Engineering Knowledge and Research Project - R8056

Capacity Building for Effective Decentralised Wastewater Management

FS Management – Review of Practices, Problems and Initiatives

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Acronyms

CBO	Community-based organizations
DWWTP	Decentralised wastewater treatment plant
FS	Faecal sludge(s)
FSTP	Faecal sludge treatment plant
GIE	Groupe d'intérêt économique
KVIP	Kumasi ventilated improved pit latrine
OSS	On-site sanitation
TS	Total solids

Abbreviations

AIT	Asian Institute of Technology (Bangkok, Thailand)
CREPA	Centre Régional pour l'Eau Potable et l'Assainissement à faible coût (Ouagadougou, Burkina Faso)
EAWAG	Swiss Federal Institute for Environmental Science & Technology
IWMI	International Water Management Institute
KNUST	Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
SANDEC	Dept. of Water & Sanitation in Developing Countries (at EAWAG)
UNR	Universidad Nacional de Rosario (Rosario, Argentina)
UESP	Urban Environmental Sanitation Project (World Bank/IDA) in Ghana

Glossary

Faecal sludge	Sludges of variable consistency collected from so-called on-site sanitation systems; viz. latrines, non-sewered public toilets, septic tanks, and aqua privies
Percolate	The liquid seeping through an unplanted or planted sludge drying bed and collected in the underdrain
Public toilet sludge	Sludges collected from unsewered public toilets(usually of higher consistency than septage and biochemically less stabilised)
Septage	Contents of septic tanks (usually comprising settled and floating solids as well as the liquid portion)
Wastewater treatment plant sludge	Sludges produced during wastewater treatment (settled solids – primary sludge – and excess bacterial biomass – excess sludge)

Photo credit

All photos by SANDEC except where stated otherwise.

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Preface

SANDEC was sub-contracted by GHK to cover aspects of faecal sludge (FS)[1] management in the DfID-financed EngKAR R8056 Project entitled Capacity Building for Effective Decentralised Wastewater Management – Phase I (Review of Existing Initiatives, Training Material and Decision Support Tools). Although the Project's prime focus is on wastewater – the managerial and institutional aspects in particular – it was recognised that the situation regarding the management of faecal sludges in urban areas of developing countries is rather dramatic. It was therefore decided to dedicate a separate study to the issues of challenges and possible improvements in managing the faecal sludges.

[1] Faecal sludges (FS) comprise sludges of variable consistency collected from so-called on-site sanitation systems; viz. latrines, non-sewered public toilets, septic tanks, and aqua privies

1 Introduction

1.1 Faecal Sludge Management – Importance and Framework

While substantial progress has been made in the field of wastewater treatment in developing countries over the past decades, the management and treatment of sludges from on-site sanitation systems has been addressed, neither by problem holders nor by researchers. This is surprising as the absence or insufficiency of adequate excreta management in many cities of developing countries, particularly so in low-income areas, continuously leads to serious health and environmental hazards. A reason for this backlog in dealing with excreta in urban areas is, among others, the paucity of appropriate managerial and technical measures. This had prompted SANDEC to engage in R+D on FS management and treatment in 1992.

Fig. 1 shows how faecal sludge and wastewater management stand side-by-side in urban environmental sanitation and how they might technically be interlinked. FS management deals with the management of sludges from on-site sanitation systems, while wastewater management deals with sewered sanitation. FS may be treated in

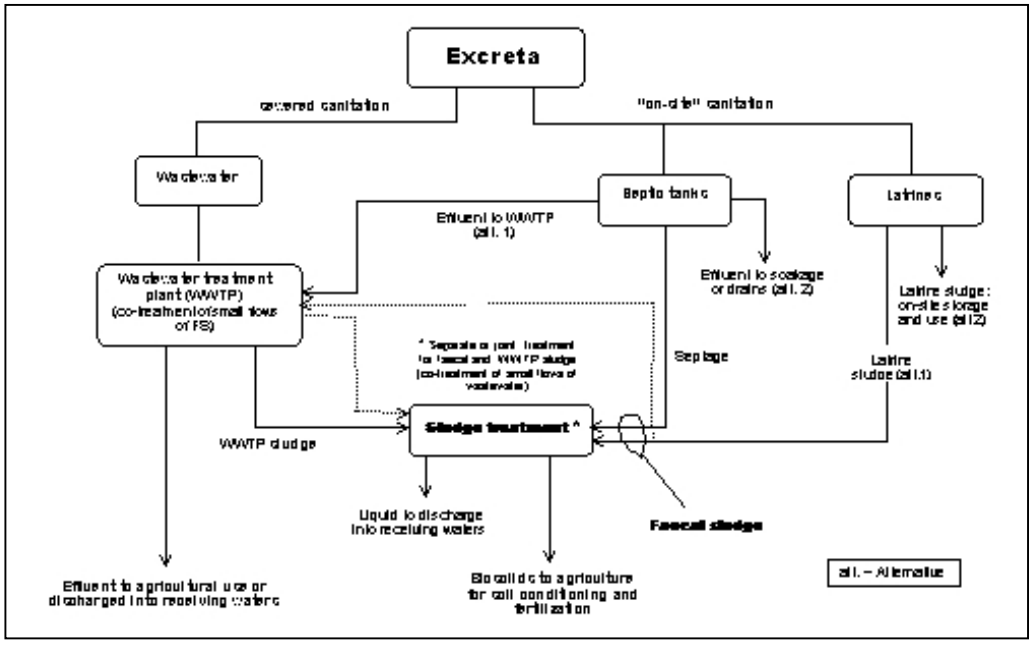


Fig. 1 Systems Framework for Faecal Sludge and Wastewater Management

separate treatment works or co-treated with sludges produced in wastewater treatment plants.

Ideally, responsibilities at municipal level for both sectors should be borne by the same authority, which deals with excreta management in an integral manner, i.e. encompassing the aspects of sanitation choices at household level, excreta or wastewater collection, treatment and use or disposal.

1.2 Scope

SANDEC was mandated to collating information on existing technologies and on implemented or planned strategic options in the field of faecal sludge (FS) management. SANDEC also attempted to identify training and decision support documents, which may have been developed in the specific field of (faecal) sludge management.

The information presented in this report are the outflow of experience, observations and field research data gathered by SANDEC and its partners upon conducting R+D over close to ten years. Our experience and accumulated knowledge predominantly pertain to appropriate technical options for treating faecal sludges. It is more recently, only, that SANDEC has initiated fieldwork on issues of FS management planning and, hence, developed some limited expertise in this specific field. Accordingly, SANDEC avails of limited information only on such important issues as the costing, economics and management of entire FS systems, which would include all relevant infrastructure components and services, viz.

- The on-site, household-level installations
- FS collection and haulage
- FS treatment
- Reuse or disposal of FS or of biosolids produced during treatment

To the authors' knowledge, there has, in fact, been little in-depth field research and evaluation of entire FS management systems to date. SANDEC is not aware of published documentation of comprehensive assessments comprising all of the above components, based on actual practices.

1.3 Report Structure

The report sets out in Chpt.2 to describe the situation in FS management worldwide and analysing the relationship between causes, problems (or challenges in more positive terminology) and consequences in the current, often dramatic situation of FS management. Chpt. 2 also addresses the fact that FS management is an integral component of urban environmental sanitation and should be viewed with its linkages to

all the other components. Further to this, economic aspects are touched upon. An overview of FS characteristics, options for FS collection and treatment is provided in Chpt. 3 (Annex 7.2 provides a more extended overview of selected treatment technologies). The chapter also contains a discussion on treatment standards.

Chpt. 4 provides the reader with accounts of initiatives for improved FS management in two selected cities in Asia (Vientiane, Laos and Nam Dinh, Vietnam) and in Africa (Kumasi, Ghana, and Bamako, Mali). Each case is concluded with a short statement on the lesson learnt. Chpt. 5 contains a synopsis of opportunities and constraints, hindering factors and gaps-in-knowledge identified by making use of the cases presented in the preceding chapter. The chapter ends with a preliminary listing of presumed needs for capacity building in the area of FS management. In Chpt. 6, the authors draw the conclusions and list recommendations.

1.4 The Decentralised Management Paradigm

The situation and problems associated with FS management are of a nature that – for achieving sustainable improvements – the need for decentralised management imposes itself almost without saying. This is being shown implicitly and explicitly throughout the document. The cases discussed in Chpt. 4 show that stakeholders in various cities have in fact started – deliberately or not – to rely on strategies, which lean on the decentralisation paradigm.

2 Excreta Management – A Great Urban Challenge

2.1 Situation and Problems

In urban areas of developing countries, the excreta disposal situation is dramatic. Every day, worldaround, several hundred thousand tons of faecal matter from either open defaecation or collected from on-site sanitation (OSS) installations (unsewered family and public toilets, aqua privies and septic tanks) are disposed of into the urban and peri-urban environment. The “waste” are either used in agriculture or aquaculture or discharged indiscriminately into lanes, drainage ditches, onto open urban spaces and into inland waters, estuaries and the sea, causing serious health impacts, water pollution and eye and nose sores.

For those urban dwellers having access to a sanitary facility, private and public OSS systems are the predominant type of installation in Africa and Asia. In Latin America, the proportion of on-site or unsewered vs. sewered sanitation is also considerable (Table 1 and Fig. 2; Strauss *et al*. 2000).

Fig. 2
Excreta disposal systems typical of urban areas in low and high-income countries

City or country	% of inhabitants served by on-site sanitation systems
Manila	78
Philippines (towns)	98
Bangkok	65
Ghana	85
Bamako (Mali)	98
Tanzania	> 85
Latin America	> 50

Table 1 Proportion of urban populations served by on-site sanitation systems

The problems and challenges in FS management rest with all the components of the faecal sludge stream – viz. pit/vault emptying, haulage, storage or treatment, and use or disposal. All aspects are involved, viz. institutional/managerial, financial/economic, sociocultural, and technical.

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 medium to large-size entrepreneurs. Individuals, small groups of individuals or micro-entreprises, offer manual emptying. It is traditionally done with buckets. Emptiers step into the vault or pit to evacuate the sludge, which has turned too solid to be scooped. Hence, the traditional manual emptying is associated with considerable health risks – for the emptiers in the first place. The general public is at risk, too, as the emptied sludge is usually deposited into nearby surface drains or into lanes. Manual emptying is often done at night and is associated with clandestineness. It is common that families have or want to rely on such a service, either because services for mechanical emptying are not reliable, too costly, solidified deposits are not removable by suction, or because the pit is not accessible by emptying vehicles. A mechanised, yet manually operated pit-emptying technology was developed in the eighties and nineties. It is reported about in Chpt. 3.2

FS collection and haulage are particularly challenging In metropolitan centres with their often large and very densely built-up, low-income districts: Emptying vehicles may not have access to pits or suction hoses must be laid through neighbours' yards and homes ! The fact that metropolitan cities are stretched out causes the haulage routes usually to be rather long. Traffic congestion further aggravates the problem and renders haulage to designated discharge or disposal sites uneconomical and financially unattractive, leading to uncontrolled dumping of collected FS at shortest possible distance from the area of collection. This shows that the FS management problem may, in most situations, be solved through decentralised schemes and institutional set-ups, only.

Suitable sites for treatment and use or for final disposal may be found at the outskirts of cities only. Vacuum tankers discharge their load at shortest possible distance from the points of collection to save time and cost. In many cities, dumping sites for FS are close to squatter or formally inhabited low-income areas where they threaten the health of this ever-growing segment of population. Children, in particular, are at greatest risk of getting into contact with indiscriminately disposed excreta.

Lack of long-term urban planning and/or enforcement of existing zonal plans have lead to the situation, whereby feasible landfilling or treatment sites at reasonable haulage distance are lacking. Emptying services are poorly managed. A minor fraction (< 10 % ?), only, of the faecal sludges accumulating in on-site sanitation installations are formally collected and discharged or treated. Where treatment schemes exist, charges are usually levied for each load of FS delivered to the plant by private collectors. As a consequence, they often prefer to dump the waste in non-designated sites to avoid fee paying. This may go unavenged due to lack of competition among collection entreprises, corruption and lack of adequate enforcement. Innovative incentive, fee levying and

licensing procedures might contribute considerably to avoiding such problems and to rendering FS management more sustainable [1].

In summary, the current situation of what might be designated “the urban shit drama”, with its causes, problems and consequences related to FS management, can be described and summarised in Table 2. Photos 1 and 2 illustrate the situation.

Photo 1
Uncontrolled discharge of faecal sludge at the city’s outskirts

Photo 2
Discharge of untreated septage into a fishpond in Vietnam

[1] In Chpt. 4.6 (FS management in Bamakao, Mali), an innovative model for levying fees based on balanced incentives for involved stakeholders is presented.

Table 2 Current FS Management Practices – Causes, Problems and Consequences

FS management component and aspect	Causes	Problems	Consequences
Emptying + collection			
• Technical	• Limited or no accessibility to pits • Inappropriate emptying equipment • Manual, non-mechanised emptying	• Overflowing pits • Emptying frequency often very low • Informal or emergency emptying of pits and indiscriminate disposal of FS	At neighbourhood level, mainly • Health hazards from openly dumped FS and through use of contaminated water • Eye and nose sores • Non-functionality of infrequently emptied septic tanks→ solids carry-over
• Institutional / financial	• Poor service management • Users' low affordability for pit emptying • Lack of information (e.g. on how septic tanks work)		
Haulage			
• Technical	• Traffic congestion • Lack of suitable disposal or treatment sites at short distance from the area of FS collection	• Collectors dump FS in an uncontrolled manner at the shortest possible distance from where FS was collected	At district or municipal level, mainly: • Pollution of surface and (shallow) groundwater • Eye and nose sores • Health hazards from use of contaminated surface water (e.g. for vegetable irrigation)
• Institutional	• Lack of urban planning → lack of suitable disposal or treatment sites at short distance from the area of FS collection • Lack of involvement of private sector service providers • Lack of suitable incentive and sanctions structure		
• Financial/economic	• Collectors minimising haulage distance and time		
Treatment			
• Technical	• Lack of proven and appropriate treatment options	• FS is used or dumped untreated	At district or municipal level, mainly: • Health hazards through use of contaminated water sources and water pollution
• Financial / economic	• Where FS treatment exists: private collectors / entrepreneurs avoid the paying of treatment fees		
• Institutional / financial	• Lack of political will to invest in treatment • Lack of effective cost recovery • Lack of urban planning • Lack of information	• Non-availability of suitable treatment sites • Use or discharge of untreated FS	

Table 2 Current FS Management Practices – Causes, Problems and Consequences (cont'd.)

FS management component and aspect	Causes	Problems	Consequences
Use in agriculture			
• Agronomic / institutional / financial / economic	• Farmers in want of cheap soil amendment + fertilizer (in many countries, farmers are traditionally accustomed to the use of untreated or only marginally stored FS ("nightsoil") • Private and public providers of FS collection + haulage services interested in generating revenue from selling FS to farmers while avoiding illegal dumping and/or payment of treatment fees • Lack of enforcement of crop restrictions where such exist	• Soils amended and vegetables fertilised with untreated FS	• Potential health risks to consumers
• Institutional	• Lack of promotion and marketing of biosolids produced in FS treatment	• Lack of incentives by producers of biosolids and by farmers to trade biosolids	•
• Health	• Farmers unaware of potential health risks • Lack of hygiene promotion	• Lack of hygiene and health protection	• Actual health hazards to farmers and consumers
Disposal			
• Institutional	• Lack of implementation of FS treatment schemes, of town planning and designation of suitable treatment sites; lack of adequate fee structure and incentives for haulage of FS to treatment sites	• Indiscriminate dumping of untreated FS	• Water pollution and risks to public health
	• Lack of promotion and marketing of biosolids produced in FS treatment	• High-quality biosolids remain unused and need to be landfilled	• Depletion of soil organic fraction and deterioration of soil productivity

2.2 Paradigms in Choosing Strategies and Technologies

Sewage and sewage sludge treatment processes and technologies, as are being routinely and widely applied in industrialised countries, viz. extended aeration, digesters (with or without gas utilization), mechanically stirred sludge thickeners, centrifuges, belt presses, and vacuum filter presses, may, in theory, also be used for the treatment of faecal sludge. However, the high degree of mechanization requires large capital investment and high cost of operation and maintenance. The concomitant high degree of sophistication calls for advanced professional skills. In developing countries, such requirements may be satisfied only in larger cities or in economically more advanced regions. In the majority of settlings in developing countries, though, the **paradigms** for making technological choices as presented in Box 1 must be adhered to:

Box 1 Paradigms for making technological choices

- Such options should be chosen, whose O+M cost and cost of repair and replacement will be affordable in the long run to the municipality or to the entity to which the works have been entrusted.

