SOS - Management of Sludges from On-Site Sanitation

Faecal Sludge (FS) Treatment

Progress in Brief

by Martin Strauss and Udo Heinss

Foreword

In 1992, SANDEC initiated an R+D project on faecal sludge management, particularly on faecal sludge (FS) treatment processes and technologies. The rationale for the project is the lack of appropriate FS treatment options in most developing and newly industrialised countries. FS treatment plants have been installed in recent years in a few cities only, e.g. in Accra, Bangkok, and Jakarta.

The aim of the project is to develop **guidelines** for appropriate faecal sludge treatment options for planners, designers and technicians. Furthermore, the project also proposes to enhance the expertise of the collaborating institutions in the field of monitoring and control of wastewater and sludge disposal.

The **three phases** of the project include an identification, a field research and a synoptic phase. We are currently engaged in the field research phase and are also periodically publishing our findings (see "bookshelf").

1 Overview of our Field Research in FS Treatment

Our field research projects are listed in Table 1. In addition to these activities, SANDEC has recently embarked on a series of special tests to refine the biochemical oxygen demand (BOD) analysis of faecal sludges (see 2.1).

2 Findings

2.1 BOD Analysis and FS Classification

BOD Analysis

Special BOD monitoring activities were initiated as the 5-day BOD analysis using the traditional Winkler titration procedure was suspected to lead to an underestimation of the BOD values for FS. Undervaluing may cause an undersizing of those treatment works where process designs are based on BOD concentrations or BOD loading rates, such as anaerobic or facultative stabilisation ponds. Comparative analyses are conducted with the following methods and parameter variations over ten days instead of five:

- Traditional Winkler titration method with bottles that are not stirred
- Oxygen probe immersed in a stirred Winkler bottle
- Manometric BOD equipment
- Seeded vs unseeded samples
- Not stirred vs stirred samples
- Unsuppressed vs suppressed nitrification

Preliminary test results obtained by SANDEC at WRRI in Accra with septage and public toilet sludges (Stalder 1996), and at AIT in Bangkok with septage (Heinss 1996), led to the following conclusions: contrary to our assumption, seeding with aerobic bacteria does not appear to be meaningful. In some, though not all of the FS tested, the exertion of oxygen demand starts after about one day only, irrespective of seeding. Stirring appears to be of significance in samples of solid-rich (Type A) sludges (see FS classification below). Stirring of public toilet sludge increased the BOD_5 by a factor 1.4. For BOD_{10}, it increased by a factor 1.4 - 2, depending on the type of method used. Furthermore, stirring appears to be of particular importance in manometric BOD analysis. The respective equipment does, in fact, have built-in stirring mechanisms.

Additional BOD analyses, including a number of test runs where nitrification is suppressed, will be conducted to determine whether carbohydrates are decomposed and, thus, oxygen demand exerted beyond a period of five days.

Table 1 SANDEC's collaborative field research on faecal sludge treatment

No.	City (country)	Research partners	Treatment processes and technologies	Investigation period
	Completed and ongoing investigations			
1	Accra (Ghana)	Water Resources Research Institute (WRRI)	Settling/thickening + anaerobic ponds; composting of separated solids with sawdust	1993-94
2	Accra (Ghana)	----"-----	Settling/thickening + anaerobic + facultative ponds Drying beds + settling columns	1996-97 1995-97
3	Bangkok (Thailand)	Asian Institue of Technology (AIT)	Planted sludge drying beds Attached growth WSP	1996-98 1997-98
4	Manila (Philippines)	National Engineering Centre, University of The Philippines	Use of septage for land reclamation	1996-98
5	Wuhan (China)	Wuhan Urban Construction Institute Wuhan, Hubei Pvce.	Co-composting of faecal sludge + domestic/municipal refuse	1995-96
	Planned investigations			
6	New Delhi (India)	Sulabh International Inst. of Technical Research & Training	Dewatering/drying beds for sludges from nightsoil biogas digesters	

FS Classification

After reviewing a large number of data on FS characteristics, we decided to classify faecal sludges into two broad categories. **High-strength sludges** from bucket privies or non-flush and pour-flush public toilets have been characterised as "Type A". They have generally undergone little fermentation and exhibit COD, ammonium and solids concentrations of 20, - 50,000 mg/l; 2, - 5,000 mg/l; and ≥ 3.5 % respectively. In contrast, sludges of relatively **weak strength**, such as septage, have been classified as "**Type B**". Their COD, ammonium and solids concentrations amount to < 10,000 mg/l; < 1,000 mg/l; and < 3 % respectively.

Truncating FS into two broad categories is important, particularly when treating sludges in ponds as described in Chpt. 2.3.

