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WATER, SANITATION, ENVIRONMENT and DEVELOPMENT

# Treatment of sludges from on-site sanitation

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## Background

In many towns and cities of developing countries, the disposal or use of sludges from on-site sanitation systems, i.e. from septic tanks, latrines, and aqua privies constitutes a huge problem. In the majority of situations, the sludges, which are collected and hauled by emptying vehicles, are dumped at shortest possible distances from the city, thereby causing serious health threats and environmental damage. With the continuing implementation of latrine programmes in urban areas, the problem becomes larger year-by-year. The lack of simple and low-cost treatment solutions has, in many cases, prevented authorities and enterprises from trying to tackle the problem. The International Reference Centre for Waste Disposal, IRCWD, has thus started an R+D project, the objective of which is to find sustainable processes and technologies for the treatment of faecal sludges. It would much welcome information on faecal sludge treatment practices and ongoing research. What is being presented in this paper is a contribution for discussion rather than a presentation of proven and tested solutions.

## Factors affecting process choice

An important question is whether the effluents or products from a selected faecal sludge treatment installation are to be used in agriculture or in aquaculture, or whether their final destination is the discharge into the environment without prior use, e.g. into a receiving water body, or on land in the case of landfilling. In the case of use of the end products, hygiene standards such as faecal coliform or helminth egg concentrations will be important, while in the case of discharge, parameters such as organic loads (BOD or COD, e.g.) or nutrients (P and N) will be more relevant. Economic, sociocultural, institutional, climatic, and geological aspects have to be considered concurrently with the above criteria.

## Faecal sludge characteristics

Table 1 lists characteristics of septage and latrine sludges reported in published and unpublished literature.

**Table 1. Characteristics of sludge from on-site sanitation systems**

| $BOD_5$ (mg/l) | COD (mg/l) | Total solids(%) | TKN (mg/l) | Eggs (no./l) | Country | Reference |
|---|---|---|---|---|---|---|
| **Septage:** | | | | | | |
| 3,100-5,900 | 16-60,000 | 1.1-3.9 | 410-820 | | U.S. | EPA (1980) |
| 7,000[1)] | 15,000 | 4 | 700 | | U.S. (design) | EPA (1984) |
| | | 2-4 | | | Asia | Pescod (1971) |
| 680 | 8,100 | | | | Ghana | Accra Waste Man't. Dept. (1992) |
| 1,600 | 5,750 | | | | Jordan | Al Salem (1985) |
| | 24,400 | 4.7 | 544 ($N_{tot}$) | | | Jak. Sewer.+ San. Project (1982) |
| 2,500- 3,000 | | 1.5-2.5 | | | Thailand (BGK) | Edwards et al. (1987) |
| 3-6,000 | 17-23,000 | 2-2,5 | 6-6,500 | | S. Korea | Yao (1978) |
| 3-5,000 | 8-15,000 | 2-3 | 5-6,000 | 40-100 | Japan | Yao (1978) |
| **Latrine sludges:** | | | | | | |
| 15-18,000 | 26-33,000 | 1.2 - 3 | 5-6,000 | 18-360,000 | China | Shiru + Bo (1990) |
| 30,000 | 50,000 | 1.2 | 450($N_{tot}$) | 54,800 | China (Jangxi ) | Shiru + Bo (1990) |
| | | | 2,800 - 4,750 | | Shanghai | Edwards (1992) |
| | | 15-54 | | | Tanzania | Hawkins (1981) |
| | | | | 1,000 (stored) | Guatemala | CEMAT (1992) |

Data about septage quality are relatively abundant whereas only few data are reported about sludges from the various types of latrines. Septage and latrine sludges usually exhibit very poor settleability (U.S. EPA, 1984).

## Treatment options

*Simple and low-cost: necessary but not sufficient!*

However adapted and appropriate a chosen solution might be, engineers and planners must be aware of the fact that unless a suitable institutional framework exists or is set up through which the installations will responsibly be taken care of, and unless those in charge of operation, maintenance and management of such installations are properly instructed, trained and their salaries regularly paid, even the simplest treatment system will fail ! What is needed is the awareness and recognition that anybody dealing with shit carries at least as much prestige as a person dealing with potable water supply, road construction or being a doctor, lawyer or minister !

