners.
- Conventional sewers require high investment costs, specialised knowledge and maintenance.

Description

Conventional gravity sewers are large networks of underground pipes conveying sewage from individual households to a central treatment facility using gravity and pumps if necessary. Gravity sewers are used for blackwater, greywater and stormwater (surface runoff). Conventional sewers do not require on-site wastewater pretreatment or storage.

Since the waste is not treated prior to discharge, the sewer must be designed to allow ‘self-cleaning’ flows, i.e. a flow of at least 0.6 m/s. Therefore, a constant downhill gradient must be kept throughout the length of the sewer, and pump stations must be installed if a downhill gradient cannot be ensured. To maintain the required hydraulic conditions, gravity sewers have to be laid deeply, e.g. between 2–3 m. This depth is also required to prevent damage from surface loading (i.e. traffic). (Tilley 2008)

Suitability

Conventional gravity sewers require extensive planning, excavation and expert design. They are expensive to build and require a well functioning management system, as installation of a sewer line is disruptive and calls for extensive coordination among property owners. Conven-

Example of an unsustainable sewer system – The case of Accra

In 1973, a full waterborne sewer system, covering 1000 ha with 28.5 km of sewers, was installed by Ghana Water Sewerage Corporation in central Accra with World Bank assistance. The system never worked well, as the narrow and winding streets and poor housing and plumbing standards predominating in central Accra hindered connection to the system. In 1997, only 6.5% of the 2000 available connections were used. (UNEP-IETC 2002)
Conventional gravity sewers are only appropriate where a centralised treatment facility is in place to receive the wastewater, and where technical expertise and financial means are available to cover operational and maintenance costs.

Health Aspects/Acceptance
For sewer users, the technology provides a very high level of hygiene. However, because the waste is conveyed to an off-site location for treatment, the ultimate health impacts are determined by the downstream treatment facility.

Advantages
- Comfortable, hands-off system with no user maintenance

Disadvantages/Concerns
- Asphalt removal, excavation, resurfacing and materials are all expensive
- Installation process is long, slow and disruptive to homeowners and traffic
- Requires detailed engineering and professional construction
- Problems with water infiltration during wet periods or in areas with high groundwater tables may compromise performance

Simplified sewers

- Simplified sewers are laid under sidewalks or in front of backyards and have less stringent design standards.
- Simplified sewers are cheaper than other sewers.

Description
Compared to conventional sewers, the term ‘simplified’ describes a sewerage system that uses smaller diameter pipes laid at a shallower depth and at a flatter gradient. Expensive manholes are replaced by simple inspection chambers. Each discharge point is connected to an inspection and/or baffle to prevent settleable solids and trash from entering the system. Another key design feature is that the sewers are laid within the property boundaries rather than beneath central roads. Since the sewers are considered more ‘communal’, they are often referred to as ‘condominial sewers’. (Tilley 2008)

Since simplified sewers are laid on or around the property of the users, higher connection rates can be achieved, fewer pipes are necessary and less excavation is required, as the pipes will not be subject to heavy traffic loads. However, this type of system requires careful negotiations between stakeholders, as design and maintenance have to be jointly coordinated.

All the greywater should be connected to the simplified sewer to ensure adequate hydraulic loading. Inspection chambers are used to attenuate peak discharges into the system. Blocks of community-based simplified sewers may be subsequently connected to an existing conventional sewer or routed to a simplified sewer main of larger diameter.

Maintenance
Manholes, installed where there is a change in gradient or alignment, are used for inspection and cleaning. In fact, sewers can be dangerous and should only be maintained by professionals.

Suitability
On rocky ground or in areas with a high groundwater table, the excavation of trenches for pipes may be difficult. Under these circumstances, the installation costs of a sewerage network are significantly higher than under favourable conditions. Nevertheless, due to its shallow installation depth, a simplified sewer is far more adequate than a conventional network.

Health Aspects/Acceptance
If constructed and maintained well, sewers are a safe and hygienic means of collecting and transporting wastewater. Users should be well instructed on the health risks associated with maintaining/cleaning blockages and inspection chambers.

Upgrading
Household inspection chambers can be upgraded to septic tanks to lower the amount of solids entering the system.

Maintenance
Cleaning blockages may become a contentious issue between neighbours, as it may require the coordination of two or more neighbours to determine the cause of the blockage. Blockages can usually be removed by forcing a rigid and strong wire throughout the length of the sewer. Inspection chambers must be emptied.
Solids-free sewers are connected to the outflow of a septic tank. Solids-free sewers rely on good solids removal in septic or interceptor tanks.

Description
A solids-free sewer is similar to a simplified sewer except that the small-diameter pipes are connected to the outflow of a septic tank. It is also referred to as solid-free sewer, small-diameter, variable-grade gravity sewer or septic tank effluent gravity sewer. (Tilley 2008)
The septic tank removes settleable particles that may clog small pipes. Due to low clogging risks, the sewers do not have to be self-cleaning, can be laid at shallow depths and can follow the topography more closely. The pipes should be at least 10 cm in diameter and should allow water to flow under gravity. They can be laid in shallow trenches and allowed to dip and curve (Figure 15).

Suitability
Solid-free sewers are well suited for areas with sensitive groundwater or where leaching fields/soak pits are inappropriate. This technology is appropriate in growing communities where there is no space for on-site infiltration. Small-bore systems should be installed in areas with a high willingness to pay and with locally available expertise and resources. Users should have well-maintained septic tanks.

Advantages
- Costs are 50–80% lower than conventional sewer systems
- May be provided to users who are often excluded from sanitation schemes
- Can be extended and adapted to community changes and growing populations
- Convenient and aesthetically pleasing
- Simplified sewers require community participation and may generate temporary employment for unskilled and skilled construction workers

Disadvantages/Concerns
- Not all parts or materials are available locally
- Planning and construction of a sewer requires skilled engineers and contractors
- Organised resource committees must be in place to ensure proper use and maintenance
- Since house connections to the collector sewers may require the laying of pipes inside the houses, the households may be inconvenienced
- A simplified sewer requires more frequent repair and removal of blockages than a conventional system

Health Aspects/Acceptance
Since the technology requires regular maintenance, it is not as passive as a conventional system. Users must assume some level of responsibility for the sewers and accept some potentially unpleasant maintenance. Since the sewer network is community-based, users will have to work with and/or coordinate maintenance activities with other users.

This technology will provide a high level of hygiene, and may offer a significant improvement over non-functioning leaching fields.

Upgrading
Solids-free sewers are good upgrading options for leaching fields that have become clogged/saturated with time. They are also good options for rapidly growing periodically to prevent solids from overflowing into the system.

Costs
The capital required is dependent on labour, resource and location costs and generally amounts to 20–50% of the costs of a conventional sewer system. Operational costs are minimal except for minor repairs and equipment to dislodge the blockages.
areas unable to accommodate more septic systems with leaching fields.

**Maintenance**
The associated septic tank must be maintained and desludged regularly to ensure optimal performance. The risk of pipe clogging is low, however, some maintenance is required periodically. Regardless of performance, the sewers should be flushed once a year.

<table>
<thead>
<tr>
<th>Item</th>
<th>Simplified</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum pipe diameter:</td>
<td>Min. 75 mm</td>
<td>Min. 120-150 mm</td>
</tr>
<tr>
<td>- House connection</td>
<td>100 mm</td>
<td>200-300 mm</td>
</tr>
<tr>
<td>- Block or street collector</td>
<td>50 mm</td>
<td>---</td>
</tr>
<tr>
<td>Gradient of collectors:</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>- For unsettled wastewater</td>
<td>Can be inflective</td>
<td></td>
</tr>
<tr>
<td>- For settled wastewater</td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Min. gradient</td>
<td>1 - 2 %</td>
<td>2 %</td>
</tr>
<tr>
<td>- House connection</td>
<td>0.6%</td>
<td>1 %</td>
</tr>
<tr>
<td>Minimum velocity</td>
<td>0.3 - 0.5 m/s</td>
<td>0.7 - 0.9 m/s</td>
</tr>
<tr>
<td>Sewer layout</td>
<td>Usually under backwards or sidewalks</td>
<td>Usually underneath street</td>
</tr>
<tr>
<td>Peak : average design flow ratio</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Minimum pipe cover</td>
<td>30 cm (no traffic load)</td>
<td>80 cm (traffic load)</td>
</tr>
</tbody>
</table>

Table 6: Characteristics of simplified and conventional sewers. (Source unknown)

**Advantages**
+ Appropriate for densely populated areas with no space for a soak pit or leaching field
+ Can handle full or partially filled flows
+ Cheaper than conventional network due to reduced pipe length, shallow excavation and lower material costs

**Disadvantages/Concerns**
- Design and planning requires experts, skilled labourers and some specialised materials

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**Further questions: technology options for conveyance of waste products to centralised treatment technologies**
- What factors influence decision to install a sewerage network in a given context?
- What are the advantages and disadvantages of sewerage networks compared to on-site sanitation?

