Sandec: Department of Water and Sanitation in Developing Countries

Sandec Training Tool 1.0 – Module 5

Faecal Sludge Management (FSM)

Summary

Compared to wastewater management, the development of strategies and treatment options adapted to conditions prevailing in developing countries have long been neglected as regards faecal sludges (FS) – the by-products of on-site sanitation installations. In recent years, an encouraging number of initiatives towards improved FS management, including appropriate FS treatment schemes, have been developed, particularly so in several West African countries (Senegal, Mali, Ivory Coast, Burkina Faso, Ghana), in South East Asia (Nepal, Thailand, Vietnam) and in Latin America. These initiatives assist urban dwellers and authorities to overcome the challenges of indiscriminate and uncontrolled disposal of faecal sludge into drains, canals and onto open spaces, thus creating a "faecal film" in urban areas that impair public health and cause pollution. (Strauss et al., 2002)

This module pays special attention to the haulage, treatment and reuse or disposal of faecal sludge. It covers both technical and non-technical (socio-cultural, economic, political etc.) aspects and provides practical information on design, financing and planning of faecal sludge treatment plants.

Despite the specific focus of this module, faecal sludge management should be considered as an integral part of city-wide sanitation planning. For a more holistic view, the reader is also referred to Module 4 dealing with sanitation systems and technologies and to Module 7 centred on planning of environmental sanitation systems.

Not included in Module 5

- Overview of sanitation systems

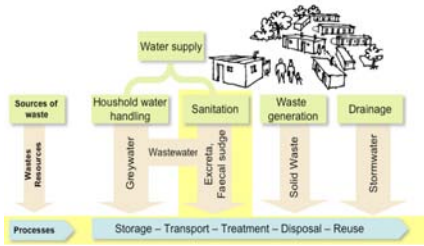

Figure 1: This module centres mainly on the management of faecal sludge from its source to its final disposal or reuse.

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Cover photo: Faecal sludge drying beds (Eawag/Sandec)

Content

1.1 What is faecal sludge, on-site sanitation and FSM?

Waht is faecal sludge

Faecal sludge comprises all liquid and semi-liquid contents of pits and vaults accumulating in on-site sanitations installations, namely unsewered public and private latrines or toilets, aqua privies and septic tanks. These liquids are normally several times more concentrated in suspended and dissolved solids than wastewater.

What is on-site sanitation?

On-site sanitation is a system of sanitation whose storage facilities are contained within the plot occupied by a dwelling and its immediate surrounding. For some systems (e.g. double-pit or vault latrines), faecal matter treatment is conducted on site and also by extended in-pit consolidation and storage. With other systems (e.g. septic tanks, single-pit or vault installations), the sludge has to be collected and treated off-site. (WHO, 2006, p. 180)

What is faecal sludge management?

FS management deals with on-site sanitation systems, while wastewater management is concerned with sewered sanitation. FS may be treated in separate treatment works or co-treated with sludges produced in wastewater treatment plants. (Strauss et al., 2002)

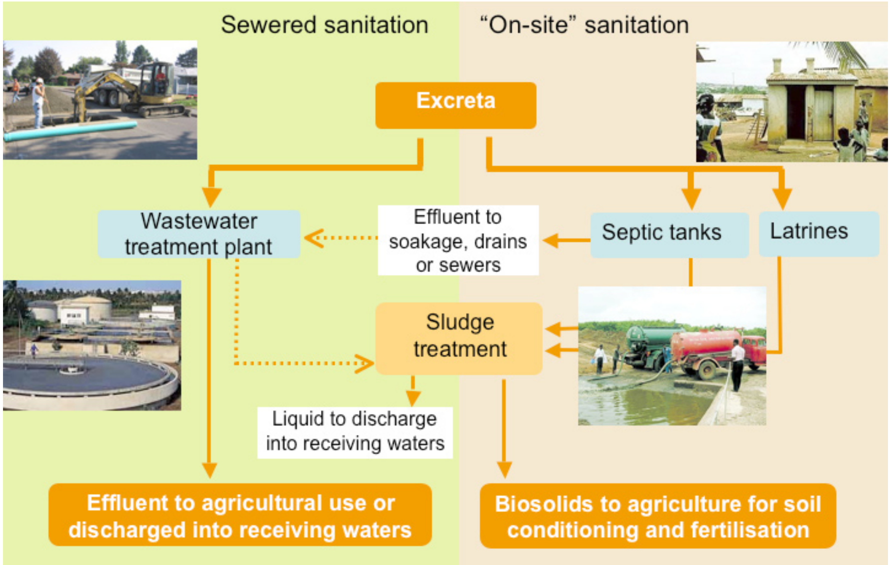

Figure 2: Faecal sludge and wastewater management side-by-side in urban environmental sanitation and their potential links. (Photos sources: right: Ghana, Sandec, 2001; left: www.kamphconstruction.com/projects.html)

Faecal sludge vocabulary	Definitions
Cesspit:	An enclosed container used for storing sewage.
Combined sewer:	A sewer system designed to carry both blackwater from homes and stormwater (rainfall). Combined sewers are much larger than separate sewers as they have to account for higher volumes.
Faecal sludge	The general term given to undigested or partially digested slurry or solids resulting from storage or treatment of blackwater or excreta.
Faeces:	Refers to (semi-solid) excrements devoid of urine or water.
Septage:	'Liquid and solid material pumped from a septic tank, cesspool or other primary treatment source'. (Bellagio, 2005)
Sewage:	General term given to the mixture of water and excreta (urine and faeces). Technically speaking, it should rather be referred to as blackwater.
Sewer:	An open channel or closed pipe to convey sewage.
Sewerage:	All the components of a system to collect, transport and treat sewage (including pipes, pumps, tanks etc.).
Sludge:	The thick, viscous layer of materials that settles to the bottom of septic tanks, ponds and other sewage systems. Sludge comprises mainly organics but also sand, grit, metals, and various chemical compounds.
Sullage:	Old term for greywater: it includes wastewater from cooking, washing and bathing but not excreta.

2.1 What is the global situation of on-site sanitation?

▸ **On-site sanitation (OSS) systems are the predominant form of excreta treatment installations in urban centres of economically less developed but also of newly industrialising countries.**

Only limited sections of urban business centres are linked to sewers (Strauss et al., 2000). In Latin America, however, more than 50 % of the houses in cities are connected to a sewerage system, and most houses in medium-sized and smaller towns are served by on-site sanitation systems, notably septic tanks. OSS systems are also common in peri-urban areas of high-income countries. In the U.S. for example, 25 % of the houses are served by septic tanks. (Montangero et al., 2002, p. 1)

Further questions
▸ What are the advantages and drawbacks of on-site sanitation?

Additional info
▸ Joint Monitoring Program for Water supply and Sanitation. www.wssinfo.org (last accessed 20.05.08).

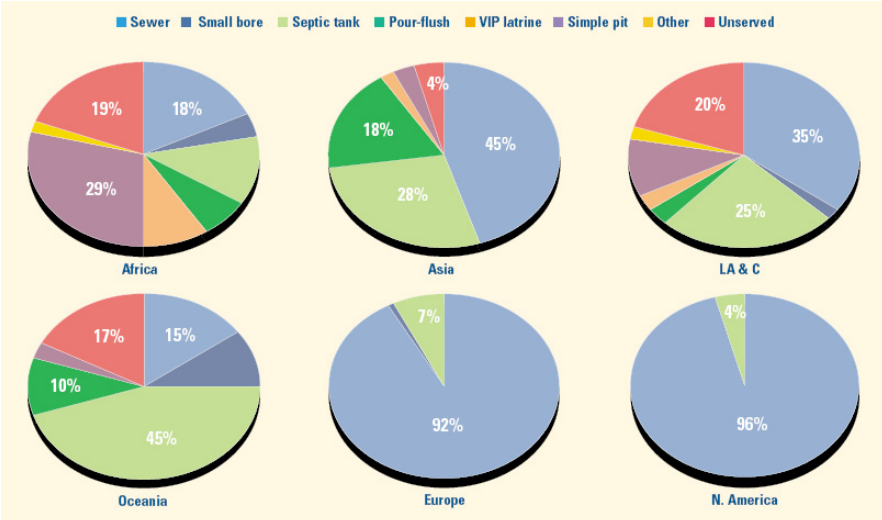

Figure 3: Sanitation in the largest cities: mean percentage for each type of sanitation system, by world region. (WHO/UNICEF, 2000)

2.2 How does on-site sanitation really look like?

▸ **Faecal sludge management has to cope with a number of challenges, i.e. health threats posed by manual pit emptying, indiscriminate disposal and by a lack or inadequate sludge treatment.**

The problems and challenges in FS management rest with all the components of the faecal sludge stream, namely pit/vault emptying, haulage, storage or treatment, and use or disposal. (Strauss et al., 2002)

Health hazard through manual emptying

Individuals, small groups of individuals or micro-enterprises offer manual emptying, traditionally carried out with buckets. Emptiers step into the vault or pit to evacuate the sludge that has generally solidified to be scooped out. Hence, traditional manual emptying is associated with considerable health risks for the emptiers. The general public is also at risk as the emptied sludge is usually deposited into dwelling concessions, nearby surface drains or into lanes. (Strauss et al., 2002)

Indiscriminate disposal

The haulage routes tend to be rather long as metropolitan cities usually stretch out. Traffic congestion further aggravates the problem and renders haulage to designated discharge or disposal sites uneconomical and financially unattractive. This leads to uncontrolled dumping of collected FS at the shortest possible distance from the area of collection. Where designated discharge sites or treatment schemes are available, a fee is usually charged by private collectors for each FS load delivered to the site. As a consequence, the inhabitants often prefer to dump the waste in non-designated sites to avoid paying the collection fee. (Strauss et al., 2002)

Mechanised emptying vehicles are more cost-intensive but also more hygienic and efficient. Due to the narrow streets in poor urban settlements, they often cannot access the pits.

Photo 1: Indiscriminate disposal of faecal sludge, Ouagadougou. (Photo: Eawag/Sandec)

Worldwide, several hundred thousand tons of faecal matter from open defecation or collected from on-site sanitation installations are disposed of every day largely untreated and totally uncontrolled into the urban and peri-urban environment. The faecal matter is either used in agriculture or aquaculture or discharged indiscriminately into lanes, drainage ditches, onto open urban spaces, into inland waters, estuaries, and the sea, thus causing serious health impacts, water pollution and eye and nose sores. In many cities, FS dumping sites are located close to squatter areas or formally inhabited low-income areas where they threaten the health of this ever-growing segment of the population. Children are especially at greatest risk of coming into contact with indiscriminately disposed and hygienically unsafe excreta. (Strauss et al., 2002)

Total lack or inadequate treatment

Health related impacts

The primary hazard is pathogen exposure from untreated or insufficiently treated faecal excreta transmitted via the faecal-oral route. Excreted urine may also contain pathogens, however, to a lesser extent and in a lesser range of etiological agents. (WHO, 2006, p. 22)

- The excreta may contaminate food or water.
- Several helminths in excreta may also infect humans through the skin. Direct contact with contaminated material and subsequent accidental ingestion from contaminated fingers or utensils are major transmission pathways. Contact may occur before treatment, during treatment, including handling or when the material is used/applied to soil.
- Additionally, contamination of food may occur directly from use but also through unhygienic practices in the kitchen. Even if the fertilised crop is cooked before consumption, surfaces may be contaminated and pathogens transferred to other foods or fluids.

Impacts on soil

Salts, heavy metals, persistent organic compounds, hormones, and nutrients are relevant substances in terms of environmental impact on soil:

- The heavy metal content in faecal sludge is generally low compared to other sources with potential impacts on soil. Metals are bound to soils at a pH exceeding 6.5 and/or with a high organic matter content. If the pH is below this value, if organic matter is consumed or if all feasible soil adsorption sites are saturated, metals become mobile and can be absorbed by crops and contaminate water bodies.
- Faecal sludge generally exhibits low contents of persistent organic compounds and hormones.
- Nutrients in sludge can accelerate the process of soil salinisation in arid and semi-arid regions.

(WHO, 2006, p. 117–121)

Impacts on water bodies

Nutrients in faecal sludge may percolate to groundwater if applied in excess or if flushed into surface water after severe rainfall.

- High concentrations of biodegradable organic matter in agricultural runoff water and high nutrient values can lead to the consumption of dissolved oxygen in lakes and rivers.

Photo 2: Farmer manuring vegetable crops with untreated FS. (Photo: McGarry, Taiwan)

- Organic chemicals originating from faecal sludge will only impact surface water bodies minimally due to their adsorption to soil particles after application.

(WHO, 2006, p. 121–122)

Additional info

▸ Strauss, M. et al. (2003): Urban Excreta Management - Situation, Challenges, and promising Solutions. In: Eawag/Sandec (Editor), IWA Asia-Pacific Regional Conference Bangkok. Eawag/Sandec, Thailand. www.sandec.ch/ (last accessed 20.05.08). Download available on the CD of Sandec's Training Tool and on the Internet.

Further questions

▸ How can the dangers related to FSM be overcome? What technical or management approaches can minimise the drawbacks?

2.3 What are the main causes for the present situation?

▸ **In numerous cases, a lack of political will and awareness, as well as financial constraints render any efforts to improve the present situation difficult. Furthermore, legal frameworks are often absent or not complied with on account of their stringency.**

Apart from a series of technical challenges associated with faecal sludge emptying, haulage and treatment, the inadequate political, organisational and regulatory context are the main causes for the appalling sanitation situation in the urban context of developing countries. Potential causes, problems and effects are presented in Figure 4.

Lack of political will and awareness

Faecal sludge management is often neglected in the water supply and sanitation sector. For local politicians, drilling of a drinking water well seems more prestigious than constructing a FS treatment plant. The importance of an adequate FS management to reduce gastro-intestinal diseases is often underestimated, and awareness of the health and economic benefits (savings in medicine, hospital costs and increased productivity of the population) is still lacking.

Furthermore, political and administrative preferences lean heavily towards large-scale, centralised wastewater and sewerage systems (Sasse, 1998, p. 26–27), often not suitable or sustainable in the prevalent context of developing countries.

Inadequate legal and regulatory basis

Most countries reveal a paucity of regulatory acts, ordinances and administrative rules on FS management. In some countries, where national acts stipulating the proper disposal of human waste exist, specific agencies are vested with the power to issue the necessary ordinances and exert control. Yet, the institutional responsibilities are often not perceived and/or performed, or else, responsibilities are assigned to several agencies and often overlap, thus leading to institutional interference and paralysis.

Since formal attribution of responsibilities to the private sector is generally missing, clarity regarding the distribution of tasks between the public and private sector is also lacking. One of the consequences of the informal character of the private sector is the lack of rules regarding, for example, pit emptying, FS haulage and disposal (range of emptying fees, official discharge points, maximum number of trucks etc.). This can lead to abuse (e.g. cartelisation, increase in emptying fees etc.).

For lack of incentives and sanctioning procedures, the different actors involved in FS management do not have the necessary motivation to comply with the existing regulations, and the local governments usually do not have the means either to control or enforce them. In most cases, there is also no provision of land for faecal sludge disposal or treatment.

Inadequate financial capacity

Local authorities are often faced with financial difficulties, which impair their ability to ensure services to the population. This is mainly due to a lack of management of the existing resources, and the non-allocation of financial resources to FS-related services.

Lack of concerted action between stakeholders

Responsibilities of the different stakeholders are not clearly defined and coordination/communication mechanisms between the different actors are nonexistent. Also the responsibilities between regional and local authorities are not clearly formulated. Moreover, some actors in the public sector represented at the regional level are missing at the local level. This slows down the concerting process.