2.2 Solids/Liquid Separation

The findings of solids/liquid separation of FS in settling/thickening tanks and in conventional beds (**unplanted, sludge drying beds**) are based on field research conducted by WRRI in Ghana (Larmie 1994), and on research carried out by Pescod and co-workers at AIT in Bangkok in the late 1960s (Pescod 1971). The information on **planted sludge drying** beds[1] is based on a literature review of the use of reed beds for treating sludges from sewage treatment plants (STP). Research at AIT will be focusing on planted drying beds as the process has not been used yet for faecal sludges, except in some preliminary pilot studies carried out by CEMAGREF in Lyon, France (Payrastre 1995). Solids/liquid separation may prove particularly useful as pretreatment step in pond treatment of FS. A substantial solids elimination can thus be achieved and allow a reduction of the specific technical and operational problems associated with the emptying of large quantities of sludge from primary ponds. Reduction of the solids load discharged into the ponds will also decrease the organic load and, thus, lead to considerable land savings. Solids/liquid separation is strongly recommended if FS is to be co-treated with

Since reeds are generally applied in planted sludge drying beds, the process is often called "reed bed treatment". The term "constructed wetlands" is also used. The German terminology uses "Schlammvererdung" and the equivalent English translation is "sludge humification".

wastewater in existing waste stabilisation ponds (WSP) or conventional STP which have not previously been designed to receive FS.

Settling/Thickening

Mechanised sedimentation tanks are normally used in continuous flow/continuous sludge removal solids/liquid separation processes. However, such equipment intensive installations may not be appropriate in most developing countries. Use of batch-operated FS settling/thickening tanks with sludge removal by front-end loaders, such as the ones installed in two faecal sludge treatment plants (FSTP) in Accra, Ghana (Annoh 1989 and 1994), is a possible alternative to the problem where front-end loaders are either used at municipal administrations or can be hired from private construction firms.

The required storage volume for the separated solids is the decisive design variable for batch-operated FS settling/thickening tanks. The tank volume thus calculated has to be verified to guarantee a minimum liquid retention time of three hours in the clear/settling zone. The sludge storage volume for the type of tanks used at the Achimota FSTP, Accra (rectangular tanks; access ramp for accumulated sludge removal by front-end loader), can be calculated on the basis of the attainable thickening concentration of the settled and floating sludge (≤ 14 %), and on the desired length of the operating cycle (e.g. 2-4 weeks).

Sedimentation and thickening tests using 1 or 2-litre cylinders should be performed, whenever possible, with the type of sludge mixture expected to be delivered to the plant. This would not only indicate the achievable degree of thickening and the relative amounts of scum and settled solids to be expected, but would also help design the settling/thickening units.

Figure 1 shows a batch-operated settling/thickening tank as used in Accra, Ghana, with a ramp for front-end loader for removal of the separated solids.

Unplanted and Planted Sludge Drying Beds

Two processes are responsible for the dewatering and drying of sludges in unplanted sludge drying beds: gravity percolation and evaporation. Evapotranspiration is a supplementary process in planted drying beds.

First published experiments on faecal sludge treatment in unplanted sludge drying beds were conducted by a group of researchers at AIT, Bangkok, in the late sixties (Pescod 1971). A sludge depth of 20 cm was found to give maximum allowable solids loading rates. The drying periods to achieve 25 % solids content required 5 to 15 days, depending on the varying total solids (TS) loading rates (70 - 475 kg TS/yr·m^2) and on climatic conditions (rainfall).

Results obtained from the first monitoring phase of the pilot sludge drying beds in Accra/Ghana (Larmie 1995 and 1996) revealed that this treatment option is applicable to septage, public toilet sludge and primary pond sludge (TS = 1.6-7 %). Experiments were conducted during the dry season with sludge depths of ≤ 20 cm. A 1:4 mixture of public toilet sludge and septage was dried to over 70 % TS in nine days at a solids loading rate of 130 kg TS/yr·m^2. A significant and persistent helminth egg removal in the sludge could not be observed during the one to two weeks drying