### Options overview

One basic distinction which can be made in classifying the treatment options is between separate treatment of faecal sludges, i.e. without mixing them with wastewater, and co-treatment, which consists in treating septage or latrine sludges jointly with municipal wastewater or with solid wastes. Another distinction is between processes which lead to a degradation of the organic matter, and processes which lead to a direct dewatering or drying without much biochemical decomposition. Thus, the options list presents itself as follows:

***Separate treatment***

***Direct dewatering or drying***

1 Drying (evaporation) lagoons

2 Drying beds (providing evaporation and drainage)

***Schemes providing degradation of the organic matter***

3 Solids separation (settling or thickening) (with subsequent dewatering/drying of the separated solids and treatment of the supernatant liquid)

4 Stabilization ponds (solids separation + partial or complete liquid treatment) + dewatering/drying of the separated solids

5 Anaerobic digestion + dewatering/drying

***Co-treatment***

6 With wastewater

7 With sludge from sewage treatment plants

8 Thermophilic composting with refuse or other bulking/compostable material

Below, each option is briefly described, including a functional sketch. Further to this, important factors, criteria, unresolved questions and potential problems which might be associated with the particular option are listed or discussed. Where relevant, related literature is cited.

## Separate treatment

### Drying (evaporation) lagoons (Fig. 1a)

***Process description:***

- Multiple lagoons operated in parallel
- Max. filling depth with fresh sludge: 30 cm (layers thicker than this will dry at the surface only and remain jelly-like below)
- Dewatering/drying of subsequent 30 cm-layers in the same lagoon until the useful depth is reached
- Emptying of the full pond manually or by front end loader, e.g.
- Decanting of supernatant theoretically possible (leading to a faster dewatering/drying) but practically difficult to operate

***Factors, criteria, researchable questions:***

- Treatment criteria: % solids of cake, hygienic quality (Ascaris eggs if ascariasis endemic in area)
- Climate (wet vs. dry periods) determines suitability of process; effect of rainfall?
- Will "old", dried layers of sludge become fully wetted and remain jell-like if subsequent layers of fresh sludge are being added?
- What level of sludge dryness is optimum to allow easy removal from the pond?
- Odor development and prevention
- Degradation of organics
- Treatment/disposal of supernatant if decantation is practiced?
- Method of removal of dried sludge from the pond

***References:***

Pescod, 1971

In Maseru, Lesotho, drying/evaporation lagoons for the treatment of pit latrine sludge will become operational in autumn 1993. A simple monitoring programme will allow to determine the main operational parameters (% total solids, organic/mineral content of the solids, Ascaris eggs) and adapt the mode of operation if necessary. One of the ponds which were not originally conceived for drying operation will be partitioned to allow filling to only 30 cm. Operation with successive 30-cm-layers of drying sludge will also be tried.

## Drying Beds (Fig.1b)

***Process description:***

- Open, shallow containments with constructed underdrains, allowing both evaporation and seepage/ drainage (in contrast to drying lagoons which allow for evaporation only)
- Batch operation in single layers of 25-30 cm of sludge

***Factors, criteria, researchable questions:***

- Climate: dry vs. wet periods; effect of rainfall
- Drying rate faster than in drying lagoons? - Odors
- Drying period to allow for worm egg die-off and easy removal and handling
- Treatment of drained liquid: quantities and quality of liquid, best disposal?
- Need for buffering lagoons for storing fresh sludge during wet periods?

***References:***

Pescod, 1971

Drying beds are or have been widely used throughout Europe and North America for dewatering sludges from sewage treatment plants. Like lagoons, drying beds require much space. In some areas, the technology therefore had to be replaced by other dewatering processes (centrifuging, filter pressing), as sludge quantities increased with the growing of the cities and the increased level of treatment and with the city-near land becoming increasingly scarce and expensive.