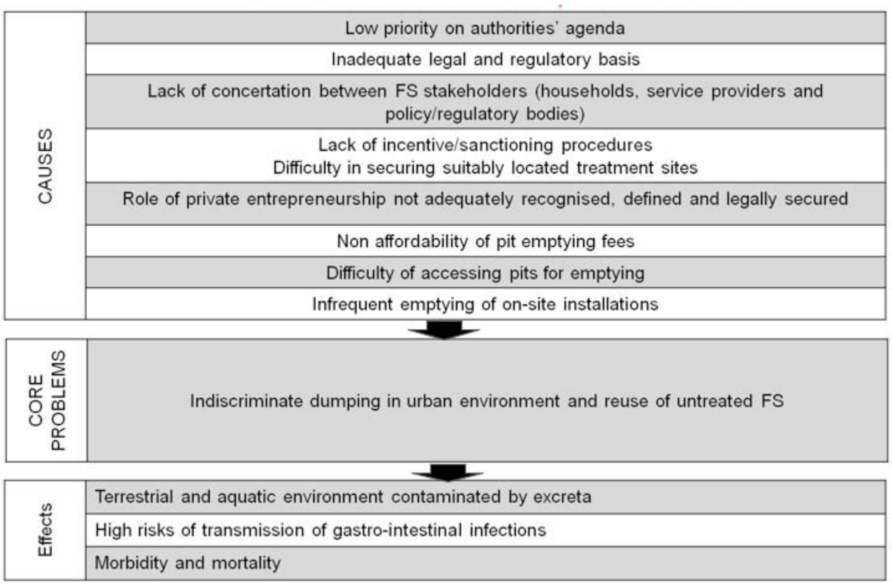

Figure 4: Causes, problems and impacts of inadequate or missing excreta and faecal sludge management. (Montangero et al. 2002, p. 24–26)

Unaffordability of mechanical emptying fees

For a large number of households, standard fees for mechanical pit and vault emptying of on-site sanitation systems are either unaffordable, just barely affordable or the family is not willing to spend the money. Deferment of the emptying frequency of the installations is a widely observed phenomenon among households. Recent studies conducted by CREPA have confirmed that emptying intervals for septic tanks, e.g. five years or more are not uncommon.

The prices charged by public or private emptying enterprises are rarely based on a sound cost calculation. Prices tend to be excessive compared to the costs incurred to those rendering the service. The reason for this is that enterprises rendering mechanised emptying tend to fix the prices in a cartel-like manner, thus excluding a truly competitive market – to the disadvantage of customers, notably low-income families. These families therefore resort to haphazard disposal of FS, and the installations, particularly septic tanks, become overloaded and cease to perform as conceived. All these factors lead to continued environmental pollution and to sustained health risks for urban dwellers.

Willingness to pay (Wtp)

- To save costs, manual pit emptiers may be called upon, whose service rates are lower than those charged for mechanical emptying. Alternatively, emptying is conducted by the members of the household themselves. In District No. VI of Bamako (Mali), for example, where pits are emptied on average every two years, prices for vacuum truck emptying vary from € 17–25 per tanker filling. Yet, families indicated a willingness-to-pay € 10–11 only. The price for manual emptying amounts to € 12 (Bolomey, 2003).

Further questions

- How can international standards for the safe discharge and reuse of faecal sludge be set? Is there really a need for uniform standards?
- What are the financing options for FSM?
- Could the management and even technical infrastructure for sanitation and solid waste be combined with faecal sludge?

Additional info

- Montangero, A. and Strauss, M. (2002): Faecal Sludge Treatment. Eawag/Sandec. IHE, Delft. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/IHE_lecture_notes.pdf (last accessed 20.05.08)

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2.4 What are the main characteristics of FS and what parameters are used to describe them?

Parameters to describe FS:	Characteristics of parameters
pH:	The hydrogen-ion concentration is an important quality parameter for FC. The hydrogen-ion concentration is usually expressed by means of a pH defined as the negative logarithm of the hydrogen-ion concentration. The concentration range suitable for the existence of most biological life is quite narrow and critical (typically 6–9). Wastewater and FS with an extreme concentration of hydrogen ion are difficult to treat biologically.
Total solids (TS):	TS is the residue remaining after a wastewater sample has evaporated and dried at a specific temperature (103–105 °C). TS is used to assess the reuse potential of wastewater and to determine the most suitable type of treatment operation and process. Suspended solids can lead to the development of sludge deposits and anaerobic conditions if untreated wastewater is discharged into the aquatic environment.
Electrical conductivity (EC):	The measured EC value is used as a surrogate measure of total dissolved solids (TDS) concentration. By measuring the electrical conductivity of treated wastewater, its salinity can be assessed. Salt content is an important parameter for agricultural wastewater reuse.
Total volatile solids (TVS):	TVS are those solids that can volatise and be burned off when the TS are ignited (500 +/- 50 °C). Fixed solids (FS) comprise the residue remaining after a sample has been ignited. The ratio of the TVS to FS is often used to determine the amount of organic matter present.
Total Kjeldahl nitrogen (TKN):	TKN is the total amount of organic and ammonia nitrogen. Since nitrogen is an essential building block for synthesis of protein, nitrogen data will be required to evaluate the biological treatability of wastewater. Insufficient nitrogen may require the addition of nitrogen to render the waste treatable. Where algal growth in the receiving water or as part of the treatment has to be controlled (e.g. in facultative ponds), nitrogen in wastewater will have to be removed or reduced.
Ammonium (NH_4^+) (AN):	Ammonia nitrogen is found in aqueous solutions as ammonium ion (NH_4^+) or ammonia gas (NH_3), depending on the pH of the solution. In wastewater treatment, about 60–70 % of the influent's TKN concentration will be in the form of NH_4-N, the rest as organic N. The total soluble organic nitrogen concentration is the difference between the TKN concentration of a filtered sample and its NH_4-N concentration.
C/N ratio:	A balanced carbon - nitrogen ratio is relevant in aerobic and anaerobic digestion of faecal sludge. In composting, for example, organic waste from households can be added if the digestion process is hampered by a lack of carbon. A balanced C/N ratio is also crucial for the production of biogas.
Ratio of biochemical oxygen demand and chemical oxygen demand: (BOD/COD):	Typical BOD/COD ratios in untreated municipal wastewater lie within a 0.3 to 0.8 range. If the BOD/COD ratio for untreated wastewater is 0.5 or greater, the waste is considered to be easily treatable by biological processes. If the ratio is below about 0.3, either the waste may have some toxic components or acclimatised microorganisms may be required for its stabilisation.
Faecal coliforms (most probable number); FC (MPN):	Communicable diseases can be transmitted by pathogenic organisms possibly present in wastewater. The presence of specific indicator organisms (e.g. Escherichia coli) or representative groups of organisms (e.g. faecal coliforms) are tested in connection with plant operation and for reuse.
Helminth eggs:	The term helminths is used to describe worms collectively. Worldwide, worms are one of the principal causative agents of human disease. Well-known and highly prevalent representatives of helminths are e.g. Ascaris lumbricoides and Schistosoma mansoni. The human infective stage of helminths varies; in some species it is either the adult organism or larvae, while in other species it is the eggs. However, it is primarily the eggs that are present in wastewater. Helminth eggs can be removed by many commonly used wastewater treatment processes, such as sedimentation, filtration and stabilisation ponds.
Heavy metals:	Heavy metals are usually found in commercial and industrial wastewater and may have to be source-controlled if the wastewater is to be reused. For example, cadmium, chromates, lead, and mercury are often present in industrial wastewater.

(Metcalf & Eddy, 2003, p. 30–96)

Additional info

▸ Heinss, U., Larmie, S.A. and Strauss, M. (1999): Characteristics of Faecal Sludges and their Solids-Liquid Separation. In: SOS - Management of Sludges from On-Site Sanitation. Eawag/Sandec, Dübendorf. www.sandec.ch (last accessed 19.05.08).

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2.5 What are the daily per capita quantities of FS?

Table 1 contains values on daily per capita volumes and loads of organic matter, solids and nutrients in faecal sludges collected from septic tanks and pit latrines, as well as from low or zero-flush, unsewered public toilets. Values for fresh excreta are given for comparative purposes. The figures are overall averages and may be used for preliminary planning and design where local data is initially lacking. Actual quantities may, however, vary widely from one place to another.

Additional info

▸ Heinss, U., Larmie, S.A. and Strauss, M. (1998): Solids Separation and Pond Systems for the Treatment of Faecal Sludges in the Tropics. In: Sandec Report No. 05/98. Eawag/Sandec, Dübendorf/ Accra. www.sandec.ch (last accessed 15.05.08).

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Table 1: Daily per capita volumes, BOD, TS, and TKN quantities of different types of faecal sludges. (Heinss et al., 1998)

Parameter	Septage [1]	Public toilet sludge [1]	Pit latrine sludge [2]	Fresh excreta
BOD [g/cap•day]	1	16	8	45
TS [g/cap•day]	14	100	90	110
TKN [g/cap•day]	0.8	8	5	10
Volume [l/cap•day]	1	2 (includes water for toilet cleansing)	0.15 – 0.20	1.5 (faeces and urine

[1] Estimates are based on a faecal sludge collection survey conducted in Accra, Ghana.

[2] Figures have been estimated on an assumed decomposition process occurring in pit latrines. According to the frequently observed practice, only the top portions of pit latrines (~ 0.7 ... 1 m) are presumed to be removed by the suction tankers, since the lower portions have often solidified to an extent that does not allow vacuum emptying. Hence, both per capita volumes and characteristics will range higher than in the material which has undergone more extensive decomposition.

2.6 What is the hygienic quality of FS?

In many areas of Africa, Asia and Latin America, helminths, notably nematode infections (Ascaris, Trichuris, Ancylostoma, Strongyloides etc.) are highly prevalent. Ascaris eggs are particularly persistent in the environment. The bulk of helminth eggs contained in faecal or in wastewater treatment plant sludges end up in the biosolids generated during treatment. Hence, in many places, nematode eggs are the indicators-of-choice to determine hygienic quality and safety where biosolids are to be used as a soil conditioner and fertiliser. The concentration of helminth eggs in the biosolids is largely dependent on the prevalence and intensity of infection in the population from which FS or wastewater is collected. Where agricultural use of biosolids is practised or aimed at, treatment must reduce helminth egg counts and their viability, or solids storage must be long enough to achieve the desired reduction. (Strauss et al., 2002)

Table 2: Prevalence of Ascaris and Trichuris eggs in Kumasi's (Ghana) raw faecal sludge.

	Ascaris [eggs/g TS]	Trichuris [eggs/g TS]
Public toilet sludge		
Sample 1	13	2
Sample 2		9
Septage		
Sample	3	2
Sample 4	94	24
Sample 5	29	15

A study conducted in Bangkok, Thailand, revealed average values for helminth eggs of 6 eggs/g TS in 256 raw septage samples. (Koottatep et al., 2005)

Where nematode infections are not endemic, helminth eggs do not lend themselves as indicators of hygienic quality of FS or respective treatment products. Bacterial pathogens (e.g. Salmonellae spp.) or bacteriophages may be used as indicators-of-choice instead. (Strauss et al., 2002)

Additional info

▸ Montangero, A. and Strauss, M. (2002): Faecal Sludge Treatment. Eawag/Sandec. IHE, Delft. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/IHE_lecture_notes.pdf (last accessed 20.05.08).

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2.7 What are the effluent standards for FS treatment plants?

▸ **Standards for effluent discharge in developing countries should be developed rather on a case-to-case basis than on an international level.**

In most newly industrialised countries, effluent discharge legislation and standards have been enacted. The standards usually apply to both wastewater and faecal sludge treatment. They are often too strict to be met under the unfavourable economic and institutional conditions prevailing in many countries or regions. Quite commonly, effluent standards are neither controlled nor enforced. Examples of faecal sludge treatment standards are known from China and Ghana. In the Province of Santa Fé, Argentina, for example, current WWTP effluent standards also apply to FS treatment. (Montangero et al., 2002, p. 5)

Standards setting – appeal for a sensible approach

In economically less advanced countries, the development of monitoring and enforcement systems is still lagging far behind and is more difficult to organise and implement than in industrialised countries. Therefore, replicating the strict standards or limits established in industrialised countries without taking into account the regional characteristics or necessary data pertaining to the local conditions is entirely inappropriate. In many instances, the numerical values of certain parameters are established without locally defined and appropriate management and treatment options for wastewater and biosolids. Such options would have to take into account the following points:

- disposal vs use scenarios;
- types of soils on which treated human waste is spread;
- influence on crops;
- health aspects;
- financial and economic factors; and
- institutional settings.

Clearly, different standards and a different selection of treatment parameters should be stipulated depending on whether treated waste is used in agriculture or discharged into the environment. For reuse, hygiene-related variables (helminth eggs in biosolids and faecal coliforms in wastewater) and nitrogen are the relevant criteria, whereas for discharge, variables such as COD or BOD and NH_4 are of key importance. (Montangero et al., 2002, p. 13–14)

In industrialised countries, pollution laws have gradually become more stringent over the decades. Concurrently, the wastewater and sludge treatment technology has been upgraded stepwise to cope with the increasing number of constituents and to reduce pollution loads discharged into the environment. (Johnstone et al., 1996)

A suitable strategy would consist in also selecting a phased approach, under the paradigm that "some" (e.g. 75 % instead of 95–99 % helminth egg or COD removal) is better than no treatment at all or the often totally inadequate operation of existing treatment systems. (Von Sperling et al., 2001)

Numerical values – at the base of the barrier principle

Following the principle of defining and setting up barriers against disease transmission – which can be used as critical control points for securing safe biosolids quality – technically and economically appropriate options for the treatment of faecal sludges and biosolids must be defined to guarantee a specific quality level. Hence, numerical quality values are required to define process specifications, yet they do not have to be monitored regularly once the process is in place. Xanthoulis and Strauss proposed a guideline value for biosolids (as defined for faecal sludge or for wastewater treatment schemes) of 3–8 viable nematode eggs/g TS (Xanthoulis et al., 1991). This recommendation is based on the WHO guideline of ≤ 1 nematode egg/litre of treated wastewater used for vegetable irrigation (WHO, 2006) and on an average manuring rate of 2–3 tons TS/ha/year. In Switzerland, for example, the standard to comply with is 0 helminth eggs/g TS and 100 Enterobacteriaceae/g TS. This standard, widely applied in Switzerland and other industrialised countries, is extremely strict and can only be met through high-cost, sophisticated heat treatment (pasteurisation). For most economically less advanced countries, however, such treatment is not sustainable nor is such an epidemiologically strict standard justified. (Ingallinella et al., 2002b, p. 289)

The Stockholm Framework

Following an expert meeting in Stockholm, Sweden, WHO published a report on Water quality guidelines, standards and health: Assessment of risk and risk management for water-related infectious disease (Fewtrel et al., 2001). This report provides a harmonised framework for the development of health-based guidelines and standards for water and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The framework encourages countries to adjust guidelines to local, cultural, economic, and environmental circumstances and compare the health risks associated with, for example, excreta and greywater use in agriculture with risks from microbial exposures through other routes, such as food, hygiene practices, drinking water or recreational/occupational water contact. This approach aims to facilitate the management of infectious diseases in an integrated, holistic fashion, not in isolation from other diseases or exposure pathways. Disease outcomes from different exposure routes can be compared by using a common metric, such as disability adjusted life years (DALYs) or normalised for a population over a time period. (WHO, 2006)

Further questions

▸ In how far does effluent quality and characteristic vary for different treatment plants?

Additional info

▸ Montangero, A. and Strauss, M. (2002): Faecal Sludge Treatment. Eawag/Sandec. IHE, Delft. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/IHE_lecture_notes.pdf (last accessed 20.05.08).

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3.1 What influences FS characteristics and how do they determine the required treatment option?