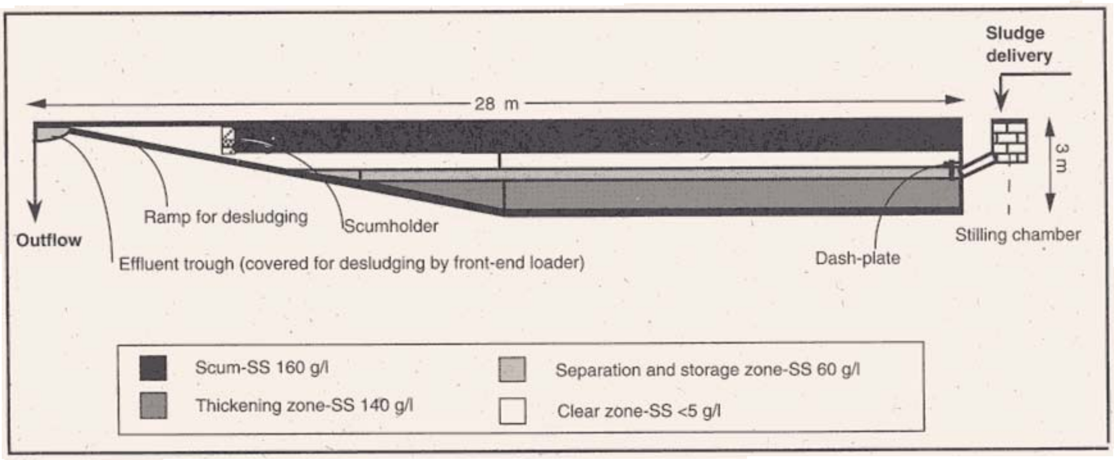


Figure 1: Improved design of a sedimentation/thickening tank providing storage for approx. 50 tons of separated solids (desludging by front-end loader)

period. A 95 % suspended solids (SS) and a 100% helminth egg elimination in the percolating liquid was achieved. Public toilet and primary pond sludges were dried to almost 40 % TS in 12 days at a solids loading rate of 200 kg TS/yr·m². Further sludge drying experiments will be conducted to substantiate these findings.

Removal of the dewatered or dried sludge from unplanted sludge drying beds is labour intensive or requires mechanical equipment. **Planted** sludge drying beds could minimise the need of frequent dried sludge removal as sludge withdrawal becomes necessary only after several years of operation. A considerable number of reed beds treat sludge mainly from smaller STP in Europe and North America. Since the applicability of reed beds for faecal sludge treatment remains to be tested, the process will be investigated in the collaborative field research of AIT and SANDEC.

The monitoring results from planted and unplanted drying beds treating sludges from activated sludge treatment plants reveal that the **percolating liquid** is significantly nitrified. The toxic effect of ammonia on algae in facultative ponds (see also 2.3 below) is therefore unlikely, and makes the drying bed effluent particularly suitable for pond treatment.

Sedimentation/Thickening vs Drying Beds

Table 2 contains the per capita surface area required for the two solids/liquid separation processes, viz. sedimentation/thickening and drying beds, which was determined by the monitoring data obtained to date. FS treatment in a sedimentation/thickening tank requires a significantly (approx. seven times) smaller area than treatment in a sludge drying bed. However, FS treatment in dewatering/drying beds yields a final sludge product of TS ≤ 70 %, whereas the achievable TS concentration in settling/thickening tanks amounts to ≤ 14 % only. The thus obtained sludge requires further dewatering or co-composting. Since the COD, SS (suspended solids) and helminth egg concentrations in the effluent of drying beds are substantially lower than in the effluent of sedimentation/thickening tanks, they require less polishing. In choosing between settling/thickening and drying bed treatment, careful attention should be paid to factors such as required surface area, quality of the liquid effluents and sludges produced, and requirements for further treatment.

2.3 Pond Treatment

Separate Treatment of FS and Wastewater

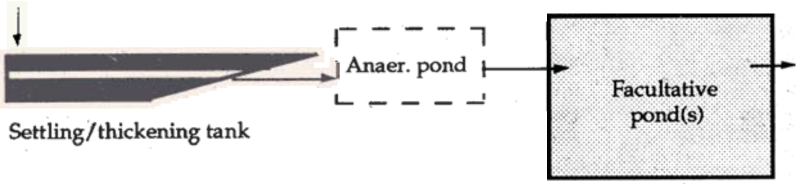
Based on the knowledge acquired to date, we recommend that high- and low-strength sludges (see 2.1 for the respective classification) be treated in separate pond systems. This would be beneficial as highly loaded, multistage **anaerobic ponds** are particularly suitable to achieve an efficient treatment of the more concentrated "Type-A" sludges. High loading rates lead to higher volumetric BOD removal rates and, hence, to less overall pond surface or volume than in diluted faecal sludge treatment. Since high ammonia concentrations inhibit algal growth, Type A or mixtures of Type A and B sludges containing high nitrogen loads are not amenable to **facultative pond** treatment. In contrast, septage is likely to be treatable in facultative ponds as its ammonia contents are relatively low.