**Additional info**
- Tiley, E. et al (2008); Compendium of Sanitation Systems and Technologies (pre-print), Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland. Can be ordered: info@sandec.ch
- Mara, D. (1996); Low-cost urban sanitation, John Wiley&Sons, Chichester, New York
- Mara, D. (1996); Low-cost urban sanitation. Whiley, Chichester, UK.
3.6 What are the main technology options for (semi-) centralised treatment?

Compared to household-centred storage technologies, these treatment technologies are designed to accommodate increased volumes of flow and provide, in most cases, improved removal of nutrients, organics and pathogens. This chapter focuses on treatment. Some of the technologies can even be used for co-treatment with faecal sludge. Two (semi-) centralised treatment technologies are presented hereafter.

### Constructed wetlands (horizontal sand filter)

- A constructed wetland is a (semi-) centralised technology for treatment of presettled wastewater.
- Constructed wetlands are very efficient but require high investment costs, space and specialised knowledge.

#### Description

A subsurface flow constructed wetland is a bed filled with gravel and planted with vegetation (Figure 16). As wastewater flows through the bed, particles are filtered out and organics are degraded by microbes. The water level is kept at 5–15 cm below the surface (subsurface flow). The bed should be wide and shallow with a wide inlet zone to distribute the flow evenly. (Tilley 2008)

The bed should be lined with an impermeable liner (clay, geotextile) to prevent leaching. Small, round, evenly sized gravel (3–32 mm in diameter) should be used to fill the bed to a depth of 0.5–1 m. Sand is also acceptable but more prone to clogging. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach and as a base for vegetation. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonise the area and degrade organics. However, most organics are degraded by facultative and anaerobic bacteria. Pathogen removal occurs by natural decay, predation and sedimentation.

Any plant with deep, wide roots capable of growing under the given conditions is appropriate. Phragmites australis (reed) is generally considered the best, as it forms horizontal rhizomes that penetrate the entire filter depth.

#### Health Aspects/Acceptance

The risk of mosquito breeding is reduced for lack of standing water. The system is generally aesthetic and can be integrated into wild areas or parks. Due to the risk of infection, contact with the waste should be avoided.

#### Maintenance

With time, the gravel will become clogged with accumulated solids and a bacterial film. The material may have to be replaced every 8–15 years. Maintenance activities should focus on ensuring that primary treatment effectively lowers organics and solids concentration before entering the wetland. Maintenance should also ensure that trees do not grow in the area, as the roots may damage the liner.

#### Costs

Compared to the free water surface wetland, the system is more expensive due to the required gravel fill; however, the cost may be reduced if the material is acquired locally. Design and construction requires skilled technical staff, though some unskilled labour is also necessary. Plants and liners may substantially add to the costs if they are unavailable locally.

#### Advantages

+ Takes up less space than a free water surface constructed wetland (FWS)
+ Requires almost no maintenance
+ Significant reduction in BOD, solids and pathogens
+ For lack of wind, solids are not resuspended and the effluent has a lower solids concentration
+ No mosquito problem as in a FWS

#### Disadvantages/Concerns

− Increased costs for gravel fill
**Waste stabilisation ponds (WSP)**

- WSPs consist in a series of ponds for centralised treatment of (even high-strength) wastewater.
- WSPs are very efficient, robust and relatively cheap, however, they require extensive space and specialised knowledge.

**Description**

Ponds are large, man-made water bodies allowing the wastewater to be treated by a naturally occurring process. Different types of ponds can be linked in series to improve treatment. There are three pond types, each with different treatment and design characteristics. (Tilley 2008)

**Anaerobic pond**

- An anaerobic pond is a fairly deep, man-made lake. The entire depth of the pond is anaerobic (i.e. deprived of oxygen). The anaerobic bacteria in the pond convert organic carbon to methane.
- Compared to aerobic ponds, anaerobic ponds are capable of treating strong wastewaters and generate little sludge.
- Anaerobic ponds should be built only to a depth of 5–10 m with a surface area allowing for 1–3 m² per person. The pond also has a relatively short retention time of up to 7 days.
- The aim is to reach a long enough retention time to obtain adequate treatment, but not too long for the liquid to ferment.

**Facultative pond**

- A facultative pond is a man-made, medium-deep lake. It is the most versatile and common of the ponds.
- Due to its depth, both aerobic and anaerobic processes occur. The top layer receives oxygen from natural diffusion and photosynthesis. Depending on wind mixing, the lower layer becomes anoxic or anaerobic. Settleable solids accumulate and are digested at the bottom of the pond.
- It is important to maintain a low enough load with a long enough retention time to ensure aerobic conditions on the surface. The different aerobic and anaerobic organisms work together to attain BOD reductions of up to 75%.
- The pond should only be 1.5–2.5 m deep with a surface area allowing for 2–4 m² per person.

**Maturation (aerobic) pond**

- A maturation (aerobic) pond is a man-made shallow lake primarily designed for faecal bacterial removal.
- The pond should only be 0.3–0.6 m deep with a surface area allowing for 3–7 m² per person. The pond also has a relatively short retention time.
- To prevent leaching, all the ponds should be fully lined. The liner can be clay, asphalt, compacted earth etc. The excavated fill can be used as a berm around the pond to protect it from runoff, erosion etc.
- Dissolved oxygen in both facultative and maturation ponds is provided by natural wind mixing and photosynthetic algae releasing oxygen into the water. Aerobic organisms degrade the organic matter in the wastewater.
- To allow sunlight to penetrate the depth of aerobic ponds (for algal growth), they must be kept shallow. Because photosynthesis is driven by sunlight, the dissolved oxygen levels are highest during the day and drop off at night.
System setup
Typically, anaerobic ponds come first in a series of ponds. They are used as a pre-treatment stage to reduce solids content and BOD. Effluent is then transferred to a facultative pond, where further BOD is removed. Any number of aerobic or maturation ponds may then follow to obtain a highly polished effluent.

Use of macrophytes and fish culture
WSPs can be integrated with reuse technologies for the production of plants (e.g. duckweed and water hyacinth). These plants proliferate in nitrogen-rich environments. Removal of the plant's biomass stimulates plant growth and contributes to the removal of nutrients from the wastewater. These technologies, called floating macrophyte ponds, may also be combined with fish farming (Photo 3). Typical macrophyte ponds have a potential of 10−40 tons dry biomass production per ha and year in tropical climates (Polprasert 1996). Some examples of integrated systems of duckweed-based wastewater treatment and fish aquaculture are known to recover all treatment costs and sometimes even be profitable. (v. d. Steen and Gijzen 2003, pp. 14)

Suitability
Ponds are among the most common and efficient methods of wastewater treatment in both developed and developing countries. They are especially appropriate for rural communities with inexpensive, ample space away from homes and public land. Due to the absence of industry in rural areas, there is less risk of a nutrient overload than in urban centres. (Tilley 2008)

Health Aspects/Acceptance
Since the pond is a large body of pathogenic wastewater, care should be taken not to come into contact with the water. Even discharged effluents pose a hazard and should be treated accordingly.

Upgrading
Ideally, several aerobic ponds should be built in series to provide a high treatment level. A final aquaculture pond can be used to generate income and a locally grown food source.

Maintenance
It is important to ensure that the pond is not used as a garbage dump. A fence should thus be installed to keep out people and animals. The pond must be desludged once every 10−20 years. Since rodents may invade the berm and cause damage to the liner, the water level can be periodically raised to keep pests away.

Costs
The very low capital costs include mainly excavation and payment of technical experts. A good quality liner will, however, also increase costs. Depending on the organic loading rates, operating costs are rather low as desludging is performed every 10−20 years.

Advantages
- A well-designed series of ponds can treat high-strength wastewater and achieve extremely high quality effluents
- Generally reliable and well functioning
- Very inexpensive compared to other centralised options
- Construction can provide short-term employment to unskilled labourers
- Virtually no operation or maintenance

Disadvantages/Concerns
- Not always appropriate in colder climates
- Possibly bad odours if poorly designed
- Requires expert design and supervision
- Requires a lot of space

Further questions: technology options for off-site wastewater treatment
- What other wastewater treatment technologies can be used for the co-treatment of faecal sludge?
- Under what conditions would it make more sense to build a constructed wetland rather than a WSP or vice versa?