  (Although capital investments for urban sanitation infrastructure are financed by external support agencies in full or part in many cases, recurrent (O+M) cost is not. Hence, politicians and high-level decision-makers should not give in to the temptation to opt for the externally-financed high-cost solution, as capital-intensive infrastructure will entail high recurrent cost. These would unduly burden the city's budget for decades to come or lead to malfunctioning or disuse of infrastructure !)
- Only such degrees of technical sophistication should be opted for, which can be matched by adequate skills at all levels, viz. operating, management + control.

Low-cost, easy-to-operate and sturdy technology alone do, however, not represent a sufficient pre-requisite for sustained treatment and for the reliable production of effluents and biosolids meeting stipulated standards. Even the simplest schemes require:

i regular and minimal operational care
ii maintenance and occasional repairs, e.g.
  - removal of settled and accumulated solids
  - cutting of plants growing on embankments
  - de-blocking of conduits
  - disposal of screenings

Without this, schemes will cease to produce the required level of treatment or may even fail completely ! Hence, institutional responsibilities in budgeting, supervision and proper staffing also extend to modest-cost, not so prestigious infrastructure !

2.3 FS Management as A Component of Urban Planning in Environmental Sanitation

Current FS management has resulted from the historical development in excreta handling (which, often, is linked to agricultural practices), general socio-economic developments and purposeful planning efforts, which indirectly or directly affect the choice of sanitation systems. Improving on and finding appropriate strategies and solutions in FS management must, thus, be dealt with in conjunction with both unplanned and planned urban and peri-urban development, institutional settings, jurisdictional conditions, and expected future sanitation infrastructure and service provision.

In short, an FS management concept should be based on the assessment of (Klingel 2001; Klingel et al. 2002):

- existing sanitary infrastructure and trends
- current FS management practices and their shortcomings
- stakeholders customs, needs and perceptions regarding FS management and use
- environmental sanitation strategy
- prevailing socio-economic, institutional, legal and technical conditions, and
- the general urban development concept

Based on an FS management concept, FS treatment objectives may then be formulated and, consequently, feasible treatment options be evaluated.

In most places, a large array of technical, economic and institutional/organizational measures are required to improve the FS management situation. Given the difficulties in collecting FS and in hauling it across cities to designated disposal and treatment sites, devising semi or decentralized FS management options is all-important. The devising of modest-scale decentralized or “satellite” treatment plants (Fig. 3) and of neighbourhood or condominial septic tanks (Fig. 4) may contribute significantly to reducing indiscriminate dumping of FS and, hence, to reducing health and pollution risks. However, every city has to be taken at its own merits, given the great variability of spatial settings, sanitation infrastructure and planning mechanisms, which influence sanitation planning and the allocation of suitable sites for either condominial septage tanks or FS treatment plants. Also, such solutions call for non-conventional managerial approaches.

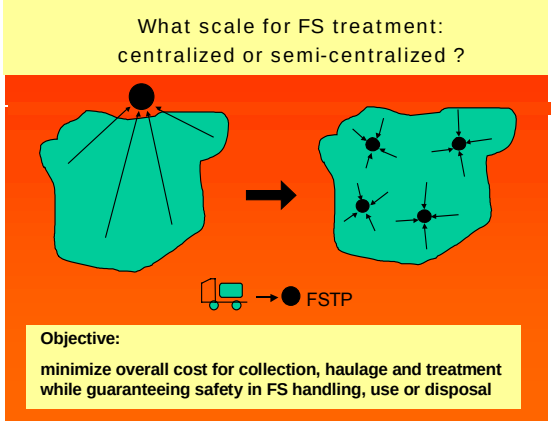


Fig. 3
Semi or decentralized FS treatment – a strategic tool to minimize cost, indiscriminate dumping, health risks and water pollution

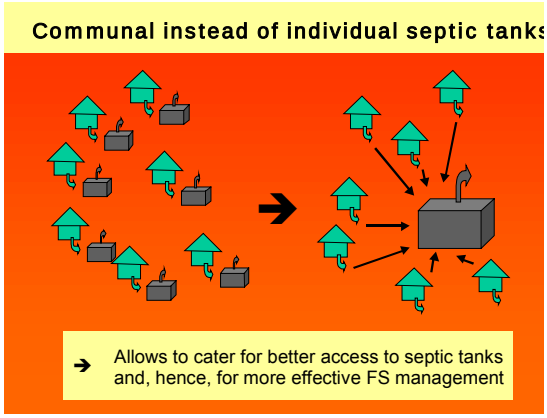


Fig. 4
The use of communal septic tanks – a strategic tool to facilitate effective FS collection

2.4 Economic aspects

2.4.1 Integrated Cost Considerations

Whenever possible, cost of existing and improved FS management should be viewed not only from a purely financial viewpoint (e.g., “what are the comparative cost of FS treatment alternatives”) but also from an economic viewpoint. Hence, it will be necessary to assess cost and revenue streams over time, to consider direct and social cost incurred by e.g. not improving FS management. This, in turn, calls for including all components of FS management, i.e. collection, haulage, treatment, use and disposal, as well as other areas upon which FS management may impact, such as sanitation planning and infrastructure (e.g. on-site sanitation vs. sewerage), health care, solid waste management, agriculture. Such comprehensive assessments are justified for large urban development projects. For smaller cities or for towns, though, such comprehensive assessments might go beyond the scope of project budgets. Nevertheless, the direct cost of FS management alternatives, inclusive of collection, treatment and reuse or disposal should be assessed to allow a well-informed judgement. Also, potential impacts on other urban activities such as health, solid waste management and agriculture should be evaluated in a semi-quantitative or at least a qualitative manner.

2.4.2 Scale of Treatment Works vs. Haulage Cost

Looking at the scale and cost of treatment works and at cost of hauling FS to these works in an integral is but one yet an important example of looking at cost in an integral manner. In Annex 7.1, a model for determining per-kilometre cost of FS haulage is presented. Such calculations are required when devising a concept for FS treatment in a particular urban setting and to enable setting up contracts with private entrepreneurs in charge of FS haulage and treatment.

3 Technical Options (overview)

3.1 Faecal Sludge Characteristics and Specific Quantities

3.1.1 Per-capita quantities

Table 3 contains the **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 planning and preliminary design. Actual quantities may, however, vary from place to place.

Where nematode infections are not endemic and, hence, eggs may be found at insignificant concentrations only in excreta and FS, bacterial pathogens (e.g. *Salmonellae spp.*) or bacteriophages might be used as indicators-of-choice.

Table 3 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 which 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.

3.1.2 FS characteristics

In contrast to sludges from WWTP and to municipal wastewater, characteristics of faecal sludge differ widely by locality (from household to household; from city district to city district; from city to city). Fig. 5 shows the vast differences of septage characteristics in the three cities of Accra, Bangkok and Manila (Montangero and Strauss 2002) and Fig. 6 depicts the differences in solids contents of faecal sludges, WWTP sludges and tropical wastewater (for wastewater characteristics, see Mara 1978).

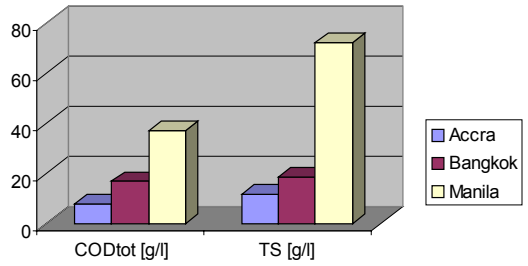


Fig. 5

Septage characteristics in Accra, Bangkok and Manila – they are widely differing !

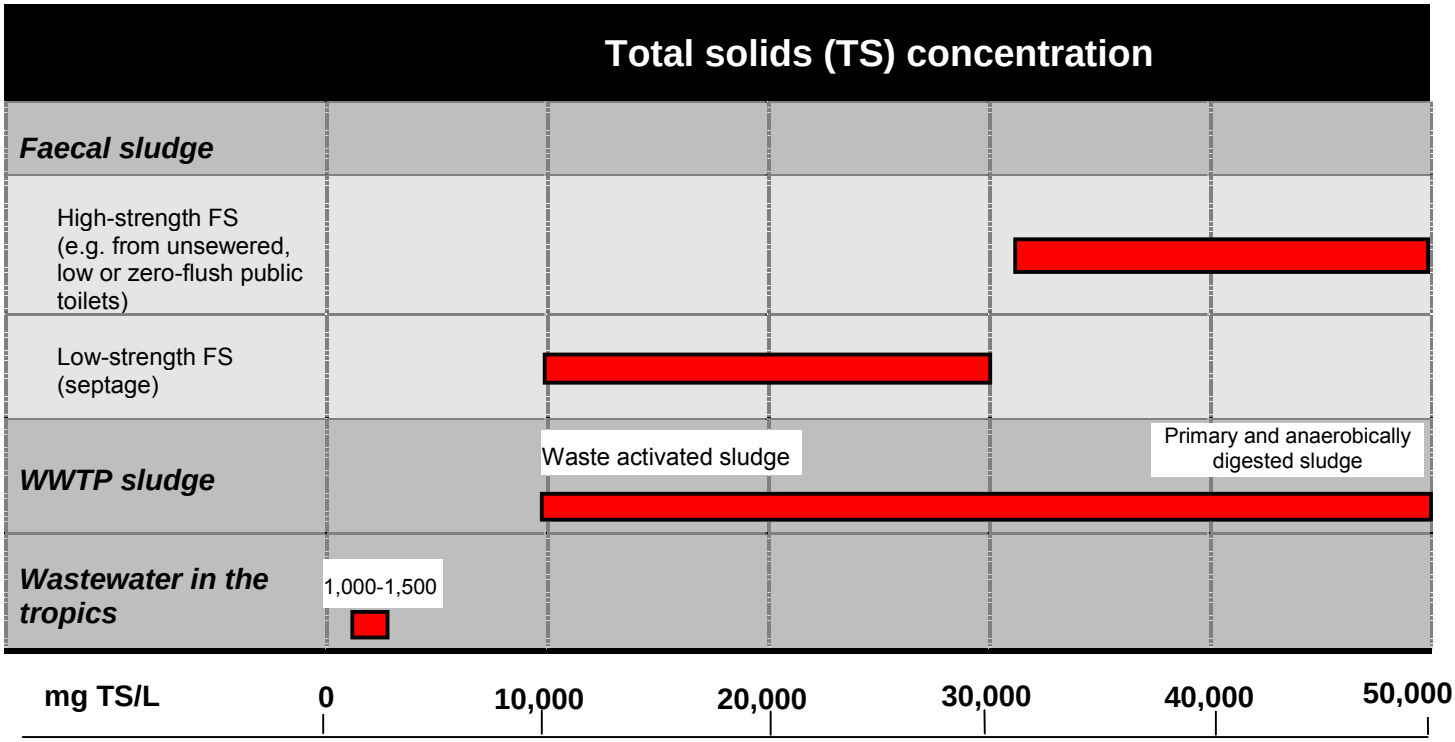


Fig. 6 Solids contents of faecal sludges, WWTP sludges and tropical wastewater

A basic distinction can usually be made between sludges which, upon collection, are 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 a biochemical degradation to a variable degree (e.g. sludge from septic tanks – septage). Moreover, varying amounts of water or wastewater are collected alongside with the solids, which have accumulated in vaults or pits. Based on numerous FS monitoring studies, the authors found that FS can often be associated with one of two broad categories, viz. high and low-strength sludge. Table 4 shows typical FS characteristics. It is 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.

Storage duration, temperature, intrusion of groundwater in septic tanks, performance of septic tanks, and tank emptying technology and pattern are parameters which influence the sludge quality and are therefore responsible for its high variability. Unlike digested

Table 4 Faecal sludges from on-site sanitation systems in tropical countries: characteristics, classification and comparison with tropical sewage (after Strauss et al. 1997 and Mara 1978)

Item	Type "A" (high-strength)	Type "B" (low-strength)	Sewage – for comparison purposes
Example	Public toilet or bucket latrine sludge	Septage	Tropical sewage
Characteri-sation	Highly concentrated, mostly fresh FS; stored for days or weeks only	FS of low concentration; usually stored for several years; more stabilised than Type "A"	
COD mg/l	20, - 50,000	< 15,000	500 - 2,500
COD/BOD	5 : 1 .... 10 : 1		2 : 1
NH_4-N mg/l	2, - 5,000	< 1,000	30 - 70
TS mg/l	≥ 3.5 %	< 3 %	< 1 %
SS mg/l	≥ 30,000	≅ 7,000	200 - 700
Helm. eggs no./l	20, - 60,000	≅ 4,000	300 - 2,000

sludge produced in mechanised biological wastewater treatment plants or in other types of wastewater treatment works (e.g. waste stabilization ponds, oxydation ditches), the organic stability of FS attains varying levels. This variability is due to the fact that the anaerobic degradation process, which takes place in on-site sanitation systems, depends on several factors, among them ambient temperature, retention period, and the presence of inhibiting substances. The fact that the faecal matter is not being mixed or stirred impairs the degradation process. The dewaterability is a varying parameter as well, which is related to the extent that the sludge has undergone biochemical degradation. Fresh, undigested sludge as is collected from public toilets, e.g., does not lend itself to dewatering.

Sludge hygienic quality

In many areas of Africa, Asia and Latin America, helminth, 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 fertilizer. 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 biosolids use in agriculture is a practice or being aimed at, treatment must aim at reducing helminth egg counts and viability, or solids storage must be long enough to achieve the desired reduction.

3.2 Emptying , Collection, Haulage

Small, Engine-Driven Emptying Vehicles and Sludge Unloading Systems

Given the great difficulties in some urban areas to access toilet pits and septic tanks through narrow lanes and backyards, emptying technologies were developed, which allow pit emptying under such circumstances. Manus Coffey, an Irish manufacturing firm, developed a 1-m3 vacuum tanker ("mini tanker") in the 1980's. The vehicle is widely used in Eastern and Southern Africa by private and public emptying services. It is un-economic for such small tankers to haul their load to the designated discharge or treatment site after each emptying. Hence, the municipal emptying service of the City of Maseru, Lesotho, e.g., has developed a system of sludge transboarding between the mini tanker and a conventional-size vacuum tanker on a road nearest to the congested area served by the mini tanker. Photos 3 and 4 show the mini tanker emptying and FS transfer [1].

Photo 3 Mini-Tanker Closing Up to A Latrine for Emptying (Maseru, Lesotho)

Photo 4 Transboarding of FS from a Mini-Tanker to A Standard-Size Vacuum Tanker (Maseru, Lesotho)

The Sewer and Drainage Company of Haiphong (N. Vietnam), a public utility entreprise, is responsible for septage collection. Collection is carried out with vacuum tankers and small vacuum tugs for areas difficult to access, used together with intermediate-storage-tanks mounted on a hook-lift truck. The mini-vacuum-tugs were developed by the company in collaboration with a local manufacturer. They have a capacity of 350 L and cost around $ 4,000. The combination of large and small equipment has proven successful and almost 100% of the houses can be covered. Photos 5 a + b show a mini tug and a storage tank, which can be hooklifted and hauled away.

[1] The Vacutug is a newer devlopment of the mini-tanker produced by Manus Coffey from Ireland. It is used in a UN-Habitat co-financed waste management project (see http://www.un-habitat.org/urbsan/9-titleunchs.htm).

The municipal emptying authority of the suburban town of Bharakpur near Calcutta have procured an India made 2 m^3 vacuum tanker, which is able to service pits in the more densely built up city areas. Haulage distances to the nearest trenching site at the town's outskirts are relatively short; hence FS transfer to larger vehicles as is practiced in Maseru, Lesotho, is not required. Photo 6 shows such a tanker during emptying operations.

Photo 5 a + b

Haiphong made mini-vacuum tug (350 L) for narrow lanes, used together with a intermediate-storage-tank placed in the nearest accessible road.

Photo 6

2m^3 vacuum tanker emptying a septic tank in a narrow lane in Bharakpur (near Calcutta, India)

Mapet – Hand-Powered Pit Emptying Technology

Mapet stands for Manual Pit Emptying Technology, a low-cost, decentralised emptying technology developed by WASTE in collaboration with the Dar es Salaam (Tanzania) Sewerage & Sanitation Department, pit latrine emptiers (scavengers), local leaders and technicians, and residents in the late eighties/early nineties (Muller 1997). The project comprised the technical as well as organisational development of a locally adapted and rooted technology enabling the traditional scavengers to depart from their humiliating and risky job of having to enter latrine pits for scooping out the faecal sludge. Further to this, the new emptying option came in response to the inaccessibility of many residential areas by normal vacuum tankers; the inadequacy of the municipal emptying service organisation, and the non-affordability of emptying prices charged by the municipality.

