Asian Institute of Technology
Bangkok, Thailand –
Urban Env. Engineering &
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Use of Reed Beds for Faecal Sludge Dewatering

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A Synopsis of Reviewed Literature
and
Interim Results of Pilot Investigations with Septage Treatment in Bangkok, Thailand

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Acronyms and Abbreviations

AIT	Asian Institute of Technology, Bangkok
BMA	Bangkok Metropolitan Administration
EAWAG	Swiss Federal Institute for Environmental Science & Technology, Zurich
EEP	Environmental Engineering Program (AIT)
SANDEC	Dept. of Water & Sanitation in Developing Countries (EAWAG)

AG-WSP	Attached-Growth Waste Stabilisation Ponds
CW	Constructed Wetlands
FS	Faecal Sludge
HRT	Hydraulic retention time
SLR	Solids loading rate
STP	Sewage Treatment Plants

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
SS	Suspended Solids
TKN	Total Kjeldahl Nitrogen
TS	Total Solids

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Preface

Most urban dwellers in developing countries use on-site excreta disposal systems, such as public and family latrines, aqua privies and septic tanks. Contrary to wastewater collection and treatment, improvements in faecal sludge management have received little attention until very recently. To date, in the majority of cases, faecal sludges collected from on-site disposal systems are still disposed of untreated, mainly for lack of affordable treatment options. Therefore, SANDEC has embarked on practice-oriented R+D of faecal sludge (FS) treatment options, with the objective to develop guidelines for the design and operation of sustainable treatment technologies based mainly on practical field research.

So far, SANDEC mainly examined the use of pond systems for FS treatment through collaborative field research carried out with Ghana's Water Research Institute. Results of these investigations and recommendations for practitioners have been published in "Solids Separation and Pond Systems for the Treatment of Faecal Sludges in the Tropics" by Heinss, Larmie and Strauss (SANDEC report no.05/98). Another focus project was on the use of septage for land reclamation of Lahar (volcano ash) stricken areas. In a new collaborative field research project with AIT (Asian Institute of Technology), reed beds will be tested for their ability to treat septage.

1. Rationale and Introduction

Sludge drying beds may be classified as a solids-liquid separation process, producing a dewatered or dried solids product and a liquid (percolate) requiring further treatment prior to discharge or use. Mostly **unplanted** drying beds have been used to date to handle sludges from sewage treatment plants (STP). However, in Europe and in the United States, **planted sludge drying beds** are finding increasing use. Reeds normally are the plants-of-choice for such beds that are therefore also designated “reed beds”. They require substantially less operating care than unplanted beds as they need to be emptied every few years, only. SANDEC hypothesizes that reed beds might prove a feasible option for treating **faecal sludge**.

Part A contains the literature review. Experience gained with the use of reed beds for dewatering/drying sewage treatment plant or excess activated sludge in mostly temperate climate is summarised. The purpose of the review was to make the information available to persons dealing with faecal or STP sludge management. Further to this, SANDEC needed hints as to the possible design of planted drying beds to carry out pilot or demonstration schemes for FS dewatering/drying. The findings from the literature review are discussed in Chpt. 2 below. Table A1 in the Annex is a synopsis of the reported design and operating parameters. Fig. 1 shows the schematic design of a ventilated reed bed. Table A2 of the Annex provides the list of reviewed publications.

In Part B, interim results of AIT/SANDEC collaborative field research conducted in Bangkok, Thailand, are presented. Three pilot reed beds (“constructed wetlands”) treating septage have been in operation and subjected to intensive monitoring since early 1997.

Part A

2. Findings from the Literature

2.1 Comparative Performance of Planted vs. Unplanted Beds

Three experiments compare the performance of planted and unplanted drying beds (4,7,8). The results obtained show the advantages of reed beds as over the conventional sludge drying beds.

Drying

- The average reported solids content in planted beds amounts to 40% compared to 32% in unplanted beds.

- According to the authors, the lower sludge layer in a planted bed is aerobic and brown in colour whereas the sludge in unplanted beds is anaerobic and black.