Cost recovery via wastewater-grown, duckweed-based fish aquaculture in Bangladesh
Since 1989, the NGO PRISM has been involved in duckweed-based wastewater treatment. In 1993, a full-scale system for wastewater treatment and duckweed-based fish culture was installed at Kumudini Hospital complex in Mirzapur. The treatment unit shows very high treatment efficiencies (BOD 96 %, NH4+ 99 % and Ptot 75 %), yielding a high quality effluent. The duckweed is harvested regularly and used as fish feed in an adjacent fish farm. Revenues generated by the fish farm are used to recover the wastewater treatment costs and sometimes even yield a profit (v. d. Steen and Gijzen 2003, pp. 14.)

Additional info
- Tilley, E. et al (2008); Compendium of Sanitation Systems and Technologies (pre-print), Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland.
  Can be ordered: info@sandec.ch
3.7 How can wastewater be safely disposed?

Two technology options, i.e. leach fields and soak pits, are used for the safe disposal of solid-free wastewater (mainly greywater or effluent from septic tanks). Both technologies are based on infiltrating wastewater into the ground and using sand, gravel or the natural soil as filter substrate.

Leach fields

- A leach field consists of a series of trenches used to disperse solid-free wastewater.
- It requires some specialised parts and construction knowledge but hardly any maintenance.

Description

A leach or drainage field comprises a series of trenches used to disperse the effluent from a septic tank or other on-site technology. The effluent feeds into a distribution that directs the flow into several parallel channels. Each channel is composed of a trench 0.3–1.5m deep and 0.3–1m wide. The bottom of each trench is filled with about 15cm clean rock over which a perforated distribution pipe is laid. Additional rock material covers and completely surrounds the pipe. A layer of fabric (to prevent small particles from clogging the pipe) is placed on top of the layer of rock. The pipe should be laid at a minimum depth of 15cm from the surface to prevent effluent from surfacing and to facilitate oxygen transfer into the leaching area. The trenches should not exceed 20m in length and should be positioned at least 1–2m apart from each other.

Suitability

The system is appropriate for spacious areas devoid of fast growing trees (otherwise plant roots will encroach upon and damage the leaching field). Good, porous soil is required to effectively disperse the effluent. To avoid contamination, a leach field should be located at least 20m from a water supply.

Health Aspects/Acceptance

Since the technology is located underground and requires virtually no maintenance, it poses little health risks, as users will rarely come into contact with the effluent. The leach field must be kept as far away as possible from any potential water source to prevent contamination.

Upgrading

A leach field should be laid out in such a way as not to interfere with a future sewer connection. Space and pipe connections should be planned prior to installation of the leach field to facilitate a changeover if a sewer connection is implemented at a later date.

Maintenance

A leach field becomes clogged with time, however, with a well-functioning septic tank (i.e. pre-treatment), this should take many years to occur. A leaching field should require no maintenance; nevertheless, if the system stops working efficiently, the pipes should be removed and replaced. To maintain the leaching field in good working condition, the immediate area should be devoid of plants, trees or heavy traffic, which could crush the pipes or compact the soil.
Soak pit

A soak pit is a simple technology which allows liquid to infiltrate the soil.

Description
A soak pit, also known as soakaway or leaching pit, is a covered, porous-walled chamber allowing water to slowly soak into the ground. Effluent from the septic tank is discharged into the underground chamber where it slowly infiltrates into the surrounding soil. As the water percolates through the soil, small particles are filtered out and nutrients are digested by microorganisms in the soil. Thus, soak pits are best suited for soils with good absorptive properties. Clay, hard packed or rocky soils are inappropriate for soak pits. (Tilley 2008)

The soak pit can either be left empty, lined with a porous material or filled with coarse rocks and gravel. In both cases, a layer of sand and fine gravel should be spread across the bottom to help distribute the flow. The soak pit should be between 1.5 and 4 m deep, but never less than 1.5 m above the groundwater table.

Suitability
A soak pit should be used to receive treated effluent from a septic tank, aqua privy, anaerobic filter etc. A soak pit is inadequate for treating raw wastewater as it will quickly clog. However, a soak pit is adequate to receive greywater (water from bathing and cooking) as long as it is settled and filtered. Soak pits are simple to construct and require no specialised knowledge or materials.

Health Aspects/Acceptance
As long as the soak pit is not used for raw sewage and the septic tank is functioning well, health concerns are minimal. Since the system is located underground, humans and animals will have no contact with the effluent. It is very important, however, that the soak pit is located as far away as possible from groundwater sources (at least 15 m). As the soak pit is out of sight, it should be accepted even by the most sensitive communities.

Maintenance
The life of a well-sized soak pit ranges between 3 to 5 years without maintenance. To extend its life, care should be taken to ensure that the effluent has been clarified and/or filtered well to prevent excessive build up of solids. The soak pit should also be kept away from heavy-traffic areas not to compact the soil above and around. As soon as performance of the soak pit drops, the material in the soak pit can be excavated and refilled. To allow future access for maintenance, a removable (preferably concrete) lid should be used to seal the pit.

Advantages

+ Low-cost option, which can be built by families and communities with locally available materials
+ Requires little space
+ Does not require regular maintenance as it is virtually hands-off

Disadvantages/Concerns

− Particles and biological activity will eventually clog the system, which will have to be cleaned or moved
− Inappropriate where the groundwater table is high

Further questions: safe disposal of wastewater

► Can leaching fields and soak pits be installed in urban areas? What are the limits and potential risks?

Additional info

► Tilley, E. et al (2008); Compendium of Sanitation Systems and Technologies (pre-print). Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland.
Can be ordered: info@sandec.ch
3.8 How can the different waste products be reused safely?

- Waste products can be reused in agriculture, aquaculture and biogas plants.
- All waste products can be reused if safety guidelines are met.
- Waste recycling is practised successfully in many countries.

The different waste products can either be disposed of (without benefit) or reused for their nutrient content. In either case, it is important not to endanger public health or pollute the natural environment.

Priority should always be given to the beneficial reuse of waste products. Organic waste recycling aims at reducing pathogen content and reclaiming valuable substances for possible reuse. Valuable nutrients include carbon (C), nitrogen (N), phosphorus (P), and other trace elements. Three main organic waste reuse methods are available.

Agricultural reuse

Organic waste can be applied to crops as fertilizer or soil conditioner. However, direct application of raw waste containing organic forms of nutrients may not yield good results, as crops normally take up the inorganic forms of nutrients such as nitrates and phosphates. Bacterial activities can be used to break down complex organic compounds into simple organic and inorganic compounds. Composting and aerobic or anaerobic digestion are examples where organic waste is stabilised and converted into products suitable for agricultural reuse. Use of untreated waste is undesirable from a public health viewpoint. (Polprasert et al. 2001, Ch. 1, pp. 5)

Wastewaters can be used to irrigate agricultural fields, although appropriate precautions should be taken. However, to reduce crop contamination and the health risk to workers, only waters subject to secondary treatment (i.e. physical and biological treatment) should be used. Wastewater irrigation supplies water to plants through channels or pipes which may normally be used to supply freshwater or rainwater.

Two types of irrigation systems are suitable for effluent reuse from wastewater systems:

1. Drip irrigation allows the water to slowly drip on or near the root area.
2. Surface water irrigation routes the water overland in a series of dug channels or furrows.

To minimise evaporation and contact with pathogens, drip irrigation is usually the most effective option. Surface irrigation is prone to large losses from evaporation. However, it requires little or no infrastructure and may be appropriate in some situations.

Crops, such as corn, alfalfa (and other feed) fibres (cotton), trees, tobacco, fruit trees (mangoes), and foods requiring processing (sugar beet) can generally be grown safely with treated effluent. More care should be taken when growing fruit and vegetables eaten raw (e.g. tomatoes). Despite safety concerns, irrigation with effluent is an effective way of recycling nutrients and water.