MAPET equipment comprises a hand pump (activated by a manually driven flying wheel), a 200 –litre vacuum tank (both mounted on a pushcart), flexible hose pipes, and a mixing rod (see also Photos 7 and 8).

Photos 7 + 8 MAPET equipment in the D.R. of Congo (Photos WASTE, Holland)

In the former pilot area in Dar es Salaam, where the system was developed, a MAPET team consists or consisted of three workers, all self-employed. The team is autonomous in organising its work and regulating the sharing of cost and income. The team operates in a service territory assigned by elected neighbourhood leaders. The neighbourhood or ward office serves as a booking office for residents who require pit emptying. The municipality supports the MAPET micro-entrepreneurs by providing technical assistance for major repairs. The emptiers can turn to local workshops for minor repairs.

The MAPET-based FS handling in Dar es Salaam is reportedly still operational to some extent, yet with equipment partly dysfunctional. There is, reportedly, a strong demand from community-based organisations (CBO) to procure equipment and introduce non-formal pit emptying services (Rijnsburger 2002). Meanwhile, MAPET has also been introduced in the town of Barumbu, D.R. Congo, through a CBO. Informal emptiers paid by a directly negotiated customer fee operate the system.

It is widespread practice to have pits or vaults emptied at intervals of several years, only. This leads to solidification of the settled solids preventing removal by suction equipment. Hence, manual curing of the lower part of the pit is required if the owners wish to utilise the entire volume of their latrine pit or vault. For curing, emptiers need to step into the pit, thereby exposing themselves to health hazards (see also Chpt. 2.1 regarding manual pit emptying and related problems). There exist on the market vacuum tankers, which are able to evacuate even solidified material, but investments and operating cost and, hence, emptying fees, are high and affordable to high-income households only.

3.3 Treatment

3.3.1 State-of-Development in Treatment Technology

Contrary to wastewater management, the development of strategies and treatment options to cope with faecal sludges, adapted to the conditions prevailing in developing countries, have long been neglected. It is in recent years only (since about 1990) that authorities in a few cities have pioneered to invest in improved FS management, notably

treatment. This was perhaps in cities mainly, where people have most heavily been affected by the “shit drama” situation (see Chpt. 2) and where problem holders have been particularly sensitised to the “faecal film” prevailing in urban areas and impairing public health, causing pollution and creating nose and eye sores. An amazing and encouraging number of initiatives for improved FS management, including the devising of appropriate FS treatment schemes, have cropped up very recently, particularly in several West African states (Senegal, Mali, Ivory Coast, Burkina Faso, Ghana, a.o.).

Like the urban infrastructure services for FS management, R+D efforts, too, have been lagging far behind those for wastewater. The authors have themselves been involved in R+D on FS management since 1993. The prime efforts were thereby laid on developing treatment options, which appear appropriate for DC. Issues pertaining to management strategies and planning processes have become a focus more recently, only.

3.3.2 Treatment Goals and Feasible Options

Treatment goals and criteria

For what purpose should FS be treated – for rendering the treatment products (biosolids and liquids) apt for discharge into the environment (inclusive of landfilling), or for producing biosolids, which may be safely used in agriculture ? [1] What effluent and plant sludge (biosolids) quality criteria should be met in treating FS for either of these goals ?

In the majority of less-industrialized countries, effluent discharge legislation and standards have been enacted. Stipulated standards have usually been copied from those enacted in industrialised countries, as the political will and the awareness regarding the need to generating an informed judgement based on the specific conditions prevailing in the particular developing country is usually lacking. Quite commonly, in DC, effluent standards or the performance of infrastructure works are neither controlled nor enforced. In most if not all cases, the standards were enacted having wastewater treatment and discharge in mind. Faecal sludges and products from their treatment were hardly taken into consideration. Thus, standards enacted in any particular country usually apply for both wastewater and faecal sludge treatment. In most cases, the standards are often too strict to be attained under the unfavorable economic and institutional conditions prevailing in many countries or regions. For FSTP, the enacted effluent standards would call for the use of sophisticated and highly capital-intensive treatment. Hence, the paradigm of opting for modest solutions would be seriously violated.

In industrialised countries, pollution laws have been made more stringent in a stepwise manner over many decades (see Fig.7; Bode 1998). Concurrently, wastewater and sludge treatment technology has been upgraded stepwise to cope with an increasing number of constituents and to reduce pollution loads discharged into the environment

[1] Unless diluted by freshwater or effluent from wastewater treatment, the liquid effluents from FS treatment are too high in dissolved solids, i.e. too salty, to be used for irrigation.

(Johnstone and Horan, 1996). A suitable strategy would consist in also selecting a phased approach, under the paradigm that “something” (e.g. 75 % instead of 95-99 % helminth egg or COD removal) is better than “nothing” (the lack of any treatment at all or the often totally inadequate operation of existing treatment systems) (Von Sperling, 2001).

The EU has adopted a rational strategy for public health protection in biosolids use. The general principle is to define and set up a series of barriers or critical control points, which reduce or prevent the transmission of infections. Sludge treatment options, which were found to inactivate excreted pathogens to desirable levels, are the prime element in this (Matthews 2000). “Barrier points” such as the sludge treatment works, can be easily

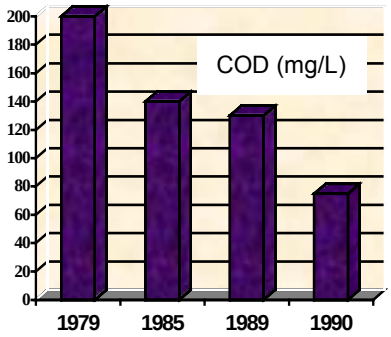


Fig. 7
Gradual development of the effluent discharge standard for COD in Germany
(Bode 1998)

controlled with respect to design and operations, thereby securing the compliance of the treated biosolids with stipulated quality standards. In contrast to this, the controlling of numerical quality criteria for wastewater or biosolids requires regular monitoring. In economically less developed countries, such monitoring is often difficult and very costly to perform. Results may not be reliable and replicable as adequate routine, quality control and cross-referencing are lacking.

Numerical values – at the base of the barrier principle

In Table 5, a set of effluent and plant sludge quality guidelines for selected constituents is listed. The suggested values are based on the considerations outlined below. 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, which will guarantee a defined quality level. Hence, numerical quality values need to be used to define process specifications, yet they do not have to be regularly monitored once the processes are in place.

Xanthoulis and Strauss (1991) proposed a guideline value for biosolids (as produced in faecal sludge or in wastewater treatment schemes) of 3-8 viable nem. eggs/ g TS. This recommendation is based on the WHO guideline of ≤1 nematode egg/litre of treated wastewater used for vegetable irrigation (WHO, 1989), and on an average manuring rate of 2-3 tons TS/ha·year.

Table 5 Suggested effluent and biosolids quality guidelines for the treatment of faecal sludges (Heinss et al., 1998)

	BOD [mg/l] total	BOD [mg/l] filtered	NH_4-N [mg/l]	Helminth eggs [no./L]	FC [no./100 mL]
A: Liquid effluent					
1. Discharge into receiving waters:					
• Seasonal stream or estuary	100-200	30-60	10-30	≤ 2-5	≤ 10^4
• Perennial river or sea	200-300	60-90	20-50	≤ 10	≤ 10^5
2. Reuse:					
• Restricted irrigation	n.c.		1)	≤ 1	≤ 10^5
• Unrestricted irrigation	n.c.		1)	≤ 1	≤ 10^3
B: Treated plant sludge					
• Use in agriculture	n.c.		n.c.	≤ 3-8/ g TS 2)	3)

1) ≤ Crop's nitrogen requirement (100 - 200 kg N/ha·year)
2) Based on the nematode egg load per unit surface area derived from the WHO guideline for wastewater irrigation (WHO, 1989) and on a manuring rate of 2-3 tons of dry matter /ha·year (Xanthoulis and Strauss, 1991)
3) Safe level if egg standard is met n.c. – not critical

Examples for faecal sludge treatment standards are known from China and Ghana. In the Province of Santa Fé, Argentina, e.g., current WWTP effluent standards also apply to FS treatment. For biosolids used in agriculture, a helminth egg standard of ≤ 1 egg p. 4 g of TS is being stipulated (Ingallinella, 1998).

Options and component overview *(see Annex 7.2 for more details)*

Fig. 8 provides an overview of options for faecal sludge treatment, which can be implemented by using modest to low-cost technology, and which therefore carries a high potential of sustainability. Some of the options were or are currently being investigated upon by EAWAG/SANDEC and its partners in Argentina, Ghana, Thailand and The Philippines and will be presented in the following paragraphs.

Proper FS treatment, either in combination with wastewater or separately, has been practiced in a few countries only to date (e.g. China, Thailand, Indonesia, Argentina, Ghana, Benin, Botswana, South Africa). The authors are aware of several, very recent initiatives for improved FS management and treatment, notably in West Africa. Treatment options used or proposed comprise batch-operated settling-thickening units; unplanted and planted sludge drying beds; non-aerated stabilization ponds; combined composting with municipal organic refuse; co-treatment of FS in wastewater treatment plants.

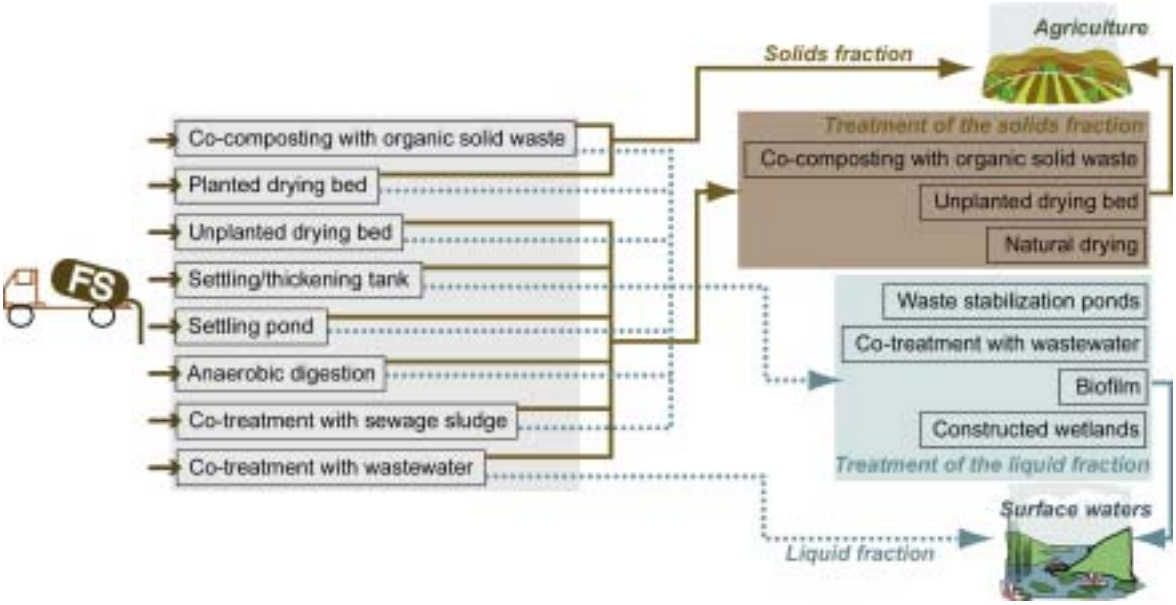


Fig. 8 Overview of potential, modest-cost options for faecal sludge treatment

Below, a few basic aspects of FS treatment are outlined. A more detailed description of selected treatment options is contained in **Annex 7.2**. They include:

- Solids-liquid separation in settling-thickening tanks or in primary sedimentation/anaerobic ponds
- Sludge drying beds (unplanted; planted)
- Pond systems for separate treatment of FS and combined treatment with wastewater
- Combined composting with organic solid waste (“co-composting”)
- Anaerobic digestion with biogas utilization

In this report, the above core processes are described. For effluent polishing, such as through pond systems or constructed wetlands, e.g., reference is made to the ample literature available on the respective options. Biosolids resulting from the core processes may have to be subjected to further storage or drying to achieve more extensive pathogen inactivation and allowing their unrestricted use in agriculture. The add-on treatment is not being elaborated upon in this report. Table 15 in **Annex 7.3** shows pathogen die-off periods in faecal matter at ambient temperatures and may be referred to for estimating additional storage periods required to render biosolids apt for use.

The fact that faecal sludges exhibit widely varying characteristics, calls for a careful selection of appropriate treatment options, notably for primary treatment. Primary treatment may encompass solids-liquid separation or biochemical stabilization if the FS is still rather fresh and has undergone but partial degradation during on-plot storage and prior to collection.

Faecal and WWTP sludges may, in principle, be treated by the same type of modest-cost treatment options.

The separating of the solids and liquids, which make up FS, is the process-of-choice in FS treatment unless it is decided to co-treat FS in an existing or planned WWTP and if the FS loads are small compared to the flow of wastewater. Solids-liquid separation may be achieved through sedimentation and thickening in ponds or tanks or filtration and drying in sludge drying beds. Resulting from this are a solids and a liquid fraction. The solids fraction, which may be designated as “biosolids”, is of variable consistency. It may require post treatment, mainly to meet hygiene requirements for reuse in agriculture as a soil-conditioner and fertilizer. Additional dewatering/drying might be required for landfilling. Polishing treatment might be necessary for the liquid fraction, too, to satisfy criteria for discharge into surface waters and/or to avoid long-term impacts on groundwater quality, where effluents will be allowed to infiltrate.

3.3.3 Cost and land requirements

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

- Economic indicators (land price, labour cost, interest rates, gasoline prices)
- Possible income from sales of treatment products (e.g. hygenised biosolids or compost; biogas)
- Site conditions (permeability, groundwater table)
- Haulage distances and traffic conditions
- Economy of scale (plant size)
- Legal discharge standards
- Extent of government subsidies and incentive structures (where schemes are funded by non-government entities, primarily; see also Chpt. 4.6.3)

Further to this, the availability and choice of construction material, whether produced locally or imported, play a role.

There is no published literature on FS management cost and no systematic search or review of construction and O+M cost for FS management schemes has been made by SANDEC to date. Consequently, only scarce information on cost is available.

Klingel (2001), in his FS management planning study for the city of Nam Dinh, Vietnam (see also Chpt. 4.3), estimated the cost for three treatment alternatives based on bills of quantities and labour salaries. The treatment schemes were designed to treat 2,500 m^3 of septage annually. Table 6 shows capital, O+M, annualised cost per ton of TS, and net land requirements for FS treatment by constructed wetlands, unplanted sludge drying beds, and ponds comprising primary treatment in settling/thickening tanks (the figures pertain to the main treatment units plus post-treatment of biosolids by extended

storage/drying, but are exclusive of polishing treatment of the liquid fraction and of land cost)

Table 6 Capital, operating, annualised cost, and net land requirements for three FS treatment options planned in Vietnam (Klingel, 2001)

Treatment option	Capital cost [1] (US $)	Yearly O+M cost (US $)	Annualised cost [2] (US $ p. ton of TS)	Net land requirement, m^2
Constructed wetlands	16,000	1,400	70	200
Unplanted sludge drying beds	17,000	2,000	85	290
Ponds w. preliminary settling	15,500	6,000	160	245

[1] Excl. cost for design + construction supervision; depreciation period = 15 years; interest rate = 5 %
[2] Comprise annualised capital and O+M cost; treatment for 2,500 m^3/year @ 20 kg TS/m^3

For small FS treatment works, gross land requirements (comprising land for the treatment units; space in-between the units and space for corollary installations) are approximately double the net requirements. Hence, for the options listed in Table 6 above, per-capita gross land requirements amount to 0.02 – 0.03 m^2 (based on an assumed per-capita FS generation of 0.5 L/day and a plant capacity of 2,500 m^3/year).

3.3.4 How to Select A Treatment Option

FS treatment objectives may be formulated based on an FS management concept, which, ideally, will have been developed as an integral component of an overall, city-wide environmental sanitation plan.

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

The second step consists in comparing the potentially feasible options chosen during the pre-selection step according to selected criteria as shown in Table 7.