BOD and COD

- BOD and COD concentrations in the percolating water of reed beds are 35-55% and 50-60%, respectively, lower than in unplanted beds.

Nitrification

- The ammonium in the percolating water of reed beds is 70-80% lower than in the liquid of conventional beds. Nitrate levels in the effluent of reed beds are, in turn, 3-10 times higher than in other beds. It can therefore be concluded that nitrification in reed beds is greater than in conventional unplanted beds.

Ventilated vs. Non-Ventilated Beds

- The difference in quality between the percolating waters of planted and unplanted beds becomes smaller when the beds are equipped with a ventilation system inducing an air current along the bottom of the bed (7) (see Fig.1). As a result, oxidising reactions also tend to occur in unplanted beds.

2.2 Hygienic Quality of the Percolating Water

- Hygienic quality improvement was also investigated (8,9). Concentrations of enterobacteria (mainly E. coli) were reduced during percolation through the reed beds by 2-3 orders of magnitude. According to one author, an unrestricted agricultural use of the sludge from reed beds is possible after 14 months of storage and drying of the sludge (8).

2.3 Need for Bottom Ventilation

- Loading rates for anaerobically stabilised sludges should be kept small in reed beds without bottom ventilation (4). Planted reeds died in non-ventilated beds when loaded with activated sludge from an oxidation ditch (7). However, in a ventilated bed the reeds survived and the average drying rate was significantly higher than in a non-ventilated bed. Reeds grew very well when aerobic stabilised sludge was applied in a non-ventilated bed (8). However, if the beds were loaded with a fresh excess sludge or digested sludge, the stock of reed plants decreased.

2.4 Reeds

- All reed beds were planted with *Phragmites*. In beds where also other Helophytes were planted, *Phragmites* was the only plant that developed a permanent plant stock and supplanted all other plants.

- Newly planted reeds reportedly formed a dense standing crop several months later (9).

- As regards cutting, different opinions prevail: from no cutting to cutting every year or after several years.

2.5 Close-Up View

- It is assumed that reeds influence the sludge dewatering and mineralisation process in different ways. Bacteria may thrive on the extensive root system as attached biofilm. The hollow roots possibly allow transport and supply of O_2 to attached aerobic bacteria. Since the root system is continuously growing, the sludge/soil layer remains permeable even through the increasing sludge layer.

- Compared to unplanted drying beds, higher TS contents but lower percolating water were obtained in planted beds (4,8). This can be attributed to the high suction pressure exerted by the root system and the leaves which evapotranspirate high quantities of water (15-25 mm/d (1, 2)).

3. Conclusions

Use of reed beds for faecal sludge dewatering in tropical countries may constitute a promising alternative to conventional sludge dewatering beds. Compared to conventional drying bed, the thereby resulting *advantages* are the following.

- **Simplicity of operation:**

Compared to unplanted beds, far less effort is required for sludge removal in reed beds as planted beds may be loaded over several years before desludging becomes necessary.

- **Nitrification:**

  Faecal sludge treatment in facultative ponds is often difficult as high ammonia concentrations may prevent the growth of algae. Nitrification in reed beds may therefore improve treatability of the drained effluent in facultative ponds.

- **Limited clogging**

  Clogging of the filter layer is likely to be minimal due to the continuous growth of rhizomes (rootstock).

Similar to sludge drying beds, the main disadvantage of reed beds is their large land requirement. This will limit the use of this treatment option to areas where sufficient land is available or where the treatment strategy consists in opting for decentralized systems.
Beside the operational advantages, the application of constructed wetlands, as the reed beds are also called, leads to beneficial effects such as wetland conservation and restoration of wildlife habitat.

4. Recommended Design for a Pilot Reed Bed

Based on the data in Table 1 for temperate climates, experimental or pilot reed beds treating faecal sludges in tropical zones could possibly be designed as follows:

- Size: 20-40 m^2, multiple units; 1 - 1.5 m freeboard
- Bottom ventilation to allow passive aeration
- Interval of faecal sludge application: weekly
- Loading rate: 100 kg TS/m^2y, initially; provision may be made to allow a stepwise increase of the loading rate to 150 kg TS/m^2·yr or above if the reed growth and the drying process are not negatively influenced.

