**Tons of excreta and ways to treat them**

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Tons of excreta and ways to treat them

U. Heinss and M. Strauss, Switzerland, S.A. Larmie, Ghana

IN MOST CITIES in developing or newly industrialised countries, collection, haulage and treatment of faecal sludges (FS) from latrines, aqua privies and septic tanks pose a multitude of problems.

Due to excessive haulage distances and to a lack of suitable treatment options, the sludges are normally dumped untreated within the shortest possible distance. To illustrate the quantitative aspect of the problem, e.g. Manila and Bangkok, where 65 per cent of the population are served by septic tanks, will have to deal daily with the haulage and treatment of 300 and 500 tanker loads, respectively, in the near future; i.e., when emptying services will have been improved (Veroy, Arellano and Sahagun 1994; Stoll 1995). Only in a few countries (e.g. Ghana, Thailand, Indonesia, and Argentina), purposely designed treatment plants exist to treat septage and nightsoil. In some countries (e.g. Botswana, Tanzania, South Africa), FS are added to the urban wastewater stream for co-treatment in wastewater treatment plants; generally waste stabilisation ponds (WSP). These are frequently overloaded and malfunctioning as they are not originally designed to receive the additional load.

Field research objectives

The lack of appropriate options for the treatment of faecal sludges (FS) in developing countries has lead SANDEC to initiate an R+D project on selected FS treatment processes and technologies. The aim of the project is to provide planners and engineers with recommendations on the design of selected medium to low-cost treatment options. The recommendations will be based mainly on the results of field research conducted on full or pilot-scale treatment plants.

Faecal sludge characteristics and treatment objectives

High and low-strength FS

Faecal sludges may be classified into two broad categories (Heinss, Larmie, Strauss 1997): high-strength sludges from bucket privies or unsewered public toilets, and sludges of weak strength, such as septage. In some countries (e.g. Botswana, Tanzania, South Africa), FS are added to the urban wastewater stream for co-treatment in wastewater treatment plants; generally waste stabilisation ponds (WSP). These are frequently overloaded and malfunctioning as they are not originally designed to receive the additional load.

Table 1. Important characteristics and classification of faecal sludges

<table>
<thead>
<tr>
<th>Item</th>
<th>High-strength</th>
<th>Low-strength</th>
<th>Sewage as comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Public toilet or bucket latrine sludge</td>
<td>Septage</td>
<td>Tropical sewage</td>
</tr>
<tr>
<td>Characterisation</td>
<td>Highly concentrated; mostly fresh FS: stored for days or weeks only</td>
<td>PS of low concentration; usually stored for several years</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>20 – 50,000 mg/l</td>
<td>&lt; 10,000 mg/l</td>
<td>500 – 2,500 mg/l</td>
</tr>
<tr>
<td>COD: BOD</td>
<td>2:1 – 5:1</td>
<td>5:1 – 9:1</td>
<td>2:1</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>2 – 5,000 mg/l</td>
<td>&lt; 1,000 mg/l</td>
<td>30 – 70 mg/l</td>
</tr>
<tr>
<td>TS</td>
<td>≥ 35%</td>
<td>&lt; 3%</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Helminth eggs</td>
<td>20 – 60,000 /l</td>
<td>≤ 4,000 /l</td>
<td>300 – 2,000 /l</td>
</tr>
</tbody>
</table>

Ammonia – the tricky variable

Faecal sludges may contain very high ammonium (NH₄) and, hence, also ammonia contents (NH₃) which may be toxic to algae at > 20 mg/l levels. This is of particular relevance to the treatment of FS in pond systems where the development of facultative pond conditions and growth of algae are desirable. We recommend the maximum allowable NH₄ concentration in the influent to a facultative pond not to exceed 400 mg/l for temperatures of 25 – 28°C and pH 7.5 – 8. At lower temperatures, the value may be increased. According to the table above, septage may thus often be treatable in facultative ponds, whereas high-strength FS would have to be diluted first (e.g. by co-treating it with domestic wastewater). NH₃ may also hinder anaerobic processes if occurring at excessive concentrations. Specific field research is needed to determine threshold limits and conditions under which this may occur.