▶ **FS characteristics are influenced by the adopted storage/treatment/emptying technologies, performance, storage duration, temperature, and composition of wastewater input.**

Compared to sludges from wastewater treatment plants or to municipal wastewater, FS characteristics differ widely according to location (from household to household, from city district to city district, from city to city). The factors influencing faecal sludge characteristics are illustrated in Figure 5.

A basic distinction can usually be made between sludges, which are upon collection still relatively fresh or contain a fair amount of recently deposited excreta (e.g. sludges from frequently emptied, unsewered public toilets) and sludges, which have been retained in on-plot pits or vaults for months or years and which have undergone biochemical degradation to a variable degree (e.g. sludge from septic tanks – septage). Moreover, varying amounts of water or wastewater, which have accumulated in vaults or pits, are collected alongside with the solids. Based on numerous FS monitoring studies, FS can often be associated with one of two broad categories, viz. high and low-strength sludges. Table 3 contains typical FS characteristics, which are based on results of FS studies in Argentina, Accra/Ghana, Manila/Philippines and Bangkok/Thailand. The characteristics of typical municipal wastewater, as may be encountered in tropical countries, are also included for comparative purposes. (Strauss et al., 2002)

Storage duration, temperature, intrusion of groundwater in septic tanks, performance of septic tanks, tank emptying technology and pattern are parameters, which influence the sludge quality and are therefore responsible for its high variability. Unlike digested sludge produced in mechanised biological wastewater treatment plants or in other types of wastewater treatment works (e.g. waste stabilisation ponds, oxidation ditches), the organic stability of FS attains varying levels. This variability, caused by the anaerobic degradation process occurring in on-site sanitation systems, is dependent on several factors, such as ambient temperature, retention period and the presence of inhibiting substances. The fact that faecal matter is not mixed or stirred impairs the degradation process. Dewaterability is also a varying parameter dependent on the degree of biochemical degradation of the sludge. Fresh, undigested sludge as collected from public toilets does not lend itself to dewatering. (Strauss et al., 2002)

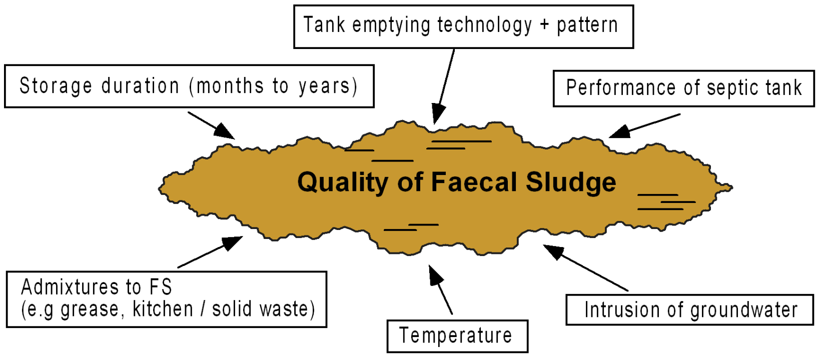


Figure 5: Factors influencing FS characteristics. (Heinss et al., 1998)

	Public toilet sludge	Septage	Sewage
Characterisation	Highly concentrated, mostly fresh FS; stored for days or weeks only	FS of low concentration; usually stored for several years; more stabilised than public toilet sludge	Tropical sewage
COD (mg/l)	20,–50,000	< 10,000	500–2,500
COD/BOD	2:1 . . . 5:1	5:1 . . . 10:1	2:1
NH_4-N (mg/l)	2,–5,000	< 1,000	30–70
TS	≥ 3.5%	< 3%	< 1%
SS (mg/l)	≥ 30,000	≈ 7,000	200–700
Helminth eggs (no./litre)	20,–60,000	≈ 4,000	300–2,000

Table 3: Characteristics of faecal sludges and comparison with tropical sewage. (Adapted from: Heinss et al., 1998, p. 4)

Photo 3: Fresh FS collected from unsewered public toilets unloaded at Buobai FS treatment plant, Ghana. (Source: Eawag/Sandec, 2003)

Photo 4: Discharge of untreated septage. (Source: Eawag/Sandec)

It can be concluded that FS is a **highly concentrated and variable material.** This implies that FS cannot be regarded as a kind of wastewater. Treatment thus calls for specific treatment schemes and design criteria. Due to the high variability of this material, design of a **treat-**

ment system should not be based on standard characteristics but rather on the results obtained on a case-to-case basis. While substantial resources have been invested in the development of wastewater technologies, both low and high-cost, sustainable FS treatment technologies still require large inputs of field research, development and testing before they may be propagated as "state-of-the-art" options. (Montangero et al., 2002)

Further questions
- How can I find the best treatment option for my setting? Is there a 'fit-it-all solution'?

Additional info
- Strauss, M. and Montangero, A. (2002): FS Management - Review of Practices, Problems and Initiatives. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/FS_management_GHK.pdf (last accessed 20.05.08). Download available on the CD of Sandec's Training Tool and from the Internet.

3.2 What are the main processing steps in FSM?

▶ FSM is based on the FS processes of collection, emptying, haulage, treatment, and reuse/storage.

A sanitation system can be described by a series of possible process steps (Figure 6). Module 4 of the Training Tool offers detailed information on this subject.

Several collection and storage systems need regular desludging, namely:

- Single pits
- Single Pit VIPs
- Settling tanks
- Septic tanks
- Anaerobic baffled reactors
- Anaerobic filters

The following (semi-)centralised treatment units also require desludging:

- Waste stabilisation ponds
- Aerated ponds
- Trickling filters
- Upflow anaerobic sludge blanket
- Activated sludge reactor
- Anaerobic biogas reactor

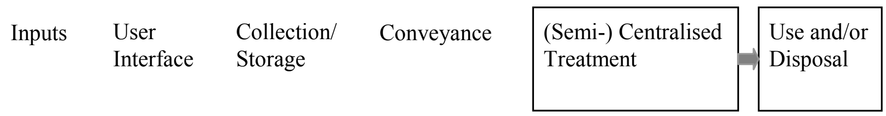


Figure 6: Classification of process steps in sanitation. (Eawag/Sandec, 2008)

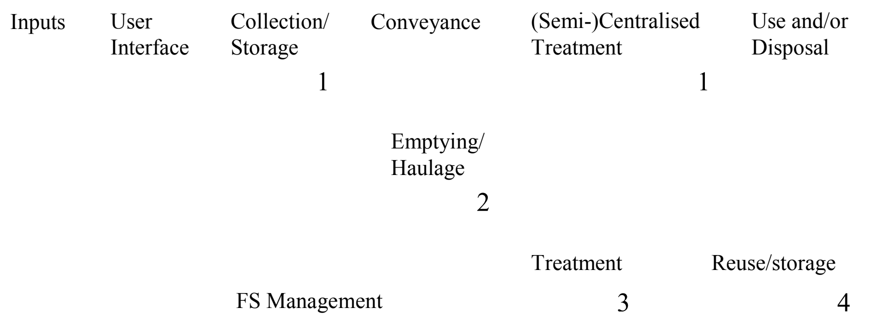


Figure 7: FS Management in the context of sanitation

Faecal sludge management is concerned with the sludge removed from the aforementioned treatment systems and can therefore be regarded as part of wastewater management in general (compare Figure 7). Faecal sludge management specifically includes the following aspects:

1. Faecal sludge collection
2. FS emptying and haulage
3. Treatment
4. Reuse/storage

Based on the aforementioned FS characteristics (Chapter 3.1), a few aspects pertaining to the design of FS treatment systems can be summarised as follows:

- A first treatment step consisting of solid separation from the liquid fraction (e.g. drying beds or sedimentation ponds/tanks) appears meaningful as most of the organic matter is contained in the solids. Besides, it allows to concentrate the helminth eggs in the separated solid fraction.
- The fresh, undigested sludge should be stabilised (e.g. through primary, anaerobic treatment in a pond or reactor). Sludges, which have already attained a high level of stabilisation, could be directly dewatered (e.g. on planted or unplanted drying beds, sedimentation/thickening ponds) and further mineralised (on the beds/ponds or through thermophilic composting).
- If the main objective is to reduce environmental pollution (e.g. of surface water), the treatment system should attain high removal efficiencies for organic matter (TOC, COD) and nutrients (N and P).
- However, high N and P removal efficiencies lead to a "loss" of valuable nutrients. As these nutrients were originally taken up in the human body through food consumption, a sustainable resource management system should consist in closing the loops, i.e. allowing the nutrients to be returned to the soil and used for crop production. In this case, the treatment system should aim at creating valuable products for agricultural reuse and allow the biosolids (the solid fraction of the faecal sludge) to stabilise and hygienise while limiting nutrient losses.
- Faecal sludges and, even more so, the biosolids produced during the solid/liquid separation processes contain high levels of pathogens. Attention should therefore be paid to their safe

handling (septic tanks emptying, haulage and treatment) and disposal. The treatment system should allow the biosolids to be hygienised in such a way that their use as soil conditioner/fertiliser or their disposal do not involve health risks.
(Montangero et al., 2002, p. 13–14)

Further questions
▸ Can the amount of FS accumulating in a system within a given time period be accurately calculated in advance?

Additional info
▸ Eawag/Sandec (2008): Sanitation Compendium. Eawag/Sandec PLEASE REPLACE WITH CORRECT REFERENCE

3.3 What are the main options for pit emptying and FS transport?

▸ **Manual pit emptying poses great health risks, however, it is often the method of choice as mechanical emptying facilities may not be available or affordable for poorer households.**

Pit emptying constitutes a major problem in many places, both technically and managerially. In many countries and cities, both mechanised and manual pit emptying services are being offered. Mechanised services are rendered by municipal authorities or by small to medium-sized enterprises.

Manual emptying

Manual emptying can mean one of two things:

1. The waste/sludge is emptied by hand using buckets and shovels or
2. By a portable, manually operated pump system (e.g. "MAPET: Manual Pit Emptying Technology").

If a container (pit, tank etc.) pit is emptied by hand, every precaution should be taken to prevent anyone from accessing the pit. If, for whatever reason the pit has to be entered, the emptier has to be fitted with adequate protection and safely secured by a rope to the surface in the event he has to be pulled out quickly. Appropriate equipment (e.g. long-handle shovels) should be provided to avoid accessing the pit.

A MAPET system, as shown on Photo 5, comprises a hand-pump connected to a vacuum tank mounted on a push-cart. A hose connected to the tank is used to suck sludge from a pit. When the hand-pump is turned, air is sucked out of the vacuum tank, which in turn sucks up the sludge into the tank. Depending on sludge consistency, MAPET can pump the sludge from a max. depth of 3 m.

Photo 5: MAPET equipment in the D.R. of Congo. (Source: WASTE, Holland)

Mechanical emptying

Most pits/septic tanks, however, are emptied by vacuum trucks or tankers equipped with a pump and a storage tank. The pump is connected to a hose, which is lowered down into a septic tank or pit, and the sludge is pumped up into the tank. Generally, the storage capacity of a vacuum tanker ranges between 4 and 6 m^3.

Depending on the system, the material to be pumped out can sometimes become so compacted that it cannot easily be removed. In these situations, the solids have to be liquefied with water in order to flow more easily. If water is not available, the waste will have to be removed manually. FS collection and haulage are particularly challenging in metropolitan centres with their often large and very densely built-up, low-income districts. Large trucks often have difficulty accessing pits/septic tanks in areas with narrow or inaccessible roads/lanes.

Photo 6: Tank lorry emptying a pit in Bharakpur near Calcutta, India. (Sandec, 1998)

Photo 7: Narrow lanes are a challenge for pit emptying. (Source: unknown)

The mini-vacuum-tugs, developed by the Haiphong drainage company in collaboration with a local manufacturer, have a capacity of 350 L and cost around USD 4,000. The combination of large and small equipment has proven successful, and almost 100 % of the houses can be serviced. Photo 7 and Photo 10 illustrate mini-tugs used together with an intermediate storage tank that can be hook-lifted and hauled away. (Strauss et al., 2002)

	Manual Emptying	**Mechanical Emptying**
Advantages	+ Accessibility + Local job creation and income generation	+ Fast and generally efficient + Minimises health risk
Disadvantages	– Time-consuming – Health hazards for workers – Hard, unpleasant work – MAPET requires some specialised repair (welding) – Requires a disposal point or discharge area (< 0.5 km) – Spillage and bad odours	– Low accessibility – Expensive, capital and O&M costs (which are passed onto customers) – Cannot pump thick, dried sludge (must be manually removed) – Pumps usually only suck down to a depth of 2–3 m

Table 4: Comparison of manual emptying vs mechanical empting. (Source unknown)

Vacutug

▸ The Sewer and Drainage Company of Haiphong (N. Vietnam), a public utility enterprise, is responsible for septage collection. Collection is carried out by vacuum tankers and small vacuum tugs for areas of difficult access and used with intermediate-storage-tanks mounted on a hook-lift truck.

Photo 8: This Vacutug mini-tanker manufactured in Bangladesh, under the supervision of Manus Coffey and Associates, is used in a UN-Habitat co-financed waste management project. (UN-Habitat, 2003)

Photo 9: Mini-vacuum tug for narrow lanes. (Sandec, 2002, Hai Phong, Vietnam)

Photo 10: Intermediate storage tank located in the nearest accessible road. (Sandec, 2002, Hai Phong, Vietnam)

Further questions

▸ Where do I find technical information on systems like the Vacutug or MAPET?

Additional info

▸ WASTE www.waste.nl (last accessed 20.05.08)

▸ Eawag/Sandec www.sandec.ch (last accessed 20.05.08)

3.4 What are the challenges of solid-liquid separation?

When treating biochemically active sludges, anaerobic digestion and solid-liquid separation take place in the same treatment unit. The biogas originating from the digestion process adheres to suspended solids that form a scum layer. As the tank is being loaded, the thickness of the scum and the settled solid layers increase, while the interstitial, "clear" liquid layer gradually decreases. The separated solids will, in most cases, require further storage, dewatering, drying or composting and lead to biosolids usable as soil conditioner-cum-fertiliser. The liquid fraction will normally have to undergo polishing treatment to satisfy the criteria for discharge into surface waters and/or to avoid groundwater pollution where effluents are allowed to infiltrate.

Septage usually settles well (≤30–60 min under quiescent conditions). In contrast, fresh and biochemically active sludges neither settle nor can they be dewatered, e. g. on sludge drying beds. Hence, sedimentation tanks with hydraulic retention times (HRT) of but a few hours (≤ 4 h) can be used for solid-liquid separation of septage but not of unstable sludges. These have to be either admixed to septage at ratios enabling quasi-discrete settling (septage: fresh sludge = 2–3 : 1 by volume) or treated in a primary anaerobic/sedimentation pond, which provides ≥15 days HRT to allow for biochemical stabilisation prior to sedimentation and solids thickening.

3.5 What are the major technologies for solid-liquid separation and FS treatment?

▶ **In most cases, FS requires separation of solids and liquids, which will undergo further treatment in a second step. Depending on FS characteristics, output criteria and available area, a number of technologies can be used for this purpose.**

Separation of the FS solids from the liquids is the process-of-choice in FS treatment, unless FS is co-treated in an existing or planned wastewater treatment plant, and if the FS loads are small compared to the flow of wastewater. Solid-liquid separation may be achieved through sedimentation and thickening in ponds or tanks or through filtration and drying in sludge drying beds. The resulting solid and liquid fractions both require further treatment.

Though the technologies used for solid-liquid separation, secondary treatment and co-treatment with wastewater are often the same, their design and mode of operation vary. A few technology options for the solid-liquid separation and further treatment are illustrated in Figure 8.