Since reeds do not appear to grow well under highly anaerobic conditions, a ventilation system allowing for natural bottom aeration is, therefore, necessary, particularly when drying highly anaerobic sludges (Fig. 1). Passive aeration is achieved with the use of hollow blocks at the filter bottom and a vent pipe of a large diameter (20 cm). The pipe should extend at least 1 m above the reeds at their highest stand; i.e. prior to bed emptying.

It should be noted that uncertainties still exist regarding long-term performance and optimum operational patterns. Extended monitoring of septage-loaded constructed wetlands shall answer essential questions: Will percolation rate in the soil filter remain constant over several years of sludge loading? How will the plants react to high organic loading and a changing water regime induced by alternating septage loading and drying?

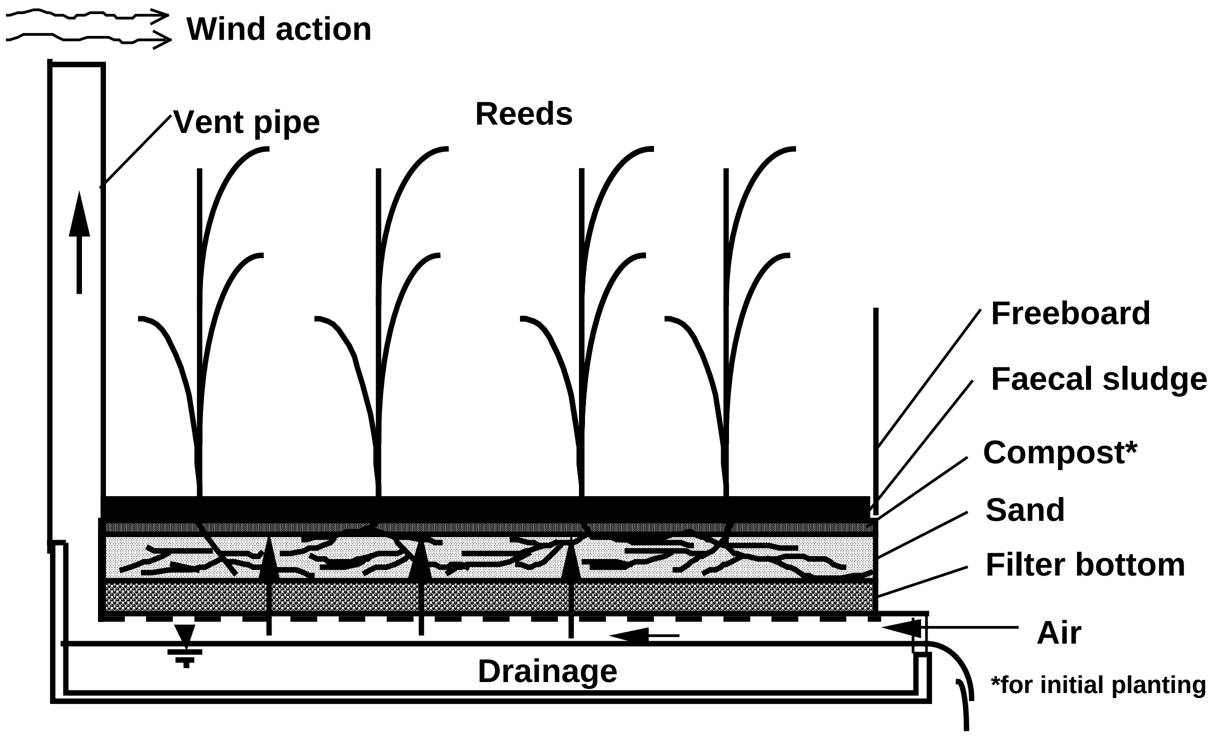

Fig. 1: Functional sketch of a reed bed with natural bottom ventilation

Part B

5. Interim Results of Treating Septage in Pilot Cattail Beds (Constructed Wetlands) at AIT, Bangkok

5.1 Introduction

Experience to date in using constructed wetlands or planted soil filters for sludge dewatering and stabilisation is limited almost exclusively to treating excess activated sludge. The majority of these sludges are either aerobically stabilised or anaerobically digested. Performance data shown in Table 1 above were determined in systems situated in temperate climates. Therefore, the three pilot sludge drying beds installed at the AIT campus and treating faecal sludge (septage[1]) hauled from Bangkok city represent a new approach in using wetlands.