Reuse in Aquaculture

In hot climates, there are three main types of aquacultural reuse methods of organic waste, i.e. production of micro-algae, aquatic macrophytes, and fish. Micro-algal production normally uses wastewater in high-rate photosynthetic ponds. The although the algal cells produced during wastewater treatment contain about 50 per cent protein but are small (generally less than 10 μm) and may be difficult to harvest. Aquatic macrophytes, such as duckweeds, water lettuce or water hyacinth grow well in polluted waters. They can be used as animal feed or as compost fertiliser. (Polprasert et al. 2001, Ch. 1, pp. 6)

In fish culture, there are basically three organic waste reuse techniques, i.e. fertilisation of fishponds with human or animal manure, rearing fish in effluent-fertilised fishponds or rearing fish directly in waste stabilisation ponds. Fish farming is considered to have a great potential in developing countries, as fish can be easily harvested and has a high market value. However, to safeguard public health in those countries where fish is raised on waste, it is essential to maintain good hygiene practices at all stages of fish handling and processing, and to ensure that fish is consumed only well cooked.

Advantages of agricultural reuse

- Great potential for income generation
- Potential to improve health and self-reliance of communities
- Reduces depletion of groundwater and improves availability of drinking water
- Drip irrigation is especially suited in arid and drought-prone areas
- Reduced need of fertilisers

Disadvantages/Concerns of agricultural reuse

- Effluent must be well settled to avoid clogging, as system prone to blockages
- Application rate must be adapted to the type of soil, crop, climate etc., otherwise it could be damaging
- Design and installation may require technical know-how

Biogas production

Biogas, a byproduct of anaerobic decomposition of organic matter, is regarded as an alternative source of energy. The biogas consists mainly of methane (65%), carbon dioxide (30%) and trace amounts of ammonia, hydrogen sulphide, and other gases. (Polprasert et al. 2001, Ch. 1, pp. 5, 6)

The biogas, produced by small-scale biogas digesters in individual households or farms, is usually used for household cooking, heating and lighting. In large wastewater treatment plants, biogas is generated by the anaerobic digestion of sludge and is often used as fuel for boilers and internal combustion engines.

Reuse guidelines and recommendations

Clearly, different standards and treatment parameters should be applied if treated waste is used in agriculture or discharged into the environment. Hygiene-related variables (helminth eggs in biosolids and faecal coliforms in wastewater) and nitrogen are the relevant reuse criteria. Variables such as COD, BOD and NH4 are of prime importance if treated waste is discharged. (Montangero and Strauss 2002, pp. 5)
Table 7 lists reuse options for different waste products and recommends guidelines for their safe reuse. However, the formulation of numerical guidelines is highly controversial, since in most economically less advanced countries, the treatment required to comply with such standards is not sustainable, and the stringent standards epidemiologically unjustified. Nonetheless, numerical quality values can be used to define process specifications, however, they do not have to be regularly monitored once the processes are in place. (Montangero and Strauss 2002, pp. 7)

Regulations and guidelines are increasingly based on the risk concept. By applying quantitative microbial risk assessments (QMRAs), based partly on predictions and assumptions, sanitation systems can be evaluated and compared with established limits for acceptable risks. QMRAs are used to determine the degree of pathogen reduction required to obtain the admissible additional disease burden of ≤10–6 DALY per person per year. Thus, the parameters in the new WHO guidelines are given in "log10 pathogen reduction needed". For further information, consult the WHO guidelines for the safe reuse of wastewater, excreta and greywater. (WHO 2006, Vol. 4, pp. 59)

Recommendations for agricultural reuse of urine:
- For vegetables, fruit and root crops consumed raw, a one-month storage period should always be observed.
- In areas where Schistosoma haematobium is endemic, urine should not be used near freshwater bodies.
- Direct use after collection or a short storage time is acceptable at the single household level.
- For larger systems, urine should be stored for some time and under the conditions given in the previous table.
- In the event of frequent faecal cross-contamination, further, more stringent recommendations may be applied at local level.
- When applying urine, precautions should be taken when handling potentially infectious material. These precautions could, inter alia, include the wearing of gloves and thorough handwashing.
- Urine should be applied using close-to-the-ground fertilising techniques that hinder aerosol formation.

Recommendations for agricultural wastewater reuse:
- Use of drip irrigation can significantly reduce contamination of root crops and leafy vegetables growing just above ground, especially crops not in contact with the soil (e.g. tomatoes).
- Use of spray irrigation systems can also reduce crop contamination. However, a buffer zone of 50–100 m to residents should be maintained.
- An increase in the period between irrigation and consumption will reduce crop contamination (0.5–2 log units/d).
- Washing, disinfecting, peeling, and cooking of fruit, crops or vegetables effectively reduce the health risk to consumers. (WHO 2006, Vol. 2, pp. 63)

Recommendations for wastewater reuse in aquaculture:
- Using protective equipment, such as gloves and boots.
- Limiting access to waste-fed aquacultural facilities.

Recommendations for agricultural greywater reuse:
- Direct reuse of untreated greywater in irrigation is not recommended. Irrigated greywater should undergo at least primary treatment (e.g. septic tank).
- Irrigated soil can act as a natural secondary treatment step. (Morel and Diener 2006, pp. 85, 86)

Recommendations for agricultural excreta reuse:
- Excreta and faecal sludge should be treated prior to their use as fertiliser, and the treatment methods should be validated.
- Equipment used for example when transporting unsanitised faeces should not be used for the treated (sanitised) product.
- Precautions with the handling of potentially infectious material should be taken when applying faeces to the soil. These precautions include personal protection, hygiene and handwashing.

<table>
<thead>
<tr>
<th>Waste product</th>
<th>Reuse Application</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine1</td>
<td>Irrigation of food and fodder crops to be processed</td>
<td>≤1 month storage (4°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥10−6 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td></td>
<td>Irrigation of food and fodder crops to be processed, fodder crops unprocessed</td>
<td>≤10−10 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td></td>
<td>Irrigation of all crops</td>
<td>≥10−10 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td>Treated wastewater2,3</td>
<td>Unrestricted irrigation</td>
<td>≤10−10 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td></td>
<td>Restricted irrigation</td>
<td>&lt;10−4 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td>Greywater2,3</td>
<td>Unrestricted irrigation</td>
<td>&lt;10−4 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td></td>
<td>Restricted irrigation</td>
<td>&lt;10−4 EC/100 ml &lt;1 helminth eggs/l</td>
</tr>
<tr>
<td>Excreta (untreated FS)</td>
<td>Agriculture (soil conditioner)</td>
<td>≤10 EC/g total solids helminth eggs/g total solids</td>
</tr>
<tr>
<td></td>
<td>Aquaculture4,5</td>
<td>≤10−6 EC/100 ml ≤1 helminth eggs/l No detectable trematode eggs</td>
</tr>
</tbody>
</table>

Table 7: Numerical guidelines for agricultural or aquacultural waste reuse. (WHO 2006, 1.) Vol. 4, pp. 70; 2.) Vol. 2, pp. 60, 70; 3.) Vol. 4, pp. 63; 4.) Vol. 3, p. 41)
• Treated excreta and faecal sludge should be worked into the soil as soon as possible and not left on the soil surface.
• Inappropriately sanitised excreta or faecal sludge should not be used for vegetables, fruit or root crops consumed raw, except for fruit trees.
• A storage period of at least one month should be applied for treated excreta and faecal sludge. (WHO 2006, Vol. 4, pp. 67)

Feasibility and social acceptance of waste recycling
Feasibility of a waste recycling scheme depends not only on technical aspects but also on social, cultural, public health, and institutional considerations. Although waste recycling has been practised successfully in many countries (both developed and developing), a large number of people still do not understand or are not aware of the benefits gained by such waste recycling schemes. Waste recycling should not only aim at producing food or energy; the cost-effectiveness of a waste recycling scheme, such as the unquantifiable benefits gained from pollution control and public health improvement, should also be taken into consideration.

Since the success of any programme is greatly dependent on public acceptance, the communities and people concerned should be made aware of the implemented waste recycling programmes, including their processes, benefits and drawbacks. So far, assessments of public acceptance of waste reuse schemes have rarely been conducted in developing countries.

Institutional support and cooperation from various government agencies in promoting, training and maintenance/monitoring of waste recycling schemes are also essential for their successful implementation. (Polprasert et al. 2001, Ch. 1, pp. 13)

Further questions
• How can the actual population risk of wastewater reuse be calculated?
• What are the pros and cons of numeric vs risk-based guidelines?
• What governmental steps should be taken to minimise the risk of waste reuse and increase its profits?

Additional info
• WHO (2006); WHO guidelines for the safe use of wastewater, excreta and greywater; Geneva, Switzerland. Download available on the Sandec Training Tool CD and from the Internet (last accessed 04.04.08): www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

### 3.9 How to proceed when designing a sanitation system?

- A sanitation system has to manage all the waste products generated.
- Waste products should be processed from “from cradle to grave”.
- Appropriate systems and technologies have to be identified based on technical, social, economic, and resource aspects.
- The most site-specific system option has to be selected on a case-to-case basis.

