SOS – Management of Sludges from On-Site Sanitation

Faecal Sludge Treatment

Challenges, Process Options and Field Research: A State-of-Knowledge Report

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Abbreviations and Acronyms

FS	Faecal sludge
FSTP	Faecal sludge treatment plant
WSP	Waste stabilisation ponds

Keywords: faecal sludge, septage, treatment processes, developing countries, on-site sanitation, research

1 Introduction and Abstract

In our last Newsletter No. 27 of August 1993, the project was in its identification phase and faecal sludge treatment initiatives were briefly outlined for some African cities. Furthermore, selected treatment options, among them sedimentation/thickening followed by waste stabilisation ponds and co-composting, were cited as potential treatment methods in developing countries. The project has now reached its field research phase.

Abstract

This article starts out with an overview of the SOS project objectives and approach, followed by an account of the specific challenges of faecal sludge treatment, including disposal practices, impacts and FS characteristics. Problems related to FS sampling and analysis are discussed and a minimum set of variables is being proposed for treatment plant design and control. Priority treatment options thought to be of particular relevance to developing and newly industrialising countries are discussed and gaps in knowledge listed. The current and planned field research activities are presented. SANDEC has chosen to initially carry out field research on the settling/thickening of FS, on co-composting of FS with solid waste, on sludge dewatering/drying beds, on stabilisation pond treatment for FS, and on extended aeration of septage. Results of the field research carried out by partners in Ghana are presented. A set of references and addresses of institutions involved in R+D for FS treatment have been included.

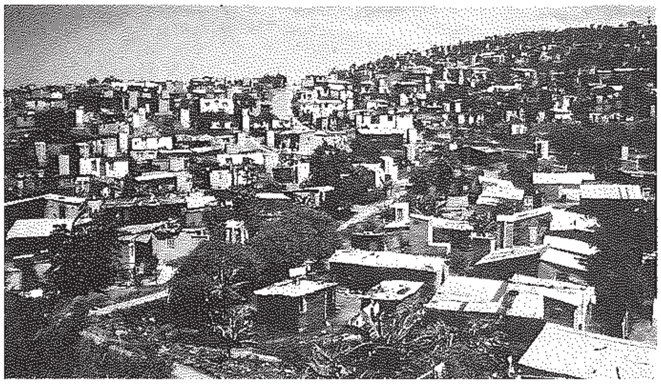


Photo 1: An urban low-income neighbourhood – what are the feasible options to treat the faecal sludges from the recently built VIP latrines?

2 The SOS Project: Objectives, Approach and Activities to Date

Objectives

The SOS Project aims at the following:

- To publish a **guideline document** for developing countries on faecal sludge treatment, including sludge and plant monitoring methods. It will be based on applied field research to be conducted in developing countries, on treatment practices elsewhere and on the review of pertinent literature.
- **To enhance the expertise** of professionals and institutions in developing countries in the field of human waste disposal monitoring and control.
- To optimise design and operation of those FSTP that have been jointly investigated by EAWAG/SANDEC and the collaborating institutions.

Approach

The project is divided into **three phases**, each phase yielding the following specific outputs:

Phase I ***Identification:***
State-of-the-situation review of treatment, disposal and use of faecal sludge in a few selected localities, site visits, identification of local collaborating institutions and researchable questions, state-of-the-art publication.

Phase II ***Field research:***
Conduct field research in developing countries jointly with local institutions on the basis of monitoring protocols, use of existing full-scale or pilot-scale faecal sludge treatment plants, data collection.

Phase III ***Synopsis:***
Field research documentation, synopsis and interpretation of data and experience, guide document (manual) for faecal sludge treatment and disposal, review and dissemination.

Overview of Activities to Date

The following main tasks were carried out in **Phase I**:

- A literature review of potentially viable treatment processes and technologies.
- Identification visits to several countries in Africa and Asia and subsequent identification of a possible field research collaboration with local institutions on specific treatment options in initially three countries/sites (Ghana, Indonesia, China).

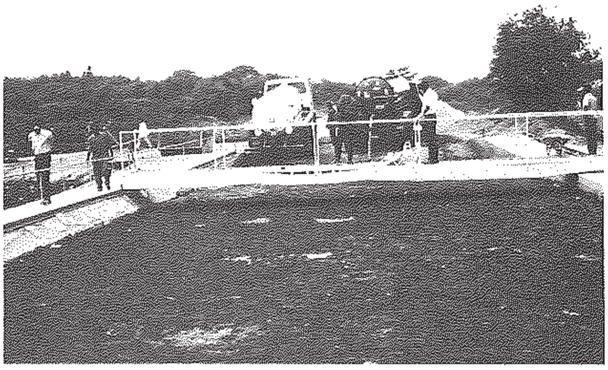


Photo 2: Faecal sludge settling/ thickening tank with sampling bridge at the Achimota FSTP, Accra (Ghana).

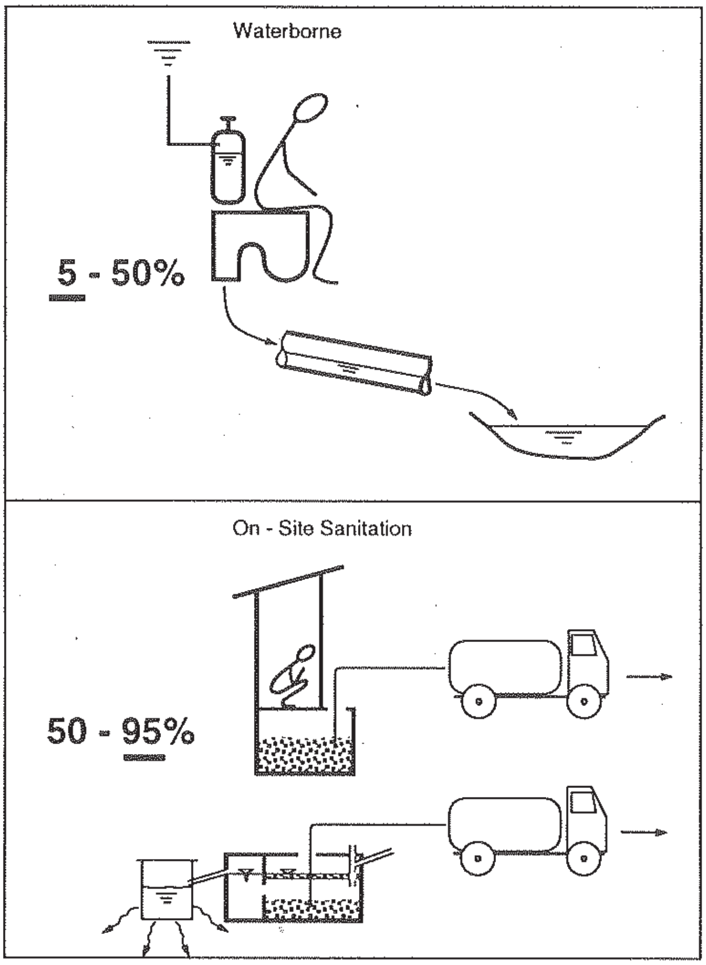
As part of **Phase II**, which started in October 1993, two field research projects were so far carried out and completed in Accra, Ghana. Field research projects in Jakarta, Indonesia, and in Wuhan, China, are in preparation. The following chapters 4, 5 and 6 describe the specific treatment options under investigation and the state of progress of the field research activities.