5.2 Operations

The three pilot reed beds have got a size of 5 x 5 m each. Fig. 2 shows schematically the structure of the beds installed at AIT. The support and filtering media installed in the concrete embankment lined units are composed as follows (from bottom to top):

-	Hollow blocks underdrain	each 20x40x20 cm
-	40 cm of large gravel	∅ 25-50 mm
-	15 cm of small gravel	∅ 10-25 mm
-	10 cm fine sand	∅ eff. 0.3-0.75 mm

Ventilation pipes (∅ 20 cm) which are connected to the underdrain system secure root zone aeration. Fig. 3 shows schematically how the reed beds are operated, including feeding arrangements and post treatment in attached-growth waste stabilisation ponds.

The wetlands have been loaded with septage for 9 months. 1,650 m3 of septage with an average TS content of 1-2 %, TCOD 14,000 mg/l, and TKN of 1,240 mg/l) have been treated and dewatered to a TS level of around 45 % during this period. Fig. 4 shows the water balance in the constructed wetlands as calculated from cumulative septage loading, water stored in the dewatered septage and percolate flow measurements.

The pilot reed beds were operated at the following regime:

- Septage loading at once-per-week and twice-per-week intervals
- Septage loading rates:
  Equivalent to 80 – 160 kg TS/m^2year, initially
  More recently set at 250 kg TS/m^2year

[1] Faecal sludge is a general expression for sludges of variable consistency collected from so called on-site sanitation systems; viz. latrines, non-sewered public toilets, septic tanks, and aqua privies. Septage as one kind of faecal sludge, consists of the contents of septic tanks and usually comprises settled and floating solids as well as the interstitial liquid.

- TS concentrations of more than 50 % were obtained in the dried septage layer. It was however observed that at this TS concentration cattails wilting occurred presumably because of insufficient soil moisture. Sustainable plant growth is ensured at TS concentrations of 25-35%. This corresponds to a septage loading rate of 250 kg TS/m^{2}year a. Percolate ponding for 2-6 days is being tested to support conditions for healthy cattail growth.