BOD – a reliable design variable?

BOD, routinely used in pond design, is difficult to be determined reliably for faecal sludges. BOD bottles should be continuously stirred or periodically shaken over the entire 5-day testing period, particularly when analysing FS...
from public toilets or pit latrines rich in settleable solids. BOD analysed in stirred bottles is on the average 1.4 times higher than the BOD determined in unstirred bottles. BOD may also be determined via COD analyses. Reported and measured COD/BOD ratios are listed in Table 1.

**Treatment objectives**

The decisive criterion in establishing treatment objectives is whether the effluent and treated solids from the faecal sludge treatment plant (FSTP) are to be discharged into the aquatic or the terrestrial environment, or whether they are meant for agricultural or aquacultural use. Variables such as COD or BOD and NH₄⁺ are of prime importance for discharge into receiving waters. If treated FS is to be reused, hygienic characteristics such as helminth eggs used as parasite indicators, and faecal coliforms as bacterial indicators, are the key variables.

Furthermore, nitrogen and heavy metals are important criteria: compared to phosphorus, nitrogenous compounds are not retained/stored in the soil matrix. Therefore, groundwater will be contaminated by nitrogenous compounds if the use of FS exceeds the plants’ nitrogen requirements. Septage collected from cottage or larger scale industrial premises may contain heavy metals. They will accumulate in soils and plants. Recommended accumulation tolerance limits must be taken into consideration (U.S. EPA 1984). Effluent and plant sludge quality guidelines for selected variables are listed in Table 2.

### Table 2. Suggested effluent and plant sludge quality guidelines for the treatment of faecal sludges

(Heinss, Larmie, Strauss 1997; WHO 1989; Xanthoulis and Strauss 1991)

<table>
<thead>
<tr>
<th>COD (mg/l)</th>
<th>NH₄-N (mg/l)</th>
<th>Helminth Eggs</th>
<th>Faecal coliforms (No/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Liquid effluent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment for discharge into receiving waters:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Seasonal stream or estuary</td>
<td>≤ 300-600</td>
<td>10-30</td>
<td>≤ 2-5/1</td>
</tr>
<tr>
<td>- Perennial river or the sea</td>
<td>≤ 600-1,200</td>
<td>20-50</td>
<td>≤ 10/1</td>
</tr>
<tr>
<td>Treatment for reuse</td>
<td>n.c.</td>
<td>3)</td>
<td>≤ 1/1</td>
</tr>
<tr>
<td>- Restricted irrigation</td>
<td>n.c.</td>
<td>3)</td>
<td>≤ 1/1</td>
</tr>
<tr>
<td>- Vegetable irrigation</td>
<td>n.c.</td>
<td>n.c.</td>
<td>≤ 3-8/g TS</td>
</tr>
<tr>
<td>B: Treated solids</td>
<td>n.c.</td>
<td>n.c.</td>
<td>3)</td>
</tr>
<tr>
<td>- Use in agriculture</td>
<td>n.c.</td>
<td>n.c.</td>
<td>≤ 3-8/g TS</td>
</tr>
</tbody>
</table>

n.c.: not critical

3) Nitrogen loads not to exceed the crops’ requirements of 300-200 kg N/ha year.

WH0 1989

Xanthoulis and Strauss 1991

### Treatment options

#### Current focus in field research

Figure 1 offers a selection of faecal sludge treatment options which may be composed of medium to low-cost technologies, especially for developing and newly industrialised countries (Strauss and Heinss 1995). The selection is not exhaustive as more sophisticated technologies may prove feasible in specific situations.

The following treatment processes and technologies are being investigated by SANDEC and its partners in Ghana (Water Research Institute), Thailand (Asian Institute of Technology) and the Philippines (University of the Philippines/ National Engineering Centre):

- Solids-liquid separation, viz.:
  - Sedimentation/thickening
  - Sludge drying beds (unplanted and planted)
- Anaerobic ponds
- Facultative ponds (conventional and with attached-growth media)
- Land treatment/soil reclamation

To date, recommendations for preliminary design have been elaborated for solids-liquid separation processes, anaerobic ponds, facultative ponds, and for options combining these processes. In addition to these field-tested options, recommendations have been formulated for the co-treatment of FS with municipal wastewater in waste stabilisation ponds and in activated sludge plants. Field research comprising septage treatment by planted sludge drying beds, attached-growth facultative ponds, and soil reclamation using septage have only recently been initiated.