3 Challenges of Faecal Sludge Disposal and Use

3.1 Urban Excreta Disposal

University students of a large African city with 2 million inhabitants have assessed the sanitary situation in the densely populated centre of their city. Their account is cited here in full: "In M. (the particular urban district), there is no clear demarcation line between the commercial and residential areas. At the back of these crowded commercial areas one can find densely packed residential areas with very few facilities for excreta, sullage, stormwater and solid waste disposal. These areas are of low income, with shared or public water supplies and with either unhealthy pit latrines or no form of sanitation. Many of the pit latrines are overflowing, filthy and dangerous. The latrines are often sited adjacent to shared kitchens, and it is common for the pit latrines to overflow into these kitchens or into people's houses. Most of the latrines in the study area are located away from access roads suitable for vacuum trucks. So, when these latrines are full, there comes a desludging problem. Sometimes, suction hoses are directed

Fig. 1 ***Excreta Disposal Practice in Urban Areas of Developing Countries***



to the pits crossing living-dining areas or bedrooms. In addition to the access problems, there are problems related to the care with which the sludge can be lifted into the vacuum truck. Since the sludge is of high viscosity it is difficult to move. The sludge from pit latrines is collected, hauled by vacuum trucks and dumped at the treatment plant (sedimentation tanks and stabilisation ponds). This sludge treatment plant as it was designed does not function and was abandoned. Vacuum trucks presently dump the sludge into the river."

In developing and in newly industrialising countries, the excreta of most of the urban dwellers is not disposed of by water-flush toilets and public sewerage systems but through on-site sanitation systems such as latrines, aqua privies and septic tanks. It is collected from there and hauled to disposal points as faecal sludges (Fig. 1). Installation of sewered excreta disposal throughout the city is unfeasible for economic and water resources reasons.

The situation, as described above for an African city, is typical of many urban areas. The sludges, which are collected and hauled by emptying vehicles, are often dumped at the shortest possible distance; i.e., into open drains, on unused land or refuse landfills, into rivers, estuaries, or the sea. This poses serious health risks and causes environmental damage to urban and periurban areas. With the implementation of new latrine programmes in the rapidly expanding urban areas, this problem is becoming more acute every year. Due to a lack of simple and low-cost treatment options, authorities and enterprises are often not in a position to tackle the problem. The introduction of appropriate faecal sludge disposal and treatment methods are therefore urgently needed.

This situation is not everywhere as dramatic as described above. The Chinese traditional excreta disposal practice consists for example in collecting the excreta from individual houses and public toilets by buckets and vacuum tankers. The faecal sludges are then hauled to sludge storage and transfer tanks from where they are transported to nearby farms and fish ponds. The faecal sludge management system is well organised, and the faecal resource has established a strong economic link between the urban dwellers and the farmers. However, most of the approximately 30 million tons of sludges reportedly collected in Chinese cities every year are used mainly untreated. Concern about the potential health impact has led Chinese authorities and research institutions to embark on treatment studies (Ministry of Construction, P.R. China 1993). In some other countries and cities, the faecal sludges are added either to the city's sewers or to existing sewage treatment plants.

In Japan, intensive agricultural use of faecal sludges from toilet vaults was also common practice over many centuries. Rapid economic development and urbanisation after World War II have led to an increase in chemical fertiliser use and a concomitant decline in FS utilisation. Parallel to this, considerable efforts have been made to treat and improve the faecal sludge technology. By 1992, roughly 80 % of the faecal sludges collected from 71 million inhabitants (total population = 124 million), linked to either non-flush vault systems or to individual septic tanks, were treated in so-called nightsoil treatment plants. Most of these plants consist nowadays of inte-

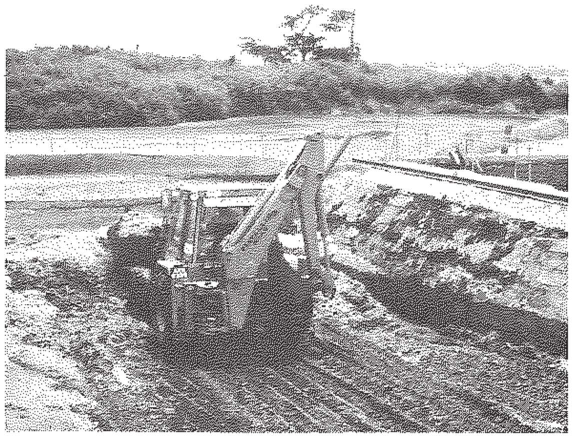


Photo 3: Sludge removal by front-end loader from a batch-operated settling/ thickening tank. Achimota FSTP, Accra (Ghana).

grated activated sludge/denitrification treatment to meet stringent environmental standards (INTEP 1994).

Table 1 lists FS disposal/treatment situations in a few selected countries and urban areas.