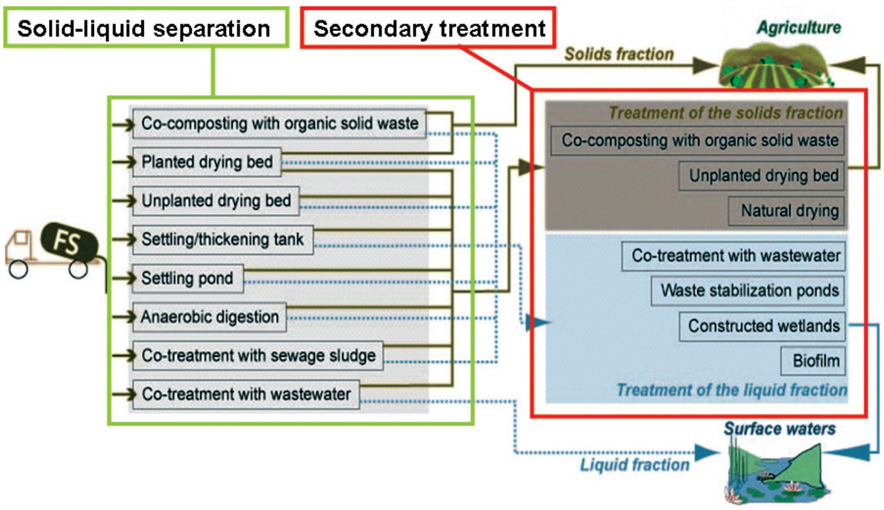


Figure 8: Overview of potential, modest-cost options for faecal sludge treatment. The schematic drawing illustrates how after separation, the solid and liquid fractions of FS can be further processed or used. (Strauss et al., 2002)

Settling tanks and sedimentation ponds

Settling tanks provide a liquid retention time of a few hours (enough to ensure quiescent settling of settleable solids), while sedimentation ponds cater for several days or a few weeks of liquid retention and, hence, also allow for anaerobic degradation of organics. Depending on the storage volume required, both types of units are designed for a desired depth and quantity of accumulating solids. At least two parallel units need to be provided to allow for batch operation, including adequate loading and resting/emptying cycles.

Non-mechanised, batch-operated settling tanks and settling ponds must be designed so as to enable easy removal of partly or fully dewatered accumulated solids, either manually or by front-end loaders (in larger plants). The solids can be further processed by drying on so-called sludge drying beds or further surface spread in thin layers by co-composting with organic solid waste or by in-pond storage in the case of settling ponds. The liquid effluent or supernatant needs to be further treated in e.g. waste stabilisation ponds prior to discharge into surface waters or infiltration beds. (Strauss et al., 2002, p. 58)

The **rate of accumulation of settleable solids**, i.e. the required solids storage volume, is the decisive design criteria for preliminary settling/thickening units or for solids storage compartments in primary ponds. The specific volume occupied by separated solids may vary from 0.02 (thin septage) – 0.15 (septage mixed with high-strength sludge from unsewered public toilets) m^3/m^3 of raw FS, depending on FS type and composition and on the period allowed for solids consolidation and thickening. Table 5 contains the **removal rates** to be expected in settling-thickening tanks and in settling ponds, respectively. (Strauss et al., 2002)

The **choice of sedimentation tanks or ponds** is not only dependent on the type of sludge to be treated but also determined by the mode of operation envisaged and by the provisions made for handling the mass of solids for periodic removal from these primary treatment units. Solids quantities produced in sedimentation/thickening tanks, which will be non-mechanised and batch-operated in loading/consolidating cycles of weeks to a few months in their low-cost version, will be much smaller than the mass of solids to be removed and handled from primary ponds. These have typical operating cycles of 6–12 months, unless measures are introduced by which settled solids are evacuated at higher frequencies without stopping pond operations. Treatment plant operators might be overtaxed by having to deal with pond emptying, particularly in larger schemes, where large machinery such as front-end loaders are required for days or weeks to cope with the solid mass. Moreover, land might be lacking for natural sun drying or for sludge drying beds required to treat such large quantities of thickened sludge within short time periods.

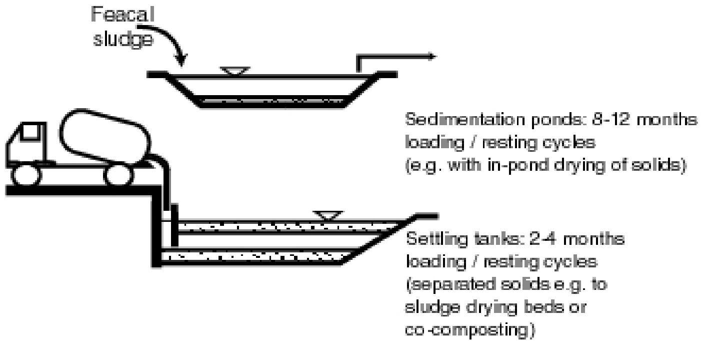


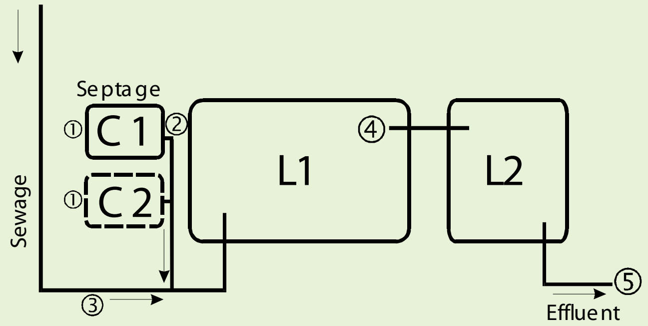
Figure 9: Non-mechanised settling-thickening tanks and anaerobic/sedimentation ponds for solid-liquid separation (schematic). (Strauss et al., 2002)

Characterisation	Settling-thickening tanks	Settling ponds
Suspended solids (SS)	60 %	> 95 %
BOD and COD (unfiltered)	3–50 %	70–95 %
BOD (filtered)	18 %	45 %

Table 5: Expected removal rates in settling-thickening units. Based on actual performance of investigated installations running at sub-optimal conditions. (Strauss et al., 2002)

Case Study Alcorta

▸ In Alcorta (Province of Santa Fé, Argentina), operation of a series of two stabilisation ponds was launched in 1987 to co-treat both wastewater and septage. Monitoring programme of the system (1993–1995) revealed that the capacity of the first pond had been reduced by half due to the high solids content of the septage. In July 1998, the University of Rosario therefore constructed two sedimentation ponds as septage pretreatment (Figure 10). The two ponds are operated alternatively: while one pond is loaded, the accumulated sludge in the other is drying. The ponds are designed to allow for in-pond dewatering/drying of the accumulated solids during the resting period. The idea is that the settled sludge should be spadable and partly mineralised/hygienised at the end of the resting/drying cycle. The effluent of the sedimentation ponds is co-treated with wastewater in a series of two waste stabilisation ponds.



C1 and C2		L1		L2	
Length (m):	25.00	Length (m):	83.00	Length (m):	38.00
Width (m):	11.00	Width (m):	57.00	Width (m):	53.00
Depth (m):	1.50	Depth (m):	1.20	Depth (m):	1.30
Baffles:	No	Baffles:	No	Baffles:	Yes

Figure 10: Co-treatment of septage and wastewater (schematic). C1, C2: Septage ponds; L1, L2: Ponds treating septage liquid (supernatant) and municipal wastewater). (Ingallinella et al., 2002a)

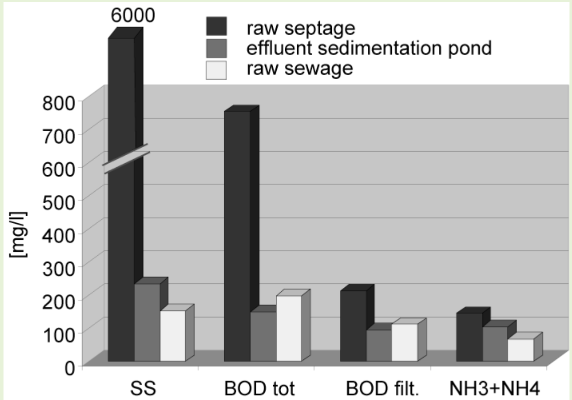


Figure 11: Raw septage, effluent of the septage pond and raw sewage concentration measured in Alcorta during the first monitoring cycle (14 campaigns). (Adapted from: Ingallinella et al., 2002a)

▸ The results of the three-year monitoring programme also show that the effluent quality of the ponds treating septage (sedimentation and degradation) is similar to that of the wastewater, both with low and high BOD loading rates (compare Figure 11). Analyses of the dewatered sludge reveal that the level of humidity reached at the end of the drying cycle allows easy handling of the sludge through spading. The final plant effluent, composed of treated septage supernatant and wastewater, satisfies conventional discharge standards. (Strauss 2002)

Unplanted sludge drying beds

If suitably designed and operated, sludge drying beds can produce a solid product that may be used either as soil conditioner or fertiliser in agriculture or deposited in designated areas without causing damage to the environment. In most cities, the solids removed from the drying beds after a determined period (several weeks to a few months) require further storage and sun drying to attain the hygienic quality for unrestricted use. Where dried sludge is used in agriculture, helminth (nematode) egg counts should be the decisive quality criterion in areas where helminthic infections are endemic (Strauss et al., 2002). A maximum nematode (roundworm) egg count of 3–8 eggs/g TS has been suggested by Xanthoulis and Strauss. (Xanthoulis et al., 1991)

Gravity percolation and evaporation are the two processes responsible for sludge dewatering and drying. A cross-section of a sludge drying bed is schematically illustrated in Figure 12. Evaporation causes the mud to crack and result in improved evaporative water losses and enhanced drainage of the sludge liquid and rainwater. (Strauss et al., 2002)

50–80 % of the faecal sludge volume applied to unplanted drying beds will emerge as drained liquid (percolate). The ratio between drained and evaporated liquid is dependent on sludge type, weather conditions and operating characteristics of the particular drying bed. Drying bed percolate tends to exhibit considerably lower levels of contaminants compared to settling tank supernatant. Nevertheless, this liquid will, in most cases, also have to be subjected to a suitable form of treatment (e.g. in facultative ponds). (Strauss et al., 2002)

Pescod (1971) conducted experiments with unplanted sludge drying beds in Bangkok, Thailand. According to his experiments, maximum allowable solids loading rates can be achieved with a

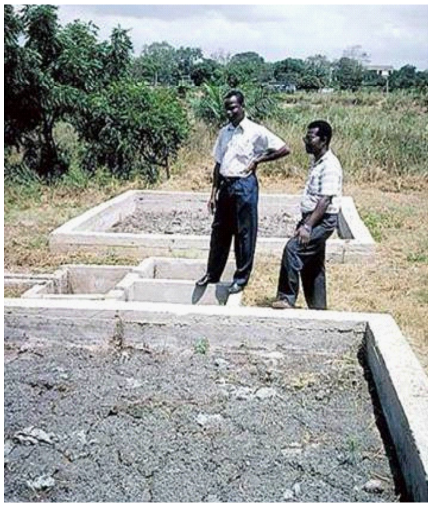


Photo 8: Drying beds in Accra, Ghana (Sandec, 2000)

sludge application depth of 20 cm. To attain a 25 % solids content, drying periods of 5 to 15 days were required depending on the different bed loading rates applied (70–475 kg TS/m^2/yr). Results from pilot sludge drying beds obtained by the Ghana Water Research Institute (WRI) in Accra/Ghana indicate their suitability for septage/public toilet sludge mixtures and primary pond sludge (TS = 1.6–7 %). Experiments were conducted during the dry season with sludge application depths of ≤20 cm. At loading rates equivalent to 200 kg TS/m^2/yr and 8 drying days, 40 % TS contents were attained, whereas at 600 kg TS/m^2/yr, only 20 % TS contents could be achieved. The fresh, non-stabilised public toilet sludge was not conducive to drying within periods of 10–20 days. (Strauss et al., 2002)

Dried biosolids dewatered to ≤ 40 % TS in the Accra/Ghana experiments still exhibited considerable helminth egg concentrations.

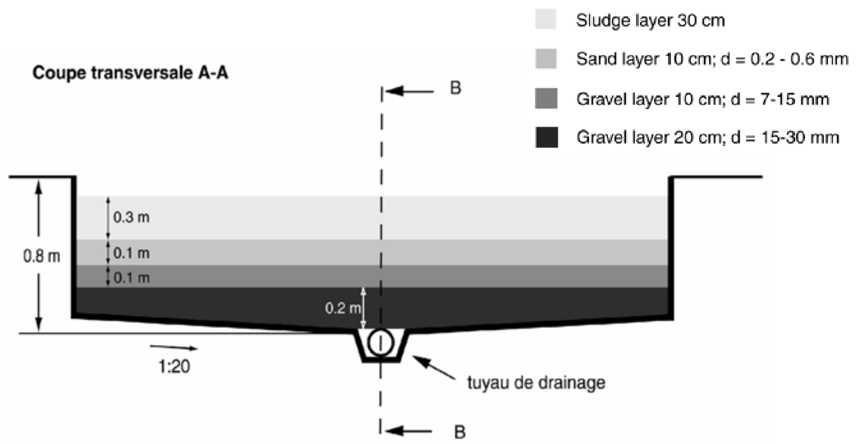


Figure 12: Cross-section of an unplanted drying bed with the different sand and gravel layers. (Strauss et al., 2002)

When the contaminant levels in the drained liquid of the pilot beds in Accra were compared with the levels in the raw sludges applied, the following average removal rates were calculated from 12 bed loadings:

- Suspended solids: ≥95 %
- COD: 70–90 %
- Helminth eggs: 100 %
- NH_4: 40–60 %

(Strauss et al., 2002)

Planted sludge drying beds

Planted sludge drying beds consist of a gravel/sand/soil filter planted with emergent plants, such as reeds, bulrushes or cattails. The applied sludge is dewatered by filtration and accumulates on the surface. The liquid fraction flows vertically through the filter media and is finally collected as percolate at the bottom (vertical flow).