A detailed description of how to plan a sanitation programme is provided in Module 7 of this Training tool “Planning of Sanitation Systems”. The present chapter focuses only on the actual selection of the most appropriate system and technologies based on local needs, demands and habits. Furthermore, the sanitation system should be designed using the existing infrastructure.

A system is a set of technologies, each processing the products until they are ultimately disposed of. In other words, processing all the waste products “from cradle to grave” should be considered. Here, eight different treatment systems are defined, each of which contains multiple technologies that can be linked to form an effective system.

Though the system templates (i.e. groups of processes and products) are...
Further questions

How can stormwater management be integrated into the systems presented here?

Who should choose the technology options and based on what criteria?

Additional info


3.10 Presentation and discussion of system examples

As illustrative introduction to the use of the Compendium, the following three sanitation systems are presented and discussed. (Tilley 2008)

Example 1: Waterless system with urine diversion

The user interface(s) in this system generate(s) two different products: faeces and urine. Thus, each product must be treated separately with its own appropriate technologies and processes.

Faeces are stored in a double dehydration vault where they dehydrate. In the absence of moisture, organisms cannot grow and, thus, smells are minimised and pathogens destroyed. By using two vaults, the faeces are allowed to dehydrate and become sanitised, while allowing the system to remain in use.

Urine can either be collected in a bucket for later discharge on the ground or a garden, or it is stored in a tank for future transport. It is generally accepted that if urine is stored for at least one month, it will be safe for agricultural reuse.

Since a sanitation system must deal with all the generated waste products, an adequate reuse solution must also be found for greywater – an often forgotten resource. Greywater should not be added to the double dehydration vault where the faeces are being dried, nor should it be added to urine. In most cases, it is conveyed by drains or sewers and finally treated centrally, although many technologies exist for the beneficial use of greywater at the household level.

For both urine and faeces there is no technology option required at the ‘Treatment’ process step: the arrows indicate that after ‘Conveyance’, ‘Reuse and Disposal’ is the next process step required.

In this system, the different processing steps do not offer any technology choices. If the Compendium user does not like the technology options associated with this system, he/she should select a different system, since it is not possible to substitute or rearrange the technology options in a given system.

Although greywater and stormwater management forms an essential part of sanitation, this document is primarily concerned with systems and technologies related directly to excreta. A more detailed and holistic approach is described in the Compendium compiled by Tilley (2008). Refer to Morel and Diener (2006) for a more comprehensive summary dedicated to greywater technologies.

Since a sanitation system must deal with all the generated waste products, an adequate reuse solution must also be found for greywater – an often forgotten resource.
Example 2: Water-based, alternating double pit

When the Pour-Flush toilet (or pan) is connected to double pits, the blackwater generated is stored and treated onsite—there is no need to convey the blackwater to a semi-centralised treatment technology.

While one pit is being filled, the other full pit is resting. The water leaches into and is absorbed by the surrounding soil. Within 1–2 years, the blackwater is transformed into an inoffensive, safe, soil-like material that can be excavated manually.

As this material can be added locally to compost heaps, conveyance and central treatment processes are not necessary and, therefore, not displayed in the graphic. Three to four months of composting are usually sufficient to produce compost safe for handling. However, 12 months are recommended to produce an entirely safe product.

Depending on its volume, greywater can be added to the double pit system where it infiltrates in the soil. If not disposed of locally, greywater must be conveyed and treated centrally.

Example 3: (Semi-) centralised blackwater treatment system

This system is characterized by the use of a water-based user interfaces: the pour-flush or the cistern-flush toilet. In either case, blackwater is produced a collection and storage/treatment technology is used to remove solids and partially treat the effluent.

The effluent wastewater is then conveyed either by a solids-free or a simplified sewer to a (semi-) centralised treatment technology. The faecal sludge that is generated should be treated in an appropriate technology like a planted drying bed.

Treated faecal sludge can be reused as soil conditioner in agriculture, applied to fields or disposed of where appropriate.

Greywater should be added to the sewer system to improve flow, although where there is a need for recycled water it may be treated and re-used onsite.

This example shows how one feasible system configuration can offer a large variety of technology combinations, which must be evaluated on a case-to-case basis in order to select the most appropriate. When selecting the most adequate system, technical, physical, economical, institutional, and socio-cultural criteria should also be considered (Chapter 4).
3.11 What immediate sanitation measures should be taken in case of emergency?

- In emergency situations, immediate sanitation measures and technologies are available that would otherwise not be recommended in normal situations.
- The technologies and service coverage is then improved incrementally step by step.

Where indiscriminate open defecation is practised, the first step in excreta disposal is to provide designated defecation sites and remove the scattered faeces. This is an unpleasant task and, in some cultures, it may be especially difficult to find willing and suitable personnel. However, it is essential to minimise the spread of faecal-oral disease. Faeces can be covered with lime and should be removed to a safe disposal site such as a pit. Workers must be provided with appropriate tools and protective clothing (Harvey et al. 2002, pp. 63). The population must be discouraged from defecating in or close to streams, ponds, any other water source or on cultivated fields.

Structures dealing with excreta will have to be provided. Since it is generally not possible to construct adequate structures in sufficient numbers straight away, the situation has to be improved gradually. (Harvey et al. 2002, pp. 66)

实施的卫生结构（按低优先级（易于安装）到高优先级（更难安装）的顺序）：
- 开放式排便场
- 坑式或井式公厕
- 集体式坑式公厕
- 集体式或井式公共厕所
- 家庭式坑式公厕

Open defecation field

In the initial stages of an emergency, areas where people can defecate, rather than where they cannot, should be provided straight away. These should be located where excreta cannot contaminate the food chain or water sources. Open areas or fields surrounded by screens may be set up with segregated sites for each gender. The population should be encouraged to use one strip of land at a time, and the areas must be clearly marked. Internal partitions can also provide more privacy and encourage greater use.

图25：开放式排便场的图形说明，仅以条带状并按性别分开。 (Harvey et al. 2002, pp. 64)
Shallow trench latrines

Open defecation fields can be easily improved by providing shallow trenches for people to defecate. This allows users to cover faeces, improves the overall hygiene and enhances convenience of an open defecation system. Trenches need only be 20–30 cm wide and 15 cm deep. Shovels may be provided to allow each user to cover the excreta with soil.

Advantages

- Implemented rapidly
- Faeces can be covered easily with soil

Disadvantages/Concerns

- Limited privacy
- Short life-span
- Considerable space required

Figure 26: Graphic illustration of field with shallow trench latrines. (Harvey et al. 2002, pp. 65)

Bucket/Container latrines

In areas with limited space, buckets or containers may be provided for people to defecate. These should have tight-fitting lids and should be emptied at least daily. Disinfectant may be added to reduce contamination risk and odour. Containers can be emptied into a sewerage system, a landfill site or waste stabilisation ponds. Since this measure is only appropriate where no other immediate sanitation options are available, and where users find the method acceptable, its use is not widespread. (Rottie and Ince 2003, pp. 271)

Advantages

- Containers are readily available and transported
- Can be used in flooded areas

Disadvantages/Concerns

- Disposal system has to be constructed
- Many users reject the method
- Large quantity of containers and disinfectant
- Extensive training on final disposal
- Containers may be used for alternative purposes

Figure 27: Graphic illustration of a simple construction with bucket latrines. (Source unknown)

Upgrading emergency sanitation infrastructure

The structures will gradually have to be improved from e.g. a defecation field to communal pit latrines and finally to household pit latrines. Initially, one latrine or one meter of trench per 50–100 users must be installed. However, this system must be improved to one latrine per 20 users as soon as possible. When installing emergency sanitation structures, the following points should be considered:

- In communal structures, cleaning and maintenance staff must be employed.
- In communal structures, gender separation and the issue of safety to women must be addressed.
- Public latrines must be installed in public places.
- All structures require a water source for hand-washing, anal cleansing, cleaning of the structure, and flushing.
- The latrines should be technically sound and acceptable to all users.
- Latrines should, if possible, not be further away than 50 meters from the dwellings, and the water sources used for drinking should not endanger sanitation structures.
- Anal cleansing material should be supplied. In defecation fields, soil to cover faeces may have to be provided.

Further questions

- What are the particular challenges of sanitation projects in disaster areas?
- What are the likely technology options for sanitation infrastructure in flooded areas?