## Settling/thickening (Fig.1c):

***Process description:***

- Use of sedimentation tanks or thickeners for the separation of the settleable and floatable solids
- Batch operation in multiple units since continuous sludge and scum removal requires relatively sophisticated mechanical equipment

***Factors, criteria, researchable questions:***

- Optimum (surface) liquid and solids loading rates
- Sludge and scum accumulation rates and optimum operational cycles
- Supernatant characteristics and treatment
- Sludge and scum characteristics and treatment
- Mode of tank emptying

Parallel units of settling tanks have been used in two septage treatment plants in Accra, Ghana, over the last few years. The tanks are batch-operated. One of the short sides of each unit is constructed as a ramp. This allows the access by front-end loaders for emptying. In the timber-rich zone of southern Ghana, sawdust is a plentiful waste product from the timber industry. It is available free of cost and used as a bulking agent and carbon source for the composting of the sludge removed from the settling tanks. The supernatant liquid is further treated in a series of waste stabilisation ponds. Only few operational and performance data have been collected to date. An in-depth process monitoring and evaluation is being planned to take place in 1993-94.

## Stabilisation ponds (Fig. 1d)

***Process description:***

- Liquid-solids separation and liquid "stabilisation" (biochemical decomposition and pathogen die-off) in a series of ponds
- Removal and treatment of the sludge produced in the first and second pond
- Alternative: ponds preceeded by settling tanks to cater for bulk of solids separation

***Factors, criteria, researchable questions:***

- Effluent "standard" for discharge or for reuse?
- Optimum pond loading rates (high-strength liquid !)
- Dilution water required to make up for evaporation losses?
- Retention time required for effective organics removal vs. time required for pathogen removal
- Sludge accumulation rates and treatability

***References:***

McGarry and Pescod, 1970; Mara and Pearson, 1986

Waste stabilisation ponds are rather widely used for the treatment of septage and other faecal sludges. However, this treatment usually consists in the joint treatment with wastewater (see the section on co-treatment below). To date, only few pond systems have been devised which treat exclusively faecal sludges or the liquid portion thereof. The author is aware of a few systems in Ghana (3 in operation, 1 being planned) and one recently constructed for the city of Cotonou, Benin. Even after removal of the settleable solids, concentrations of the organic matter in the liquid fraction of faecal sludges are 10-20 times higher than in normal wastewater. Pond schemes treating such sludges or their liquid fraction would thus consist of a series of several anaerobic ponds before concentrations low enough for facultative pond conditions can be attained. McGarry and Pescod (1970) recommend to use the highest possible loading on successive anaerobic ponds so as to minimize the total pond surface area.

## Anaerobic digestion (Fig. 1e):

***Process description:***

- Digestion of the sludge in an anaerobic digester prior to dewatering/drying
- Potential for methane gas recovery

- Solids-liquid separation in a second digester or in a sludge lagoon
- Treatment of the supernatant e.g. in a waste stabilisation pond, in an anaerobic filter or in a UASB (upflow anaerobic sludge blanket) reactor

***Factors, criteria, researchable questions:***
- Technology relatively capital-intensive and requiring skilled operating personnel; applicable in economically and technologically fairly advanced countries, only

***References:***
Snell, 1943; Pescod, 1979

Anaerobic digestion is a process widely used e .g. in Japan and in South Korea for the treatment of septage and other faecal sludges in so-called nightsoil treatment plants. In South Korea, the sludges are dewatered after digestion and either landfilled or co-composted with organic waste from farms in small rural-based composting plants. The supernatant from the anaerobic digestion is diluted with fresh water and treated by activated sludge.

## Co-treatment

### With Wastewater (Fig. 2a):

***Process description:***
- Co-treatment in waste stabilisation pond schemes or in so-called conventional sewage treatment plants (activated sludge or trickling filter)
- Either: plant/scheme was originally designed to take on a given mix of wastewater and faecal sludge; or: practice of blending sludges with wastewater has just established itself over the years

***Factors, criteria, researchable questions:***
- In the case of adding faecal sludge to a wastewater treatment system which was not originally designed for co-treatment:

  How are the operation and the effluent quality of the plant affected by the sludge addition? What are maximum added organic loads before a plant "fails"?

  How much more sludge is being produced and how is its treatability affected?
- In the case of designed co-treatment:

  Is it more economic and technically feasible to co-treat faecal sludges or to treat them separately? What are relevant criteria which determine the maximum percentage of faecal sludge in the plant inflow?