3.2 Faecal Sludge Quantities and Characteristics

Daily per capita FS production or, rather, daily volumes of FS collected and discharged per person served, are essential data for planning and design of improved FS treatment and disposal systems. Compared to the daily per capita sewage production, FS quantities, as collected and discharged in a plant or elsewhere, are dependent on a multitude of factors and thus difficult to estimate. Moreover, much of the generated and disposed of faecal sludge remains unaccounted for since only some urban sectors are generally served by emptying and collection vehicles.

The collected or collectable daily per capita **FS quantities** are dependent on the following factors:

- Latrine or septic tank emptying practice (frequency, ease and depth of emptying, water quantities used for dilution during emptying).
- Groundwater level: high levels during the rainy season may for example limit the infiltration capacity of soakaways and call for more frequent tank emptying.
- Capacity of soakaways (clogging leads to back up problems).
- Origin of FS: septic tanks, latrines, public toilet vaults.

It is not surprising that the per capita quantities, as reported in the literature, vary widely. Figures for collected septage (= faecal sludge stored in septic tanks) can be as low as 0.3 litres/cap·day and as high as 13 l/cap·day. Most of the reported values vary between 0.5 and 1 l/cap·day.

Similar to the figures for collected per capita quantities, **FS characteristics** vary greatly too, and are mainly dependent on the following factors:

- Origin/type of FS: the concentration of specific constituents and the "freshness" of the material; i.e., actual degree of organic stability prior to collection, vary according to the FS origin (septic tanks, pit latrines, public toilet vaults).
- Extent of stormwater or groundwater infiltration into latrine or septic tank vaults.
- Emptying frequency.

Table 2 lists septage and FS characteristics from unsewered public toilets and pit latrines. In 1994, the Water Resources Research Institute in Accra, Ghana, and SANDEC have conducted numerous analyses of untreated septage and public toilet sludges as part of their joint field research on FS treatment. The results obtained are also included in Table 2.

Although routinely used in wastewater analysis and in the design of waste stabilisation ponds, it is difficult to accurately determine BOD in faecal sludges. Firstly, BOD bottles should be shaken continuously over the entire five-day testing period. Yet, laboratories in developing countries are rarely equipped with shaking equipment. Secondly, FS samples should be seeded with aerobic bacteria capable of breaking down organic matter from human excreta. Without the presence of such bacteria, samples will take a certain time to develop an aerobic biomass that will lead to an oxygen demand. BOD values are consequently too low. Most laboratories are neither equipped

Table 1 Examples of Faecal Sludge Disposal/Treatment Practices

City/Country	Dispoal / Use without Treatment	Separate Treatment	Combined Treatment
• Gaborone and Lobatse (Botswana)	-----	-----	Co-treatment with wastewater in WSP
• Maseru (Lesotho)	Trenching ground	Drying lagoons	-----
• South Africa	-----	-----	Mostly co-treatment in activated sludge treatment plants
• Grahamstown (South Africa)	-----	-----	Co-composting with municipal refuse
• Kumasi (Ghana)	Discharge into streams	(being planned)	-----
• Accra (Ghana)	Sea disposal (for excess sludge)	Settling/thickening followed by ponds, composting of separated solids with sawdust	-----
• Cotonou (Benin)	----	Ponds	-----
• Dar es Salaam (Tanzania)	Sea disposal through wastewater outfalls	-----	Co-treatment with wastewater in WSP
• Manila (Philippines)	Mostly unaccounted for, discharge into drains + outfalls	-----	Minor quantities: co-treatment with wastewater in WSP
• Jakarta (Indonesia)	Storm drains and canals, mostly unaccounted for	Extended aeration followed by ponds,drying beds for separated sludge	-----
• China (unsewered parts of urban areas)	Agricultural or aquacultural use	-----	-----

Table 2 Characteristics of Faecal Sludges from On-Site Sanitation Systems

BOD_5 (mg/l)	COD (mg/l)	(TS %)	TVS (% of TS)	TKN (mg/l)	Eggs (no./l)	Country	Reference
Septage:							
3,100-5,900	16,000-60,000	1.1-3.9		410-820		U.S.	EPA (1980)
7,000	15,000	4	60	700		U.S. (design)	EPA (1984)
		2-4				Asia	Pescod (1971)
680	8,100					Ghana	Accra Waste Management Dept. (1992)
1,600	5,750					Jordan	Al Salem (1985)
	24,400	4.7		544 (N_{tot})			Jakarta Sewerage + Sanitation Project (1982)
	23,000 (11,000-51,000)	1.4 (0.5-2.9)		920 (280-1500)		Thailand (Bangkok)	Edwards et al. (1987)
3,000-6,000	17,000-23,000	2-2,5	60-65	6,000-6,500		S. Korea	Yao (1978)
3,000-5,000	8,000-15,000	2-3	60	5,000-6,000	40-100	Japan	Yao (1978)
630 (360-1,300)	8,500 (820-52,000)	SS: 0.7 (0,07-3.4) TS: 1.4 (0.3-11.4)	% VSS: 70 % TVS: 63		4,300 (200-13,000)	Accra, Ghana	WRRI/SANDEC (1994)
Sludges from latrines (L) and unsewered public toilets (PT):							
15,000-18,000	26,000-33,000	1.2-3		5,000-6,000	18,000 - 360,000	China (PT)	Shiru + Bo (1990)
30,000	50,000	1.2		450 (N_{tot})	54,800	China (Jangxi) (PT)	Shiru + Bo (1990)
				2,800 - 4,750		Shanghai (PT)	Edwards (1992)
		15-54				Tanzania (L)	Hawkins (1981)
					1,000 (stored)	Guatemala (L)	CEMAT (1992)
7,650	64,000	8.3	64	4,200		Ethiopia (L)	Dyce (1993), pers. comm.
8,800 (3,800-15,000)	47,600 (10,400-97,000)	SS: 6.4 (2-19)	% VSS: 58 % VTS: 62		29,000 (3,600-62,000)	Accra, Ghana (PT)	WRRI/SANDEC (1994)

TKN - Total Kjehldahl nitrogen
BOD - Biochemical oxygen demand
COD - Chemical oxygen demand
TS - Total solids
TVS - Total volatile solids
SS - Suspended solids
VSS - Volatile suspended solids

nor have they acquired the analytical routine to develop, maintain and use seed cultures from aerobic bacteria (e.g. from settled sewage). Reported BOD data may therefore not be taken at their face value.