Additional info

  Can be ordered: info@sandec.ch
4.1 What technical and physical criteria are required when designing a sanitation system?

Space is a key criterion in the selection of both storage and treatment technologies. Availability of water may influence the choice of off-site or rather on-site technologies.

**Availability of space**
In urban areas, small plot size is frequently given as a reason for discounting the use of pit latrines. The evidence shows, however, that in most low-income housing areas this is not a valid reason. A pit latrine requires little more than one square meter of land, and even the most densely populated areas usually have that much land available on the plot outside the house. If the property has sufficient land to construct a toilet room, then it has enough room for a pit latrine, as the pit is constructed beneath the toilet.

In many parts of Asia, pour-flush latrines are constructed with the pit right outside the property. The toilet is located adjacent to the boundary wall and connected to a pit or pits built under the footpath immediately outside. Constructing a pit latrine inside the house is not always recommended, however, there are examples of well-functioning indoor pit latrines; in Lamu (Kenya) they have been in use for hundreds of years. Pour-flush latrines are particularly suitable to meet the demand for low-cost indoor latrines, and can even be implemented in multi-storey buildings.

In rural areas, the emptying of a pit latrine is not necessary. Sufficient land is usually available for construction of a new pit when the others are full (i.e. when the contents are within half a meter from the surface). In urban areas with land scarcity or with specifically unsuitable soil conditions, pit latrines will usually require emptying. Pits to be emptied must be made of more durable material, and the pit itself must be fully lined to withstand the suction forces.

When selecting an appropriate option for pit or tank emptying, space and access are crucial factors. Vacuum tankers are frequently unable to negotiate the narrow roads and alleys of urban slums. The alternative is manual emptying, which is common practice in many parts of the world, though not recommended. (DFID 1998, Ch. 2.7, pp. 182)

**Groundwater level and contamination**
With a seasonally high groundwater table, a raised latrine may be the most appropriate on-site sanitation option. The pit should be dug at the end of the dry season to maximise the available depth of unsaturated soil to be excavated. In areas with a recurring high groundwater table, this may be as little as 1–3 meters. (Sarah Parry-Jones 1999)

Potential groundwater pollution is a common argument against pit latrines. However, about two meters or so of sand or loam (i.e. the flowpath) is all that is required to remove, virtually all bacteria, viruses and faecal organisms. (Cotton et al. 1995, pp. 24)

Provided a pit latrine is located more than ten metres horizontally from a groundwater source, such as a spring or well, there is little chance of source pollution. Even if technical advisers identify a potential cross-contamination, it will often be more economic to find an alternative water source than to opt for a more expensive sewered alternative to a pit latrine. (DFID 1998, Ch. 2.7, pp. 183)

**Water availability**
Most sewer systems are major users of precious potable water – a factor to be considered when implementing them, especially in water scarce areas. Potable water is usually supplied to the house and used for flushing toilets – as much as 40 per cent of household water is used for this purpose. In some countries, dual-supply systems use non-potable water (often seawater) for toilet flushing. However, such systems require more complicated infrastructure and are obviously more capital cost intensive. (DFID 1998, Ch. 2.7, pp. 173)

**Climate**
Temperature, rainfall and sunlight are important climatic factors influencing the choice of sanitation technologies. Some technologies work best in tropical climates. All pond and wetland systems, for example, work best in hot and humid conditions, as high temperatures increase plant growth and biological activity. Humidity and abundant rainfall prevent the ponds from drying out. Furthermore, facultative and matu-
4 – Non-technical Aspects

4.2 What socio-cultural aspects do you have to consider when designing a sanitation system?

- Socio-cultural aspects are often neglected although they strongly influence acceptance of the sanitation infrastructure by the local population.
- Factors such as cleansing material and posture are highly site-specific and influence the user interface.

Clear differences in attitude towards the use of sanitation facilities and handling of excreta prevail among the different cultural groups. These attitudes are based on religious or cultural beliefs, gender or generational differences. Hence, sanitation facilities and their management have to fit the ‘socio-cultural’ context; planners need to understand these attitudes when designing and implementing sanitation projects.

However, selecting the most appropriate socio-cultural sanitation option does not automatically mean success. For example, when people migrate to urban areas they must adapt to living in a more densely populated environment where poor sanitation can lead to a much greater risk of infection from pathogens than in rural areas. It is therefore important to bear in mind that in most cases it will be necessary to train people in the correct use of the new facilities to ensure the use of best hygiene practices. (WASTE, <www>)

Posture
During defecation, some people prefer to sit, others to squat. Although there is a good physiological argument in favour of squatting (better evacuation of faeces), life is too short to persuade “sitters” to become “squatters”. Those who sit should simply be provided with pedestal seat units, and those who squat with squat-pans. (Duncan 1996, pp. 166)

Cleansing Material
Some people use water for anal cleansing; others prefer paper or other material. Anal cleansing with water requires a continuous source of water; this is usually not a problem in households with an on-plot water supply but, for those rely-

...
ing on a hand-carried water supply (e.g. from a public standpipe or well), arrangements should be made for a suitably sized water storage vessel to be located in or near the latrine. Wipers need access to a supply of cheap toilet paper or their latrines must be compatible with alternative anal cleansing materials. Bulky materials, such as corncobs, are not compatible with pour-flush toilets. An easily cleaned receptacle must be provided for the disposal of the contaminated material. (Duncan 1996, pp. 166)

Privacy
Since everyone prefers to use a latrine or toilet in private, the system must ensure privacy. If the latrine has a door, it should extend right down to the floor, as some societies do not like their feet to be seen from the outside. People, especially women, may also feel their privacy compromised if seen going to the latrine, for example when carrying water or leaves for anal cleansing. (Duncan 1996, pp. 165,166)

Gender
It is important to identify gender constraints. Household-level latrines are generally acceptable to all users, however, compound-level latrines may pose a gender problem, especially if several unrelated families live in the same compound. In some societies, female members of one family may not use the same latrine as the males: for example, a daughter reaching puberty may not be allowed to, or may prefer not to, use the same latrine as her father. Similarly, a husband may not allow his mother-in-law to defecate in the same latrine.

Another gender aspect of importance is to ascertain what women use to absorb menstrual blood and whether this is disposed of in the latrine; if it is, then the system must be able to cope with it. (Duncan 1996, pp. 167,168)

Orientation
Orientation of the body during defecation may also be important. For example, Muslims generally do not defecate facing Mecca or have their backside towards Mecca. (Duncan 1996, pp. 168)

Further questions
- How can socio-cultural aspects be assessed?
- What are the challenges of working in a heterogeneous community?
- What can be done when technical and socio-cultural factors are contradictory?

Photo 6: A public toilet providing very limited privacy to its users. (Sandec 2001, Sideng/Shaxi, China)

Cultural considerations when locating toilets and selecting plots in India.
A slum area in Vijayawada, Andhra Pradesh, India, had been upgraded; however, the community was not using the new toilets provided on the house plot. This was not immediately apparent to outsiders, however, when a local woman resident was asked by a native Telegu speaker, the local language, if there were any problems with the recent developments, she explained that most of the residents had not been using the toilets provided. The reason she gave was that the toilets had been placed on the northeast corner of the house plots, which, according to Hindu astrology, is a bad place to locate toilets. The northeast corner is reserved for the water source, the prayer room or the main door. Toilets should be located in the south corner of the plot. This is why many residents were not using the toilets provided and went to the edge of the upgraded area to defecate in the open. (House and Reed 1997)

Additional info
- Duncan M. (1996); Low-cost urban sanitation, John Wiley & Sons, Chichester, New York.
4.3 What political and institutional aspects do you have to consider when designing a sanitation system?

- It is important to be familiar with the local regulatory framework.
- Political will and support is absolutely necessary to create an enabling environment.
- Unclear responsibilities and bureaucratic processes can significantly delay sanitation programmes.
- In a sanitation programme, the roles of the different stakeholders have to be clearly defined.

**Regulations and standards**

There are many different systems for controlling the release of wastewater into the environment. One such system that is common in North America and Europe is a permit system: when used water or wastewater is discharged into the environment, a permit is issued which describes, quantitatively, the wastewater that can be discharged. Parameters that may be described include the amount of water to be discharged (volume), the parameters to be monitored (e.g. BOD, total phosphate etc.) and their monitoring frequency (weekly, monthly etc.). All these factors will be based on the type of water body into which the water is being discharged (i.e. recreational, ocean etc.). In many developing countries, such a permit system may not exist or if it does it may not be enforced. Household and community-based sanitations systems are generally beyond the scope of most regulations. However, their growing number will also increase the likelihood of regulations and standards being introduced.