***References:***
Jewell, Howley and Perrin, 1975; U.S. Environmental Protection Agency, 1984

In many situations where wastewater treatment schemes exist and are functioning, septage or latrine sludge are added to either the last manhole upstream of the treatment works, at other points in the sewerage system, at specifically designed receiving or storage installations at the headworks of an STP, or directly into ponds. In the United States, the practice of co-treatment in activated sludge or trickling filter plants is fairly common. Problems are reported because STPs get overloaded and much septage disposal still goes on uncontrolled (U.S. Environmental Protection Agency, 1984; Mancl, 1986). Examples of co-treatment in ponds are the city of Gaborone as well as other towns in Botswana, Dar-eş-Salaam and various towns in Malawi. The Al Samra waste stabilisation pond scheme treating the sewage from the city of Amman, Jordan, receives in the order of 60,000 m3/day of wastewater-cum-septage, 10 % of which is septage collected in the Greater Amman Area.

### With STP Sludge (Fig. 2b):

***Process description:***
- Where anaerobic digestion is used already for the treatment of sewage treatment plant (STP) sludge, such installations might be suited to co-treat faecal sludges
- STP sludge and faecal sludge flows are blended and digested in a single or two-stage digesting system
- The supernatant is co-treated with the wastewater
- Drying or co-composting of the digested sludge

***Factors, criteria, researchable questions:***
- How do faecal sludges affect the process? Maximum mixing ratios? Gas production? Dewaterability of mixed digested sludge as opposed to STP or faecal sludges alone?
- In a plant not originally designed to receive this extra sludge stream: what is the maximum additional hydraulic or solids load which still permits proper operation and treatment?
- Effect on supernatant quality, quantity and treatability?

### Co-composting (Fig. 2c):

***Process description:***
- Turnable or static, forced aeration windrows made up from appropriate mixtures of fresh or settled or dewatered faecal sludges and refuse
- Attainment of thermophilic temperatures (50-60 °C) which lead to rapid inactivation of pathogenic organisms
- Mixing of faecal sludge (high in nitrogen) with refuse (high in carbon) allows for more optimum C:N ratios than if either of the wastes is composted separately.

***Factors, criteria, researchable questions:***
- Storage and pretreatment requirements for the faecal sludge?
- Mode of mixing the two components; health risks in handling

- Process limitations as a function of mixing ratios, humidity, C:N ratios; process control
- Appropriate degree of manual vs. mechanized operation
- Quality of the end product
- Compost marketing
- Compostability of fresh sludge (e.g. nightsoil from bucket latrines) vs. partially or largely decomposed faecal sludge (e.g. from septic tanks or from pit latrines)

***References:***
Scott, 1952; Shuval, Gunnerson and Julius, 1981; Obeng and Wright, 1987; La Trobe and Ross, 1992

Co-composting is both a traditional process as well as a fairly recent "discovery" being tried in a few places. In China, India, Malaya, Singapore and Nigeria, e.g., co-composting is being practiced for at least several decades already. Nightsoil is co-composted with either refuse and/or other organic or bulking material. Mixing ratios are in the order of 1:5 - 1:10 (sludge : added material) on a wet weight basis if underwatered sludge is used. With dewatered sludge and woodchips the ratio can be increased to as much as 1:1.5.

An example of a very recent operation is the installation at Rininear Grahamstown in Cape Province, South Africa. There, the refuse and bucket latrine sludge from a community of 100,000 are co-composted in a simply mechanized plant using forced-aearated, static windrows. The nightsoil is pre-settled and then hosed on to the windrow as the garbage is being heaped up. On a volume basis, the mixing ratio is approx. 1:10. The process is controlled by the temperatures developing within the piles. 55°C are reached and the windrows are left to react for 3 weeks. After composting, the mixture is being sieved and the rejects landfilled. The compost is used by the Grahamstown garden department.