The advantage of planted over unplanted sludge drying beds is that the root and rhizome system of the plants used in a constructed wetland (CW) creates a porous structure in the layer of accumulated solids, thus enabling to maintain the dewatering capacity of the filter for several years. In contrast to CWs treating wastewater, those treating sludge are equipped with a freeboard allowing dewatered solids to accumulate over several years. Removal frequency of accumulated biosolids is consequently far lower than in unplanted sludge drying beds, and operating costs thus considerably reduced. Extended storage of biosolids therefore allows for biochemical stabilisation. The plants pass through repeated cycles of growth and wilting. Sludge will have to be removed from the filters

Constructed wetland (pilot plant) –Bangkok


Photo 9: New installation of a constructed wetland with ventilation pipes at the Asian Institute of Technology (AIT) in Bangkok, Thailand. (Sandec, 1997)

▸ Since early 1997, three cattail-planted pilot constructed wetlands are under investigation at the Asian Institute of Technology (AIT) in Bangkok. The 3 x 25 m^2 pilot plants, equipped with a drainage and ventilation system (Figure 13), treat the septage of approximately 3,000 people. They were first acclimatised with wastewater, gradually fed with Bangkok's septage and operated as a vertical-flow system. The percolate was at first treated in a waste stabilisation pond system, and in a constructed wetland bed planted with ornamental plants at the later project stage. The project aimed at assessing the suitability of this option for septage treatment and at establishing design and operational guidelines. (Strauss et al., 2002) only after 5 to 6 years. The biosolids may have to be dried to a limited degree, i.e. only from 65–60 % water content at the most to ensure sustained plant growth. CW percolate will require post-treatment depending on local conditions and discharge regulations. (Strauss et al., 2002)

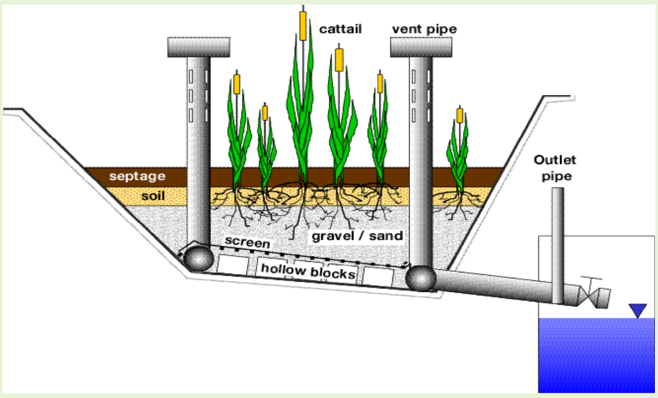


Figure 13: Pilot constructed wetland fed with septage since 1997. (AIT, Bangkok)

- The system was monitored under different operating conditions. Parameter tests comprised variations in solids loading rate, sludge loading frequency and percolate ponding period. Ponding of the percolate water in the beds' underdrain system was initiated to reduce plant wilting observed especially during the dry season (Koottatep et al., 1997–2000). The optimum operating conditions with maximum removal efficiencies and minimum cattail wilting symptoms are the following: (Koottatep et al., 2001)
- Solids loading rate: 250 kg TS/m^2*a
- Loading frequency: 1 x per week
- Percolate ponding: 6 days
- 90 cm of dewatered and stabilised solids had accumulated in the CW beds at the end of 4.5 years of septage loading, which is equivalent to a column of 75 m of raw septage loaded onto the beds. Nitrogen and phosphorus contents of the sludge accumulating on the planted drying beds compare very favourably with the ones found in matured compost.
- Helminth eggs analysis reveals that the accumulated biosolids in agriculture do not pose any public health risks. Nematode concentrations found in raw septage amount to approx. 40 eggs/g TS. The number of nematode eggs counted in the solids and accumulated over several years was still high (170 g/TS on average). However, only a small fraction (2/g TS on avg. or 1.2 %) was found to be viable (Schwartzbrod, 2000). Average viable nematode egg concentrations are thus below the suggested quality guideline of 3–8 eggs/g TS.
- Mass balance calculations across the CW beds reveal that 50 % of the entire solids load discharged onto the beds are retained as biosolids on the bed surface. 10 % are contained in the percolate. 40 % are partly "lost" by degradation of organic material, yielding water and CO2, and partly retained in the bed's underdrain system. A third of the water brought with septage onto the beds is subjected to evapotranspiration and two thirds are drained. Some 2 % only are retained in the accumulating solids. Of the nitrogen loaded onto the CW beds, 50 % are accumulated in the biosolids and 25 % each leave the system through volatilisation and in the percolate. (Strauss et al., 2002)

(Non-aerated) waste stabilisation ponds (WSPs)

Figure 14 illustrates a WSP system suitable to treat low to medium-strength faecal sludges. It comprises pretreatment units (tanks or ponds) for solid-liquid separation followed by a series of one or more anaerobic ponds and one facultative pond. This allows the production of a liquid effluent apt for discharge into surface waters. Effluent use in agriculture is not possible due to its high salinity. However, biosolids generated during pretreatment and in the anaerobic ponds constitute a valuable resource easily treated to satisfy safe hygienic standards. (Strauss et al., 2002)

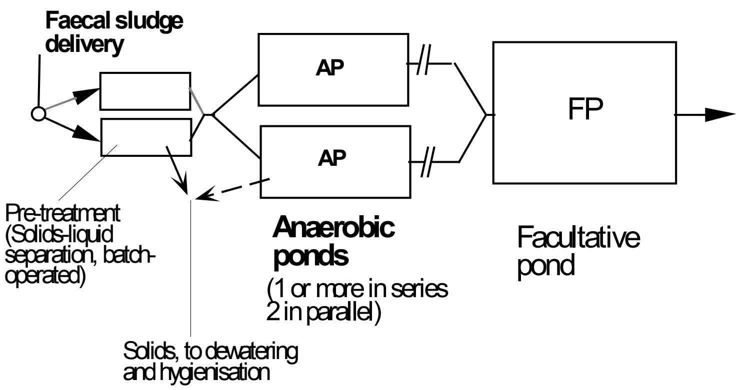


Figure 14: WSP system treating low to medium-strength faecal sludges. (Strauss et al., 2000)

Further details on processes, design and maintenance in anaerobic, facultative and maturation ponds are available in Module 4 "Sanitation Systems and Technologies". This chapter focuses on co-treatment of sedimentation tank effluent with wastewater and its related problems.

Factors impairing proper functioning of WSP systems

Ammonia levels might be high where FS comprises critical proportions of sludges originating from unsewered public toilets with zero flush or low flush installations or from latrines with so-called watertight pits. Excessive ammonia (NH_3) contents will impair or suppress anaerobic degradation and/or algal growth. The critical toxicity level of NH_3 for anaerobic degradation is in the order of 70 mg NH_3-N/L, while that for toxicity to algae is around 40 mg NH_3-N/L (or equivalent to approx. 400 mg (NH_3+NH_4-N)/L at 30 °C and pH 7.8, conditions typical of FS in warm climates).

Faecal sludges from unsewered public toilets emptied at intervals of 1–3 weeks only are often little conducive to solids separation due to their biochemical instability. Primary treatment in anaerobic ponds could be the method-of-choice in developing countries to render such FS conducive to further treatment, viz. solid-liquid separation (in the primary unit itself), dewatering/drying of the biosolids and polishing of the liquid fraction.

A number of problems may arise where waste stabilisation ponds are used to treat municipal wastewater and co-treat FS. In many instances, the problems are linked to the fact that the wastewater ponds were not originally designed and equipped to treat any additional FS load. The most common problems encountered are:

- Excessive organic (BOD) loading rates may lead to overloading of the anaerobic and facultative ponds. This overloading causes odour problems and prevents the development of aerobic conditions in the facultative pond.
- Due to the high solids content of FS, ponds may fill up with solids at undesirably fast rates. The high rate of solids accumulation calls for a higher frequency of solids removal and handling than with wastewater alone.
- Fresh, undigested excreta and FS contain high NH_4 concentrations, which may impair or even prevent algal development in facultative ponds.

The aforementioned problems can be avoided by, for example, the addition of a solids separation step ahead of the first pond and establishment of a maximum admissible FS load. Similar to pond schemes exclusively treating FS, the (NH_4^+, NH_3)-N concentration in the influent to a pond supposed to work in the facultative mode should not exceed 400 mg/l. (Strauss et al., 2002)

Composting with organic solid waste ("co-composting")

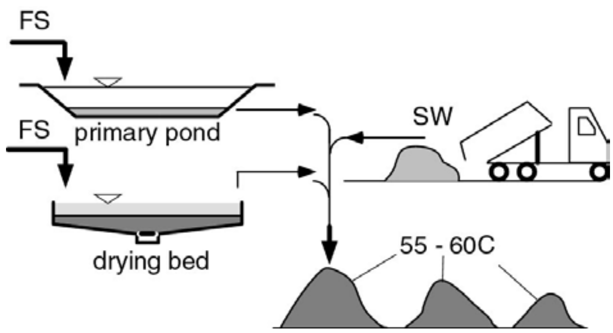


Figure 15: Municipal solid waste and biosolids from settling ponds and drying beds are mixed and co-composted. (Klingel et al., 2002)

Composting is the process with which biodegradable waste is biologically decomposed by microorganisms (mainly bacteria and fungi) under controlled aerobic and thermophilic conditions (for further information on composting, refer to Module 6 of the Training Tool). In co-composting, two or more raw materials are composted together – in this case, faecal sludge and organic solid waste (cf. Figure 15 and Photos 12 and 13). Other organic materials, which can be used or subjected to co-composting, comprise animal manure, sawdust, wood chips, bark, slaughterhouse waste, sludges or solid residues from the food and beverage industry. (Strauss et al., 2003, p. 17)

Co-composting is practiced worldwide, generally in small, informal and uncontrolled schemes or on a yard scale. The process occurs most likely at ambient temperatures with concomitant inefficient inactivation of pathogens. In contrast, thermophilic composting, i.e. composting at 50–60 °C, is an effective process, which destroys pathogens, stabilises organic material and creates a valuable soil conditioner-cum-fertiliser (Strauss et al., 2002). Co-composting of FS and municipal solid waste is a most appropriate process, since the two materials complement each other. Human waste is relatively high in N content and moisture, whereas municipal solid waste has a relatively high organic carbon (OC) content with good bulking qualities. (Strauss et al., 2003, p. 17)

Technologies and processes

To condition FS for co-composting, the solid and liquid fractions of FS are usually separated by the described technologies of sedimentation ponds or drying beds. Reported mixing ratios for co-composting of FS and organic material range from 1:2 to 1:10, depending on the FS characteristics and water content. The optimal mixing ratio of organic waste and FS, and the ideal process specifications for production of a hygienically safe compost, are still being investigated.

The technologies chosen for aerobic composting (or co-composting) will depend on the location of the facility, available capital, including amount and type of waste delivered to the site. Strauss et al. (2003, p. 17–18) distinguish two main types of co-composting systems:

1) Open systems

Windrow, heap or pile composting

The material is piled up in heaps or elongated heaps (so-called windrows). The size of the heaps ensures sufficient heat generation. Aeration is guaranteed by the addition of bulky materials, regular turning and passive or active ventilation.

Bin composting

Compared to windrow systems, bin systems are contained by a constructed structure on three or all four sides of the pile. The advantage of this containment is a more efficient use of space.

Trench and pit composting

Trench and pit systems are characterised by heaps partly or fully contained under the soil surface. Structuring the heap with bulky material or turning is usually the best aeration choice, though turning can be cumbersome if the heap is in a deep pit.

2) Closed „in-vessel" systems.

In-vessel or „reactor" systems can be static or movable, closed structures, where aeration and moisture are controlled by mechanical means and often require external energy. Such systems are usually cost-intensive and also more expensive to operate and maintain.

Based on Strauss et al. (2003, p. 17, 29), the following conclusions on co-composting of FS and organic solid waste can be drawn:

- Faecal sludges can be co-composted with any biodegradable organic material if the process control composting rules are adhered to.
- Mixing ratios reported in the literature vary widely, depending on the type of organic bulking material co-composted with faecal matter, consistency of the FS itself, dewatering degree prior to composting, and attention paid to co-composting practice and operation.
- Reported mixing ratios of dewatered FS (TS = 20–30 %) and other, more bulky organic material tend to range from 1:2 to 1:4. For fresh, non-dewatered FS, ratios used and reported tend to range from 1:5 to 1:10.

Photo 10: Co-composting heaps in a pilot plant near Kumasi, Ghana (Source: Sandec)

Photo 11: Collection of municipal solid waste for co-composting with faecal sludge. (Source: Sandec)

Co-Composting Case Study: Rini

▸ Rini's demonstration scheme (pop. = 100,000) near Grahamstown, South Africa, is an example of recent co-composting operations using bucket latrine sludge and MSW. (La Trobe et al., 1992)

▸ The plant co-composted refuse and bucket latrine sludge in static windrows with forced-aeration. Some 20 m^3 of faecal sludge were delivered daily in 20-L barrels to the station by a tractor-drawn vehicle. The faecal sludge was then screened and collected in a pump sump from where it was pumped to two overhead, cone-shaped settling/thickening tanks. The tank's supernatant was treated in waste stabilisation ponds, which had previously received the bucket latrine sludge. The thickened FS (TS = 5 %) was gravitated over the windrow while the mixed refuse was being heaped up. Final windrow size amounted to around 100 m^3. The windrow was covered with finished compost for insulation and bird control. The volumetric mixing ratio amounted to about 1:10 (FS : refuse). Temperature was measured in different locations in the windrow. When temperatures of 55 °C were reached, the windrows were left to react for three weeks. The compost was left to mature for another three weeks. The matured compost was sieved (Photo 12) and the rejects landfilled. Grahamstown garden department used the finished compost, which was reportedly free from helminth eggs. Unfortunately, no scientific data was generated or published on this valuable co-composting experience.

▸ The scheme became redundant after the bucket latrines had been replaced by sewered toilets in 1997. (Strauss et al., 2003, p. 23–24)

Photo 12: Sieving matured compost in a rotary sieve at Rini/Grahamstown (South Africa) co-composting works. (Strauss et al. 2003b)

- The following factors contribute to minimising nitrogen losses during thermophilic composting:
  – Keeping the maximum temperatures below 65 °C.
  – Maintaining the periods of maximum temperatures as short as possible.
  – Limiting turning frequency.
  – Maintaining the water content of the composting material as high as possible (50–70 %).
- Only limited information is available on existing experience, especially on organisational, institutional and financial aspects of co-composting practices and schemes operated in developing countries.

If the co-composting process is chosen as an option for treating a city's faecal sludge and organic solid waste, issues will be raised as regards the most appropriate technology approach, required organisational set-up for operation and management of the composting site, including delivery of feedstock (raw material) and distribution of the compost product. (Strauss et al., 2003, p. 29–30)

Anaerobic digestion with biogas use

This option may theoretically be perfectly suited to treat higher-strength FS not yet subjected to substantial degradation. Such sludges may comprise the contents of unsewered public toilets whose vault contents are emptied at relatively high frequencies of a few weeks. Figure 16 illustrates FS-based anaerobic digestion with biogas utilisation, and Photo 13 depicts a biogas-fuelled cooking stove. Two types of digesters, viz. fixed and floating dome units are available in practice. (Strauss et al., 2002)

Where urine is mixed with faeces, the C:N ratio of the FS is too low to generate maximum gas yields, however, the option may prove technically and economically feasible under specific local conditions. The only municipal biogas systems known to the authors and operated exclusively with FS, are those fed by public pour-flush toilets run by Sulabh, an Indian NGO. Some 100 such plants are currently in operation. The National Environmental Engineering Research Institute (NEERI, India) conducted applied research on FS-fed biogas plants in the sixties and seventies. In many developing countries, biogas plants processing FS mixed with cattle dung are generally operated as small, decentralised schemes serving one or several households or institutions. (Strauss et al., 2002)

Though anaerobic digestion with gas use has been an option widely proposed for sludge treatment and energy recovery, the number of respective schemes implemented in developing countries has remained rather low. The relatively high investment costs of such plants and concurrent low affordability by target users are likely to be the reasons for the restricted number of schemes. Moreover, removal of accumulated solids from the digesters appears to be a difficult task as it caused the shutdown of many such plants. (Strauss et al., 2002)

Photo 13: Cooking with biogas in a home in Chauhanas Vas, near Ranthambhore, India. (Wright, 2004)

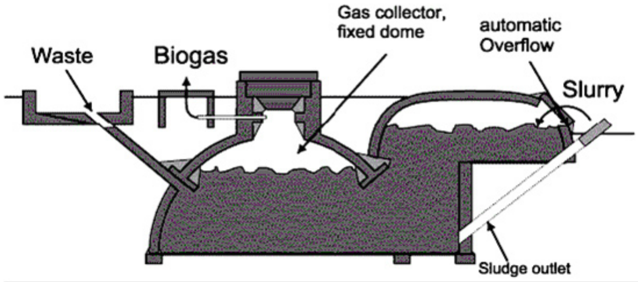


Figure 16: Illustration of a CAMARTEC biogas unit consisting of a FS-fed anaerobic digester (fixed-dome) with biogas collection. (TBW GmbH, Frankfurt)

Further questions

▸ Can performance of FS treatment technologies be compared with indicators, such as BOD reduction? What difficulties could arise regarding their commensurability?

