Planted Drying Beds for Faecal Sludge Treatment: Lessons Learned Through Scaling Up in Dakar, Senegal

Experiments have revealed that planted drying beds are a promising technology for faecal sludge treatment in tropical climates. However, most of the current knowledge has been developed through lab-scale experiments. Full-scale planted drying beds have been in operation since 2008 at the Cambérène treatment facility in Dakar, Senegal. Monitoring and evaluation have resulted in important conclusions for scaling up and managing the critical start-up phase of this eco-technology.

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Introduction

Planted drying beds for faecal sludge treatment in tropical climates are a promising technology thanks to their improved loading performance, resistance to clogging and resulting stabilised end product that can be used directly as a soil conditioner and fertiliser. The recommended loading rate for tropical climates is 200 kg/m^2/year of total solids (TS), applied in a loading cycle of one day per week, with six days for percolation and drying. This provides the plants with optimum moisture levels [1].

The start-up period for planted drying beds is critical in both temperate and tropical climates [2]. However, start-up guidelines for tropical climates are lacking or incomplete. Previous studies have only been conducted at the pilot-scale level in tropical climates with high rainfall, and were mainly focused on the treatment performance of the beds and not on overall plant health [3], [1]. The start-up period is especially important in drier tropical climates as it allows plants to acclimatise and ensures plant health and survival. Moisture stress, together with the high salt conditions, resulting from the application of faecal sludge, creates harsh conditions for plant growth.

Methodology and objectives

The performance of pilot- and full-scale planted drying beds at the Cambérène treatment facility (Dakar, Senegal) has been monitored since 2008. The full-scale beds have a surface area of 130 m^2 and the pilot-scale 4 m^2.

Three species of plants and varying loading rates were monitored and evaluated, with a focus on general plant growth (colour, wilting, density, size), sludge layer accumulation rate and composition, similar to the study described by Nielsen [4].

The study resulted in recommendations for the scaling up of planted drying beds and progressive sludge loading during the start-up period to ensure plant acclimatisation, density development and improved operation.

Planting

Based on pilot- and full-scale results, *Echinochloa pyramidalis* (Antelope grass) was selected for the planted drying beds, as it was more robust than *Typha australis* or *Phragmites vulgaris* during the start-up period. At the time of planting, the stems were 20 cm high and the roots had developed at least two nodes. The plants were planted at a depth of 5 cm with nine stems per m^2 to ensure rapid growth during start-up. The beds were fed supplemental water immediately prior to and following planting.

Acclimatisation phase

During the start-up period, plants were watered daily with low-strength sludge (< 2 g TS/L) or wastewater (Photo 1). Preliminary tests with less frequent watering regimes resulted in a high plant mortality, as the sand beds dried out quickly without a layer of sludge on the bed surface. The sludge layer that accumulates helps to retain moisture. Use of higher-strength sludge led to significant plant wilting, which suggests the influence of salinity as previously observed by Kengne et al. [5]. Tests were also conducted with intermediate watering regimes with the outlet pipe blocked in order for ponding to occur at the surface. However, this required perfectly watertight beds. The water also needed to be flushed and replaced frequently to prevent salt concentrations from accumulating due to water evaporation.

During the dry season, the plants required a one-month acclimatisation period to ensure adequate moisture and to avoid salt stress. It is recommended that the start-up phase be implemented during the rainy season to reduce water stress and create an environment more similar to native growth conditions. The acclimatisation period should continue until the plants no longer show signs of stress (e.g. yellowish colour), and until a thin layer of sludge is observed on the bed surface.

Gradual loading rate increase

A gradual increase in loading rates is required during transition from the plants' acclimatisation period to full loading rates. This is necessary to avoid plant stress and to develop adequate plant density.

Plant growth was monitored during a gradual increase in loading rates from 50 to 200 kg/m^2/year every two weeks over a period of 3–4 months with at least two applications per week.

Plant development was highly heterogeneous and seemed dependent on sludge distribution on the bed surface. The plants showed signs of wilting in areas that were lightly loaded and/or sometimes in areas that were heavily loaded (Photo 2).

Faecal sludge distribution on the bed surface

Hydraulic distribution is critical during loading of the drying beds, as the faecal sludge needs to be spread evenly on the entire bed surface to allow good plant growth.

During the start-up trial period, two different methods were evaluated: the first pumped the sludge from a holding tank where trucks discharge sludge; the second directly applied the sludge from the trucks.

Direct discharge from the trucks worked well and was effective in achieving an

Photo 1: t = 0. Planting after sand watering.

Photo 2: Progressive increase in loading rate. Plant growth disparity.

Photo 3: t + 5 months. A robust development is achieved.

Photo 4: 10 cm sludge layer with 45 % DM content.

Photo 5: Manual and mobile screening grid.

even hydraulic distribution. However, it involved a more time-consuming management strategy to ensure that sludge was not loaded continually onto the same location. It also required a portable and mobile screening device (e. g. Photo 5). The sludge discharge points should be taken into consideration and planned in the initial bed design. Though this method is effective, it requires more time and managerial skill.

The results of the pumping tests revealed that multiple pipe outlets for each bed are necessary to ensure even hydraulic bed loading. This is also critical during the start-up period when the faecal sludge is less concentrated and infiltrates more rapidly. The uneven hydraulic distribution led to irreversible plant wilting after about ten days during the dry season.

A smooth and levelled bed surface is important to ensure even hydraulic loading and adequate moisture during the start-up phase.

Summarised results

Twenty-one weeks following planting in the full-scale drying beds, average plant density totalled 1000 stems/m^2, and the plant stem had grown from 25 cm to 3 m (Photo 3).

At the end of the gradual loading phase, the average thickness of the sludge layer amounted to 10 cm. *Echinochloa* roots were growing throughout the sludge layer (Photo 4). Just prior to weekly loadings, the average sludge dryness amounted to 45 % dry matter (DM) content and varied according to layer thickness (less dry with thicker sludge).

During the five-month testing period, the average loading rate amounted to 80 kg/m^2/year.

Qualitative data revealed that mosquitoes develop more in planted than in unplanted drying beds, yet still much less than in the adjacent activated sludge wastewater treatment facility. This phenomenon may be attributed to the intermittent sludge loading rate leading to less frequent periods with higher moisture.

Conclusions

Sludge loading frequency and TS concentration are two important factors to account for during acclimatisation. This poses a difficulty, as TS concentration of faecal sludge varies greatly from one truck to another and is not measured in advance under normal operating conditions.

This study reveals that planted drying beds are a viable faecal sludge treatment option that can be implemented on a large scale in dry climates. Constraints related to the starting phase (for instance low-strength sludge, even distribution) should be considered in bed design and integrated into operators' training and planning phase during the first year.

It can also be concluded that *Echinochloa pyramidalis* is a robust plant for use in planted drying beds, even during the critical acclimatisation phase in the start-up period.

Visual indicators, including plant stress (e. g. yellowish colour, slow growth rate), as well as sludge amount and dryness on the drying bed surface can be used to control application rates with the gradual loading method.

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