Table 7 Criteria for selecting FS treatment options for Nam Dinh (Klingel et al, 2001)

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 supervision • Risk of failure related to installations or to managerial or procedural measures:	• Land requirement. • Investment costs • Operation and maintenance cost

3.3.5 Where FS Treatment Schemes are Being Operated or Planned

Table 8 lists a number of countries and cities where, according to the authors' knowledge, FS treatment schemes have been implemented and are being operated or where schemes are being planned. The list is not exhaustive. More treatment schemes might exist elsewhere. The listing shows that efforts are under way in a number of countries, although several of the schemes might have become partially or fully dysfunctional, or operate below their design performance. To the authors' knowledge, only very few schemes have been investigated upon and monitored to varying levels of details to date, viz. a full-scale pond scheme in Accra, Ghana; a pond scheme in Cotonou, Benin, and a pilot co-composting plant in Kumasi, Ghana. The fact that the majority of the treatment works have never been monitored makes it difficult to judge on their performance and to make inferences as to their shortcomings. Hence, no lessons could be learnt from these schemes to date.

The list also comprises the conceived, planned and implemented treatment schemes, which form part of the FS management cases, described into further detail in the subsequent Chpt. 4. There exist plans for monitoring one of them in due course, the Kumasi (Ghana) FSTP, which consists of a series of satbilization ponds.

Table 8 Examples of existing and planned FSTP [1]

Country or city	Information and remarks
Asia	
Indonesia	- Approx. 100 plants (pond schemes, some of which are preceded by Imhoff tanks) implemented; many plants reportedly underloaded or non-functional - 2 plants in Jakarta comprising extended aeration followed by facultative and maturation ponds
Thailand	- Low-cost schemes (digesters + drying beds + ponds) in provincial towns; high-tech plants (physico-chemical treatment followed by act. sludge) in metropolitan Bangkok
Ho Chi Minh City (Vietnam)	- Drying ponds + sale of biosolids
Nam Dinh (Vietnam)	- Constructed wetlands planned
Vientiane (Laos)	- Low-cost treatment planned
P.R. China	- Anaerobic digestion and other options
Africa	
Ghana	- 2 schemes in Accra + 1 in Kumasi + a few smaller FSTP (all pond-based) - Pilot co-composting scheme in Kumasi
Cotonou (Benin)	- 1 pond scheme
Bamako (Mali)	- 2 FSTP (constructed wetlands and ponds) planned
Ouagadougou (Burkina Faso)	- Co-treatment in ponds (under construction)
Botswana, Tanzania	- Co-treatment with wastewater in ponds
South Africa	- Co-treatment with wastewater in activated sludge plants

[1] A listing based on authors' observations and collated information

4 Selected Initiatives for Improving FS Management

4.1 General Observations

The current practice of FS management, i.e. collection, haulage, discharge and use is extremely diverse among different cities (even of the same country) and countries. While mostly private entrepreneurs cater for the collection and haulage of FS in some selected towns and cities (e.g. in Indonesia, Ghana, Burkina Faso, South Africa), other cities are serviced exclusively by public utilities, i.e. parastatal entities or municipal departments to date (e.g. Vietnam). In a third category of towns and cities, services are shared among public utilities and private entrepreneurs. The public sector is likely to dominate the scene in countries where a socialist political system prevails or has been prevailing until recently and where private entrepreneuralship is as yet little developed, while the private sector role tends to be more developed in non-socialist countries. In a few cases, FS treatment schemes are or are planned to be operated by private entrepreneurs on a contract or franchise basis (examples reported from Kumasi, Ghana, and Bamako, Mali – see Chpts. 4.4 and 4.5 below – and from Kalimantan, Indonesia; Pollard 2002).

In many cities, there presumably exist also informal emptying and collection services rendered by individuals or “mini entrepreneurs” who empty pits manually using buckets or baskets, with subsequent on-plot burying of FS or haulage to nearby drains or surface waters (see Chpt. 4.3, example from Nam Dinh, Vietnam; Klingel 2001). Such practices may fall under the traditional modes of scavenging and should not be considered as models for replication.

The authors are not aware of any FS management scheme or initiative, where responsibilities and tasks would have been devolved to community based organisations (CBO) or individual beneficiaries. Exceptions were reported by Muller (1997) and Rijnsburger (2002) for places where MAPET, the manual pit emptying technology (see Chpt. 3.2), has been developed and introduced (in Dar es Salaam, Tanzania, in the early nineties; in Barumbu, Democratic Republic of Congo, in 2001).

4.2 Rationale for Choosing Vientiane, Nam Dinh, Kumasi and Bamako as Selected Initiatives

Although the authors are familiar with FS management in a good number of towns and cities, there are only a limited number of cities on which the knowledge is sufficiently detailed or where, to the authors’ knowledge, initiatives for improvements are underway. The four cities Vientiane, Nam Dinh, Kumasi and Bamako were selected because initiatives comprising elements of decentralisation have been started in recent years and useful lessons can be learnt from these cases. The authors are familiar with the FS management situation and plans in these localities or have got at hand documentation

allowing presenting a fairly detailed description. In particular, the authors have themselves familiarised with the FS management situation – to variable degrees, though – during field visits to Nam Dinh, Kumasi and Bamako. For the description on FS management in Vientiane, the authors have relied on information provided by Parkinson (GHK 2001), leader to this EngKAR project. Beside own field observations, Jeuland (2002) and Mensah (2002) have provided in-depth documentation on the Bamako and Kumasi initiatives, respectively.

4.3 Vientiane (Laos) – Plans for improved FS collection and treatment formulated

4.3.1 The City, the Sanitation Situation and Challenges

A planning study for improving sanitation, drainage and wastewater management in the City of Vientiane, Laos PDR, has been completed in early 2001 (GHK 2001). This forms a component of the proposed Vientiane Urban Infrastructure and Services Project (VUISP), which is to be implemented by the Vientiane Urban Development and Administration Authority (VUDAA) and to be co-financed by the Asian Development Bank (ADB). The existing sanitation infrastructures, the collection and disposal or use of FS from the on-plot sanitary installations and the problems associated with the current practice have been assessed by the study. Proposals for infrastructure improvements, service enhancement and modes of implementing the plans have been presented.

The City of Vientiane is divided into 112 villages, comprising a total area under VUDAA jurisdiction of 30 km^2 and with a current estimated population of 160,000. The city lies on low-lying alluvial soils deposited by the Mekong River. The area is flood-prone and characterised by generally high groundwater table and clayey-loamy soils with low permeability.

Box 2

Vientiane's current FS management in a nutshell (GHK 2001)

- **Sanitary installations:**
  - 35 % septic tanks
  - 63 % cesspools and latrines of various kinds
  - Widespread and frequent failure of toilet and soakage systems → pollution and health hazards in neighbourhoods
- **Collection, haulage, treatment, and disposal:**
  - Emptying frequency = 1…5 years
  - 8 out of 10 vacuum tankers privately owned
  - FS co-treated with wastewater in a WSP scheme
  - Fees levied for treatment, hence, substantial FS quantities are dumped illegally or used untreated

Photo 9
Pour-flush toilet with soakage pit in Vientiane, Laos (Photo J. Parkinson, GHK)

Photo 10

Emptying of a difficult-to-access septic tank in Vientiane, Laos (Photo J. Parkinson, GHK)

All sanitary installations are on-plot. Their contents overflow directly into surface drains. Installation design, construction and maintenance are generally very poor, leading to heavy pollution of soils and water in people's surroundings, particularly in low-income areas. The current situation with respect to FS management in Vientiane is summarised in Box 2. Photos 9 and 10 show the typical situation of household sanitation.

4.3.2 Towards Improved FS Management

The comprehensive sanitation-upgrading plan builds heavily on the decentralization paradigm; both regarding the development of improved sanitation infrastructure (at household, neighbourhood and municipal levels) and services, as well as regarding the procedures through which the plan should be implemented. The collection of FS shall be enhanced by making provision for increasing truck fleets of entrepreneurs mainly (e.g. through the City leasing out trucks it may purchase through external funds, or by devising suitable credit programs), while strengthening the supervisory role of the municipality, e.g. by enforcing FS delivery to the designated treatment sites. Modest-cost, decentralised FS treatment facilities shall be constructed. The project for a previously conceived FS treatment plant to be sited some 18 km from the city shall be given up (a FS treatment plant located at such a long distance from the area of collection may hardly ever receive any FS !).

The proposed improvements shall first be tried through pilot projects in selected City districts with socially stable communities ("villages"), which avail of land tenure. Village groups shall be formed as the administrative planning foci, whereas appropriate infrastructure solutions shall be devised based on the City's sub-catchment (and housing ?) areas.

4.3.3 Lesson

Experience has led to a policy whereby private entrepreneuralship for FS collection and haulage shall be promoted by the municipality. The need for physical decentralisation of future FS treatment schemes is being recognised and has been taken into consideration

when formulating the plans for improved FS management. Concurrently, neighbourhood or city district ("village") groups shall form the planning foci, hence, there is intention to devolve specific responsibilities from the municipal authority to the beneficiary level. The initiative for FS management improvements originated from the municipality. Overall responsibilities for planning, implementation and future enforcement rest with the municipality.

4.4 Nam Dinh (Vietnam) – Rapid upgrading of household sanitation calls for effective FS collection and treatment

4.4.1 The City, the FS Management Situation and Challenges

The City of Nam Dinh is located in the Red River delta in Northern Vietnam, 90 km SE of Hanoi. Like Vientiane, it is built on the alluvial, finely divided soils deposited by the river.

Box 3
State-of-practice in sanitation and FS management in Nam Dinh (Klingel 2001)

- **Sanitary installations (1997):**
  - 50 % septic tanks (expected to rise to 85 % by 2005)
  - 20 % bucket latrines (private and public)
  - 10 % dry latrines
  - 16 % toilets directly conmnected to drains
- **Collection, haulage and disposal:**
  - Low frequency of septic tank emptying
    → blockage of stormwater drains trhough solids carry-over; pollution of surface waters
  - Public utility service poorly managed and equipped
  - Vehicles not having acces to narrow lanes
  - Self-employed latrine scavengers provide cheap emptying service
  - Discharegh of FS into fish ponds
- **FS use:**
  - Traditionally, high demand for bucket latrine sludge; today's demand >> supply
  - Fish pond fertilization

Photo 12
Typical nam Dinh alley; special equipment is needed to enable emptying of latrines and septic tanks at adequate frequencies (see also Chpt. 3.2 for emptying technology)

Photo 11
Heavily polluted and partially blocked rainage ditch in Nam Dinh

The City has heavily suffered from flooding until a few years ago. It has substantially improved the drainage infrastructure and its operations in the course of implementation of the Nam Dinh Urban Development Project, a joint undertaking of municipal and provincial authorities wit the support by SDC. The City has a population of 230,000. It is surrounded by intensely cultivated farmland, where mainly rice and vegetables are grown. There exist also several natural lakes on the City's outskirts and constructed ponds in public recreational areas. Fish are proliferating in both ponds and lakes.

Box 3 contains the relevant information on the current status of sanitation developments and FS handling. A drainage ditch in Nam Dinh, typically polluted by excreta-loaded surface runoffs and partially blocked with faecal and other solids in shown in Photo 11.

Sanitation systems in place in Nam Dinh comprise septic tanks, bucket latrines, pit and double-vault/urine separating latrines (Klingel 2001). Bucket latrines, the contents of which are collected and used by farmers in peri-urban agriculture are rapidly being phased out and replaced by pour or cistern-flush toilets connected to a septic tank. Nam Dinh does not have a sewerage system. Overflows from septic tanks are discharged into the surface drainage system (when walking through the City, one can clearly see the pipes crossing underneath the walkway and discharging into the street drains; this is certainly not unique in Vietnam), which finally discharges into either the Red River or lakes and fishponds. Hence, there is a lot of excreta-fertilised fish production (natural and induced). Faecal sludge, which comprises septage (the contents of septic tanks), bucket latrine sludge (nightsoil in its proper sense) and sludges from other pit or vault toilets, is formally emptied by URENCO, the City's emptying service (but the service is weak for several reasons) and informally by municipal workers who render the service in their free time as micro-entrepreneurs. Their service is cheaper than the one offered by the public utility. The hand-emptied sludge is discharged into the nearest drains or (fish) ponds. Bucket latrine sludge is still collected by farmers or sold to farmers by those who collect it, but this happens at a diminishing rate as bucket toilets are being replaced by septic tanks at a high pace.

4.4.2 Plans for Coping and Improving

A recently conducted FS management planning study (Klingel 2001) has documented the problems and challenges based on an in-depth assessment of the current situation, stakeholder needs and perspectives and expected sanitation developments. Stakeholders contacted and interviewed are:

- Farmers and fishermen (often the same as many farming families own small domestic fish ponds)
- Farmers' cooperatives
- Provincial Agricultural and Rural Development Service
- Municipal Agriculture Department
- URENCO
- UCMC
- Households

The need for emptying increased numbers of septic tanks is imminent, as thousands have been installed in recent years in the course of the Nam Dinh UDP credit scheme. They will gradually fill up with solids and, hence, cease functioning. The frequency at which citizens have their septic tanks emptied remained low to date, like in most countries, also because of limited willingness or ability-to-pay by the users. The inadequate frequency of septic tank emptying causes considerable carry-over of wastewater solids into the surface drainage system, thereby causing public health risks and silting of drainage canals. As a consequence, canals may not fulfil their function during periods of increased surface runoff. Flooding will then be aggravated. Hence, the intensive use of septic tanks for excreta and wastewater management remains inappropriate unless efforts are undertaken to arrive at increased frequencies of septic tank emptying. Even with better emptying practices, though, non-negligible loads of pathogens are discharged from septic tanks into street drains, drainage ditches and canals via the settled effluent. Devising an emptying management based on efficient and cost-effective public or private entrepreneurship is therefore needed. In densely built-up neighbourhoods, septic tanks may often not be accessible due to the narrowness of lanes. Appropriate equipment needs to be procured and put at use to overcome this.

Faecal sludges collected from septic tanks and bucket toilets remains untreated to date. Devising appropriate treatment has now become an issue of high priority among the Nam Dinh authorities, as increasing numbers of septic tanks become due for emptying. Treatment schemes are required which need to be strategically located to minimise haulage distances and allow for easy marketing of treatment products to farmers and fishermen. Experience has shown that identifying areas for treatment of either liquid or solid waste is difficult due to public resistance from nearby dwellers or from dwellers living along access roads.

Two FS management improvement options and three potentially feasible FS treatment options have been proposed by the FS management planning study (Klingel 2001). Box 4 describes the options in a summarised form.

Box 4
FS management and treatment options for Nam Dinh

- **Management option A**
  - Improving on public utility's collection and haulage capacity
  - Public awareness campaign for enhanced frequency of septic tank emptying
  - Considering subsidzing of emptying fees
  - Regulations for and licensing of private entrepreneur involvement in FS collection and haulage
  - Devising appropriate FS treatment schemes
- **Management option B**
  - Frequency of septic tank emptying regulated by authorities
  - Public awaerness campaign
  - Devising (subsidized ?) empyting fees or introducing a public utility tax covering water, pit emypting, electricity, etc.)
  - Regulating private entrepreneur involvement
  - Devising appropriate FS treatment schemes
- **Treatment and use**
  - Three low-cost options, producing biosolids safe for use in agriculture, viz.:
    - Constructed wetlands w. effluent polishing in a pond
    - Drying beds + post-storage of biosolids and effluent polishing in a pond
    - Settling/thickening followed by a series of ponds for liquid treatment + drying of biosolids on drying beds + effluent polishing in a pond
  - Demonstration trials for biosolids-manured soils and crops and marketing through the traditional outlet channels, viz. farmers' cooperatives

4.5 Kumasi (Ghana) – Managerial and Technical Solutions in Place

4.5.1 Geographical Setting and Developments in Environmental Sanitation

Kumasi, located 300 km Northwest of Accra, covers 150 km^2 and counts about 1 million inhabitants. The city is an industrial centre with formal industries in timber, food processing (including beer brewing) and soap manufacturing, together with informal activities in woodworking, light engineering, vehicle repair, footwear, furniture manufacture and metal fabrication.

Most residents in Kumasi (about 38%) use public toilets for which they pay between ¢20 and ¢100[1] per visit depending on the type of facility. Another 26 percent use household water closet facilities; The unhygienic bucket latrine system caters for around 12% of the population; 8% rely on sewerage while pit latrines (KVIP/traditional; 10%) and the bush provide for the rest of the population (Mensah 2002 a).

[1] 1 US$ = 7,800 cedis (March 2002)

One of the most critical waste disposal problems of the city of Kumasi is the disposal of nightsoil and septage from public latrines, household bucket latrines, and septic tanks. The current system of human waste management in Kumasi is inadequate; waste removed from the public and bucket latrines end up in nearby streams and in vacant lots within the city limits creating an unhealthy environment. Many government offices, schools and private institutions require improved sanitation facilities. Industrial effluent from the breweries, leachate from sawmills and waste oil spillage from the vehicle repair complex is also discharged into receiving waters without treatment. The storm water drainage system is essentially an open sewer, which discharges surface water, and as a result the beneficial uses of these rivers (domestic water supply, irrigation, livestock watering and recreational activities) are adversely affected for a number of miles downstream.