Additional info

▸ Montangero, A. and Strauss, M. (2002): Faecal Sludge Treatment. Eawag/Sandec. IHE, Delft. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/IHE_lecture_notes.pdf (last accessed 20.05.08)

▸ Strauss, M. and Montangero, A. (2002): FS Management - Review of Practices, Problems and Initiatives. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/FS_management_GHK.pdf (last accessed 20.05.08)

Downloads available on the CD of Sandec's Training Tool and from the Internet.

3.6 What are the characteristics of aerobic vs anaerobic digestion of FS?

Aerobic treatment is currently the most common process used to reduce the organic pollution level of both domestic and industrial wastewaters. Aerobic techniques, such as trickling filters and oxidation ponds with more or less intense mixing devices, are applied for domestic wastewater treatment in many small communities. Activated sludge processes were introduced for larger communities and industrial wastewaters. Recent developments have, however, revealed that anaerobic processes may be an economically attractive alternative for the treatment of different types of industrial wastewaters and, in (semi-)tropical areas, also of domestic wastewater.

Anaerobic digestion has been rediscovered in the last two decades, mainly as a result of the energy crisis. Major developments have been made with regard to anaerobic metabolism, physiological interactions among different microbial species, effects of toxic compounds, biomass, and biomass accumulation. Anaerobic digestion has revealed a number of benefits over aerobic purification. An obvious advantage of anaerobic digestion is the production of biofuel (methane) from organic waste. Moreover, the anaerobic processes do not require aeration, have a low nutrient requirement and produce only little excess microbial biomass.

	Aerobic	Anaerobic
Application example	Trickling filters, oxidation ponds	Anaerobic reactor
Carbon balance	50 % - CO_2 50 % - Biomass	95 % - CH_4+CO_2 (Biogas) 5 % - Biomass
Energy balance	40 % - Heat production 60 % - Biomass	5 % - Heat production 5 % - Biomass 90 % - Retained in CH_4
Biomass production	Fast	Slow

Table 6: Characteristics of anaerobic vs aerobic digestion. (Source: unknown)

3.7 What are the pros and cons of the different treatment technologies?

Proper FS treatment, either in combination with wastewater or separately, has yet been practiced only in a few countries. Still, an amazing and encouraging number of initiatives for improved FS management, including the devising of appropriate FS treatment schemes, have emerged only recently, particularly in several West African countries (Senegal, Mali, Ivory Coast, Burkina Faso, Ghana).

Important efforts are currently being undertaken to develop FS treatment options adapted to developing countries, such as batch-operated settling-thickening units, unplanted and planted sludge drying beds, non-aerated stabilisation ponds, combined composting with municipal organic refuse, and co-treatment of FS in wastewater treatment plants.

Table 7 and Table 8 provide an overview of modest to low-cost faecal sludge treatment options with a high sustainability potential. Some of the options were or are currently being investigated by Eawag/Sandec and its partners in Argentina, Ghana, Thailand, and The Philippines.(Strauss et al., 2002)

Table 7: Overview of design and expected performance of selected low-cost options for faecal sludge treatment. (*SAR: Solids Accumulation Rate). (Source: Strauss et al., 2002)

		Treatment goal/achievable removal		
Treatment process or option	**Design criteria**	**Solid-liquid separation**	**Unsettled organic pollutants**	**Parasites (helminth eggs)**
Settling/thickening tank	SAR*: 0.13 m^3/m^3 of raw sludge HRT: 4 h Surface: 0.006 m^2/cap Accra	SS: 60–70 % COD: 30–50 %	To be treated for further improvement in ponds or constructed wetlands	Concentrated in the settled and floating solids
Settling anaerobic ponds	300–600 g $BOD_5/m^3/d$ HRT: SAR: 0.02 m^3/m^3 (Rosario) and 0.13 m^3/m^3 (Accra) HRT< 15 days	BOD_5 > 60–70 %	Not for this purpose	Concentrated in the settled and floating solids

Treatment process or option	Design criteria	Treatment goal/achievable removal		
		Solid-liquid separation	Unsettled organic pollutants	Parasites (helminth eggs)
Drying/dewatering beds	100–200 kg TS/m^2/year 0.05 m^2/cap (Accra)	SS: 60–80 % COD: 70–90 % N-NH_4^+ : 40–60 %	To be treated for further improvement in ponds or constructed wetlands	100 % retained on top of the filter media
Constructed wetlands	≤ 250 kg TS/m^2/year SAR: 20 cm/year (Bangkok)	SS > 80 % SAR: 20 cm/year	To be treated for further improvement in ponds or constructed wetlands	90 % retained on top of the filter media
Facultative stabilisation ponds	350 kg BOD_5/ha/d (Accra)	Not for this purpose	> 60 % removal of SS	Removed by settlement

Table 8: Characteristics of various pretreatment processes. (Source: Strauss et al., 2002)

Pretreatment process	1 – Management		2 – Pretreatment performance	
	Solids production and handling frequency	Required labour management input	Hygienic quality of biosolids	Quality of effluent for post-treatment
Settling/thickening tank	High	Medium	Low	Low to medium
Settling/anaerobic pond	High	Very high	Low	Poor to low
Drying/dewatering beds (unplanted)	High	High	Low to medium	Medium to good
Constructed wetlands (planted drying beds)	Low	Medium	Good to high	High
Co-Composting	High	High	High to very high	No effluent
Anaerobic digestion-cum-biogas production	Medium	High	Medium to good	Medium to good

Pretreatment process	3 – Post-treatment requirements		4 – Remarks
	Post-treatment options for solids	Post-treatment options for liquids	
Settling/thickening tank	• Storage • Planted/unplanted drying beds • Co-composting	• Planted/unplanted drying beds • Co-treatment in WSP	• Not suitable for fresh FS (TVS > 65 %) • Front-end loader should be available for regular desludging
Settling/anaerobic pond	• Storage • Planted/unplanted drying beds • Co-composting	• Planted/unplanted drying bends • Co-treatment in WSP	• Not recommended as first treatment • Process impaired by high FS ammonia content
Drying/dewatering beds (unplanted)	• Storage • Co-composting	• Planted drying beds • Co-treatment in WSP	• Sand quality
Constructed wetlands (planted drying beds)	• Extended storage	• Constructed wetlands or WSP	• Technology proven with Typha and Phragmites and their availability
Co-Composting	• No further treatment	• –	• O & M are highly influenced by market demand for compost
Anaerobic digestion-cum-biogas production	• Planted/unplanted drying beds • Co-composting	• Constructed wetlands or WSP	• Very few existing off-site digesters

4.1 Who are the stakeholders in faecal sludge management and what are their roles and challenges?

▶ **Key stakeholders in FSM are the households, the community, governmental decentralised services, CBOs, NGOs, authorities, public utilities, private sector members and, often left unnoticed, donors.**

The following actors play a role in the management of faecal sludges: (Kline et al., 2002)

Households

- Usually decide what type of on-site sanitation system they build in their houses.
- Use the toilet facilities.
- Decide when they want their pits/tanks to be emptied and call for emptying services.
- Pay for the emptying services.

Participation of the local population in the decision-making process of faecal sludge management is low, so is awareness of the need for adequate faecal sludge management. Willingness-to-pay for FS management is thus lower than for water supply (Bolomey, 2003). Knowledge on the need to empty the septic tanks/pits regularly is often lacking. (Klingel et al., 2001)

The community

FSM requires collective actions reaching beyond households or individual initiatives pertaining to a latrine technology. In areas where latrines are already implemented and FS is not managed properly, the community or neighbourhood's willingness-to-improve (WTI) the current FSM situation may be assessed. The WTI is defined as a function of subjective costs (willingness-to-pay), expected benefits (return), convictions to change, concern, attitudes towards improvement, and social pressure by the neighbours. These driving elements can be assessed by a psycho-sociological survey.

Decentralised government services

Key government services may include:

- Health department, head of local hospital or medical centres. Hygiene department.
- Agricultural department, Urban agriculture.
- Environmental department, water, sanitation, pollution control.
- Urban planning and infrastructure. Housing department.

Community-based organisations/ non-governmental organisations

- Raise awareness (hygiene, health and sanitation) among the population and other actors.
- Assist the informal private sector (training, equipment etc.).
- Increase the capacity of stakeholders through specific courses, training materials and guidelines.
- Represent the community and express its needs and concerns at hygiene, health and sanitation meetings (gathering representatives from the authorities, the private sector etc.).
- Promote sustainable solutions in the water and sanitation sector.

There are several accounts of community-based organisations (CBOs) and non-governmental organisations (NGOs) working in the field of water supply, sanitation and hygiene education. With regard to faecal sludge management, the aforementioned organisations are mainly active in promoting the construction of on-site sanitation systems through awareness raising, assistance to entrepreneurs building latrine slabs etc. However, very little has been reported on CBOs or NGOs involved in activities related to pit emptying, faecal sludge haulage, treatment or disposal.

Authorities

Public authorities, which may be involved in FS management at different levels (e.g. local, city, national):

- Are responsible for the development of a sanitation policy.
- Are responsible for setting up of a legal framework.
- Define measures, sanctions and incentives to assist in meeting the objectives defined in the policy.
- Control and enforce the legislation.
- Define roles and responsibilities of the different stakeholders.
- Assume a coordinating role (between the different administrative levels and different actors (in particular between the public and private sector).

As aforementioned, most of the responsibilities of the authorities are insufficiently assumed in practice, i.e. faecal sludge management is often not given adequate priority, and government as well as municipalities often lack the required institutional and financial capacity.

Public utilities

- Pit emptying services.
- Operation of public toilets.
- Operation of faecal sludge treatment plants.

According to Klingel et al. (2001), Nam Dinh's, Vietnam, public utilities do not actively promote their services nor increase awareness of the population for more frequent emptying. Municipal emptying vehicles are frequently inoperative (e.g. Bamako/Mali, Kumasi/Ghana). Treatment plants run by the municipality are often inadequately operated and maintained (e.g. Accra/Ghana, Alcorta/Argentina). Public utility companies are often facing financial difficulties.

Private sector

- Pit emptying services (small-scale enterprises or individual manual desludgers).
- Operation of faecal sludge treatment plants.
- Operation of public toilets.

In the field of FS management, the private sector is mainly involved in pit emptying services and plays a demand-oriented role (full septic tanks or pits, farmers willing to reuse faecal sludge on their fields). Private manual pit emptiers are either small-scale enterprises (equipped with vacuum trucks or donkey/tractor-drawn collection vehicles) or individual desludgers. They mainly work independently from the public sector where public services are insufficiently ensured (Bolomey, 2003). They are also involved in operation and maintenance of public toilets (e.g. Bamako/Mali and Kumasi/Ghana) and in faecal sludge treatment (e.g. Bamako/Mali, Cotonou/Benin and Kumasi/Ghana).

Farmers, farmers' associations and cooperatives

Users or potential users of treated/untreated faecal sludge

Farmers perception of the use of excreta as organic fertiliser, their demand for biosolids (treated FS), their needs of biosolid characteristics, their willingness and ability to pay for biosolids are all factors influencing the planning of an improved FS management (disposal or reuse, treatment type, financing mechanisms etc.). The demand is strongly governed by the availability of other fertilisers and their prices, as well as by the policy in place (e. g. promotion of organic farming).

Donors

In many countries, the sanitation and water sector is predominantly financed by ESA and supported by international consultancy. The external financial support is then predominantly geared towards the construction of infrastructure to provide access to sanitation to a large number of the population within a short period – a challenging task for the international sanitation community. However, to sustain this trend of infrastructure provision, a strong capacity building programme is needed to provide local expertise for operation, maintenance and upgrading of these infrastructures.

Further questions

▸ What role does FSM play within a holistic planning concept like the Household-centred Environmental Sanitation Approach?

Additional info

▸ Module 7 of the Training Tool on Planning of Environmental Sanitation Systems.

▸ Klingel, F., Montangero, A. and Strauss, M. (2001): Nam Dinh - Planning for Improved Faecal Sludge Management and Treatment. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/WSA_paper_Klingel.pdf (last accessed 19.05.08). Download available on the CD of Sandec's Training Tool and from the Internet.

4.2 How to select the most appropriate FS treatment option?

▸ **The range of FS treatment options is always limited by a set of factors requiring careful analysis prior to project implementation. By excluding unfeasible technologies, a "white list" of options remains that can be further adapted to the given requirements and preconditions.**

FS treatment objectives may be formulated based on an FS management concept, which will ideally have been developed as an integral part of an overall, **city-wide environmental sanitation plan**. It will describe the organisational/institutional, financial, legal, and technical aspects of the entire FS management scheme – from the sanitary facility to final disposal or reuse of treatment products – and include a description of adequate:

- sanitary infrastructure types,
- collection system,
- transport system,
- treatment goals, level of decentralisation and selected potential sites, and
- reuse/disposal schemes of the treatment products.

The management concept will be based on the **assessment of:**

- current management practices and their shortcomings,
- existing sanitary infrastructure and trends,
- stakeholders' customs, needs and wishes,
- prevailing socio-economic, institutional, legal and technical conditions, and
- a general urban development concept.

Performance criteria	Process simplicity and reliability criteria	Cost-related criteria
• Achievable consistency and biochemical stability of biosolids • Achievable hygienic quality of biosolids • Achievable quality of liquid effluent	• O + M requirements • Skills required for operation and monitoring • Risk of failure related to installations or to managerial or procedural measures	• Land requirement • Investment costs • Operating and maintenance costs

Table 9: Criteria for selecting FS treatment options for Nam Dinh, Vietnam. (Klingel et al., 2001)

A **pre-screening of options deemed unsuitable** for the particular setting should subsequently be conducted. For example, if the city does not avail of a sewer system, the option "co-treatment with wastewater" will be excluded. The option of anaerobic digestion with biogas use must be excluded if, for example, technical expertise is lacking, and FS originates mainly from septic tanks and other on-site systems, which are normally emptied at intervals of one or more years only and, hence, has already undergone substantial biochemical degradation.

The second step consists in **comparing the potentially feasible options** chosen during the preselection step and based on the selected criteria as shown in Table 9. (Strauss et al., 2002, p. 29)

The following table illustrates the evaluation process of three preselected options for the city of Nam Dinh, Vietnam.

The third step for decision-makers consists in **weighing different criteria** and determining the most appropriate option(s) for the faecal sludge management concept. (Montangero et al., 2002, p. 31–32)

Table 10: Evaluation of treatment options for Nam Dinh. (Klingel, 2001)

Performance			
Criteria	**Constructed Wetlands**	**Drying Beds**	**Settling Tanks + Pond**
Physical quality of solids	Sludge mass of initial m.: 3 % Water content: 70 % (+) High volume reduction (+) Low water content, solids easy to handle (spadable)	Sludge mass of initial m.: 4.5 % Water content: 60 % (+) Low water content, solids easy to handle (spadable)	Sludge mass of initial m.: 14 % Water content: 85 % (–) Water content too high, settled sludge neither pumpable nor spadable, bulking agent needed and resulting in volume increase
Hygienic quality of solids	(+) Safe for reuse without post - treatment	(–) Post-treatment required for safe reuse	(–) Post-treatment required for safe reuse
Quality of liquid effluent	(–) Vietnamese discharge standard not met (+) Quality relatively close to standard, minimal polishing treatment required	(–) Vietnamese discharge standard not met	(–) Vietnamese discharge standard not met
Simplicity and Reliability of Process			
Criteria	**Constructed Wetlands**	**Drying Beds**	**Settling Tanks + Pond**
O+M requirements	(+) Sludge removal only once every 2 years (every 4 years for each unit) (–) Pumping required for septage loading and percolate removal (–) Care for plant growth, periodic harvesting and control of bed moisture	(–) Sludge removal 2–3 times a week (once every 10–15 days for each unit) (–) Pumping required for septage loading and percolate evacuation (–) Regular refilling of sand	(+) No pumping required (+/–) Sludge removal from tanks every 4 weeks (–) Sludge removal difficult due to high water content, mixing with bulking agent (–) Regular supply of bulking agent (rice husks) required
Skills required for operation and monitoring	(+) Day to day operation: unskilled labour Monitoring: technical degree	(+) Day to day operation: unskilled labour Monitoring: technical degree	(+) Day-to-day operation: unskilled labour Monitoring: technical degree
Risk of failure	(–) Problems with healthy plant growth, e. g. due to bad regulation of bed moisture, negative impact on filter permeability	(–) Loss of filtering capacity if sand is not refilled regularly (–) Increased drying time due to wet climate (–) If post-treatment is not properly conducted, reuse is not safe	(–) Loss of settling capacity if the tanks are not desludged at the designed intervals (–) Sludge removal may be difficult and availability of bulking agent may be limited, leading to prolonged desludging intervals (–) If post-treatment is not properly conducted, reuse is not safe
Costs			
Criteria	**Constructed Wetlands**	**Drying Beds**	**Settling Tanks + Pond**
Land requirement	Net treatment area: 200 m^2	Net treatment area: 250 m^2 (–) Highest land requirement	Net treatment area: 200 m^2 (+) More land-use efficiency with higher septage load
Investment costs	US$ 23,200	US$ 24,350	US$ 24,100
Operation and maintenance costs	1,400 US$/year	2,010 US$/year	6,180 US$/year

Further questions

- Does scaling of treatment systems influence their performance?
- In how far can different technologies be combined?
- How much upscaling freedom do the different technologies offer?