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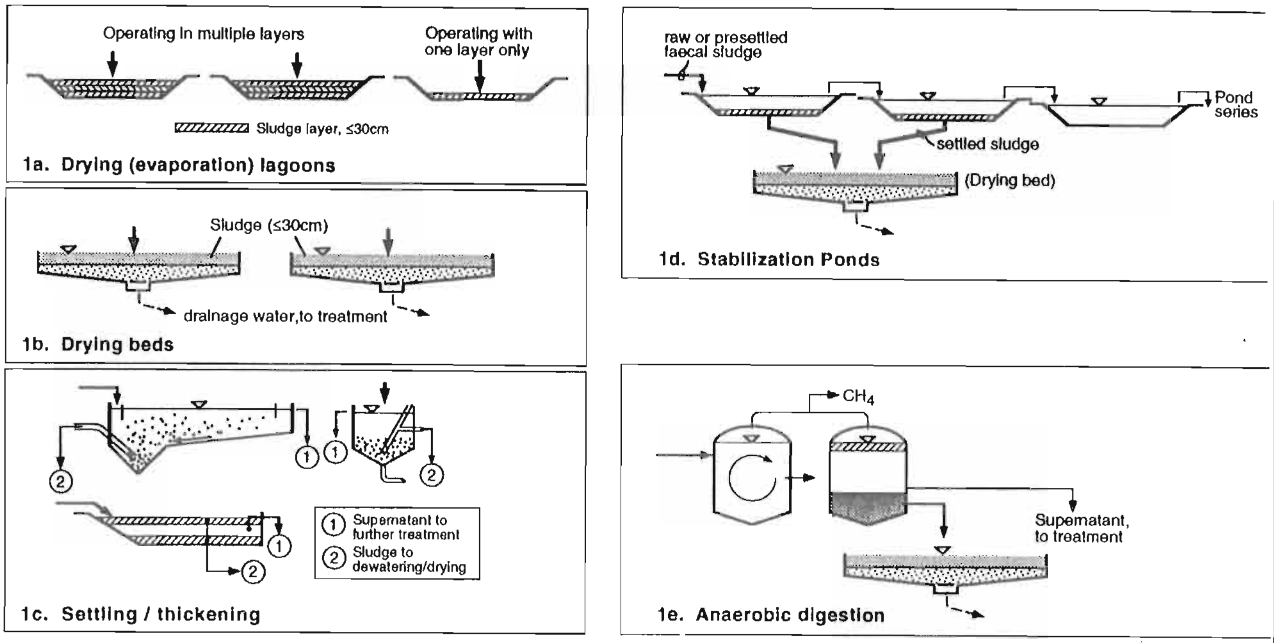


**Figure 1. Options for separate treatment of faecal sludges**

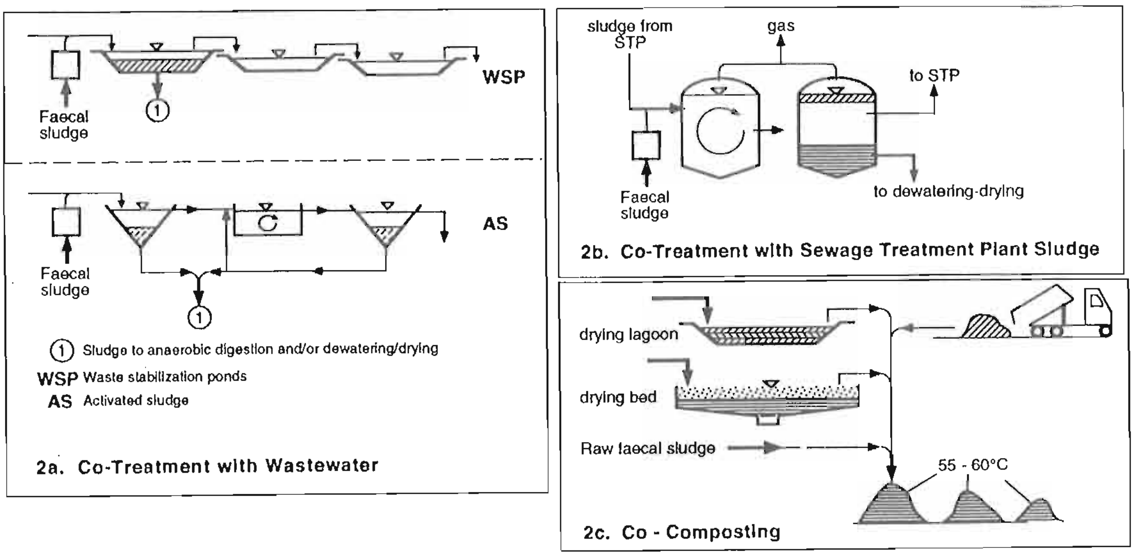


**Figure 2. Options for co-treating faecal sludges**