The Kumasi Metropolitan Assembly (KMA) with the assistance of the UNDP/World Bank Water & Sanitation Program (now the World Bank Water & Sanitation Program) produced a Strategic Sanitation Plan for Kumasi (SSP-Kumasi) for the period 1990-2000. The Plan was updated for the period 1996-2005. The SSP-Kumasi identifies the facilities needed to provide comprehensive services; describes the implementation and financing arrangements for each component; and sets priorities.

Technical options were recommended for each type of housing areas in the city based on the characteristics of these areas as well as user preference, willingness and ability to pay. The SSP-Kumasi recommended the use of simplified sewerage in the high-density area, latrines in the medium-density areas and WC/septic tanks in the high-cost/low-density areas. The cost of household latrines would be shared equally by the city and beneficiaries on a 50:50 basis. The construction of new public sanitation facilities were encouraged in markets, schools and light industrial areas, while existing public bucket latrines were phased out. Two faecal sludge treatment plants were planned, one of them is built and ready to be commissioned, the construction of the second one should start this year.

4.5.2 Stakeholder Involvement

KMA moved from direct provision of sanitation services, and started promoting and establishing active **involvement of both communities and the private sector in their delivery**. According to the SSP, the private sector should be involved in the faecal sludge collection and haulage, operation and maintenance of the facilities (public toilets, sewerage systems, treatments systems for sewer and faecal sludge) including the collection of user charges (Kumasi Metropolitan Assembly 1995). Holding workshops to which entrepreneurs as well as service users are convened has meanwhile become established practice in Kumasi.

4.5.3 FS Management

Sanitary facilities

There are about 400 public toilet facilities in Kumasi, which provide service to 400,000 of the city's population. Public toilets are equipped either with flush toilets and a holding tank or VIP latrines with 2 pits per latrine (used alternatively) or one pit per latrine. The use of double pit latrine has not proved successful. As the pits were filling faster than expected the sludge retention time in the unused pit was too short to allow sludge stabilization.

High maintenance standards at the public toilets have been difficult to achieve over the years. The introduction of franchise management arrangement involving the private sector in 1992/1993 saw some significant improvement. During this period, a private partnership (franchise) approach was carried out. KMA controlled the construction and had the overall responsibility for the toilet facilities. The private contractors were responsible for the operation, maintenance and management of the toilets. However, since January 97, when the Assembly members started managing the toilet sites, the situation has deteriorated considerably. Users complain about dirtiness, smell and user fees. Only 10% of the users are satisfied with the quality of the public toilets. According to Frantzen (1998), the toilets were managed much better and more effectively by private contractors than by Assembly Members. In a public-private partnership, tasks and responsibilities are divided between the different actors, the role of the various actors and the relationship between public and private actors are clearly defined and the various actors can work in a more accountable and transparent way. Ineffective pubic toilet management under the Assembly Members is reportedly due to unclear divisions of tasks and responsibilities between the various actors involved. Frantzen (1998) concluded that in public-private partnerships, clear rules concerning the division of tasks and the roles of the different actors can be included in contracts, increasing accountability, efficiency and transparency and hence quality of provided services.

About 120,000 people use bucket or so-called pan latrines. Due to the unhygienic nature of this type of toilet and lack of conservancy labourers, WC-septic tanks or KVIP latrines (home latrine programme) are replacing bucket latrines.

There are several sanitary sites in the city. The sanitary sites consist of a refuse collection point and a public toilet. In areas where bucket latrines are still in use a holding tank for bucket latrine sludge is located at the sanitary site. Vacuum trucks empty the holding tanks

About 260,000 people use WCs linked to septic tanks and seepage pits. Septic tanks perform well in areas where there is sufficient space for a drain field; however, most of the existing septic tanks overflow to surface drains due to undersized or non-existent drain fields.

About 268 (out of 301) secondary schools in Kumasi have sanitation facilities integrated into the school compound. Most facilities lack organised management, and the aqua privies and cistern flush systems, which are the most common systems, do not have drain fields. As a result most school facilities are in serious state of neglect and provide a

poor basis for teaching hygiene and environmental awareness to students (Mensah 2002 a).

Faecal Sludge Collection and Haulage

There are currently seventeen haulage trucks (see Table 9), which provide desludging service in Kumasi. As proposed in the Strategic Sanitation plan, faecal sludge collection and haulage has been partly privatised. The KMA, the Army, the Police, Prisons and KNUST own one truck each while the remaining 12 belong to four different private operators. The 17 trucks haul an average of 84 trips of septage a day, which represents sufficient capacity to meet the septage haulage needs of the city (Mensah 2002 a).

Table 9 Desludging Service Operators in Kumasi

Item	*Company/Organization*	*No. of Trucks*	*Average No. of Trips/Day*	*Operating Status*
1	KMA-WMD	1	2	Protocol Service
2	Babdako Enterprise	5	35	Commercial Service
3	Albert Joseph & Co.	1	3	Commercial Service
4	Planet Green Enterprise	2	10	Commercial Service
5	Afranie Sanitation Services	4	28	Commercial Service
6	Ghana Prisons Service	1	2	Protocol Service
7	Ghana Police Service	1	1	Protocol Service
8	Ghana Army	1	1	Protocol Service
9	University	1	2	Protocol Service
	Total	17	84	

Privately owned vehicles transport 76 out of the 84 truckloads. Private contractors are licensed by KMA. KMA sets a range of collection fees within which the operators are supposed to operate. KMA's truck empty tanks/pits belonging to government employees (protocol service). The service is free. It also provides desludging service for non-governmental employees, in case KMA's truck operators are available (besides protocol service). In this case, KMA' service is cheaper than the private one, however, clients have to wait longer. Emptying fee is about $ 10 (the monthly salary of a truck driver was $ 40 in 1990, for comparison' sake).

FS disposal + treatment

Faecal sludge (average 500 m^3 per day) is currently disposed of at the Kaasi site with reasonable degree of cooperation in terms of payment of tipping fees and emptying at the designated site. Private truck operators have to pay a tipping fee of 1.5$. The Kaasi pond system was built as temporary treatment system in January 2000 (Africa Cup). The desludging of the system is not feasible; ponds have been filled with solids resulting in inadequate treatment of the effluent that flows into the Subin River. Ponds will soon be

taken out of operation as a new treatment facility has been built at Buobai, 14 km north east of the city centre under the Urban Environmental Sanitation Project (UESP/world Bank) and is yet to be commissioned.

The Buobai plant consists of two settling ponds followed by facultative and maturation ponds and is designed to treat about 200 m3 sludge per day. Trucks will have to pay a tipping fee, probably a bit higher than in Kaasi due to the fact that operational and maintenance costs will be higher. KMA trucks will not have to pay. According to the experience gained in Kaasi there is indication that truck drivers will not discharge their load indiscriminately but transport it to Buobai and pay the discharge fees. The Waste management and the Environmental Health departments of the KMA have been warning truck drivers through letters and periodic meetings regarding the need for high environmental protection standards. Moreover they risk loosing their license if they are caught discharging at an illegal site. Operation and maintenance will be handled by the private sector under franchise scheme. However the waste management department will manage the plant during the first 3 months of operation in order to determine the surtax to be paid by the private contractor to KMA based on FS inflow and cost for operation and maintenance. The contractor will also be responsible for biosolids management. Drying beds were planned to dewater the settled solids desludged from the settling ponds but could not be built because of shortage of funds (Mensah 2002 b).

The Environmental Sanitation Policy states among others that “recycling of waste for industrial, agricultural and other uses shall be practiced wherever it produces a net cost reduction or positive environmental impact” and also that “the promotion of waste reduction shall be an integral part of waste management”. It is mentioned in Annex 2 that “composting shall be carried out using simple methods and on decentralised basis, as near as possible to the point of generation. It shall only be carried out if it results in the net savings to the Assembly in terms of reduced transport and landfill requirements and possible revenue (estimated with due regard to the limited market for compost)”. Salifu (2001) demonstrated that for a 500 houses scheme, a 20% composting of the biodegradable organic fraction can save up to US$ 100/month in transportation costs as well as extend the landfill space by nearly 5 years.

A pilot co-composting plant (composting of organic solid waste and dewatered faecal sludge) has been put in operation at the beginning of 2002. The plant is located at the Buobai FS treatment site. Investigation of the system just started and will deliver information on the sustainability (marketability, etc.) of this treatment option in the Ghanaian context. The pilot project is co-ordinated by IWMI (International Water Management Institute) in collaboration with the University of Science and Technology in Kumasi, the Waste Management Department (KMA) and SANDEC. Results of the investigation will help the WMD (Waste Management Department) develop its biosolids management strategy.

A new landfill will be built in the South of the city (Dompoase). Another FS treatment plant will also be built at the landfill site and serve the southern section of the city.

Besides faecal sludge landfill leachate will also be treated in the plant. Construction works is expected to start in 2002.

4.5.4 Wastewater Management

Overview

Five small-scale sewerage systems with target coverage of about 40,000 people currently exist in Kumasi. They include:

- The Conventional Sewerage System at KNUST;
- Asafo Simplified Sewerage System built in 1994;
- Ahinsan Satellite Sewerage System rehabilitated under UESP in 2001;
- Chirapatre Satellite Sewerage System rehabilitated under UESP in 2001; and
- Komfo Anokye Teaching Hospital (KATH), City Hotel and the central parts of the 4BN Army barracks Conventional Sewerage System.

The treatment facilities to the University (KNUST) and KATH systems are currently not functioning (Kumasi Metropolitan Assembly 1995).

Asafo Simplified sewerage System

The Asafo simplified sewerage network was built in the high-density area in 1994 as recommended in the SSP. Sewage is treated in a waste stabilization pond system. The Asafo scheme has not been as satisfactory as planned. The main problem is the price the users have to pay. Water fees in Kumasi increase with water consumption. The inhabitants of this area just fall into a higher price category (commercial price) as they use flush toilets (9l/flush). They are not able to pay a sewerage fee in addition to this high water fee. The scheme was supposed to be franchised. A private contractor should manage the system, operate and maintain the scheme and collect the sewerage fee by the beneficiaries. The sewerage fee was supposed to cover operation and maintenance costs of the sewerage and pond system. The actual situation is different: a private contractor manages the Asafo treatment plant for a fixed monthly fee paid by KMA. KMA has been paying the fixed fee to the contractor, as the payment of maintenance fee could not be enforced. 60% of the people who have connections use them. These 60% paid the connection fees but don’t pay the monthly sewerage fee.

Satellite sewerage networks: Chirapatre and Ahinsan

The two low cost housing estates – Chirapatre and Ahinsan – were built in the late seventies. They were equipped with networks of sewer collection and communal septic tank systems for black water. Chirapatre counted 6 communal septic tanks for a population of 1800 inhabitants and Ahinsan 5 for about 1500 inhabitants. Sewer lines were blocked and septic tanks were in a bad state of maintenance. Both schemes have been replaced with 2 sewerage networks for blackwater and waste stabilization pond systems. Greywater (effluent bathrooms and kitchens) is discharged in the drainage

system. The need for an effective maintenance and management structure was recognised. The unsuccessful maintenance of the previous schemes is reportedly due to lack of resources and technical know-how of residents. A management plan was prepared by the KMA. Private contractors will undertake the operation and maintenance. The community has been involved in the preparation of the management plan. It will also be involved in the execution of the scheme, especially in its maintenance. The sharing of the operation and maintenance costs has also been defined. A steering committee (community members) will advise the company responsible for operation and maintenance. The operator will collect the fee (Mensah 2002 b).

4.5.5 Reuse practices

Farmers located along the Subin drain (one of the four main drainage canals) or Subin River (in which the Subin drain discharges) use the Subin water for irrigation. The drainage channels are partially covered and transport rainwater as well as greywater, septic tank overflows and blackwater. Drains and streams are heavily polluted and exhibit high FC concentrations (Mensah et al. 2001).

Untreated faecal sludge reuse in agriculture as it is practised in Tamale (northern Ghana) is apparently not common in Kumasi. A preliminary study aiming at assessing farmers perception with regard to faecal sludge reuse (compost produced with organic solid waste and faecal sludge) as well as their willingness/ability to pay was conducted among 90 farmers in 2001. The results indicate that 2/3 of the farmers are willing to pay for the compost. The main factor that could motivate the farmers is field trials (IWMI 2001). However, the study was carried out before the operation of the co-composting plant started. The study will therefore be repeated once compost will be available.

4.5.6 Lesson

Efforts to improve on Kumasi's sanitation are dating back to the late eighties and have in its nature been a top-down approach with initial decisions taken on the central, municipal level. Hence, the decision to improve the city's FS management through an array of measures comprising the household-level and public toilet installations, FS collection and FS treatment was taken at the "top". However, elements of decentralisation were introduced from the early stages: by devolving parts of the decision-making to local stakeholders, by promoting private entrepreneurship for public toilet management, FS collection and FS treatment, and by devising two FS treatment plants to cater for the sludge loads currently being collected.

4.6 Bamako (Mali) – The dynamics of small entrepreneurship [1]

4.6.1 The City and the FS Management Situation

The City of Bamako, Mali, is the country's capital. It straddles the river Niger and has a population of 1–1.2 million. The City is administratively truncated into 6 districts ("Communes"), each comprising from 10-12 wards. Sanitation systems in use in Bamako encompass private and public latrines of various types, septic tanks and a low-cost sewerage scheme covering a small zone of the City. The emptying of pits and vaults is accomplished by 25 vacuum trucks and 4 collection vehicles with manual suction pumps (33 tractor and 1 donkey-drawn). Urban agriculture plays an important role, with some 6 % of the population involved in vegetable, flower and tree growing (Visker 1998; Towles 2001). FS are widely applied in vegetable, cereal and tree growing, usually after some type of processing (storage upon mixing with organic solid waste, plant residues or cattle dung). The fact that excreta are traditionally used in agriculture should render it fairly easy to sell a finished treatment product (biosolids or compost) to farmers.

Photos 13 and 14 show, respectively, a NGO operated public toilet and manually operated pit emptying equipment.

Photo 13

Bamako (Mali), Lafiabougou market: public toilet operated by the Women's Cooperative for Family Health and Sanitation (COFESFA)

Photo 14

Tractor-drawn suction tank with manual membrane pump operated by Commune III of Bamako (Mali)

Starting in the early nineties, small entreprises ("groupes d'intérêt économique", GIE – economic interest groups) became established in response to the Malian government's reduction in hiring for civil posts. In order to help many of the unemployed graduates affected by this decision, the government offered small loans to these private enterprises. They started rendering services in the public needs sectors such as sanitation. A group

[1] This paragraph is largely based on contributions by Marc Jeuland and Cordes Towles, Peace Corps Volunteers seconded to Sema Saniya, a Malian micro-entreprise devising FS and solid waste collection, haulage and treatment services in the City of Bamako.

or entreprise called “Sema Saniya” was the first of the GIE to be founded in 1991, with others been established meanwhile. Sema Saniya is currently (April 2002) preparing plans for a faecal sludge treatment plant (FSTP) to treat FS collected from the City’s Communes V and VI.

CEK-Kala Saba, an NGO working in the environmental sanitation sector as facilitators, project co-ordinators and technical-managerial consultants, are developing plans for another FSTP to treat FS from Commune IV [1].

Sema Saniya started with a few donkey carts to dispose of garbage and has now advanced to two tractors with a biweekly collection serving over 1,500 families. They have also acquired two vacuum trucks in the process. The company has reportedly other satellites in other areas, but due to some governmental regulations is not in direct control of them. Sema Saniya has built and operates many public toilets in other districts of Bamako area and is planning to expand on these services. Their main source of revenue, however, is the removal of faecal sludge from septic tanks (septage) and public toilet vaults.

Government currently plays but a minor role in the sector of FS collection and haulage to date. Emptying, collection and haulage services are largely privatised. There are no contracts or regulations governing the locations served by a particular company. Sema-Saniya frequently empties latrines throughout the city, as it is currently the largest and most dependable sanitation company.

Citizens of Bamako wait to empty their toilets until they are completely filled, in the interest of saving money, generally over 2 years though this time depends on the number of people using the toilet. Public toilets can require evacuation monthly or more frequently during periods of great population passage. The sludge is being dumped in fields in and outside of Bamako. Government does not exert any control. Hence, unsafe handling and dumping of FS goes by unavenged.