Additional info

- Strauss, M. and Montangero, A. (2002): FS Management - Review of Practices, Problems and Initiatives. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/FS_management_GHK.pdf (last accessed 19.05.08). Download available on the CD of Sandec's Training Tool and from the Internet.
- Tilley, E. et al (2008); Compendium of Sanitation Systems and Technologies (pre-print). Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland. Document can be ordered: info@sandec.ch

4.3 What are the financial and economic costs?

With regard to the national economy, investments in sanitation technologies or in any other public sector services, whose benefits are not fully quantifiable, require a method to determine their real costs (economic costs). For example, local engineers might favour conventional sewerage but its dependence on large volumes of flushing water might place too great a demand on local water resources and require too much of the country's capital to exploit these water resources. Therefore, it is important to first evaluate the economic costs (includes all costs, regardless of who incur them or on what level) of competing sanitation alternatives and then to determine what the users will have to pay (financial costs). Economic costing provides the policy-makers with a proper economic basis for their decisions. Financial costs are entirely dependent on policy variables that may greatly differ. However, they are for example useful to householders and sewerage authorities. (Mara, 1996, p. 171–179)

4.4 How can different FS treatment technologies be economically evaluated and compared?

► **In a first step, investment and O+M costs have to be accounted for on a case-to-case basis and broken down to annual values. To compare the different technologies, one or more additional criteria have to be chosen, such as treated tons TS per year. The resulting unit would then be US$ per ton TS.**

Cost factors

Investment and O+M costs of FS collection and treatment must be determined on a case-to-case basis as local conditions are decisive. The following factors play a key role:

- Economic indicators (land price, labour cost, interest rates, petrol prices).
- Possible income from the sale of treatment products (e.g. hygienised biosolids or compost, biogas).
- Site conditions (permeability, groundwater table).
- Haulage distances and traffic conditions.
- Economy of scale (plant size).
- Legal discharge standards.

Moreover, availability and choice of construction material, whether produced locally or imported, play a role. (Montangero et al., 2002)

Shaping cost factors for economic accounting

To allow economic accounting and render different system options comparable, the cost factors have to be shaped as described below.

In a first step, all relevant cost factors have to be annualised to allow accounting of the different cost elements of one treatment option. Economic accounting of an installation includes:

- **Annual capital costs** on the investment (construction, land acquisition, studies etc.). The annual capital costs (or annuity or capital recovery factor) are the amount payable annually in order to attain reimbursement of all the capital and interests at the end of the depreciation period.
- **Annual operation and maintenance (O+M)** costs also have to be assessed. The running costs, such as salaries of workers, electricity or general repairs are included in the O+M costs. (Steiner et al., 2002)

To compare the annualised costs with those of other treatment options, they are usually expressed per ton TS per year (contained in arriving sludge to the treatment plant). It is possible to convert the chosen unit cost (US$ per t TS) into a theoretical per capita unit if a daily mean TS per capita of 14 g in septage is assumed (Heinss et al., 1998). Hence, plant capacity can also be expressed in population equivalent (PE). 1 PE corresponds to 14 g TS/day per capita.

An example is presented herewith of how the annual costs per ton of TS are calculated and listed in a specific case.

Heinss (1999) estimated the annualised cost per ton of TS treated (investment and O+M) for constructed wetland plants treating septage of 10,000–30,000 inhabitants. The calculations are based on experience gained from a pilot plant installed and tested by AIT, Bangkok, over the past four years. The plant treated septage of approximately 3,000 inhabitants (Heinss, 1999). Moreover, he also estimated the cost for polishing treatment of the wetlands' percolate in waste stabilisation ponds. Whenever possible, the costs for FS treatment should be evaluated in conjunction with the collection costs, aspects of optimal plant size and availability of appropriate land size. The costs estimated in Table 11 reflect an ideal situation with a FS constructed wetland plant located in the centre of a chosen urban district. For this, the following assumptions were made or real cost figures used:

Depreciation period: 20 years
Interest rate: 5 %
Skilled worker's salary: US$ 350/year
Land price: US$ 8/m^2
Daily per capita TS
contribution: 14 g/cap*day

Economy of scale

▸ It is important to note that the per capita or per TS costs of a plant are dependent on its size. In general, small pilot-scale plants have significantly higher specific capital costs than full-scale plants (cf. Figure 17). However, although investment and O + M costs do not follow a linear increase with plant size, it is possible to extrapolate the capital costs of a small to a larger plant using a mathematical model. (Maystre, 1985)

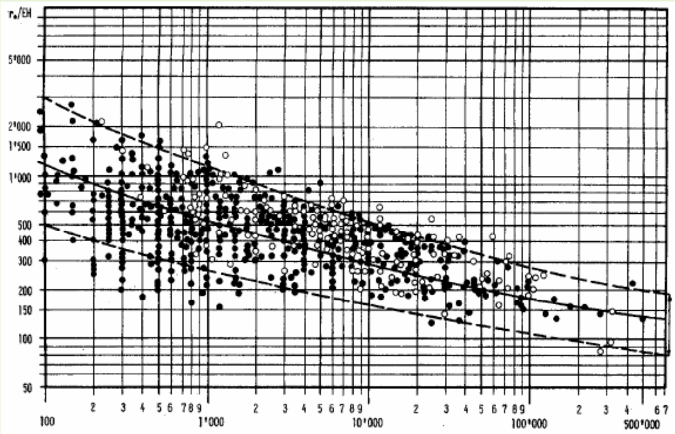


Figure 17: Illustration of the economy of scale of WWTP in Switzerland. X coordinate represents the plant's capacity in PE and the y coordinate the average specific cost in CHF/PE (after Maystre, 1985). Larger plants exhibit relatively lower costs than smaller ones.

$$P = \partial \cdot C^{\partial}$$

P = plant costs, C = plant capacity,

a = coefficient of proportionality,

∂ = parameter of economy of scale

▸ A simple way to obtain a financial upscale from a pilot plant to a full-size plant is to apply the principles of the economy of scale based on the pilot plant costs, and to assume an appropriate value for the parameter ∂. When using a parameter ∂ of about 0.8 (or slightly higher for a conservative estimate), it is possible to obtain a raw but extremely rapid capital cost estimate (total plant cost or cost per t TS of incoming FS) of any plant capacity. This economy of scale principle can be applied to units (tank, pond etc.) of a treatment plant or even to an entire installation, such as a FSTP.

▸ The upscaling parameter ∂ does not appear to be constant, however, it will tend to range between 0.8 and 1. If this value amounts to 1, then we will have reached the zone where no further economy of scale is possible, and where the potential zone of diseconomy of scale starts. (Steiner et al., 2002, p. 31, 38)

Item	**Annual cost [US$ per ton TS]**
Constructed wetlands	
– O + M	47
– Capital cost (plant)	33
– Capital cost (land)	3
Total constructed wetlands	**82**
Polishing of percolate in ponds	
– Capital and O + M	10
FS collection	
– km-dependant cost	6
– Capital cost for vacuum tanker	32
Overall annual cost per ton of TS treated	**US$ 130**

Table 11: Annual cost of FS collection and treatment of septage in constructed wetlands. (Heinss, 1999)

Further questions

▸ How much importance should be attached to values like US$ per t TS, given the fact that not only the quantity of FS treated is of importance but also the effluent quality?

Additional info

▸ Steiner, M., Montangero, A., Koné, D. and Strauss, M. (2002): Economic Aspect of Low-cost Faecal Sludge Management - Estimation of Collection, Haulage, Treatment and Disposal/Reuse Cost. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/FSM_cost_report.pdf (last accessed 08.04.08). Download available on the CD of Sandec's Training Tool and from the Internet.

4.5 What should be considered when designing a financing scheme for sanitation systems?

▸ **Private FS collectors, which have to pay fees when delivering FS to designated treatment or disposal sites, will illegally discharge their loads at non-designated places at short haulage distances to avoid paying such fees.**

Sustainable environmental sanitation may be achieved or enhanced only by applying appropriate financial incentives and sanctions (Wright, 1997). Hence, municipalities must devise an effective sanctioning system (e.g. by imposing fines or non-renewal of FS collection contracts with entrepreneurs) and an incentive-based policy by, for example, paying entrepreneurs for delivering FS to the legally designated treatment or disposal site. (Jeuland et al., 2004); (Steiner et al., 2003);

Based on a money flux reversal model for FS management set up by Jeuland et al. (2004) for one of the districts of Bamako (Mali), Steiner et al. (2003) developed a series of possible financial models for the flow of fees to be paid within the customer service provider/ public authority triangular network existing or to be developed in improved FS management. Figure 18 illustrates such a financial scheme, the most crucial element of which is the reimbursing of collectors for FS brought to the treatment site (discharge premiums). The flux reversal principle is about to be introduced in the city of Danang, Vietnam. The city of Ouagadougou, Burkina Faso, is planning to pay collectors the equivalent of € 3.70 upon delivery of FS to the new wastewater-cum-FS treatment scheme to reduce illegal and illicit dumping of FS or use of untreated FS in agriculture. For FS management to function on a sustainable basis, national or municipal governments must consider the provision of subsidies. The rationale for such a policy is to render pit emptying affordable to all urban dwellers, to enable entrepreneurs to operate FS services with adequate profit margins and to keep prices for agriculturally used biosolids competitive. Intensive information, awareness raising and social/commercial marketing campaigns are needed to render new money flux procedures acceptable by the urban customers and to promote farmers' demand for biosolids.

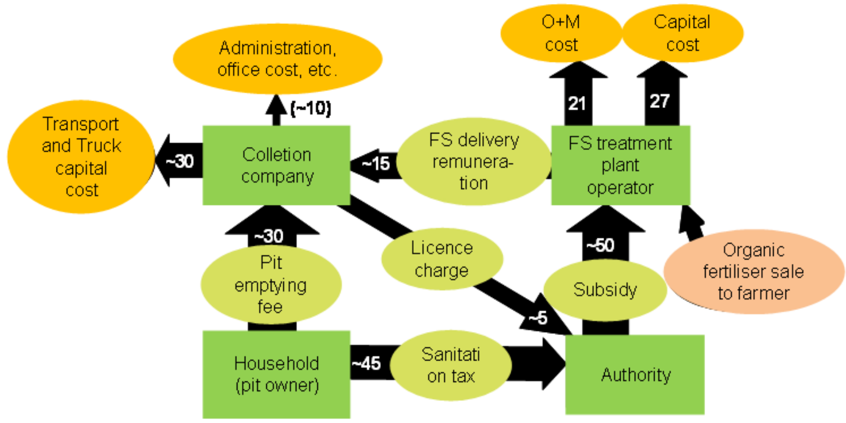


Figure 18: Novel money flux scheme. Stakeholders (dark green; Cost/revenue (light green); cost (orange); money flow (black arrows) (Jeuland et al., 2004); (Steiner et al., 2003)

Further questions

▸ What option do authorities or service providers have to recover the costs spent on incentives?

Additional info

▸ Steiner, M., Montangero, A., Koné, D. and Strauss, M. (2003): Towards more Sustainable Faecal Sludge Management through Innovative Financing. In: SOS - Management of Sludges from on-Site Sanitation. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_ewm/downloads_ewm/money.flow.models.pdf (last accessed 08.04.08). Download available on the CD of Sandec's Training Tool and from the Internet.

4.6 How can FS management be improved?

▶ **When trying to improve FSM, a whole set of factors, covering technical and non-technical aspects as well as involving stakeholders on all levels, have to be considered.**

How can the aforementioned situation be sustainably solved? In a nutshell, the challenge and goal to be met is to ensure that all FS generated in the urban environment is discharged at designated storage or treatment sites, that illegally and indiscriminately dumped untreated FS is stopped and that FS is subjected to adequate treatment prior to agricultural use or landfilling (cf. Figure 19). An array of measures is required to achieving this: (Montangero et al., 2002)

A. Advocacy
B. Capacity building
C. Technical measures
D. Institutional and regulatory measures
E. Financial/economic measures

Awareness and political will must be available or created at various government levels to attain sustained improvements in FS management. Municipal or entrepreneurial bodies must be in place or developed to provide effective FS collection, haulage and treatment services, and urban dwellers must feel the need and be willing and able to pay for improved excreta disposal.

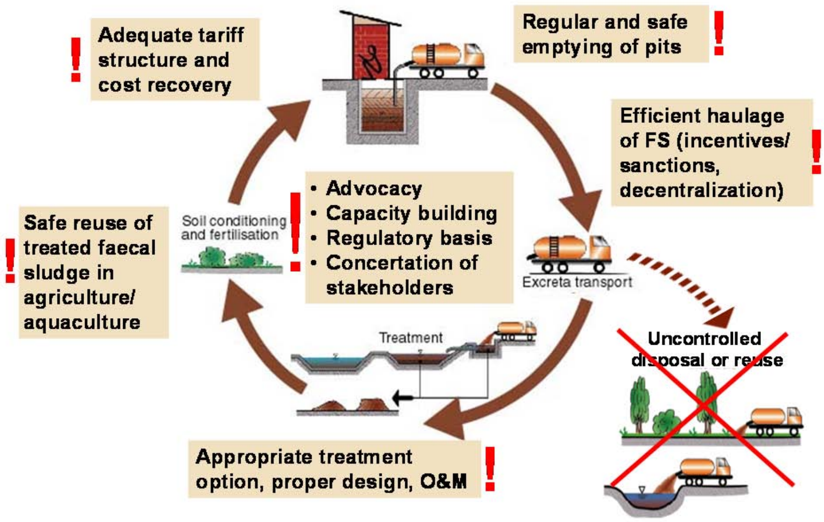


Figure 19: Schematic illustration of an environmentally sustainable management of on-site sanitation and factors to be considered.

A. Advocacy

Awareness-raising among all stakeholders

Authorities should be made aware of the key importance of improved FS management in attaining a better health and well-being of the population, of the economic benefits as well as protection of the natural resources. This would help increase the involvement of the authorities in FS management and the allocation of means for FS management to become an integral part of sanitation planning.

Awareness raising campaigns should also aim at increasing the acceptance of improved FS management by the local population (e.g. by motivating them to call for emptying services frequently in order to avoid overflowing septic tanks) and their willingness to pay for the service.