**Organisational setup and responsibilities**

The success of any sanitation programme greatly depends on the existence of a functional organisational set-up of sanitation stakeholders with clearly defined responsibilities.

In general, three types of organisations manage and organise sanitation systems: private organisations, which run the businesses at a profit; public utility companies, financed by public funds (taxes) and operating at a loss or on a cost-recovery basis; and community groups or individuals who operate and maintain a sanitation system without any external funds.

Private companies have recently emerged as an alternative to state-run utilities, which are sometimes inefficient and financially unsustainable. They have, however, been criticised for catering only to customers who can pay. They do not provide equitable services nor invest in infrastructure. On the other hand, public utilities are often overburdened and underfunded. Although they have a mandate to provide services to all inhabitants of an area, the need for cost recovery and the sheer volume of work make these institutions appear inefficient and obsolete. To fill these service gaps, community groups, NGOs, homeowners, and citizens groups have begun to organise themselves and provide their services, often with little or no input from government institutions. These groups are solely responsible for operation, maintenance and upkeep of their own facilities.

**Political will and support**

A supportive political environment is essential for the successful implementation of a sanitation programme, especially when departing from conventional methods. In reality, most governments tend to sacrifice environmental concerns for other fiscal priorities. Furthermore, political and administrative preferences lean heavily towards large-scale, centralised wastewater and sewerage systems. (Sasse 1998, pp. 26, 27)

An overarching vision and political will at the highest level, taking on the challenges and articulating broad objectives, may be the first step to changing the environment. To be effective, government support should be translated into expressions of support for environmental sanitation, advocacy messages and other appropriate mechanisms for mass communication to raise public awareness. Programme promoters should plan to increase their efforts in familiarising elected officials, senior sector staff and advisers with the concepts of the implemented sanitation programme. (WSSCC/Eawag 2005, pp. 17)

**Bureaucracy**

In many developing countries, the responsibilities of different authorities are not clearly defined and reveal a lack of coordination/communication mechanisms between them. The responsibilities between central, regional and local authorities are also not well defined, thereby resulting in a slow and inefficient working manner. Sanitation programmes can be hindered by such bureaucratic procedures. Applications may be delayed because documents require the approval of various offices. Requests to different authorities can lead to contradictory answers.

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**Pay-and-use in India**

Over the last 35 years, the NGO “Sulabh International” has successfully applied the public latrine model of pay-and-use in India. About ten million people are using these public toilets everyday. They are, popularly known as Sulabh Complexes with bathing, laundry and toilet facilities.

**The Sulabh Experience – Success and Risks (Sandhya Venkatshwaran)**

A key operational aspect of Sulabh is its entrepreneurial approach, which deviates from the traditional norms of agencies working in the social field. Sulabh has responded to the market without any fear of competition. This approach has obviated the need for dependence on external grants and made Sulabh a self-financed organisation.

Critics have, however, raised their concern about an inevitable shift in focus from people to monetary issues. An entrepreneurial approach induces to exploitation and harassment for monetary reasons, for which Sulabh is currently being accused. In future, Sulabh will therefore practise increased community involvement. (Sulabh International, <www.sulabh>)

**Further questions**

- How can political will be increased?
- Who decides which stakeholders should be involved in a sanitation programme?
- What potential methods and approaches can be used to select stakeholders?
4.4 What financial and economic aspects do you have to consider when designing a sanitation system?

- **Community participation** is valuable not only at the planning and implementation stages but also during monitoring and evaluation.
- Using local skills and materials increases project sustainability and supports the local economy.

**Local skills and community participation**
The skills and experience of locally available personnel may be important constraints when selecting appropriate interventions. Complex technical designs may be inappropriate if construction personnel are unable to implement them. (Harvey et al. 2002, pp. 61)

However, community participation is not merely the provision of self-help labour (e.g. to excavate latrine pits), which is certainly important to reduce costs, however, the facilities have to be managed (supervised) to ensure their effectiveness. Inputs by a participating community are valuable not only at the planning and implementing stages, but also during monitoring and evaluation. (Duncan 1996, pp. 212, 213)

**Availability of local materials and tools**
If facilities can be constructed with local materials, it may significantly reduce implementation time and costs. It is therefore important to ascertain what resources are available and whether they can be used without adverse effects on the local environment and economy (Harvey et al. 2002, pp. 61). For example, the kind of filter material available influences the choice of treatment option. Expertise is needed to modify standard designs or, if necessary, develop new designs, which can be constructed with locally available material. (Sasse 1998, pp. 26)

**Affordable technology**
In many instances, on-plot or local sanitation facilities will be less expensive to build and operate than centralised sewerage systems. However, experience in Africa has revealed that not all on-plot facilities are equally affordable. For instance, VIP latrines can appear to be an unaffordable luxury to low-income communities. The experience in Mozambique with pre-cast slabs for simple pit latrines shows that other, more affordable options are available.

**Appropriate service level and willingness to pay**
Urban services only need to satisfy the level of service appropriate to the need of communities and relate to the communities’ willingness to pay for the service. For instance, stormwater drainage systems should not be sized to drain the largest flood events but may be designed for a six-month rather than for a recurring 10-year storm period. (GHK 2002, pp. 10)

**Operation and maintenance**
Operation and maintenance (O&M) of latrines should be given equal emphasis as their construction. For example, if responsibility for O&M is assumed by the implementing agency (i.e. if the end-users will not or cannot clean and maintain facilities), then only communal facilities should be provided. If community members are willing to assume the responsibility for O&M, family latrines may be a more appropriate option. (Harvey et al. 2002, pp. 61)

**Availability of credits and loans**
Where households and communities struggle to pay the investment costs of sanitation infrastructure, provision of credits and loans should be considered. Especially in low-income communities, credit programmes have great potential to increase sanitation coverage. More details on financing approaches for sanitation programmes are given in the following chapter.

**Appropriate technology and levels of service for the urban poor**
A housing estate for council employees was constructed in a town in Uganda during the 1960s. The houses were all equipped with internal plumbing and flush toilets with water-borne sewerage. The council undertook to pay all the employees’ water bills. Since Idi Amin’s regime, the council has stopped paying these bills; a survey in 1996 reveals that as a result, 92 per cent of the inhabitants of this estate had been disconnected from the water supply system but were still using flush toilets with water-borne sewerage – a clearly unsanitary situation. The lesson is that people should be provided with facilities and levels of service they can fully afford to maintain without relying on external subsidies. (DFID 1998, pp. 159)

**Further questions**
- What should be done if the target community is not willing to pay for the services provided?
- How can the sustainability of sanitation programmes be increased?
4.5 What possible schemes can finance a sanitation programme?

- Financial costs are only relevant for individual stakeholders (e.g. households).
- Accounting for economic costs allows users to compare alternative system or technology options.
- Subsidies and loans may help the poor pay the investment costs of sanitation infrastructure but at the expense of ownership and maintenance.

Subsidies or loans?
It is a fact that for many low-income and especially very low-income communities, low-cost sanitation is not necessarily cheap. Possible solutions could include subsidies for the cost of the sanitary facility or making loans available (even perhaps at a subsidised rate of interest).

Subsidies obviously cost money! If money is available (e.g. from central government or bilateral aid agency), it is still questionable if it should be invested in direct subsidies to households rather than used to cover the overheads of a hygiene education programme. Another alternative is to provide reduced interest rates or sell some key component for half-price or less, such as the fly screen for a VIP latrine. However, subsidies must not eliminate or reduce the household’s sense of ownership and responsibility.

Loans, possibly at a subsidised interest rate, can possibly be made available to households to allow them install their sanitary facility. Care should be exercised when setting the interest rate and loan repayment term. Some control is certainly necessary to ensure that the loan is actually spent on sanitation. (Duncan 1996, pp. 213,214)

Model for urban sanitation programmes
A procedure adopted by the urban sanitation improvement team (USIT) in Lesotho may serve as a model for urban sanitation programmes. Application for a loan is submitted to a loan approval committee (LAC) formed by different local opinion leaders. The committee interviews the client before the loan is approved. The money is finally provided by a commercial bank. The LAC and USIT are also responsible for following up on late repayment. (Duncan 1996, pp. 213,214)

Further questions
- How can the costs of alternative sanitation systems be compared?
- How can O&M costs be integrated in this comparison?
- What are possible financial schemes for public toilets, sludge haulage etc.? What are the potential problems with these schemes?