Faecal sludges in developing countries are likely to contain high loads of helminth eggs (mostly nematodes such as *Ascaris*) as seen in Table 2. Where helminthic diseases are endemic, eggs constitute the best hygienic indicator for untreated sludges as well as for sludges and compost produced in the treatment process. Analytical techniques for helminth egg counts and viability analysis are being applied only in a few laboratories to date. Laboratories equipped and capable of routinely performing egg analyses are often found in the health sector. Waste control laboratories should therefore use those services rather than purchase their own equipment.

Sludges from latrines and unsewered public toilets are more concentrated than septage as no flushing water is normally used. In Accra, Ghana, where septage and public toilet sludges are collected separately, septage exhibits higher organic matter contents than public toilet sludges (expressed as VSS) (see Table 2). The reasons for this surprising result may be explained by the fact that public toilet sludges are more concentrated, do not contain soap nor detergents and are therefore subject to much faster anaerobic digestion than the faecal mass in septic tanks.

3.3 R+D Needs and Variables for Minimum Evaluation of Faecal Sludges and Faecal Sludge Treatment Plants

Although well-defined and standardised methods are available for wastewater characterisation, no standardised methods have yet been developed for faecal sludges nor guidelines for minimum characterisation; i.e., for a limited set of variables describing FS in a meaningful way. It is thus necessary to define selected variables and related methods of analysis suitable for laboratories in developing countries of usually limited capacities. This tool will enable practitioners to reliably assess the faecal sludge characteristics relevant to FS treatment scheme design, performance monitoring and process/operation control. The choice of variables must also allow a reasonable judgement about the usability or dischargeability into a receiving water body of the partially or fully treated sludges.

In most developing countries, analytical techniques for assessing waste characteristics are not routinely applied yet, and the respective routines still remain to be developed. **Sample preparation** and **dilution** methods for faecal sludges are different from those used for wastewaters. For reliable analysis, thorough mixing and **homogenisation** are of utmost importance. Initial volumes of original samples used for dilution may have to be larger than those for wastewater analysis, particularly if the sample cannot be homogenised prior to analysis.

Untreated faecal sludges show great variability as to the ease with which **solids-liquid separation** may occur, as well as to the **rate of thickening**. Difficulties with solids-liquid separation in septage were reported from the U.S. (Jewell 1975; U.S. EPA 1984). Septage (initial SS average = 7,000 mg/l) collected in Accra, Ghana, settles rather well within half an hour, whereas public toilet sludge (initial SS average = 65,000 mg/l) still does not show any separation after six hours (WRRI/SANDEC 1994). Such sludges are likely to undergo thickening without prior sedimentation. Development of standard methods to characterise the potential of faecal sludges for solids-liquid separation and thickening are therefore required. Similarly, simple and reliable methods to define

Table 3 Minimum Set of Variables for FS and FSTP Assessment

Variables to be assessed by laboratory analyses (Raw sludge and performance assessment)	**Variables to be assessed by field measurements or observations** (Process and operational control)
• TS (total solids = residue after evaporation at 103 °C) • Volume of settleable and floatable solids • Dewaterability and filterability test • COD (chemical oxygen demand) • BOD (biochemical oxygen demand) • Helminth eggs • Faecal coliforms • Biochemical stability of sludge	• Volume of settleable and floatable solids • pH • DO - dissolved oxygen • Colour check for algal growth • Microscopic examination (e.g. for pond organisms) • Temperature (in thermophilic composting) • Settled sludge and scum thickness

dewaterability/filterability of untreated and treated faecal sludges should be developed.

Based on the experience gained to date in faecal sludge treatment and assessment as well as in faecal sludge treatment plants, standardised sampling, sample preparation and analytical methods are to be compiled and/or developed for the variables indicated in Table 3.

Raw faecal sludges can be characterised with this **minimum set of variables**. It also allows the design and monitoring of treatment schemes comprising solids-liquid separation (e.g. in settling/thickening tanks) followed by liquid treatment (e.g. in a series of ponds). Variables for rapid field assessment of raw sludge quality and for treatment plant control are also indicated. Additional variables may have to be considered if other types of treatment and/or more in-depth monitoring programmes are considered.

Equipment of laboratories, training of personnel and monitoring of sludges and plants must be carefully evaluated. Sampling and analysis can only be justified if the respective authorities and laboratories are able to maintain the analytical routine and secure regular equipment maintenance and repairs. Servicing of equipment must also be available nearby. Monitoring should only be conducted if the results obtained can be critically interpreted and the necessary corrective actions taken.

4 Processes and Technologies

4.1 Theoretical Options

When classifying faecal sludge treatment options, one basic distinction can be made between **options with** and **options without solids-liquid separation**. Another way of classifying FS treatment options is to distinguish between separate treatment of faecal sludges and co-treatment. In co-treatment options, septage or latrine sludges are treated jointly with municipal wastewater, wastewater treatment plant sludge, household/municipal solid wastes or with organic residues such as sawdust or wood chips. Fig. 2 lists theoretical faecal sludge treatment options. The listing is classified according to options with and without initial solids-liquid separation.

4.2 Priority Options

In developing and in newly industrialising countries, human waste treatment methods must comply with the pertinent socio-economic situations which generally differ from the conditions prevailing in industrialised countries. The methods chosen should be relatively low-cost; i.e., low in capital and in operating costs. The systems applied must be compatible with the available expertise at different professional levels of the country concerned. These criteria call for systems requiring little mechanical installations and hardly or no energy input. Treatment schemes are therefore more land demanding.

On account of the relative simplicity of the processes and technologies used and on their favourable cost effectiveness, options A - E listed hereafter are considered particularly suitable for developing and newly industrialising countries.