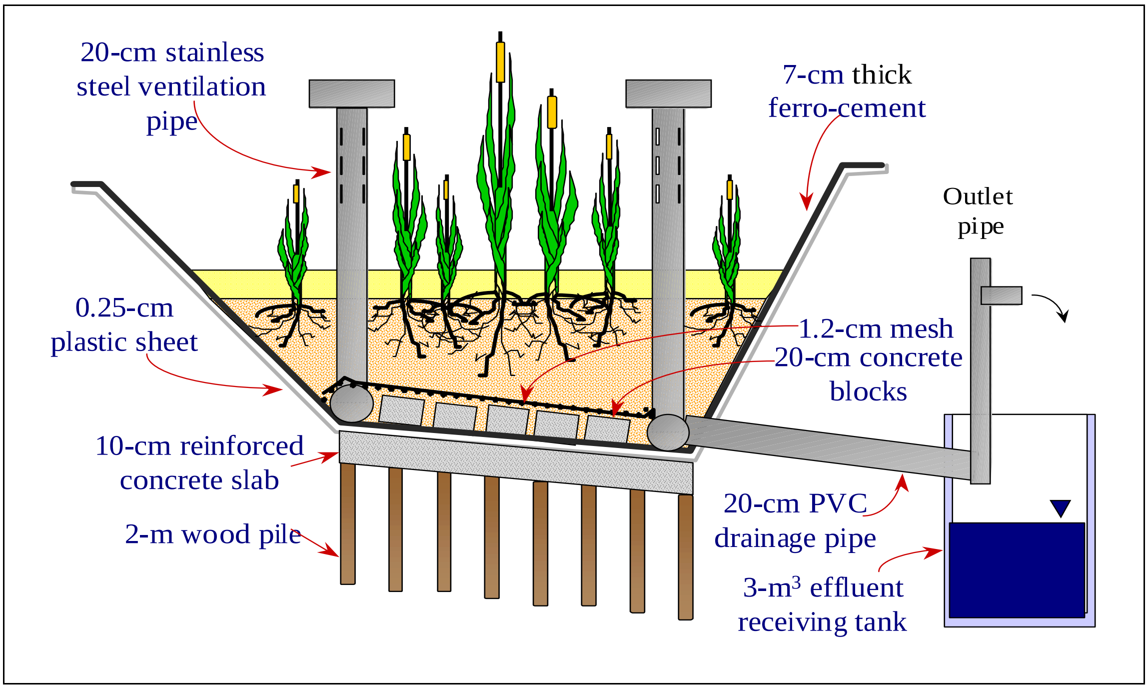

Fig. 2: Pilot Reed Bed Installed at AIT (schematic)

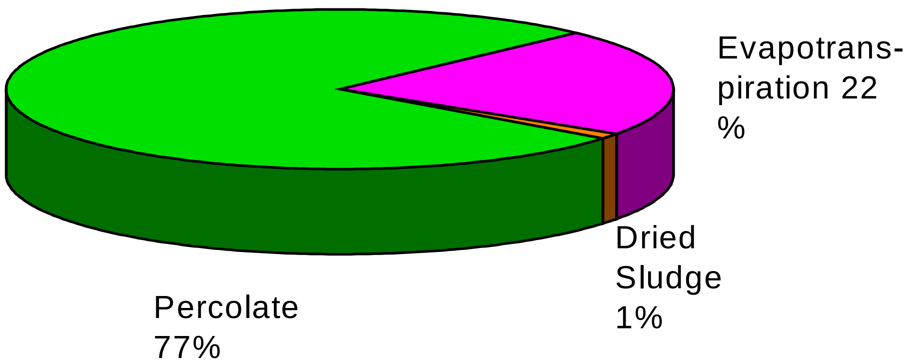

Fig. 3: Water Balance in the Pilot Constructed Wetlands Used for the treatment of Septage in Bangkok, Thailand (Initial phase)