### Selection of treatment options

Low-strength (e.g. septage) and mixtures of low and high-strength FS should be subjected to solids-liquid separation
prior to pond treatment (high-strength sludges are hardly
or not at all conducive to solids-liquid separation). This is
likely to lead to considerable land savings as compared
with direct pond treatment. Furthermore, technical and
operational difficulties associated with the emptying of
large quantities of separated solids from primary ponds
could be avoided.

High and low-strength sludges should be treated sepa-
rate in places where signiﬁcant amounts of high-strength
sludges are produced (e.g. from unsewered public toilets or
from bucket latrines).

Pond treatment of high-strength, rather fresh FS
is not
recommended due to the reasons outlined above and
possible ammonia (NH3) toxicity problems. Anaerobic
digestion with biogas utilisation followed by sludge drying
beds may constitute a technically feasible option. Co-
composting with e.g. municipal refuse (LaTrobe and Ross
1992), wood chips or sawdust may offer another alterna-
tive. Finally, high-strength FS if produced in relatively
small quantities may be co-treated with low-strength sludges
(as practised e.g. in Accra, Ghana) or with wastewater.

Recommendations for preliminary design

Solids-liquid separation – sedimentation/thickening

Batch-operated, non-mechanised FS settling/thickening
tanks might be the option-of-choice where continuously
operated settling tanks equipped with mechanical sludge
scraping installations may not be appropriate.

Annoh and Neff (1988) and Annoh (1989; 1994) have
conceived and implemented batch-operated FS settling/
thickening tanks in Accra (Ghana). The tanks are accessi-
able and can be emptied by front-end loaders to remove the
separated solids. Figure 2 shows an improved version of
the tank which comprises FS loading at the deep end and
effluent draw-off near the shallow end (H einss, Larmie,
Strauss 1997).

The required storage volume for the separated solids is
the decisive design variable for batch-operated FS settling/
thickening tanks, in contrast to wastewater sedimentation
tanks which are designed on the basis of the liquid and
solids surface loading rates. Guidance on tank design and
expected contaminant removals in the liquid fraction are
presented in Figure 5.

Solids-liquid separation – unplanted sludge drying beds

Drying beds are or have been widely used throughout
Europe and North America for dewatering sludges from
wastewater treatment plants. Similar to lagoons, drying
beds also require much space. Therefore, in many industri-
alised countries, this treatment option had to be replaced
by less land-intensive dewatering processes such as chemi-
cal-aided centrifuging or ﬁlter pressing.

In unplanted sludge drying beds, application or loading
depths should amount to max. 30 cm as shown in Figure
3. With solids loading rates of 100-200 kg TS/m2 yr., 40
per cent TS content in the dewatered sludge may be
attained within 8-12 days. The dewatering/drying rate is
dependent on the type of sludge and its solids content, on
weather conditions, loading rate, application depth, and
on the operating ‘age’ of the bed. The hygienic quality of
the dewatered or dried sludge (best expressed by the
residual concentration of nematode eggs) is dependent on
the combined effect of time, dryness and temperature.

| Table 3. Comparison of the land area required for settling/thickening vs. drying bed treatment for solids/liquid separation of faecal sludges |
|---------------------------------|-----------------|-----------------|-----------------|
| Attainable TS % | Assumed loading cycle | TS loading kg TSM2 yr | Required area m² (cap. 1) |
| Sedimentation/thickening tank | ≤ 14 | 8-week cycle (4 weeks loading + 4 weeks rest; 6 cycles per year); two parallel settling tanks | 1,200 | 0.006 |
| Sludge drying bed (unplanted) | ≤ 70 | 10-day cycle (loading-drying-removing; 36 cycles per year) | 100 - 200 | 0.05 |

1) Assumed parameters: FS quantity = 1 litre/cap-day; TS of the untreated FS = 20 g/l

Figure 2. Batch-operated sedimentation/thickening
tank providing storage for approx. ﬁfty tons of
separated solids (Desludging by front-end loader)

Figure 3. Sludge dewatering/drying bed

SANDEC § 6
Complete helminth egg inactivation may be achieved if the sludges are allowed to dry for 10–12 months at water contents > 5 per cent. Egg survival periods are greatly reduced by sun drying to water contents < 5 per cent, below which nematodes are unlikely to survive.