A Drying (evaporation) lagoons.
B Dewatering and drying in sludge drying beds.
C Solids/liquid separation and thickening in

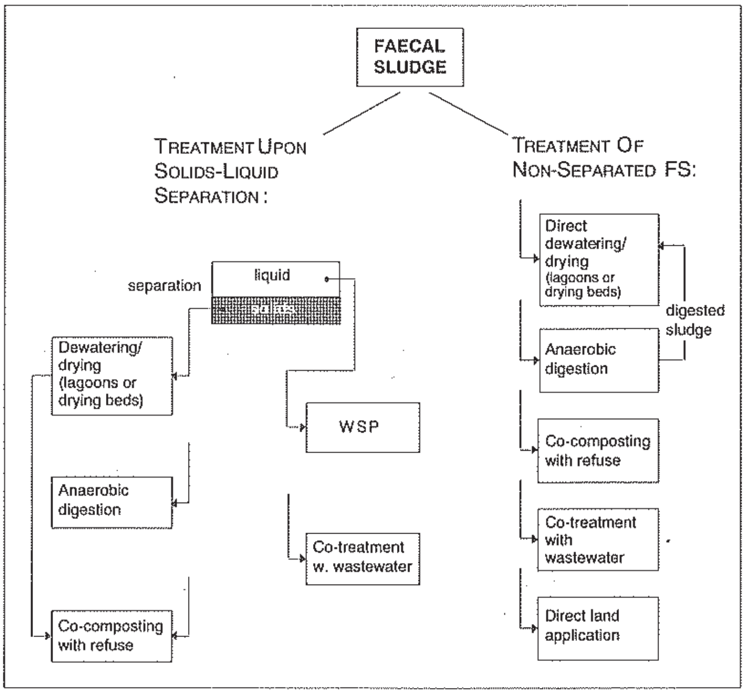


Fig. 2 Theoretical Options for Treating Faecal Sludges

settling/thickening tanks (as pre-treatment step).

D Stabilisation pond (lagoon) treatment (with or without prior solids-liquid separation).

E Co-composting of faecal sludges with household/municipal refuse.

SANDEC has started to conduct **field research** on the **options B, C, D**, and **E**. Option A (drying lagoons) might be added later if a suitable treatment/monitoring site can be found. Where land is not available within useful haulage distances, systems requiring more capital and energy but less land might constitute feasible options. In Jakarta, Indonesia, there are two FSTP which are composed of extended aeration followed by polishing ponds. This option might be suitable for metropolitan areas where land is scarce. We have therefore adopted extended aeration of septage as an additional **option G** within our programme of investigation.

4.3 Process Discussion and Research Issues

The **options B, C, D, E, and G** are discussed below along with the rationales for their preference and with the main research issues. Figures 3-7 are functional sketches of the selected options.

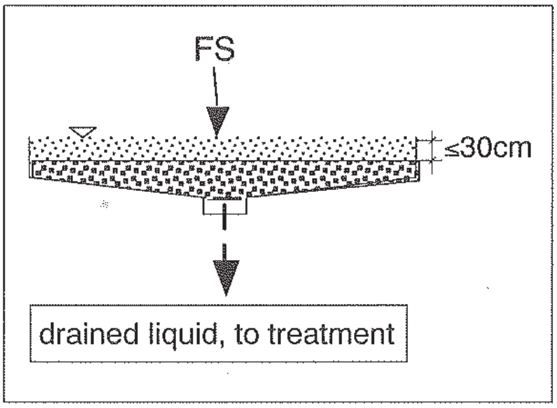


Fig. 3 Drying Beds

DRYING BEDS are or have been widely used throughout Europe and North America for sludge dewatering and drying in wastewater treatment plants. Drying beds and drying lagoons are relatively land-intensive. Owing to the expansion of the cities and the increased level of wastewater treatment, sludge quantities have also increased. In many areas, the use of drying beds and drying lagoons therefore had to be abandoned and replaced by dewatering processes such as centrifugation or filter pressing.

Pescod (1971) reports about treating septage in drying beds that run parallel to drying lagoon experiments at AIT, Bangkok. At ≤30 cm raw septage loading depths, the drying periods necessary to increase the solids content from ≤6.5 % to 25 % amounted to 7 - 27 days. Loading rates of **67 - 475 kg dry solids/m^2·yr** were applied during these experiments. This corresponds to a land requirement of approx. **0.3 - 0.04 m^2 per inhabitant** (based on a per capita dry solids contribution of 60 g per day as delivered to the treatment plant). In contrast, drying lagoons have to be loaded at lower rates as drying occurs by evaporation only. According to Pescod, minimum loading rates of 50 kg dry solids/m^2·yr (≤0.4 m^2/cap) may be used for drying lagoons in wet tropical climates if the supernatant is decanted.

Dewaterability rates for non-stabilised or non-conditioned faecal sludges are often low. Investigations should therefore be conducted in order to determine the cost benefit ratio of stabilisation (e.g. by anaerobic digestion or extended aeration) prior to treatment in drying beds. Stabilised sludges have a better dewaterability than non-stabilised sludges.

SOLIDS/LIQUID SEPARATION and thickening in separate treatment units might be a necessary treatment step in a scheme comprising FS stabilisation ponds. Removal of settled sludge and scum in "manageable" portions from settling tanks at a weekly rate or every few weeks may be operationally more advantageous than removing much larger volumes of settled sludge from primary

Option B: Dewatering and Drying in Sludge Drying Beds

Rationale	*Main research issues*
• *Allows simultaneous drainage and evaporation of liquid (as opposed to drying lagoons)*	• *Treatment standards (solids content, hygienic quality)* • *Dewaterability of raw and stabilised sludges* • *Rainfall effect* • *Design criteria (surface loading, drying periods required)* • *Odour development and control* • *Drained liquid treatment* • *Sludge loading and removal operations*

Option C: Solids/Liquid Separation and Thickening in Settling-Thickening Units

Rationale	*Main research issues*
• *Solids separation in relatively small volumes is operationally more flexible than if using primary anaerobic ponds of WSP systems for solids accumulation*	• *Feeding cycles for batch-operated units* • *Separation/solids retaining performance as a function of FS type* • *Attainable degree of thickening* • *Tank geometry, hydraulics, inlet, draw-off and emptying arrangements* • *Design criteria*