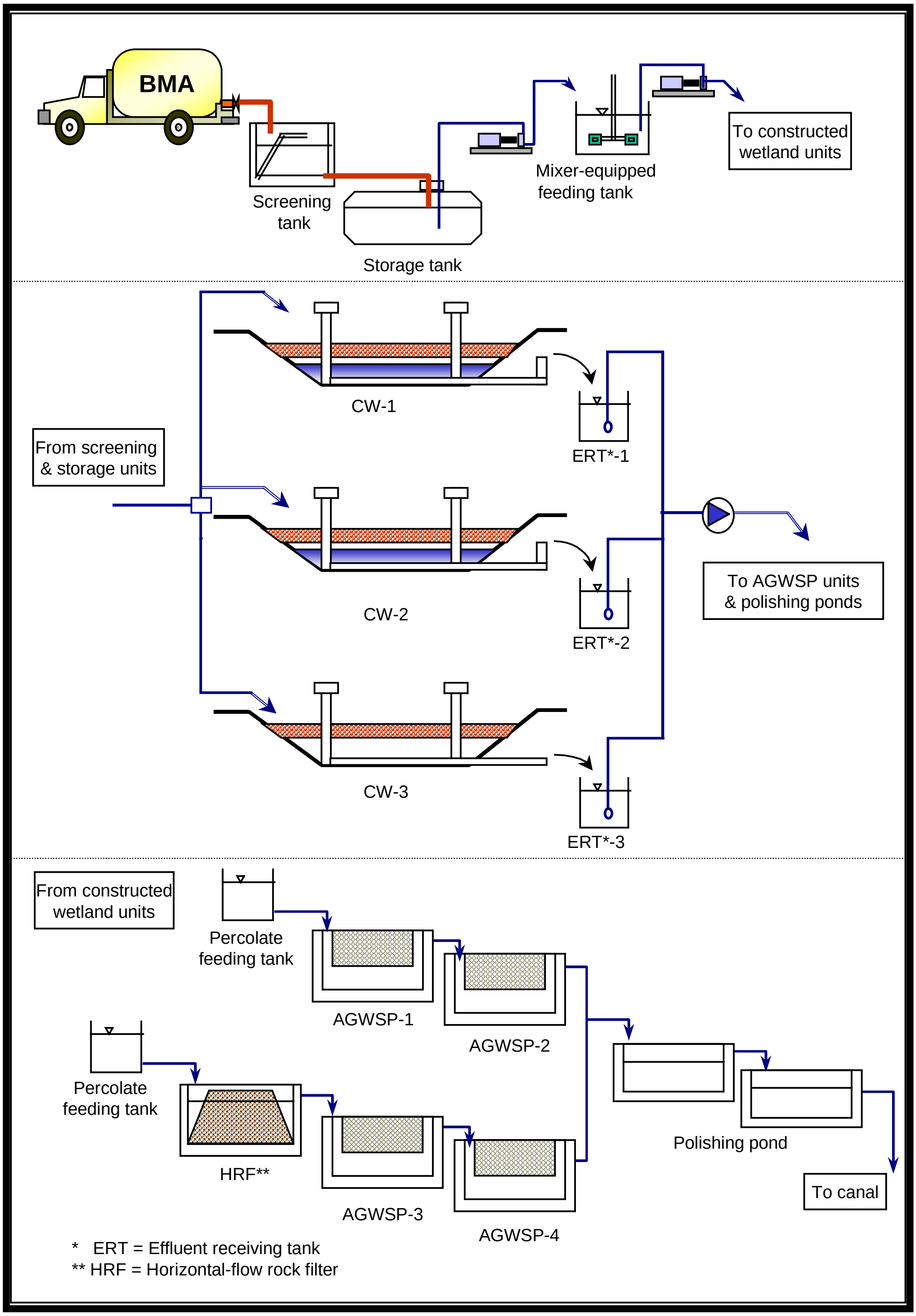

Fig. 4 Functional sketch for unit operations of the constructed wetlands and AGWSP systems

5.3 Evaluation

Results generated during the first nine months of operations (1997-98), tend to indicate that the process is feasible in principle, for treating septage. However, long-term operation and monitoring over 2-4 years are required to determine design and operating criteria, which will allow for a stable process. Moreover, faecal sludges other than septage would have to be tested too, to determine the feasibility of the process for varying types of FS. It is expected that sludges, which exhibit a fair degree of biochemical stabilisation, such as pond sludges, may lend themselves well for reed bed dewatering. Treatment of fresh, public toilet type sludges may constitute a greater challenge, though.

The important question is whether it will be possible to operate the beds over years without removing the sludge and without clogging of the filter layer.

Encouraging results with respect to removal efficiencies in the percolating liquid and with respect to sludge dewatering have been obtained to date. Periodic reed wilting has occurred at the same time. Further investigations are required to understand the reasons for it and to develop sustainable measures to achieve stable plant growth. One measure, which has been tried to date, and which appears to improve plant growth is the effluent ponding to a level just below the stored sludge layer. At the current regime, the effluent is then allowed to flow off every 2-6 days, the main criterion being to avoid anaerobicity in the root zone.

Table 1 shows the average values of percolate quality achieved to date. Post-treatment of the percolate will be required for most discharge situations in spite of the fact that high removal efficiencies are attained in the reed beds.