Table 2 :
Comparison of settling/thickening and drying bed treatment for solids/ liquid separation of faecal sludges

	Attainable TS %	Loading Cycle	TS Loading kg TS/m²yr	Area Required m² /cap.[1]
Sedimentation Tank	≤ 14	8-week cycle (4 weeks loading + 4 weeks resting) with two parallel settling tanks	1,000	0.007
Sludge Drying Bed (unplanted)	≤ 70	10-day cycle (loading, drying, removing)	100 - 200	0.05

[1] Assumed parameters: FS quantity = 1 litre/cap · day; TS of the untreated FS = 20 g/l

Figure 2 provides design guidance for treating septage in a facultative pond system in warm climates, preceded by a settling/thickening unit and an optional anaerobic pond.



Sedimentation/ Thickening	Anaerobic pond	Facultative pond(s)
• Batch-operated • Attainable TS: 15% • Liquid retention ≥ 3 h in the clear / settling zone • Attainable elimination: BOD and COD: 50 %; SS: 60-80 %; Helminth eggs: 50 %	• The need/benefit of anaerobic ponds for treating septage is still uncertain. It is likely to be advantageous if a BOD elimination of ≥ 40 % can be achieved. • $L_v \leq$ 350 g/m^3·day, depending on temperature	• BOD elimination 80% • Retention time > 5 days • $L_a \leq$ 350 kg/ha·day, depending on temperature
L_v = Volumetric organic loading rate	L_a = Aerial organic loading rate	

Figure 2: Functional sketch and design guideline for pond treatment of septage *

Field research is conducted by WRRI at the Teshie FSTP in **Accra**, Ghana, on **treatment of septage** in a **pond** system comprising five ponds in series and preceded by settling/thickening. The monitoring programme will determine whether and to what extent septage is amenable to **anaerobic** pond treatment. The data generated from the first monitoring phase in May 1996 (Larmie 1996) indicate that BOD removal in the primary anaerobic pond following settling/thickening was in the order of **50 %**. The monitored volumetric and surface loading rates of this pond amounted to 100 g BOD/m^3·day and 1,300 kg BOD/ha·day respectively.

Co-Treating FS and Wastewater in Waste Stabilisation Ponds

The organic loading rate, the solids load and the ammonium/ammonia nitrogen concentrations are critical variables to be considered when co-treating wastewater and faecal sludges in waste stabilisation ponds. Their relevance is outlined below.

Organic loading rate: anaerobic and facultative ponds are sensitive to excessive organic (BOD) loading. The most serious symptomatic effect in overloaded anaerobic ponds is odour. In facultative ponds, overloading will impair the development of aerobic conditions and algal growth. The permissible additional faecal sludge load is dependent on the organic load already exerted by the wastewater, and on the loading rates for which the ponds were originally designed.

- **Solids load:** ponds may fill up at undesirably fast rates as a result of high solids contents in FS. Separating the FS solids in solids/liquid treatment (e.g. settling/thickening or dewatering beds), and treating the liquid in wastewater stabilisation ponds is, thus, the recommended option which is likely to lead to a reliable and long lasting WSP operation. A 60-80 % removal of suspended solids can be achieved in well-designed and operated settling/thickening tanks. A ≥ 90 % removal of suspended solids and a 100 % removal of helminth eggs from the FS liquid can be attained in dewatering/drying beds.

Ammonia nitrogen: the permissible ammonia (NH_3) concentration in the facultative pond is a further factor influencing the permissible FS load in a WSP system. Excessive ammonia levels may cause a suppression of algal growth. This, in turn, reduces the supply of oxygen required by the aerobic bacteria for the decomposition of organic matter, and by nitrifiers for the oxidation of NH_4. For the conditions prevailing in facultative ponds in tropical climates, the permissible NH_4 concentration in the influent of the combined waste has been established at 400 mg/l, or 500 mg/l if the waste is pretreated in an anaerobic pond. The FS:wastewater load ratio may be calculated on the basis of these critical concentrations.

3 References

Annoh, C. (1989 and 1994). Project Designs for the Koforidua and Teshie (Accra) Faecal Sludge Treatment Plants.

Heinss, U. (1996). Back-to-the-Office Report of a Mission to Thailand and the Philippines, September. SANDEC.

Larmie, S.A. (1994). *Sedimentation Tank Sludge Accumulation Study.* Field Report, WRRI.

Larmie, S.A. (1995 and 1996). *Drying Bed Experiments.* Field reports on pilot treatment of faecal sludges in unplanted drying beds. WRRI/ SANDEC. Unpublished.

Payrastre, F. (1995). *Pilot Treatment of Faecal Sludges in Reed Beds.* Report by CEMAGREF,