Fig. 4 Settling/Thickening

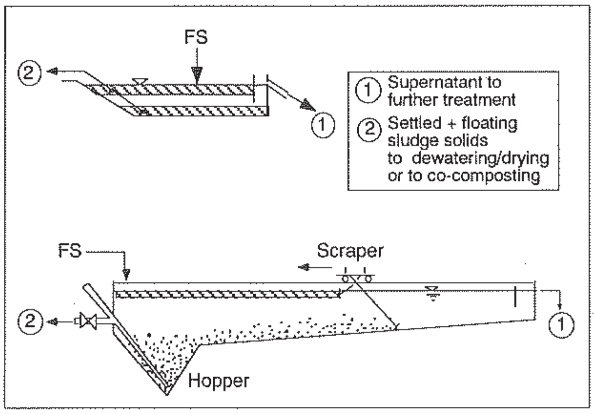
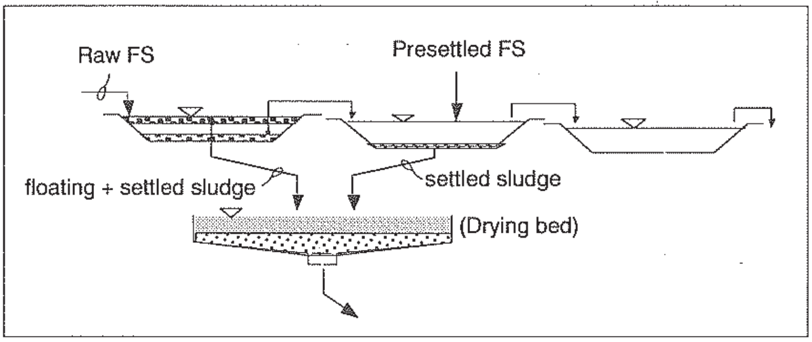


Fig. 5 Stabilisation Ponds



ponds once every few years. Large sludge volumes retained in ponds require excessively long periods to dry to consistencies amenable to removal by front-end loaders. If retained sludge is to be pumped in large quantities, intermediate storage basins would be required for operational flexibility prior to further treatment by for example drying beds or co-composting.

Since 1989, parallel units of batch-operated settling/thickening tanks have been used in two septage treatment plants in Accra, Ghana. Results of field research conducted jointly with the Ghana Water Resources Research Institute are summarised in chapter. 5.

Option D: Stabilisation Pond (Lagoon) Treatment (With or Without Prior Solids-Liquid Separation)

Rationale	*Main research issues*
• *Substantial removal of organic constituents and pathogens at low cost* • *Absorbs shock loads*	• *k-values for BOD and faecal coli reduction* • *Ammonia toxicity for algae* • *Design (loading) criteria for organic and pathogen removal* • *Sludge handling with and without prior solids-liquid separation*

WASTE STABILISATION PONDS (WSP) are a low-cost, potentially sustainable technology which finds increasing use worldwide for liquid and semi-liquid waste treatment. Substantial knowledge has been accumulated in recent decades as to the design and operation of WSP schemes treating wastewater (Mc Garry and Pescod 1970; Mara and Pearson 1986 and 1992).

Waste stabilisation ponds for municipal wastewater treatment are often used or misused to also treat faecal sludges. In most cases, WSP are not designed to co-treat FS. The admixture of faecal sludges to WSP or to sewers discharging into a WSP scheme causes a shift in nutrient ratios of the raw wastes entering the ponds. This may be more advantageous in the sense that carbon, nitrogen and phosphorus become available to the bacteria breaking down the waste in ratios more similar to the C/N/P mix of the cells of these organisms than if the schemes were to treat wastewaters alone. This may lead to a more efficient removal of C, N and P from the waste stream. However, WSP schemes are rarely designed to treat FS. Diluting the more concentrated FS makes little sense from a treatment viewpoint as the scheme is likely to become overloaded and the handling of excessive sludge volumes may result in serious operational problems.

WSPs have been adopted as the method of choice for septage treatment in Indonesia (Ministry of Public Works, Gov. of Indonesia 1992). Over ten plants have been constructed in recent years. Imhoff tanks have been installed in some plants as pre-treatment for solids and partial organic removal. In Jakarta, two plants use extended aeration to oxidise a considerable fraction of the organic load prior to pond treatment. Lagoon treatment of septage (without the wastewater admixture) is widely used in the United States, particularly so in the north-eastern states[1] (U.S. EPA 1984). There, pond schemes usually consist of a primary pond for solids separation and partial degradation, followed by a secondary percolation/infiltration pond. A few pond systems also operate in Ghana (three in operation, several being planned, all using settling/thickening as pre-treatment step for solids removal) and one recently constructed in the city of Cotonou, Benin. Ponds are also used in several places in Argentina.

1 25% of the U.S. Population are served by septic tanks rather than by sewerage schemes.

Even after removal of settleable solids in settling/ thickening units, BOD and COD concentrations in the liquid fraction of faecal sludges are still several times higher than in normal wastewater. A series of several anaerobic ponds are thus required to treat such liquids before low enough concentrations are attained for facultative pond conditions. McGarry and Pescod (1970) recommend to use the highest possible loading on successive anaerobic ponds. Such a design would lead to successively smaller pond surfaces and, thus, to a minimisation of the overall pond surface area necessary to attain a given BOD or COD removal. This recommendation is based on the treatment of tapioca starch waste in a series of anaerobic ponds, each loaded with up to 600 g BOD/m^3·day. When the organic load exceeds a certain limit, pH decrease and odour formation become the critical variables in anaerobic pond design and operation. A special problem in ponds treating FS is the inhibition of algal growth due to high ammonia (NH_3) concentrations. The kinetics of BOD, COD, ammonium and faecal coliform removal occurring in FS ponds need therefore to be further investigated and appropriate **loading and operation criteria** developed.