Additional info
- Harvey, P.A., Baghri, S. and Reed, R.A (2002); Emergency Sanitation: Assessment and programme design, Water, Engineering and Development Centre (WEDC), Loughborough University, UK.
- Downloads available on the CD of Sandec’s Training Tool and/or from the Internet.
4.6 What are the advantages and constraints of decentralised systems?

- In the context of developing countries, decentralised sanitation systems and technologies are often more affordable and sustainable.
- Decentralised solutions are usually more responsive to local needs and conditions.
- Decentralised and centralised systems should complement and not exclude each other.

Shift in paradigm

The conventional, centralised wastewater management concept, consisting of a water-borne wastewater collection system leading to a central treatment plant, has been successfully applied over many decades in densely populated areas of industrialised countries and has greatly contributed to improving the hygienic conditions in these areas. However, the appropriateness of this model in the context of cities in developing countries must be questioned, given their urgent need for affordable and sustainable infrastructure.

Limitations of centralised systems

Aside from its proven benefits, the centralised wastewater management system is nothing more than a transport system for human excreta and industrial waste to a central discharge point or a treatment system. By using valuable drinking water as transport medium, this system is wasteful of water and nutrients that could otherwise be easily treated and reused. A centralised wastewater management system reduces wastewater reuse opportunities and increases the risk to humans and the environment in the event of system failure. (Eawag 2007, www)

In the past, conventional thinking favoured centralised systems since they are easier to plan and manage than decentralised treatment units. This belief is partly true if municipal administration systems are centralised. However, experience reveals that centralised systems have been particularly poor at reaching peri-urban areas and informal settlements (Parkinson and Taylor 2003). Centralised treatment systems are usually much more complex and require professional and skilled operators. Operation and maintenance of centralised systems must be financed by the local government often unable or unwilling to guarantee regular operation.

According to Black (1994), engineering solutions based on centralised systems built and maintained by subsidised public agencies are inappropriate to the extraordinary pace and character of the urbanisation process in the developing world.

Potential of the decentralised sanitation approach

At the international level, increased emphasis has been placed on a more holistic approach to waste disposal, stressing the benefits of reducing the strength or quantity of waste at source and, whenever possible, treating, recycling or reusing it close to its generation point (Schertenleib and Morel 2003). It is obvious that a decentralised wastewater management approach is better suited to solve sanitation problems as close to their source as possible. Decentralised systems appear to offer a number of potential advantages.

Centralised treatment facilities in Latin America

Most cities in Latin America have some sewer networks, but few have functioning treatment plants. Only 2% of the collected sewage receives some treatment. In Mexico, over 90% of the wastewater treatment plants are inoperative. In cities like Bogotá, Buenos Aires, Mexico City, and Santiago, some 50–60 million cubic meters of mostly untreated sewage is discharged every day into nearby aquatic systems. (Wright 1997)
• Decentralised management may apply a combination of cost-effective solutions and technologies, which are tailored to the prevailing conditions in the various sections of the community. For example, a sewerage system and treatment works can be provided to highly developed and densely populated commercial and residential centres of a community. Sparsely populated housing neighbourhoods can be served by a settled sewerage system or dry sanitation systems where soil and groundwater conditions allow such options.

• Decentralised treatment processes can be tailored to the quality of the wastewater stream generated by each separate subsystem and to the effluent quality required. The treatment requirements will vary considerably depending on the final destination of the treated wastewater (e.g. agricultural reuse, discharge into water bodies, infiltration).

• Decentralised wastewater management decreases the risk associated with system failure. The probability of simultaneous failure of many small systems is significantly lower than failure of one system serving the entire community.

• Decentralised management increases wastewater reuse opportunities by keeping the wastewater as close as possible to the generating community. Demand for treated liquid waste in developing countries often comes from urban centres for use in public parks and urban agriculture. Where wastewater is used for irrigation, it is pointless to collect the waste flows in one location for treatment and subsequently distribute the treated effluent where it is needed.

• Decentralised management allows incremental development and investment in community wastewater systems. Settled sewers can be used to upgrade already existing decentralised systems such as septic tanks if necessary. New, independent and properly sized systems can be added to serve new and well defined residential, industrial or commercial developments. In contrast, investments in centralised systems have to be made within a short time, thus burdening the local economy. Centralised systems are usually sized to handle wastewater flows planned to occur in 30−50 years. Centralised systems are initially often oversized but eventually become undersized.

**Constraints when implementing the decentralised approach on a wide scale**

Even where policy-makers accept the decentralised approach, they may lack the capacity to plan, design, implement, and operate decentralised systems, thus leading to severe constrains in ensuring its widespread implementation. Most developing countries have no suitable institutional arrangements for managing decentralised systems and lack an appropriate policy framework to promote a decentralised approach. There is a risk that decentralisation will lead to fragmentation and failure to address overall problems adequately. Without technical assistance and other capacity building measures, problems of institutional capacity existing under a centralised operation are simply passed on to the new structures (Parkinson and Taylor 2003). Without a formal institutional framework within which decentralised systems can be located, efforts to introduce decentralised management are likely to remain fragmented and unreliable. Decentralisation therefore requires greater coordination between the government, private sector and civil society. Decentralised systems must be compatible with the knowledge and skills available at local level, as even the simplest technologies often fail in practice for lack of attention to operational and maintenance requirements. (Yhdego 1992)

Decentralised systems may reduce the investment costs required for wastewater management. However, the majority of local government agencies and departments lack the resources to invest in new infrastructure and rely on grants from higher levels of government to finance improvements in service provision, thus often leading to centralised liquid waste management solutions.

It should be noted that the decentralised concept is not the answer to all wastewater management problems. Just as the inappropriate “one size fits all” mentality of those who view conventional, centralised systems as the only reasonable approach, there are cases where decentralised management is not the best answer (Venhuizen 1997b). Decentralised and centralised systems should complement and not exclude each other. The decentralised concept is an overarching concept that can and will include centralised systems.

**Further questions**

- How can centralised and decentralised systems complement each other?
- Are decentralised sanitation systems and technologies also a realistic alternative in the cities of industrialised countries? What are the particularly appropriate options?
4.7 How do you proceed systematically when planning a sanitation system?

- There is no “best” planning model. Different approaches can complement each other.
- Sanitation programmes should respond to local demand and build on existing infrastructure.

This issue will be discussed more in depth in the Planning Module (Module 7) where the Household-Centred Environmental Sanitation Approach (HCES) is also introduced. This chapter presents only a brief, systematic and procedural overview.

Poor planning, design and operation, as well as inadequate maintenance mean that the services in place are often also qualitatively poor. Most sanitation master plans have paid insufficient attention to financial and institutional constraints and have tended to ignore what sanitation users actually want and are willing and able to pay.

Those who advocate a market-based approach argue that since people are consumers of sanitation services, the market should be able to provide them with the services they want at a price they are willing to pay. Others advocate a collective action model in which improved facilities are provided through the efforts of voluntary organisations. Both these approaches reduce the direct burden on the state and, hence, allow limited resources to extend further. However, both also have their limitations.

A review of existing models suggests that no single approach to sanitation provision can address all aspects of the problem, irrespective of whether it is based on planning, the market, local or collective initiatives. The question is not “which is the best model”, but rather how to combine planning, market-oriented aspects and local initiatives into strategies making best use of all three. (GHK 2002, pp. 5–9)

Three basic questions define the framework for strategic planning:

1. Where are we now? – Grounding plans of current situation
   - Take account of what already exists
   - Respond to actual problems and deficiencies

2. Where do we want to go? – Identifying objectives
   - Deal with the needs of all, including the urban poor
   - Establish environmentally acceptable objectives
   - Develop sustainable systems (ensure not only provision but also their subsequent operation and maintenance)

3. How do we get from here to there? – How to move towards objectives
   - Identify the fundamental principles to improve sanitation services
   - Strategic plans need to be flexible and adaptable

Further questions
- To what extent can the planning process be outsourced to local partners? What are the relevant criteria?

Additional info
- WSSCC/Eawag (2005); Household-Centred Environmental Sanitation, Implementing the Bellagio Principles in Urban Environmental Sanitation, Provisional Guideline for Decision-Makers, Water Supply and Sanitation Collaborative Council (WSSCC) and Swiss Federal Institute of Aquatic Science and Technology (Eawag), Duebendorf, Switzerland.

Downloads available on the CD of Sandec’s Training Tool and/or from the Internet.
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