The drained liquid will amount to 50-80 per cent of the raw sludge volume loaded into the beds. Substantial reductions of suspended solids (≥ 95 per cent), COD (70-90 per cent) and helminth egg counts (100 per cent) are achieved in the percolating liquid. Inorganic nitrogen (NH₄-N; NH₃-N) removal ranges from 40-60 per cent. The drained liquid may then be treated in waste stabilisation ponds.

**Sedimentation/thickening vs. drying beds**

Table 3 contains the per capita surface area required for the two solids/liquid separation processes described above, viz. sedimentation/thickening and drying beds (Heinss, Larmie, Strauss 1997). A sedimentation/thickening tank requires a much smaller area (approx. ten times) to treat FS than a sludge drying bed. However, FS treatment in dewatering/drying beds may yield a sludge product with a TS content ranging from 25-70 per cent after 10 days of drying. The solids separated in settling/thickening tanks may be thickened to TS contents of ≤ 15 per cent only, and require further dewatering or co-composting. Since the COD, SS (suspended solids) and helminth egg concentrations in the effluent from drying beds are significantly lower than in the effluent of sedimentation/thickening tanks, they require less polishing treatment.

**Stabilisation pond (Lagoon) treatment with preceding solids-liquid separation**

Waste stabilisation ponds (WSP) present a low-cost, potentially sustainable technology with increasing worldwide application in treating liquid and semi-liquid waste. Substantial knowledge has been accumulated in recent decades on the design and operation of WSP schemes treating wastewater (Mara and Pearson 1986; Mara et al. 1992). However, scarcely any R&D work on pond systems treating faecal sludge has been done so far.

The authors are aware of the existence of separate pond treatment of faecal sludges (septage mainly) currently...
being practised in Indonesia, Ghana, Benin, Argentina, and the United States.

Figure 4 is a functional sketch of a pond system treating presettled septage. Figure 5 provides a design guidance for treating septage by settling/thickening followed by an anaerobic/facultative pond system in warm climates (H eiss, Larmie, Strauss 1997). The recommendations are based on field research conducted by the Ghana Water Research Institute and SANDEC at a full-scale FSTP in Accra, and on related literature.

Co-treatment with wastewater in waste stabilisation ponds

Where waste stabilisation ponds (WSP) treat municipal wastewater, the pond systems are often used to co-treat faecal sludges.

Organic loading rate, solids load and ammonium/ammonia nitrogen concentrations are the critical variables (H eiss, Larmie, Strauss 1997). The guidance given above for separate FS treatment can also be applied to co-treatment.

Planning aspects for faecal sludge management: centralised vs decentralised treatment

The haulage of relatively small faecal sludge volumes (5-10 m³ per truck) through congested streets over long distances in large urban agglomerations is not sustainable neither from an economic nor from an ecological viewpoint. New concepts of excreta collection, transport and treatment will, therefore, have to be developed in conjunction with sanitation systems adapted to the varying socio-economic segments of urban populations.

Faecal sludge haulage volumes and mileage are to be minimised. Planning and installing small to medium-sized decentralised FS treatment plants could contribute to easing the haulage problem. Such a decentralised treatment system may consist e.g. in faecal sludge dewatering and subsequent treatment and discharge (or reuse) of the separated liquid. Assuming that the dewatering process (e.g. by sludge drying beds) yields a reduction in water content from 98 per cent to 75 per cent, the dewatered sludge volume to be transported would be 12 times smaller than the raw FS volume. Compared to wastewater treatment, the advantage of FS treatment is its adaptability to any type of topography.

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