Option E: Thermophilic Co-Composting of Faecal Sludges with Household/Municipal Refuse

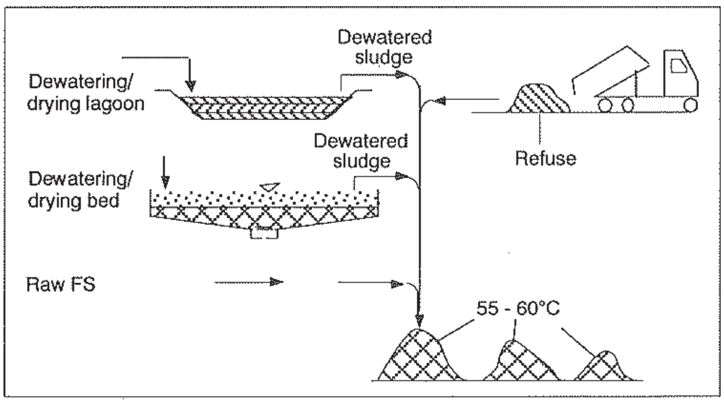
Rationale	*Main research issues*
• *Rapid sludge hygienisation* • *Biochemical stabilisation* • *Little odour nuisance* • *Compost = resource*	• *Optimum mix depending on water, C and N contents of the materials to be co-composted* • *Process control (temperature, air supply) for optimum biochemical activity and safe hygienisation* • *FS handling and FS pre-treatment requirements* • *Static pile vs. windrow composting*

CO-COMPOSTING usually designates combined composting of faecal or wastewater treatment sludges with household or municipal compostable refuse. In a wider sense, it may also comprise the joint composting of sludges with other organic material to achieve optimum C:N ratios in the mixture to be composted. Sawdust, wood chips, bark, slaughterhouse or food processing waste are suitable materials. The reason for adding the materials to the sludge is to provide a bulky structure to the mixture to be composted and to create a C:N ratio favourable for optimum composting; i.e., between 20-30. The C:N ratios in faecal sludges range from about 2 in fresh faeces to around 6-15 in septage. Co-composting of FS is being practised in China, India, Malaya, Singapore, and Nigeria over several decades. The mixing ratios are in the order of 1:5 - 1:10 (sludge : added material) on a wet weight basis if fresh or thickened sludge is used. With dewatered sludge or wood chips, the ratio can be increased to as much as 1:1.5 (Scott 1952; Shuval et al. 1981; Obeng and Wright 1987).

A co-composting unit has been recently installed at Rini near Grahamstown, South Africa (La Trobe and Ross 1992). The refuse and bucket latrine sludge from a community of 100,000 are co-composted in a simple mechanised plant using forced-aerated, static windrows. The nightsoil is pre-settled and then windrowed along with the refuse. On a volume basis, the mixing ratio is about 1:10. The process is controlled by the temperatures developing within the piles. When 55 °C are reached, the windrows are left to react for 3 weeks. After composting, the mixture is screened and the rejects landfilled. The compost is used by the Grahamstown Garden Department after additional maturing. The Council for Scientific and Industrial Research of South Africa is presently conducting pilot investigations on the co-composting of latrine sludges with municipal solid waste.

SANDEC is collaborating with municipal authorities and a research institution in the Hubei Province, China, on the establishment and monitoring of pilot plants for the co-composting of faecal sludges and municipal solid waste.

Fig. 6 Co-Composting



Option G: Extended Aeration of Septage

Rationale	*Main research issues*
• *Requiring less land than low-energy, low-cost options*	• *Optimising energy input vs. land requirement to meet the prescribed effluent standards* • *Solids separation and dewaterability*

EXTENDED AERATION of septage is an option requiring substantial capital investment and considerable energy for operation. Yet, these disadvantages may be offset by reduced land requirements, thus allowing a plant to be installed closer to urban centres than more land-intensive systems. In order to achieve substantial BOD and COD removal, septage is aerated in an initial treatment step and then subjected to polishing treatment (e.g. WSP). Aeration will also lead to enhanced solids-liquid separation. The sludge formed after separation is then more easily dewatered than non-aerated septage. SANDEC and some Indonesian institutions are preparing a joint field research project to evaluate and optimise one of the two treatment plants in Jakarta which uses extended aeration of septage.

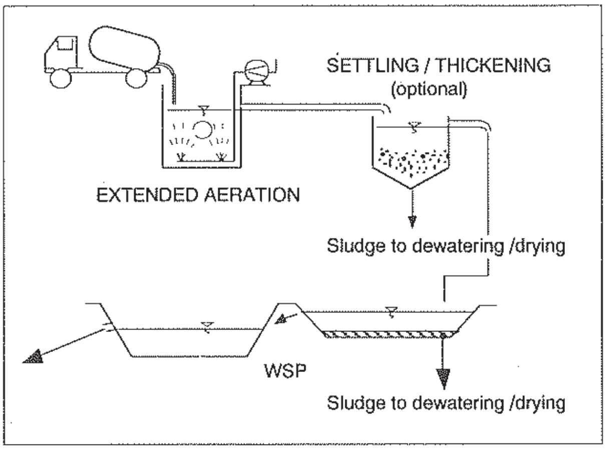


Fig. 7

Extended Aeration + Pond Treatment

5 Current and Planned Field Research

Table 4 lists SANDEC's already completed field research projects, its ongoing schemes and those currently under preparation.

Table 4 SANDEC's Field Research Activities on Faecal Sludge Treatment

No.	City (country)	Waste treated	Treatment option	Main research partners	Investigations
	Completed and ongoing investigations				
1	Accra (Ghana)	Septage and public toilet sludge	Settling/ thickening + anaerobic ponds, composting of separated solids with sawdust (full-scale plant)	Water Resources Research Institute Accra/Ghana	• 1993-94: overall plant performance • 1994: detailed assessment of the settling/thickening units
2	Wuhan (China)	Septage and bucket latrine sludge	Co-composting of faecal sludge + domestic/ municipal refuse (pilot plant)	Wuhan Urban Construction Institute Wuhan, Hubei Province	• Pilot plant design and monitoring for process optimisation, performance control and optimum physical handling of sludge and refuse
	Planned investigations				
3	Jakarta (Indonesia)	Septage	Extended aeration followed by ponds, dewatering/ drying of separated solids in sludge drying beds (full-scale plant)	The Urban and Environmental Study Office, Jakarta + Research Institute for Human Settlements, Bandung	• Optimisation of the aeration process • Definition of sludge quality standards • Development of sludge dewaterability criteria • Optimisation of the settled sludge dewatering/drying process • Monitoring of the overall plant performance
4	Accra (Ghana)	Septage and public toilet sludge	Settling/ thickening + anaerobic ponds, composting of separated solids with sawdust (full-scale plant) Drying beds (pilot plant)		• Development of FS settling/thickening criteria • Parallel settling and thickening of unmixed septage and public toilet sludges • Pond treatment of settled FS • Dewatering/drying of raw and settled/ thickened septage and public toilet sludges