B. Capacity building

Technical capacity building alone is not sufficient to ensure sustainable FSM. Strengthening the municipal technical services and consulting firms with non-technical competence (financial, legal, institutional, socio-economic, urban planning) is urgently needed. Simultaneously, mechanical and manual emptying entrepreneurs, funding agencies and local stakeholders require capacity building in their fields of activity and responsibility.

Universities and research institutes (e.g. EIER, national universities, CREPA, Eawag/Sandec) are the main potential providers of basic skills and continuing education for professionals. Target audiences or clients are the private sector (collection entrepreneurs, FSTP operators, consulting firms), officials, technical and social service staff at municipal level, technical staff, planners, and decision-makers/politicians at central and donor agency level.

The Dakar Declaration

▶ Working groups of a Symposium on faecal sludge management in Dakar proposed to pass on to policy-makers the message that sanitation efforts improve public health, reduce poverty and create employment. This message can be convey via the media (newspapers, TV, radio) and pressure groups (civil groups, municipal, traditional, religious leaders). It was suggested that selected high-level leaders/ politicians be approached and invited to raise awareness and advocate the FSM issue in their respective countries and among their pairs or other high-level decision-makers abroad. Following the three-day discussion, several participants of the Symposium drew up The Dakar Declaration with a view to promoting the faecal sludge management cause at high level. The declaration, available in English and French, will be widely disseminated by the participants and their organisations (e.g. PDM, CREPA, PS-Eau), as well as through organisations' websites, electronic newsletters and at upcoming international events in the field of sanitation, hygiene and urban development.

C. Technical measures

Choice of the most adequate FS treatment option

A viable treatment system should be adapted to the specific conditions prevailing in a city or country. The system should:

- be low in capital and operating cost
- require low or modest levels of mechanisation
- require minimum external energy input
- be compatible with the expertise available
- be compatible with the institutional framework

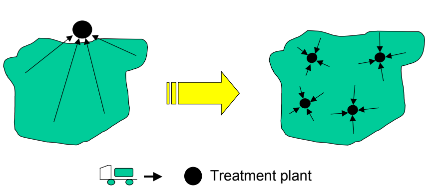
Low capital and operating cost treatment options are usually associated with large land requirements. When selecting a treatment option, a balance between economic and technical feasibility, on the one hand, and land requirement, on the other, must be found to match the conditions and specific needs of the particular situation. (Montangero et al., 2002, p. 14)

Decentralisation of FS haulage

Given the difficulties in collecting FS and hauling it across cities to designated disposal and treatment sites, the devising of modest-scale "satellite" treatment plants (Figure 20) and neighbourhood or condominial septic tanks (Figure 21), to be sited in easily accessible locations may contribute significantly to reducing collection and haulage costs. This would increase the pit emptying frequency and reduce indiscriminate dumping of FS. The equipment should be adapted to allow emptying of pits located in narrow lanes. Effective technical solutions do exist, such as a combination of small, hand-pushed vacuum tugs of 350 L and truck-mounted vacuum tanks of 5 m^3, as operated in Haiphong, Vietnam (compare Chapter 3.3). (Klingel, 2001)

Capital and O & M costs decrease with increasing plant size (economy-of-scale; compare Chapter 4.4). However, since larger treatment plants require longer haulage distances between pits and disposal sites, not only haulage costs are increased but also the risk of indiscriminate dumping. Based on an assessment conducted in Kumasi, Ghana, Steiner et al. (2002) calculated that a plant capacity of 20,000 to 200,000 person-equivalents (PE) corresponds to the minimum treatment and haulage costs (Figure 22).

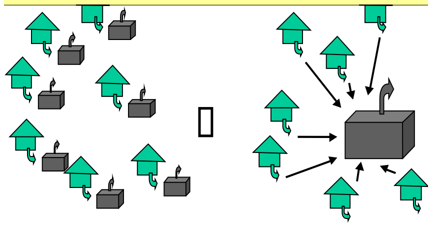
Scale: centralized or semi-centralised?



► Minimize overall management (transport + treatment) cost (raw FS separated solids, liquid effluent)

Figure 20: Semi-centralised FS treatment – a strategic tool to minimise costs, indiscriminate dumping, health risks and water pollution. (Montangero et al., 2002, p. 3–4)

Communal instead of individual septic tanks



► Minimizes emptying tips (km x m^3)

► Improves access to septic tanks

Figure 21: Use of communal septic tanks – a strategic tool to facilitate effective FS collection. (Montangero et al., 2002, p. 3–4)

However, optimum plant size has to be determined on a case-to-case basis as it depends on the local context (labour cost, land price, treatment plant scale, haulage distance, treatment site conditions etc.).

D. Institutional and regulatory measures

Legal framework with defined roles and responsibilities

An ordinance specific to FS management should be developed defining also allocation of stakeholder responsibilities.

Based on an institutional study conducted in Bamako (Mali), Bolomey (2003) recommends that the public sector should fill the gaps in the FS legislation, coordinate awareness raising activities, promote participation of the population and create a favourable framework (e. g. public-private partnership) in order to offer the private sector the necessary stability for optimum development. Moreover, it should subsidise the services so that they are not only the privilege of the high-income population. Responsible authorities should be allocated capital to control and enforce the regulations. (Bolomey, 2003)

Establishment of concertation/coordination mechanisms

Participation of key actors can be promoted through workshops for entrepreneurs and service users (Strauss et al., 2003), since a discussion platform among stakeholders is important.

Define sanctioning procedures

Issuing licenses to pit emptying enterprises is a way to control and enforce regulations. In Kumasi, for example, where the percentage of faecal sludge delivered to an official site is reportedly very high, the competitive market and the fact that the municipal authority can revoke the licenses if truck drivers do not discharge their loads at the official site appear to be the reasons for satisfactory compliance. In Danang, Vietnam, certification and licensing of pit emptying enterprises, including procedures for control and enforcement, are being introduced (Strauss et al., 2003). The financial incentive approach is presented later in this chapter.

FS committee in Bamako

In Bamako, Mali, the emptying companies founded an association comprising all municipal emptying enterprises and technical services, including the municipal sanitation officer. Problems can be discussed within this framework. Moreover, a "FS committee" was formed composed of the key actors in FS management (public sector, associations, consulting firms, research institutes, and the private sector). Its role is to promote transparency and dialogue. Each actor's role is defined in a ToR. This committee is headed by an independent actor – CREPA Mali – active in sanitation at national and regional level. The same approach was applied in Bouaké, Côte d'Ivoire. (Bolomey, 2003)

Framework for optimal development of the local private sector
To offer the local private sector the required stability for optimal development, the public and private sector entered into partnership. The authorities should clarify their responsibilities towards the private sector and define coordination/communication mechanisms between both sectors. Public sector involvement in favour of the private sector could enable the latter to improve its management of risks and responsibilities related to FS management services. (Bolomey, 2003)

Formal involvement of the private sector and recognition of the private sector by the authorities could motivate the authorities to reduce financial and administrative constraints for pit emptying companies. This could, in turn, help lower emptying fees and motivate truck companies to build financial reserves (e.g. for truck repair). It could also motivate them to comply with legal provisions (discharge at officially designated disposal/treatment sites).

The public sector should control the fees of FS management services applied by the private sector. It should control the quality of services delivered by the private sector, the number of enterprises active in this sector and define operation rules. It will thus legitimise the private sector, limit saturation of the market and hinder cartelisation (Bolomey, 2003). In Kumasi, for example, the municipal authority set a range of collection fees within which the operators are supposed to operate. It has been warning truck drivers through letters and periodic meetings about the need for high environmental protection standards. (Strauss et al., 2002)

To formalise the activities of pit emptying enterprises, the idea of an "emptier license" has been promoted in Bamako. This license would define the disposal point, quality of services and number of trucks allowed to operate in the specific district. Licenses for pit emptying enterprises already exist in Kumasi and Danang. In Kumasi, an FS treatment plant started operations recently. Operation and maintenance will be handled by the private sector under a franchise scheme. However, the waste management department will manage the plant for the first three months of operation to determine the surtax to be paid by the private contractor to KMA, based on FS inflow as well as operation and maintenance costs. The contractor will also be responsible for biosolids management. (Strauss et al., 2002)

E. Financial/economic measures

Financial schemes and tariff structure*:* For sustainable functioning of a faecal sludge management system, it is of utmost importance for all stakeholders to be motivated and assume their roles and responsibilities. Tariff structures should be designed in such a way that expenses of the treatment plants are covered, haulage enterprises are encouraged to deliver their loads to the treatment plants and users able and willing to pay their fees. A rather new strategy is to reverse the money flux.

Subsidies and loans: It should be noted that for many low-income, especially very low-income communities, low-cost sanitation is not necessarily cheap. Possible solutions are to subsidise the cost of the sanitary facility or to arrange for loans.

Obviously, *subsidies* cost money! In the event of available capital (e.g. from central governments or bilateral aid agencies), it is still questionable whether it should be invested in direct subsidies to households or rather used to cover overhead costs of a hygiene education programme. Another alternative is to provide reduced interest rates or sell, at half-price or less, some key component, such as the fly screen for a VIP latrine. However, subsidies should not eliminate or weaken the householders' feeling of ownership and responsibility.

Loans*,* possibly at a subsidised interest rate, should be made available to householders to allow them to install their sanitation facility. Care should be exercised when setting the interest rate and loan repayment term. Of course, some control is needed to ensure that the money lent is actually spent on sanitation. A procedure adopted in Lesotho by the urban sanitation improvement team (USIT) may serve as a model for urban sanitation programmes:

The loan application is submitted to a loan approval committee (LAC) formed by different local opinion leaders. The committee must interview the client before the loan is approved. The money is finally provided by a commercial bank. LAC and USIT are also in charge of following up on late repayment. (Mara, 1996, p. 213, 214)

Credit scheme for poor families
Septic tanks should generally be emptied on an annual basis. The emptying fees are often far too high for poor households, who prefer to pay in smaller instalments throughout the year by a microcredit scheme.

In a microcredit system, a small group of members (e.g. households) are permanently paying small instalments into a collective account of a microcredit institute. After a defined period, the group becomes financially viable and their members can, for example, rotatingly obtain a credit.

Microcredit systems are used in many countries. In Burkina Faso and India, for example, microcredit systems allow poor families finance sanitation infrastructure like VIP toilets.

Market opportunity for reuse of biosolids
Chinese peri-urban vegetable farmers have reported that customers prefer excreta-fertilised rather than chemically-fertilised vegetables. Therefore, vegetables grown on excreta-conditioned soils yield higher sales prices (Strauss et al., 2002). Also in Tamale, a city in northern Ghana, it is common to reuse untreated faecal sludge in agriculture. A preliminary study aiming at assessing farmers' perception with regard to faecal sludge reuse (compost produced with organic solid waste and faecal sludge) indicated that 2/3 of the farmers are willing to pay for the compost. (IWMI, 2001)

In places where treated sludge is not traditionally used in agriculture and where commercialisation of treated sludge is not available, substantial efforts have to be made to develop a market for that product. Potential customers have to be identified and their needs and wishes analysed. The customer's confidence has to be developed by guaranteeing product benefits, best conducted in collaboration with an agricultural service or research institution. Manners of distributing and promoting the product need to be established. It may be very useful to use existing structures, such as commercial fertiliser distributors or agricultural cooperatives. (Klingel et al., 2002, p. 23)

Financial benefit of sludge reuse

▸ The sale of treated FS to farmers or other FS users or the saving of landfill cost through treated FS reuse instead of disposal are direct economic benefits of improved FS management. Steiner et al. (2002) mention that saving of landfill cost amounts to US$32 per ton TS, and that the sale of treated FS can generate US$ 15 per ton TS. However, in case treated faecal sludge is reused as organic fertiliser rather than disposed of in landfills, an additional treatment step (hygienisation through storage or composting) is necessary. Additional treatment costs were estimated at 5 US$/t TS. Total economic benefits from treated sludge reuse therefore amounts to 42 US$/t TS. This corresponds to a reduction of the net FS management costs of 38 %.

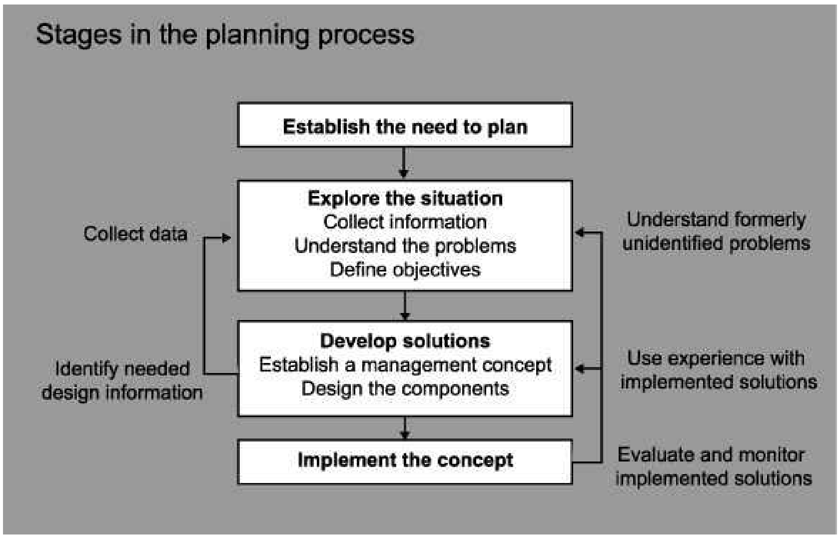


Figure 23: Stages in the planning process and feedback loops. (Klingel et al., 2002)

How to plan for improved FS management?

A holistic planning approach (HCES) for sanitation systems is presented in Module 7. This chapter is limited to a short description of the main planning stages and a few principles likely to be relevant in the planning process.

Planning for FS management must form an integral part of long-term urban sanitation planning. Ideally, the need to initiate such concerted planning should evolve simultaneously from public authorities, entrepreneurial service providers and communities. Alternatively, needs may first become felt and pronounced in one of these groups only, making it necessary to "market" the needs and make the others aware of the fact that their active role is required too. Once consensus of the planning need is reached, the actors should further consider that planning does not end with implementation of measures. Based on feedback through observable impacts and monitoring, further and improved solutions will have to be found.

Figure 23 illustrates the phases of a planning process, viz. exploring the situation (stakeholder identification; assessing existing practices, settings and problems; formulating paradigms and objectives); developing solutions (institutional, financial, technical); and implementation of concepts or measures) as applicable in urban sanitation or FS management planning, once agreement on the need has been reached (Klingel et al., 2002). Where use of biosolids produced by FS treatment is envisaged, farmers and farmers' cooperatives also form part of the stakeholder groups, since they determine whether or not a market develops for hygienically safe biosolids produced in future treatment schemes. (Klingel, 2001)

Identification, continuous involvement, defining of the specific roles of all actors and sustained concertation among them, constitute the single most important set of measures for devising and maintaining improved FS management. In the case of Danang and Kumasi, stakeholder identification and coordination were sought by the authorities, whereas in the case of Bamako, the respective initiative emerged from the entrepreneurs.

Developing the strategic and conceptual solutions will comprise organisational/institutional, financial, legal, and technical aspects of the entire FS management scheme from the sanitary facility to the final disposal or reuse of treatment products. It will include a description of improved or appropriate:

- Sanitary infrastructure
- FS collection systems
- FS transport system
- Treatment goals, level of decentralisation and selected potential sites
- Approaches and schemes for reuse or disposal of the treatment products

The management concept will be based on the assessment of:

- Current management practices and their shortcomings
- Existing sanitary infrastructure and trends
- Stakeholders' customs, needs and wishes
- The prevailing socio-economic, institutional, legal and technical conditions, as well as the general urban development concept

(Adapted from Strauss et al., 2002)

Additional info

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Bold: The key readings (additional info) are available on the CD of Sandec's Training Tool. They are open source products. The user must always give credit in citations to the original author, source and copyright holder.

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