Technico-Financial Optimisation of Unplanted Drying Beds

Faecal sludge treatment is a key factor for controlling and reducing the impact of faecal matter from on-site sanitation systems used by more than 80 % of the African population. Yet, technical recommendations are still scarce and inaccurate. Since 2006, a treatment system using unplanted drying beds has been implemented and operated by ONAS (The National Sanitation Utility) in Dakar, Senegal. It offers a unique opportunity to formulate general recommendations for technical design and budgeting. Pierre-Henri Dodane, Mbaye Mbéguéré, Doulaye Koné

Faecal sludge treatment is considered an essential sanitation step in developing countries [1]. Its implementation requires, like any other sanitation infrastructure, appropriate design guidelines as well as a sound knowledge of investment and operating costs. The limited number of operational treatment plants certainly illustrates the current lack of these aspects.

With a capacity of 100 m^3/day and 700 kg TS/day, the faecal sludge treatment plant of Cambérène (Dakar, Senegal), combining settling/thickening tank and unplanted drying beds, is operational since 2006. This installation offers the opportunity to improve the state-of-the-art of unplanted drying beds under real-life conditions. Daily measurements of the pollutant fluxes were conducted at the inlet and outlets of the two-step treatment. Continuous monitoring of sludge characteristics (concentration, dry matter content) in the thickening tank and on the drying beds was conducted during several treatment cycles. Drying beds efficiency fed directly with raw sludge was also measured (bypassing the primary treatment tank).

Moreover, breakdown of the investment and operating costs has been established on the basis of bills of quantities of plant works and accounting figures for 2007. These elements allow to determine the conditions required for a balanced operating account. They are also used to assess the costs for the directly fed unplanted drying beds.

Lessons learned from plant performance

As regards the actually received sludge loads, plant performance (Fig. 1) reveals a hydraulic surcharge of 340 % and a loading surcharge of 240 %. This reveals an inaccuracy in previous studies that led to serious problems. The sludge volumes to be treated were underestimated and the sludge concentrations overestimated by 40 %.

Based on the previous raw sludge feeding experiments, the drying beds were conceived to receive 200 kg TS/m^2/year [2]. When feeding thickened sludge (60 g/L), the measured load amounts to 400 kg TS/m^2/year for a 50 % dry matter content after one-month drying period. However, the operator is currently running the plant at 300 kg TS/m^2/year, thus allowing for an additional bed-scrubbing period of about ten days. Moreover, since thickened sludge dewatering was observed to occur by evaporation, the drained free water is negligible.

Operating tasks and financial optimisation potential

Allocation of the operational tasks and their costs are assessed for a nominal condition. The accounting statement reveals (Fig. 2) that the administration costs (collecting disposal fees and organising subcontracting) and the overhead costs (cleaning of the facility and surrounding area, gardening) are more important than the technical tasks.

Based on the current state of technology, cleaning of the primary treatment step presents the main cost factor for the combined thickening tank and unplanted drying beds system. Moreover, the energy costs for sludge pumping onto the beds are insignificant compared to the other expenses.

The treatment plants also generate revenue. The treated sludge is in fact reused as soil amendment in urban landscaping. Its current sales price of 0.8 USD/m^3 biosolids (0.002 USD/kg) does not yield important revenues. The income generated could nonetheless have a significant motivating effect on the operator to increase sludge production and, thus, improve treatment efficiency. The actual sales price of 0.002 USD/kg, associated with an 80 % yield in relation to TS, allows,

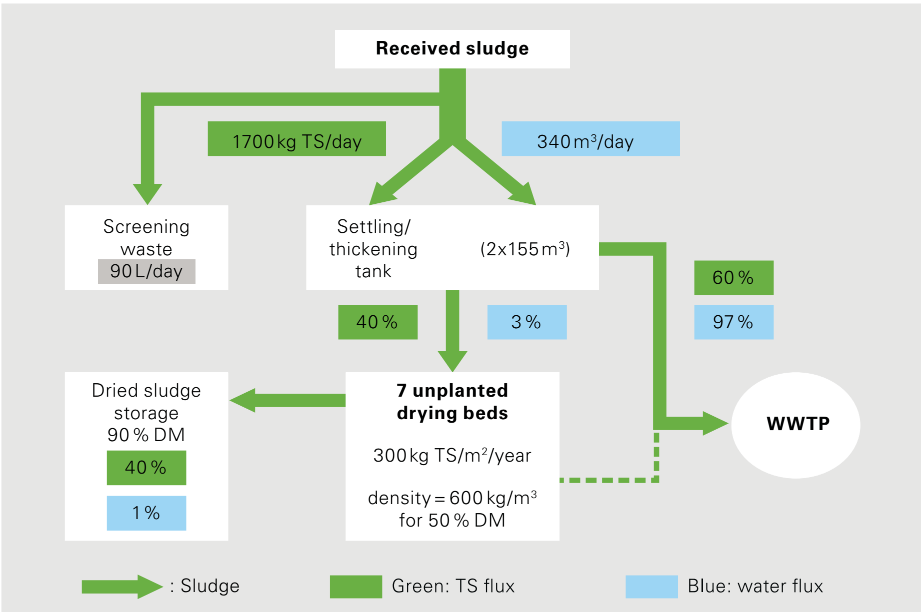

Figure 1: Material flux scheme at Cambérène (Dakar, Senegal), faecal sludge treatment plant in 2007.