Table 1 Reed Bed Performance With Respect to Percolate Quality

		Raw septage mg/l	**Percolate mg/l**	**% Removal**
SS	mg/l	10, - 20,000	700	> 90
COD_{tot}	mg/l	14,000	1,500	95
$COD_{filt.}$	mg/l	470	200	57
TKN	mg/l	1,200	150	90

Table 2 Reviewed Publications

Ref.	Title	Reference
1	Klärschlammvererdung mit Hilfe von Helophyten (in German) (Sludge Humification Using Helophytes)	Reinhofer M./Berghold H. (1994). Korrespondenz Abwasser, 8/94, pp.1302-1305.
2	Klärschlammvererdung in bepflanzten Schlammtrockenbeeten (in German) (Sludge Humification in planted drying beds)	Mori K. (1996). MORITEC Internal document.
3	Sludge Dewatering and Mineralisation in Reed Bed Systems	Nielsen S. M. (1990). In Proceedings - Constructed Wetlands in Water Pollution, Pergamon Press.
4	Use of Phragmites in Sewage Sludge Treatment	Hofmann K. (1990). In Proceedings - Constructed Wetlands in Water Pollution, Pergamon Press.
5	Use of Reed Beds for Dewatering Sludge in the USA	Kim B.J./ Cardenas R. (1990). In Proceedings - Constructed Wetlands in Water Pollution, Pergamon Press.
6	Klärschlammvererdung auf zwei ostfriesischen Inseln (in German) (Sludge humification on two East Frisian Islands)	Ingenieurgesellschaft für Umweltplanung (INFU) (1995). Internal document.
7	A Study of Activated Sludge Dewatering in Experimental Reed-Planted or Unplanted Sludge Drying Beds	Liénard A. / Duchène Ph./ Gorini D. (1994). In: Proceedings, 4th IAWQ Int. Specialist Conference on Wetland Systems for Water Pollution Control, Guangzhou, P.R. China, 6-10 Nov..
8	Der Einsatz von Pflanzen zur Klärschlamm-Entwässerung (in German) (Using plants for sludge dewatering)	Zacher B. / Strauch D. (1987). Korrespondenz Abwasser 9/87, pp. 922-930.
9	Klärschlammvererdung in Schilfbecken Ergebn. und Erkenntn. eines praxisbez. Pilotprojektes (in German) (Sludge humification using reed beds: results of a pilot project)	Scholl W. /Wurster H. /Thalmann A. (1985). Korrespondenz Abwasser 5/85, pp. 386-395.

Table 1 Summary of Reed Bed Performance Data for Sludge Dewatering/Drying

Ref. no. (see Table 2)	Size of one bed (m^2)	No. of drying beds	Pop'n Equiv.	Comparison w. unplanted bed ?	Bottom ventilation ?	Kind of treated sludge	TS in Loaded Sludge, g/l	Sludge vol. Applied m3/m2·year	Applic. interval	TS loading Rate Kg TS/m2,yr	TS Attained %
1	80	2	10,000	no	no	aerobically stabilised	2.8	4.4	weekly 4-7cm	120	33.5
2	-	-	-	no	no	not specified	-	5.2	-	75	45
3	100	4	-	no	yes	aerob stab. anaerob dig.	0.7 3.5	1.9 -	- -	-	20
4	60	4	-	yes	no	aerob. stab.	-	-	fort-nightly	20-30 SS	40
5	37-279 (survey results)	1 to 10	- -	no no	no no	anaerobically digested aerob. stab.	1 to 10 0.5 to 5	0.41-0.82 0.73-3.38	- -	13-74 29-106	40-50
6	-		50,000	no	no	?	-8	-	-	-	40-50
7	20	3	exp. beds	yes	yes	aerob. stab.	0.3	13-15	daily	55	15
8	46	4		yes	no	aerob stab.	1.5	1.5	weekly	25	-
9	66	2		no	yes	excess activated sludge	8	0.45	weekly	100	40

Remarks:

Ref. No

- 1 Water balance evaporation/drainage 50:50; average evapotranspiration: 11mm/d
- 2 40 % org. N elimination in the drainage; average evapotranspiration: 12-20 mm/day
- 5 Survey of 28 beds in the US
- 6 Average evapotranspiration: 5 mm/d

TS - Total Solids

SS - Suspended solids