4.6.2 Recent FS Management Initiatives

The GIE Sema Saniya and the NGO CEK-Kala Saba are planning two treatment works for Communes IV and V+VI on their own initiative, i.e. without any involvement of the government. The search for and purchasing of suitable land for treatment has, reportedly, been rather difficult and lengthy. A reported reason for this was the lack of acceptance of the treatment works by local residents.

The treatment works for Communes V and VI will probably be owned and operated by Sema Saniya, as the government does currently not have the capacity to manage such

[1] SANDEC has been asked for advice from both entities and become discussion partner to them. CEK is receiving support from Waste Consultants in Holland under the umbrella of UWEP, a Dutch financed capacity building and urban sanitation infrastructure and services improvement programme.

works. Investment cost, however, will have to be co-financed by tertiary (foreign ?) sources, which might activate government involvement. Moreover, government's responsibility needs to be activated to make sure that FS collected by other companies will be delivered to the plants and that indiscriminate dumping will be stopped. Also, authorities may have to play an important role in devising a fee and/or sanitation tax structure, which will allow rendering the treatment works financially viable for the companies. Although Sema Saniya is intending to either sell the processed and hygienized biosolids produced at the two sites to farmers and horticulturists and/or use the biosolids to produce cash crops in own farms, revenues generated from these activities may recover cost partially at best[1].

4.6.3 How to Make Sure That FS Ends up in The Treatment Plant Rather Than in a Drainage Ditch

Making sure that FS collected from city districts will actually be hauled to the designated treatment sites appears to be one of the greatest managerial and institutional challenges. Numerous examples cited in this report and observed all over the world demonstrate that FS will continue to be discharged in an uncontrolled manner if 1), FS treatment plants are too distant from the collection areas and 2) if collection entreprises are compelled to pay for treatment. Such a rule although being sensible from an economic and cost recovery viewpoint, is easy to by-pass through illegal dumping or bribing.

As has been repeatedly stipulated in international working groups, guidance documents and aid agency consultations, sustainable environmental sanitation may be achieved or enhanced only by applying appropriate **incentive** and **sanctioning** structures.

Box 5 shows one of several money flux models developed by Marc Jeuland (2002), technical advisor to the GIE Sema Saniya, in attempting to devise a sustainable future management of faecal sludges in Bamako. It is based on the premise that adequate financial incentives are necessary to make things work, i.e. that FS end up at the designated treatment works instead of being dumped illegally and untreated without having to establish an elaborate enforcement and policing system. This calls for novel ways of pricing and money fluxes.

The most important element of Jeuland's model is the "reimbursement for dumping" principle [2]. Cost of plant operations would be recovered by the company earning on subscription fees paid by citizens and/or other companies delivering FS to the site. Altermnatively, Government would levy FS haulage and treatment taxes, from which it subsidizes the operations by company owning the plant. Subscription fees would be required for use of the emptying service and of the treatment plant, and would be collected according to appropriate rules. The difficulty of this type of money flux model might come in resistance from citizens to an additional subscription, since they already

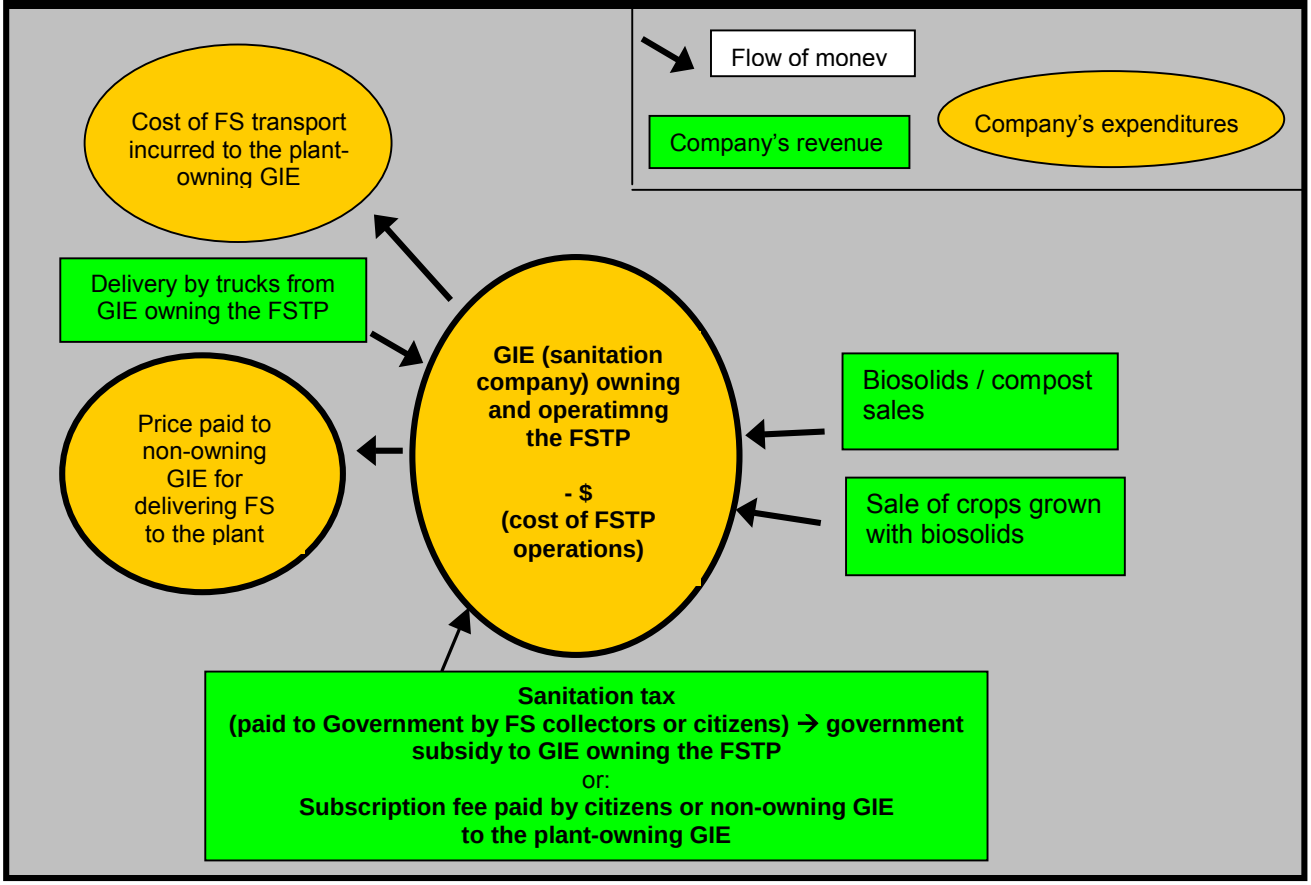
[1] The intended use of the plants' effluents for irrigation is not possible due to the salt content of effluents of FSTP normallly being beyond plant salt tolernace.

[2] A similar procedure is being planned for FS management in Ouagadougou (Burkina Faso).

pay for refuse collection. However, a well-devised system might also allow reducing the price of the actual evacuation, which, in turn, would mean people might not wait until the last minute to evacuate latrines or septic tanks.

Box 5

Proposed incentive and fee structure to enable financially viable FS treatment operations (Jeuland 2002)



4.6.4 Lesson

The Bamako case shows that and how, in the absence of government support, initiative and policy, small entrepreneurs and NGOs can move in and set up FS management in a largely sustainable and socially and environmentally responsible manner. Contrary to Kumasi (see 4.5 above), the approach, which developed in Bamako, is bottom-up. Yet, the two contrasting examples show that, apparently, both the top-down and the bottom-up strategies may, in principle, lead to sound and largely sustainable solutions.

5 Opportunities and Constraints

5.1 Case analysis and discussion

An analysis of problems associated with the current practices in FS management was elaborated upon in Chpt. 2 (Table 2). The four cases presented in Chpt. 4 above illustrate, how, in selected cities in Asia and Africa, private and public stakeholders have already devised or are attempting to devise improved strategies and technical options to improve on FS management. All these attempts, besides aiming at reducing health and environmental hazards caused by improper FS handling, have as an explicit or implicit objective to render FS management more sustainable. Table 10 shows whether and what, in the cases presented above, elements of decentralisation (as defined by the EngKAR project of which this report is an integral part) are in place or proposed to be put in place.

Table 10 Elements of decentralisation in the cases described in Chpt. 4

	Vientiane	Nam Dinh	Kumasi	Bamako	Mapet-based schemes [1]
• **Are private entrepreneurs involved ?**	✓ Entrepreneurs' role to be enhanced in future	---- Entrepreneurship to be promoted	✓	✓	✓
• **Are CBO involved ?**	CBO to be involved in district-based FS management planning	Farmers' cooperatives to be involved in biosolids marketing	✓	✓	✓
• **Physical decentralization of collection and treatment / disposal**	Decentralized treatment being planned	Decentralized treatment being planned	✓	✓	✓ Localized disposal, treatment and use

[1] see Chpt. 3.2

In Table 11 below, problems identified in the illustrative examples above and from authors' observations on FS management in numerous other towns are listed following the path of the FS from the pit to the final point of use or disposal (column 1). Attempted and planned for solutions are summarised in column 2 of the Table. Finally, in column 3, the authors list their analysis of the attempted solutions.

Table 11 FS management – problems, attempted solutions and solution analysis

Identified problems with ….	Solutions attempted in practice (cited examples)	Analysis of attempted solutions
• ***Emptying***		
- Pits difficult to access - Inappropriate emptying equipment (size and performance for complete sludge removal)	- Manufacturing and increased use of small vacuum equipment (MAPET; mini-tug Haiphong; mini tanker Maseru)	- Technical solutions at hand - Little replication; lack of funding for low-cost equipment
- Poor service management (technically as well as organisationally) by public utilities - Low willingness-to-pay for service	- Devolvement of public service rendering to private entrepreneurs through contracting, licensing, franchising (Vientiane; Kumasi; Bamako)	- Necessary though not sufficient prerequisite for FS management improvements; needs to be complemented by an effective incentive and sanctioning system
• ***Haulage***		
- Lack of suitable disposal or treatment sites close to the areas of collection; indiscriminate FS dumping - Traffic congestion	- Devising localised, semi or decentralised treatment (MAPET-serviced neighbourhoods; Kumasi; Bamako)	- Necessary though not sufficient prerequisite for FS management improvements; needs to be complemented by an effective incentive and sanctioning system - Likely to lead to reduced illegal dumping of FS
- Lack of effective long-term urban planning, hence, lack of suitable, nearby treatment sites kept in reserve	- (A common phenomenon in municipal administration in dev. countries; authors are unaware of exemplary municipalities)	
- Lack of suitable incentive and sanctioning procedures	- Devising a suitable revenue and fee structure for FS emptying, collection, haulage and treatment (reversed tipping fee proposed for Bamako)	- Beside devolvement to private entrepreneurship, single-most important measure to improve FS management; models still to be applied and tested in practice
	- Promoting private entrepreneurship (partly privatised in Vientiane; largely privatised in Kumasi and Bamako; planned in Nam Dinh)	- Improves services to customers
	- Catering for a competitive market in FS collection and haulage, and linking contracts or licenses to compliance with rules and regulations (Kumasi)	- Contributes greatly to improvements in FS management if sanctioning procedures are made to work

• ***Treatment***		
- Lack of proven and appropriate treatment options	- R+D in appropriate treatment options (pilot and full-scale monitoring) (field research of SANDEC with partners in Latin America, Africa and Asia) - Preparation of plans for implementing suitable, modest-cost options (Kumasi – just completed; Bamako; Vientiane; Nam Dinh)	- Has started to contributing to close the gap-in-knowledge on treatment - Several recent initiatives in Asia and Africa; few experiences and performance data to date
- Entrepreneurs avoid tipping / treatment fee → illicit dumping	→ see under **haulage**, above	
• ***Use***		
- Health risks to farmers and consumers through the use of untreated FS	- FS treatment → safe biosolids (Kumasi – treatment in place at full-scale FSTP, yet biosolids polishing not established yet; planned treatment schemes in Vientiane, Nam Dinh and Bamako; pilot co-composting scheme established in Kumasi)	- Technically simple to produce hygienically safe biosolids
- Non-use or limited use of potentially usable biosolids	- Farmer involvement, promotion and marketing (through joint efforts of public authorities and private entrepreneurship) (planned in Nam Dinh and in Bamako)	- Considered as expedient and necessary; yet, authors are not aware of related initiatives and activities
• ***Disposal***		
- Illicit dumping; health and pollution risks from dumping at designated sites	- Planning for and implementing semi or decentralized treatment and introducing effective incentive and control / sanctioning procedures (Kumasi – in place; Vientiane, Nam Dinh, Bamako – planned for)	→ see under **haulage**, above

5.2 Enabling and Hindering Factors

Table 2 in Chpt. 2 and the above Table 11 summarise problems, consequences, and solutions attempted in a few selected situations to date. What may be learned from these ? In Table 12 below, the authors summarise how, in their opinion, institutional, financial/ economic and technical factors enable and impair or hinder effective (faecal) sludge management.

Table 12 Enabling and hindering elements in FS management

Factor	Enabling element	Hindering element
Technical	- Emptying / collection technology developed and at hand - Tentative solutions and guidance on treatment technology at hand	- Planners and engineers still unaware of available options - Options have not been developed sufficiently to become proven state-of-the-art - Stipulation of overly strict standards for FSTP effluent and biosolids quality and standards not adapted to the local situation
Institutional, political (“governance”)	- Devolvement of emptying, collection and haulage services to private entrepreneurs - Existence of a competitive market among FS collection entreprises - Existence of a licensing or contracting system, which authorities use also as a sanctioning instrument - Decision-makers and authorities dedicated to improve on urban env. sanitation - Appropriate incentives at all levels (e.g. appropriate fee structure) - Municipality capable of developing and exerting control over licenses and contracts - Appropriate legal code regulating FS management	- Non-existence or non-involvement of private entrepreneurship - Conventional fee structure for FS-related services - No or insufficient involvement of stakeholders (owners and users of sanitation facilities, farmers, private entrepreneurs, authorities) - Lack of guidance and documented experience about networking among stakeholders and their institution-alised involvement - Responsibilities at municipal level spread over too many entities - Irrational treatment or discharge standards; lack of will And/or capacity to control and enforce regulations - Lack of knowledge or willingness to make use of treatment by-products - Responsibilities at institutional level spread over too many entities
Financial / economic / agronomic	- Farmers aware of manuring value of biosolids and willing to buy biosolids produced in FSTP - Fees established enable safe revenues and profits for entrepreneurs	- Unaffordable emptying fees (→ pit or vault blockages; discharge of fresh excreta and wastewater into the environment)

5.3 Gaps-in-Knowledge on (Faecal) Sludge Management

Based on the analyses developed above and on problems identified in Chpt. 2 (Excreta Management – The Great urban Challenge), major gaps-in-knowledge can be identified on the issues listed below:

- On low-cost **sludge treatment** options:

  - Long-term operational experience
  - What is “best” or quasi-proven technology ?
  - Lack of detailed costing data

- On sustainable **sludge management concepts**:

  - Experience and guidance on stakeholder networking and institutionalising stakeholder involvement
  - Sound quality standards for end products of sludge treatment (biosolids and liquid effluent), suiting local environmental, socio-economic and institutional conditions
  - Exemplary, tested and sustainable models for fee structures and money fluxes in FS management

- On the **use of biosolids** in agriculture:

  - Exemplary and sustainable marketing models for biosolids
  - How to institutionalise networking between farmers and stakeholders in FS management, treatment in particular

- On the needs for capacity building for various stakeholders and stakeholder groups [1]:

  For engineers and technical personnel:

  - FS: definitions; characteristics; sampling and analysis
  - FS treatment: features of feasible options; pre-selection; basic design, costing and evaluation; operational guidance
  - Quantities and characteristics of sludges from decentralised wastewater treatment systems
  - Training manuals for unskilled operators

[1] Note: this is but a preliminary listing of suggested capacity building needs; better defined needs can be identified based on the case-study findings from Phase II of the porject.