6 Results of Field Research Conducted in Accra, Ghana

The Achimota FSTP in Accra, Ghana, comprises two parallel batch-operated settling/thickening tanks (current minimum retention time = 3 hours) followed by four waste stabilisation ponds (overall retention time = approx. 30 days). One of the short sides of each settling unit is fitted with a ramp to enable access and emptying by front-end loaders. The separated settling and floating solids, which are thickened in the settling/thickening tanks, are windrow-composted with sawdust, an abundant waste product from timber mills. Since this material serves as carbon source and liquid absorbent, it improves the C:N ratio and the natural aeration of the windrows. Where sawdust is not available as a complementary carbon source and bulking agent, the use of household or municipal refuse might be considered. The supernatant liquid is further treated in a series of waste stabilisation ponds. Monitoring and evaluation studies of the overall plant and the settling/ thickening tanks were completed between 1993 and 1994 (WRRI and SANDEC, unpublished field reports). The results obtained to date indicate that the four ponds, run in series, operate as anaerobic ponds without algal growth. The absence of algae is probably caused by excessive NH_3 concentrations. Overall BOD reduction amounts to 80 %, and the effluent BOD in the fourth pond totals 300 mg/l. Most of the reduction has been observed to occur in the first pond. The role of additional ponds is to reduce the pathogen load. Faecal coliforms are reduced from about 10^6 to 10^4 in the four ponds. It is not surprising that this reduction is much lower than corresponding reductions in facultative and maturation ponds treating wastewater. In normal WSP, bacterial die-off is greatly accelerated by the pH increase induced by algal CO_2 uptake. Consequently, enteric bacteria exhibit prolonged survival in ponds without algal growth.

The batch-operated settling tanks in Accra's FSTP receive septage containing 7 g SS/l and public latrine sludge with 65 g SS/l. In the actual sludge mixture, the SS concentration amounts to 25 g/l. There is an 80 % SS elimination at first which gradually decreases to 35 % within 24 days of operation. The decrease in removal efficiency is due to the unfavourable tank geometry and effluent draw-off arrangements. The density of the settled and floating sludge retained in the settling/thickening tanks amounts to ≥150 g/l after 4 weeks of operation. This fact points to a substantial thickening effect. The solids load discharged into the anaerobic ponds is thus significantly lowered. Furthermore, the solids can thereby be recovered and used in agriculture after having been hygienised through thermophilic composting.

Additional field research with pilot schemes is required to develop suitable designs, tank geometries, effluent draw-off arrangements, and operational patterns for low-cost settling/thickening units capable of a continuous 70-80 % SS removal. Comparative investigations with batch and continuous-flow units should be conducted.

Photo 4:

Process control by measuring windrow temperatures at the Rini/Grahamstown co-composting plant (South Africa).

7 Call for Field Research Collaboration

In a few countries, SANDEC has found partners who carry out field research on a limited number of treatment options (see Chpt. 5 above). Our centre is interested in widening the selection of FSTP options to be evaluated. Persons interested in collaborating with us in the examination of sustainable FS treatment options, are invited to contact **Martin Strauss, Programme Officer Sanitation**

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8 References and Useful Addresses

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Useful Addresses

This list contains a number of institutions and contact persons actively involved in faecal sludge R+D work. Some are SANDEC's partners in field research activities on FS treatment. They could also act as disseminators of relevant information.

Country	Institution + Contact Person	Known Activities
Ghana	Water Resources Research Institute Mr Seth A. Larmie Box M 32 Accra/Ghana Tel. +233 - 21 - 77 53 51/2 Fax +233 - 21 - 77 71 70	• Monitoring of FSTP (raw sludges, settling/thickening, ponds, thickened sludge) • Collaboration with SANDEC
Indonesia	Research Institute for Human Settlements Mr Aim Abdurahim Head, Development Division Box 812 Bandung 40008 / Indonesia Tel. +62 - 22 - 79 83 93 Fax +62 - 22 - 79 83 92	• FSTP monitoring in preparation (raw sludges, extended aeration, ponds, drying beds) • Collaboration with SANDEC
South Africa	Council for Scientific & Industrial Research (CSIR) Mr Ian Pearson Water Technology Division P.O. Box 395 Pretoria 0001/South Africa Tel. +27 - 12 - 841 22 54 Fax +27 - 12 - 841 47 85	• Pilot FSTP installation and monitoring (co-composting of pit latrines sludges and municipal refuse) • Networking with SANDEC
China [1]	Wuhan Urban Construction Institute Prof. Jin Rulin Wuhan, Hubei Province/P.R. China Tel. +86 - 27 - 780 92 78 / 780 32 98 Fax +86 - 27 - 780 17 33	• Pilot FSTP installation and monitoring (co-composting of pit latrines sludges and municipal refuse) • Collaboration with SANDEC
	Dr (Mrs) Ling Bo Institute of Environmental Health and Engineering Chinese Academy of Preventive Medicine 29 Nan Wei Road Beijing 100050/P.R. China Tel. +86 - 1 - 303 87 61 Fax +86 - 1 - 301 43 42	• FSTP R+D on anaerobic digestion (completed) • Information dissemination
	Department of Urban Construction Department of International Cooperation Ministry of Construction 9 Sanlihe Road Beijing 100835/P.R. China	• Information dissemination
Japan	International Environmental Planning Centre (INTEP) Department of Urban Engineering Faculty of Engineering The University of Tokyo 7-3-1 Hongo, Bunkyo-ku Tokyo 113/Japan Tel./Fax +81 - 3 - 58 02 29 56	• Documenting FS treatment and use history in Japan • Forthcoming: compendium on FS treatment technology developed in Japan • Information dissemination

[1] The proceedings of the *Seminar on Appropriate Technology for Nightsoil Treatment*, held in Beijing April 20-22, 1993, provide information regarding R+D activities on faecal sludge treatment in China. The seminar was organised and the proceedings published in Chinese and English by the Dept. of Urban Construction whose address is listed above.