For planners and facilitators:

- Developing tools for stakeholder involvement
- Tools for assessing stakeholder needs and perceptions
- Principles of (faecal) sludge management planning (as an integral component of planning in urban environmental sanitation)

For politicians / decision makers:

- On the need of and basic strategic solutions for improved FS management and treatment
- Awareness-building documentation regarding health risks and cost of not improving FS management; nuisance impacts; environmental impact
- On economic aspects of improved FS management and recycling
- Standards for biosolids and treated FS liquid quality: need, objectives and sensible values
- Developing incentive structures and procedures to facilitate sustainable FS management (innovative models of money fluxes!)
- On the roles of municipal authorities vs. private entrepreneurs and NGOs in FS management: licensing; franchising; controlling and enforcement, entrepreneuralship

For farmers:

- Opportunities and constraints of using biosolids produced in FS treatment
- Cultivation on demonstration plots
- Financial aspects of biosolids use

For private entrepreneurs (operators of treatment works; providers of FS collection and haulage services):

- Marketing of biosolids
- Financial management for small entrepreneurs
- Technical guidance for treatment plant franchisees
- On the complementing roles of private and public partners in FS management: entrepreneurial, management and control aspects

6 Conclusions and Recommendations

To the extent that authors have become aware during their R+D work in FS treatment and FS management planning, only a few projects on sustainable and decentralised management of (faecal) sludges have become established to date (examples cited from Kumasi, Ghana and Bamako, Mali). Yet, several promising and laudable initiatives have emerged very recently (examples cited from Nam Dinh, Vietnam and Vientiane. Laos; several unquoted initiatives in West and South Africa). There appears to be growing concern among municipal authorities in Asia and Africa about the dramatic situation in excreta management. In several places, the need to act has emerged and initiatives have been started to improve the situation. Hence, the need for guidance and training of the various stakeholders in sustainable sludge management is rapidly increasing.

Documents, which can serve, in whole or in parts, as training tools for planners and engineers, mainly, are listed in Chpt. 7.5.

The authors recommend that the focus in a possible Phase II of the Project be equally laid on wastewater and on (faecal) sludge. The great challenge in FS management improvement relates to FS collection and haulage, i.e. to actually getting the sludge to where one would like to have it. This is a problem inherent to FS management, while wastewater will automatically "find its way" to the points of designation once sewerage is in place. Hence, it's mainly the sludges originating from on-site sanitation systems which form the "faecal film" being spread and maintained through entire city districts. Without improving on the managerial and financial/economic aspects of FS collection and haulage, indiscriminate and illicit spreading of untreated faecal matter will continue, even though adequate treatment schemes may have been put in place !

The initiatives and practices reported about in Chpt. 4 for Kumasi, Bamako, Nam Dinh and Vientiane are likely to serve as fruitful grounds to identify felt needs of stakeholders for capacity building and training in the field of decentralised (faecal) sludge management. A list of presumed needs is contained in Chpt. 5 above.

7 Annexes

7.1 About Minimising FS Haulage Cost (see also Chpt. 2.4)

7.1.1 What Speaks Against Large, Centralised Treatment Schemes

The average haulage distance from the houses where FS is collected to the FS treatment plant and with this the actual size of the plant is a very decisive variable for the total cost of the disposal system as well as for its efficiency and sustainability. A commonly observed practice is the uncontrolled dumping of FS by the driver of the emptying truck although a treatment plant, which should receive the FS, is in operation. The reason for such behaviour is that the distance to the plant is often excessively long. Hence, collection service providers and vacuum truck drivers are tempted to cut haulage time and cost. The haulage of relatively small faecal sludge volumes (5-10 m^3 per truck) through congested roads over long distances in large urban agglomerations is unfeasible also from an environmental viewpoint as it is associated with excessive fuel consumption end hence air pollution. It is therefore of key importance to minimise overall FS haulage volumes and mileage. This means that small to medium-size plants, semi-centrally or decentrally located, must be aimed at whenever possible.

While the economy-of-scale factor for the treatment works must also be taken into consideration, there is no clear-cut tendency that larger plants will entail lower cost. Large plants may require a more sophisticated technology to save on land requirements. This would, in turn, increase capital and operating cost.

7.1.2 Calculation of estimated km-dependent haulage costs

Overall haulage cost depend on the size of the area from which the FS is collected. Assuming a circular collection area with an FS treatment plant in the centre, the average distance from a sanitary installation to the plant amounts to:

$$\text{D (average distance)} = \sqrt{\frac{(\text{maximal distance from the plant})^2}{2}}$$

The maximal distance from the plant determines the served area (A) and, with a given population density, the served number of people. Assuming again a nearly circular area, the average distance from the sanitary installation to the treatment plant may also be written as:

$$D = \sqrt{\frac{\text{served population (SP)}}{2\Pi \circ \text{population density (PD)}}}$$

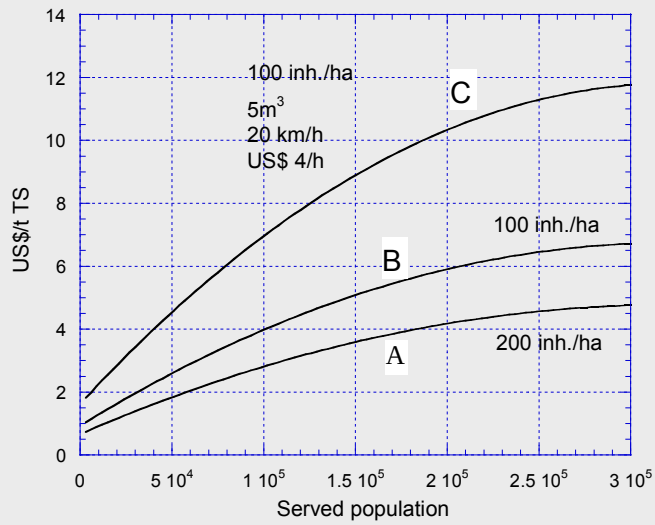
The collection costs per m^3 collected FS can then be calculated as:

$$C_{collection}\left[US\$/m^3 FS\right] = \mathrm{D}\left[\mathrm{km}\right] \circ \left(\frac{\text{truck - km cost} + \dfrac{\text{man - hour cost}}{\text{average speed}}}{\text{truck capacity } [\mathrm{m}^3]} \right)$$

The calculations and diagram presented in the Box below show the ratio of km-dependent cost per ton of TS and haulage-km as a function of population served, based on information from Thailand and Ghana.

Haulage cost as a function of total population served and population density

	Standard conditions (curves A and B in the diagram)	**Unfavourable Conditions (curve C in the diagram)**
Truck km-cost (fuel, wear of tyres etc.):	US$ 0.30	US$ 0.30
Truck capacity:	7 m^3	5m^3
Average speed:	30 km/h	20 km/h
Man hour (driver + worker):	US$ 3	US$ 4.00
Average TS:	18 g/l	18 g/l



The Diagram shows that for the chosen standard conditions, the km-dependant haulage cost for served population ranging from 50,000 to 300,000 are in the range of US $ 2 to 7 per t TS and per km, depending on population density. For a population of 20,000, e.g., specific haulage cost would amount to $ 4.2 / t TS·km under the assumed standard costing conditions. Hence, for a treatment plant located 10 km outside the settlement area, the haulage cost would amount to $ 42 / t TS·km. Under unfavourable conditions (unpaved roads, higher salaries and smaller trucks), haulage cost per km as per this model may be as high as $ 10.5 per t TS.

7.2 Technical Options for FS Treatment (see also Chpt. 3.3)

Screening and energy dissipation/stilling

Faecal sludges usually contain considerable quantities of non-degradable, coarse objects, such as plastic bags, rags, small glass or metal containers. Hence, screening the sludge prior to actual treatment is desirable and expedient.

Further to this, installations are required at the receiving end of FSTP, which cater for energy dissipation of the FS upon discharging from the vacuum tankers. Stilling chambers or channels will serve this purpose, thus helping to avoid excessive turbulence in settling units or scouring of sand layers in sludge drying beds.

Solids-liquid separation

Settling-thickening tanks or primary ponds can be used for solids-liquid separation (Fig. 9). Settling tanks provide a liquid retention time of a few hours (enough to ensure quiescent settling of settleable solids), while settling ponds cater for several days or a few weeks of liquid retention and, hence, also allow for anaerobic degradation of organics. Both types of units are designed based on the storage volume required for a desired depth and quantity of accumulating solids. At least two parallel units need to be provided to allow for batch operation comprising adequate loading and resting/emptying cycles.

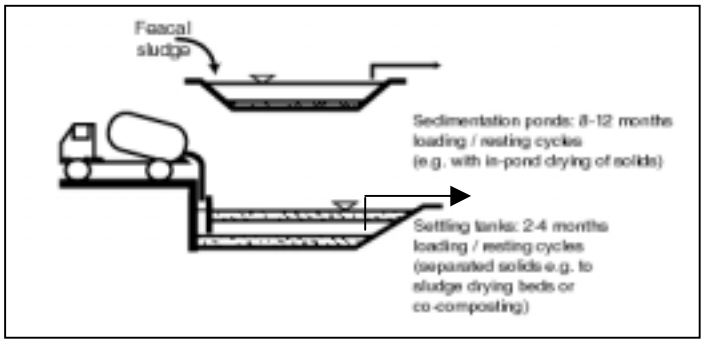


Fig. 9

Non-mechanised settling-thickening tanks and sedimentation/anaerobic ponds for solids-liquid separation (schematic)

Non-mechanised, batch-operated settling tanks as well as settling ponds must be designed such as to enable easy removal of partly or fully dewatered accumulated solids, by either manual means or by front-end loaders (in larger plants). The solids can be further processed by drying on so-called sludge drying beds or upon further surface spreading 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.

Table 13 shows the **removal rates**, which may be expected in settling-thickening tanks and in settling ponds, respectively:

Table 13 Expected removal rates in settling-thickening units [1]

	Settling-thickening tanks	Settling ponds
Susp. solids, SS	60 %	> 95 %
BOD and COD (unfiltered)	30 – 50 %	70 – 95 %
BOD (filtered)	18 %	45 %

1 Based on actual performance of investigated installations running at sub-optimal conditions

The **rate of accumulation of settleable solids**, hence, 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 (Heinss et al., 1998; Ingallinella et al. 2000).

Unplanted Sludge Drying Beds

Sludge drying beds, if suitably designed and operated, can produce a solids product, which 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. A maximum nematode (roundworm) egg count of 3-8 eggs/g TS has been suggested by Xanthoulis and Strauss (1991).

Gravity **percolation** and **evaporation** are the two processes responsible for sludge dewatering and drying. Sludge drying beds are schematically illustrated in Fig 10. Evaporation causes the mud to crack; thereby leading to improved evaporative water losses and enhanced drainage of the sludge liquid and rainwater.

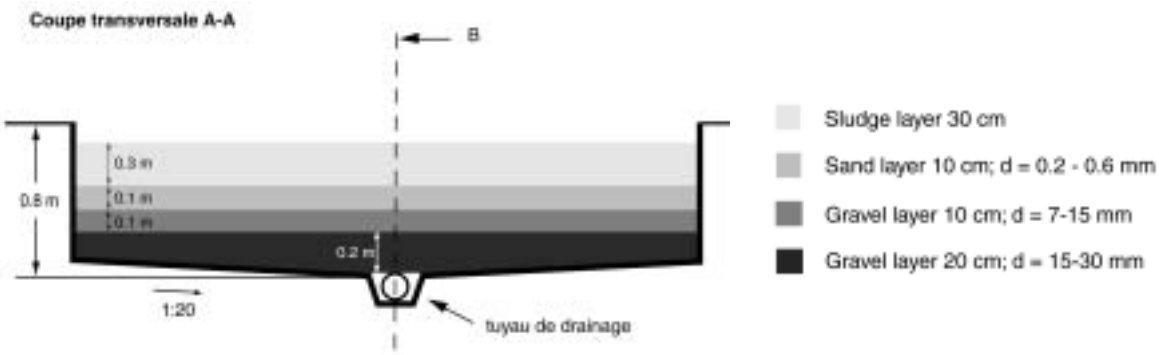


Fig. 10 Unplanted sludge drying beds (schematic)

From 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 type of sludge, weather conditions and operating characteristics of the particular drying bed. Drying bed percolate tends to exhibit considerably lower levels of contaminants than settling tank supernatant. This liquid will, nevertheless, also have to be subjected to a suitable form of treatment (e.g. in facultative ponds) in most cases.

Pescod (1971) conducted experiments with unplanted sludge drying beds in Bangkok, Thailand. According to the experiments, maximum allowable solids loading rates can be achieved with a 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 days of drying, TS contents of 40 % were attained, whereas at 600 kg TS/ m^2·yr, TS contents of 20 % only could be achieved. The fresh, non-stabilised public toilet sludge was not conducive to drying within drying periods lasting from 10-20 days.

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

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:

- Susp. solids: ≥ 95 %
- COD: 70-90 %
- Helminth eggs: 100 %
- NH_4: 40-60 %

Constructed Wetlands (planted sludge drying beds)

Constructed wetlands (CW) for treating sludge consist of a gravel/sand/soil filter planted with emergent plants such as reeds, bulrushes or cattails. The advantage of planted over

unplanted sludge drying beds is that the root and rhizome system of the plants used in CW create a porous structure in the layer of accumulated solids and thus enables to maintain the dewatering capacity of the filter during several years. In contrast to CW treating wastewater, CW for sludge are equipped with a freeboard. This allows dewatered solids to accumulate over several years. As a consequence removal of accumulated biosolids is required at a much lower frequency than unplanted sludge drying beds. Operating cost are thus considerably reduced. The extended storage of biosolids allows for biochemical stabilisation. The plants pass through repeated cycles of growth and wilting. Sludge is due to be removed from the filters only after 5 to 6 years. The biosolids may be dried to a limited degree only – to 65–60 % water content at the most – in order to ensure sustained plant growth. CW percolate will require post-treatment as per local conditions and discharge regulations.

Three pilot constructed wetlands – planted with cattails – have been investigated since early 1997 at the Asian Institute of Technology (AIT) in Bangkok. The 3x25 m^2 pilot plant is equipped with a drainage and ventilation system (Fig. 11) and it treats the septage from approximately 3,000 people. It was first acclimatised with wastewater and gradually fed with Bangkok septage in a vertical-flow mode of operation. The percolate was treated in a waste stabilisation pond system at first, and in a constructed wetland bed planted with ornamental plants in the later project stage. The objectives of the project are to assess the suitability of this option for the treatment of septage and establish design and operational guidelines.

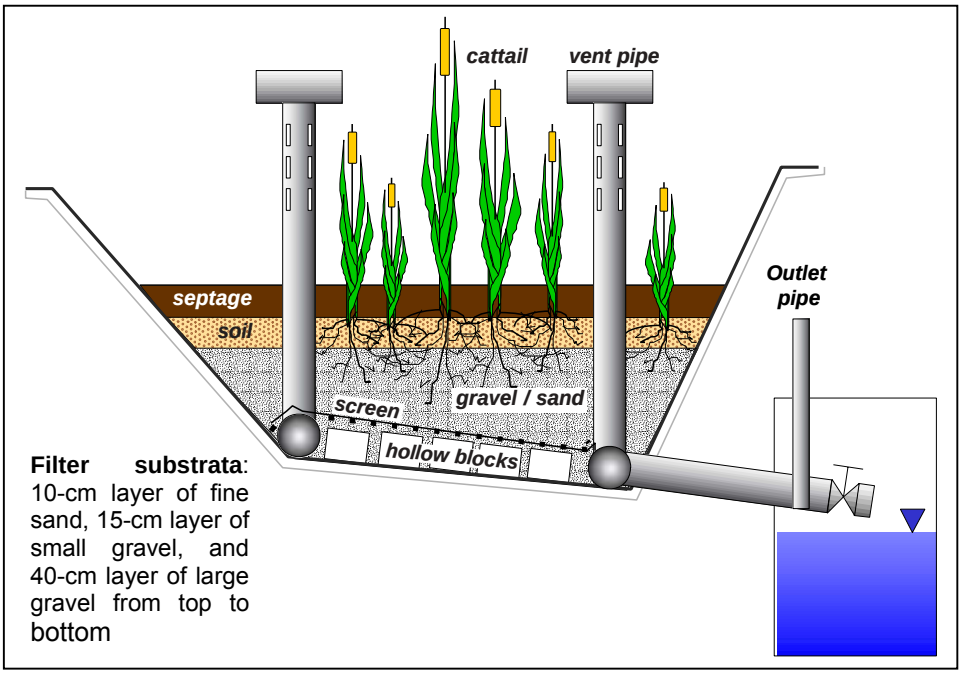


Fig. 11 Pilot constructed wetlands fed with septage since 1997 (AIT, Bangkok)

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 the plant wilting observed especially during the dry season (Koottatep and Surinkul 1997-2001). Optimum operating conditions under which maximal removal efficiencies were measured and cattails didn't show any 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

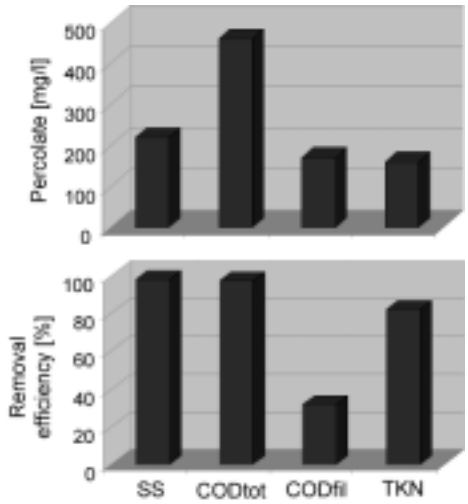


Fig. 12

Percolate concentration and removal efficiency of the constructed wetlands (average data based on 12 composite samples)

90 cm of dewatered and stabilised solids had accumulated in the CW beds by the end of 4.5 years of septage loading, equivalent to a column of 75 m of raw septage loaded onto the beds. Fig. 12 depicts contaminant concentrations and related removal efficiencies across the CW beds.

Table 14 Agronomic characteristics of the biosolids accumulating in the AIT constructed wetland plant treating septage (Kost and Marty, 2000). Nutrient levels in matured compost are also included for comparison's sake (FAO 1987)

	TS [%]	TVS [% of TS]	Total N [%TS]	Total P [%TS]	Total K [%TS]
Dried sludge layer	35-45	60-65	3	1.2	0.2
Matured compost			0.4-3.5	0.1-1.6	0.4-1.6

Table 14 illustrates the characteristics of the accumulated sludge layer, as it was determined after three and a half years of operation. 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 showed that the use of the accumulated biosolids in agriculture would not result in a risk to public health. Nematode concentrations found in raw septage were approx. 40 eggs/g TS. The number of nematode eggs counted in the solids

accumulated over several years was still high (170 g/TS on avg.). 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 (see chapter 3).

Mass balance calculations across the CW beds have shown that of the entire solids load discharged onto the beds, in the order of 50 % are retained on the bed surface as biosolids, 10 % are contained in the percolate and 40 % are “lost” through degradation of organic material yielding water and CO_2 and possibly through accumulation in the bed’s underdrain system. Of the water brought onto the beds with septage, in the order of one third is evapotranspirated 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.

Non-Aerated Stabilization Ponds for the Separate Treatment of FS

Fig. 13 shows a WSP system suitable to treat low to medium-strength faecal sludges. It comprises pre-treatment units (tanks or ponds) for solids-liquid separation followed by a series of one or more anaerobic ponds and a facultative pond. This allows producing a liquid effluent apt for discharge into surface waters. Effluent use in agriculture is not possible due to its high salinity. Biosolids produced during pre-treatment and in the anaerobic ponds, however, constitute a valuable resource and may easily be treated to satisfy safe hygienic standards.

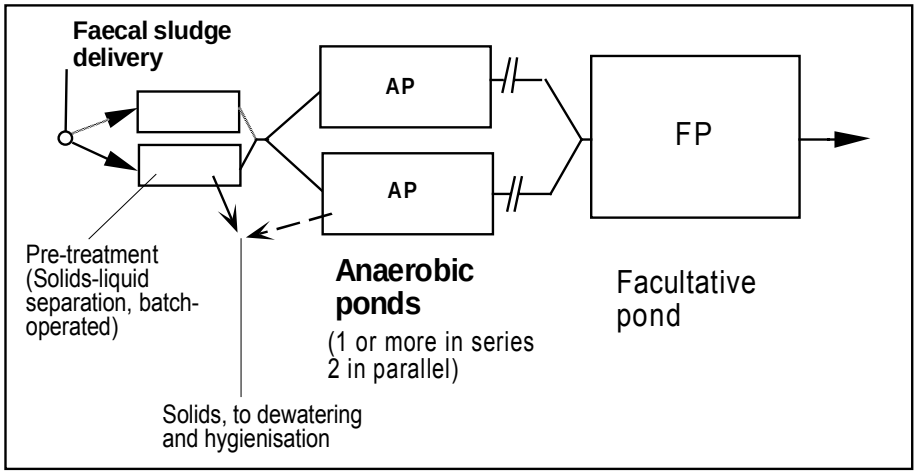


Fig. 13 Schematic Drawing of a WSP System Treating Low to Medium-Strength Faecal Sludges (Strauss et al. 2000)

Where FS are made up by critical proportions of sludges from unsewered public toilets with zero or low-flush installations or in latrines with so-called watertight pits, ammonia levels might be high. 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 (being equivalent to approx. 400 mg (NH_3 + NH_4-N)/L at 30 ° C and pH 7.8, conditions typical of FS in warm climate).

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 might be the method-of-choice in developing countries to render such FS conducive to further treatment, viz. solids-liquid separation (in the primary unit itself), dewatering/drying of the biosolids and polishing of the liquid fraction.

Problems encountered when co-treating FS and wastewater in waste stabilisation ponds

Where waste stabilisation ponds exist to treat municipal wastewater, and where these are used to co-treat FS, a number of problems may arise. In many cases, the problems are linked to the fact that the wastewater ponds were not originally designed and equipped to treat additional FS load. Common problems 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.

- Ponds may fill up with solids at undesirably fast rates due to the high solids content of FS. 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. These may impair or even prevent the development of algae in facultative ponds.

Preventative measures, such as the addition of a solids separation step ahead of the first pond, and the consideration of a maximum admissible FS load can avoid the aforementioned problems. Like in 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, may not exceed 400 mg/l.

The Combined Treatment of FS and Wastewater in a Pond System

To avoid the above-mentioned problems when co-treating FS and wastewater and to, FS may be pre-treated in primary settling-thickening ponds. Their effluent can then be co-treated with wastewater in follow-up facultative and maturation ponds (Fig. 14). The FS settling ponds, which will also allow for anaerobic degradation of dissolved organics, enables to separate off the bulk of solids ahead of the main WSP system proper.

In Alcorta (Prov. of Santa Fé, Argentina), A series of two stabilisation ponds was put in operation in 1987 to co-treat both wastewater and septage. A monitoring program of the system (93-95) revealed that the capacity of the first pond had been reduced in half due to the high solids content of septage. Based on these investigations conducted by the

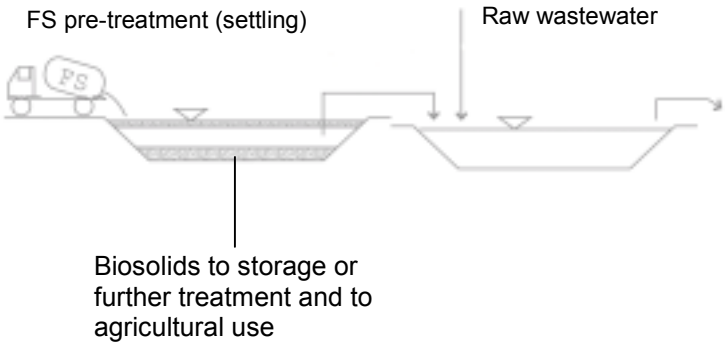


Fig. 14
Co-treatment of FS and wastewater in ponds (schematic)

University of Rosario, a **septage pre-treatment** consisting of two **sedimentation ponds** was constructed in July 98 (Fig. 15). The two ponds are operated alternatingly: one pond is loaded while the sludge accumulated in the other one 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/hygienized 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.

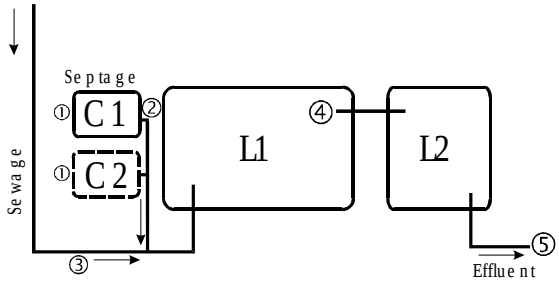


Fig. 15
Co-treatment of septage and wastewater (schematic)

C1, C2: Septage ponds
L1, L2: Ponds treating septage liquid (supernatant) and municipal wastewater)

The sedimentation ponds were designed based on the following criteria:

- The accumulated sludge layer should be less than 0.5 m
- The sludge accumulation rate amounts to 0.02 m3/m3
- 6 months loading + 6 months in-pond resting/drying of accumulated biosolids

The results of three-years of monitoring show that the efficiency of the ponds treating septage (sedimentation and degradation) is such that the effluent quality is similar to the wastewater quality, both under low as well as high BOD loading rates. Raw septage, sedimentation pond effluent and wastewater quality are illustrated in Fig. 16.

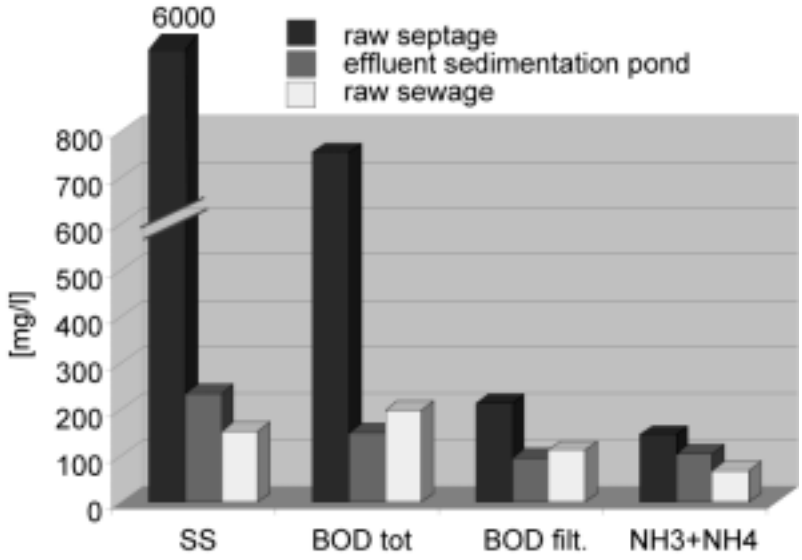


Fig. 16

Raw septage, effluent of the sepatge pond and raw sewage concentration measured in Alcorta during the first monitoring cycle (14 campaigns). (Ingallinella et al., 2000)

Analyses of the dewatered sludge show that the level of humidity reached at the end of the drying cycle enables an easy handling of the sludge through spading. The final plant effluent, which is composed of treated septage supernatant and wastewater satisfies conventional discharge standards.

Composting with Organic Solid Waste ("Co-Composting")

Co-composting, i.e. the combined composting of faecal matter and organic solids waste is practiced all around the world, usually in small, informal and uncontrolled schemes or on a yard scale. Presumably, most of this proceeds at ambient temperatures, with concomitant inefficient inactivation of pathogens. In contrast to this, thermophilic composting, i.e. the composting at 50-60 °C, is an effective process for pathogen destruction while stabilising organic material and creating a valuable soil conditioner-cum-fertilizer. Co-composting of sewage treatment plant sludge with organic solid waste is widely practiced in industrialized countries. The authors are not aware, though, of any thermophilic co-composting scheme treating FS and organic waste, except for one scheme in South Africa, which was operational from 1992-96, and in which bucket latrine sludge was co-composted with municipal waste. The scheme was closed down when the bucket latrines were replaced by a sewerage system.

SANDEC, in collaboration with IWMI-West Africa and the Municipality of Kumasi (Ghana) have recently started investigating FS and organic solid waste co-composting on pilot scale. FS, which is composed of high-strength sludge from unsewered public toilets and of septage, is dewatered to the required solids content by sludge drying beds or, alternatively, thickened in a primary settling pond. The FS-organic waste mixture is windrow-composted for a period of 1 month (thermophilic phase) followed by a maturing phase of 1-2 months. The raw mixture is composed of 1 part dewatered FS vs. 3 parts sorted waste. Matured compost, produced at a rate of 1 ton/month, will be tested in comparative planting trials to ascertain its marketability. First results on the treatment

process are expected by June 2002. Fig. 17 is a schematic representation of the Kumasi pilot scheme.

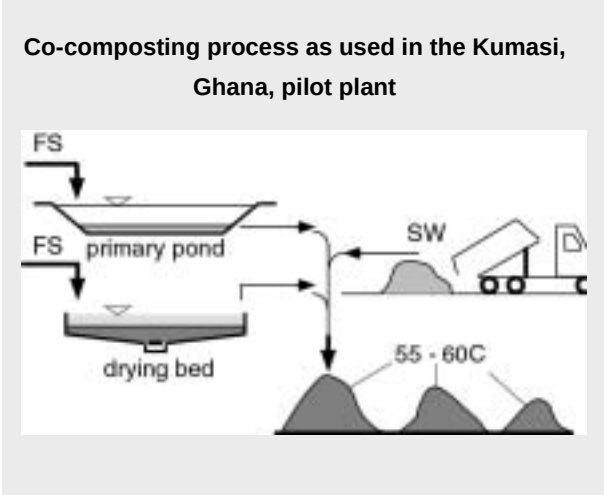


Fig. 17 Co-Composting Flow Chart – the faecal sludge needs to be dewatered or thickened to enable the treatment of inhabitant-equivalent quantities of FS and solid waste

Anaerobic digestion with biogas utilization

This option may, in theory, be perfectly suited to treat higher-strength FS, which have not undergone substantial degradation yet. Such sludges may comprise the contents of unsewered public toilets, whose vault contents are emptied at relatively high frequencies of but a few weeks. Fig. 18 is a schematic sketch of FS-based anaerobic digestion with biogas utilization and Photo 15 shows a cooking stove fuelled with FS-base biogas. There exist, in practice, two types of digestors, viz. fixed and floating dome units.

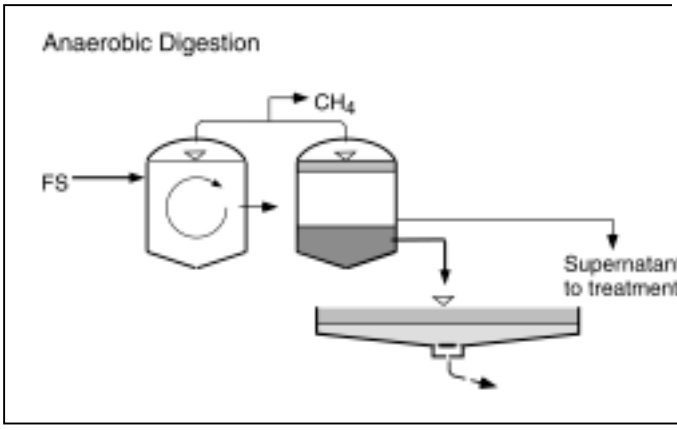


Photo 15

Public toilet caretaker in his quarter, cooking with biogas produced from FS (Nagpur, India)

Fig. 18 FS-fed anaerobic digester w. biogas recovery (schematic) and biogas fuelled cooking stove in a public toilet caretaker's quarter

Although, where urine is mixed with faeces, the C:N ratio of the FS is too low to generate maximum gas yields, the option might nevertheless proof technically and economically feasible under specific local conditions. The only biogas systems known to the authors, which are operated on FS as exclusive organic feed are plants attached to public pour-flush toilets operated by Sulabh, an Indian NGO, for municipal authorities. There are, reportedly, approx. 70 such plants in operation. NEERI (India) conducted applied research on FS-fed biogas plants in the sixties and seventies. Biogas plants processing FS mixed with cattle dung are presumably being operated in many developing countries as small, decentralised schemes serving one or several households or institutions. Yet, the authors do not avail of and have not collated information on such schemes. Gaps-in-knowledge pertaining to FS-fed anaerobic digestion pertain to supernatant post-treatment, settled solids evacuating and hygienization; costing and affordability, mainly.

Although anaerobic digestion with gas utilization 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. A possible reason might consist in the relatively high investment cost of such plants and the concurrent low affordability by target users. Further to this, removal of accumulated solids from the digestors appears to be a difficult task, which has caused many such plants to turn unused.

7.3 Pathogen Die-off in Faecal Sludge at Ambient Temperatures

Table 15 Pathogen survival or die-off periods in wet faecal sludge

Organism	Average Survival Time in Wet Faecal Sludge at Ambient Temperature [1]	
	In temperate climate (10-15 °C) [days]	In tropical climate (20-30 °C) [days]
• ***Viruses***	< 100	< 20
• ***Bacteria:***		
- Salmonellae	< 100	< 30
- Vibrio cholerae	< 30	< 5
- Faecal coliforms[2]	< 150	< 50
• ***Protozoa:***		
- Amoebic cysts	< 30	< 15
• ***Helminths:***		
- Ascaris eggs	2-3 years	10-12 months
- Tapeworm eggs	12 months	6 months

1 When exposed to the drying sun, the survival periods are much shorter

2 Faecal coliforms are commensal bacteria of the human intestines and used as indicator organisms for excreted pathogens

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7.6 Selected Institutions and Persons Actively Engaged in FS Management and FS Management Applied Research

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