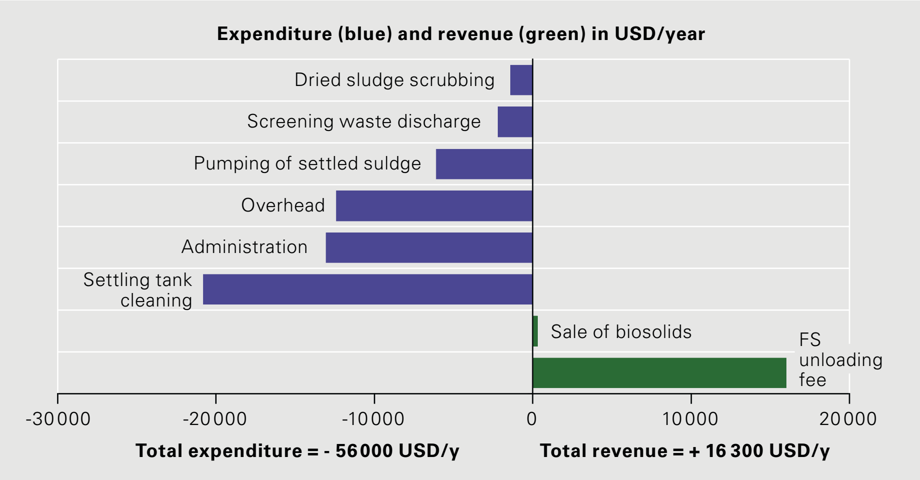

Figure 2: Management, operation and maintenance costs at nominal loading of the faecal sludge treatment plant combining settling/thickening tank and unplanted drying beds in Dakar.
Administration costs = Salaries and supplies
Overhead costs = Security, water & electricity, area cleaning
Settling tank cleaning = Scrubbing of settling tank using a high pressure truck

via the sale of biosolids, to offset the direct production costs of biosolids (pumping and scrubbing) and turn these into a source of income. Market research will soon be conducted in Dakar to optimise the sales strategy of the operator. According to Vodounhessi [3], a 50-kg compost bag is sold at 0.03 USD/kg in Kumasi (Ghana), a price 15 times higher than the one for biosolids in Dakar.

The unloading fee of 0.4 USD/m^3 sludge collected from the emptying companies generates important revenues. An increase of this fee to 1.4 USD/m^3 would allow to offset the operating costs of the treatment plant. This corresponds to a 20 % increase in the average household pit emptying fee (from USD 50 to 60) [4], as currently practised in the serviced area.

With an estimated investment cost of UDS 665 000, the net present value[1] of the treatment plant is offset by a 2.7 USD/m^3 unloading fee. This amount corresponds to an average household emptying fee of USD 73 or to a 50 % increase. This would seem daunting within the current social and economic context and lead to finding different pricing mechanisms.

Performance of raw sludge-fed drying beds

Measurements conducted on full-scale drying beds fed with raw sludge confirm the data reported by Heinss [5] in Thailand and Ghana, i. e. a 95 % efficiency as a function of the SS or 85 % as a function of the TS with loading rates between 100 and 200 kg TS/m^2/year. 50 % dewatering occurs by infiltration through the filter material. Improvement of the screening step and optimisation of the hydraulic distribution are recommended for a uniform feed over the entire surface of the beds.

With or without settling/thickening tank?

As regards the necessary infrastructure, the thickened sludge feeding option requires a primary treatment step, but allows smaller drying areas, thus contributing to lower the investment costs (Fig. 3).

However, based on the present state of technology, maintenance costs of the primary settling tank render operation of the thickened sludge option less attractive. Indeed, although the investment costs for the combined option are lower than for the raw faecal sludge-fed option (552 000 compared to 699 000 USD), its operating costs (56 000 USD/year) remain very high, about 38 % more expensive.

As regards the treatment quality level, the settling/thickening tank combination is less effective. An increased efficiency presupposes an improved hydraulic system with particular focus on the required storage volume of the thickened sludge.

At the operating level, cleaning operation of the primary treatment step proves to be a major constraint requiring systematic operation skills from the operator.

At the raw sludge feeding level, 50 % of the sludge is dewatered by infiltration of the free water through the sand filter material. This type of sludge feeding therefore requires use of a reasonably good sand quality, which will possibly have to be more frequently replaced than the thickened sludge option.

It can be concluded that state-of-the-art installation of a settling/thickening plant seems pertinent only if large surface drying beds pose problems, such as in places where the admissible direct feeding loads are low (low-strength raw sludge or in regions with considerable precipitation).

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[1]At an assumed 5 % inflation rate and 20-year service life of the plant.

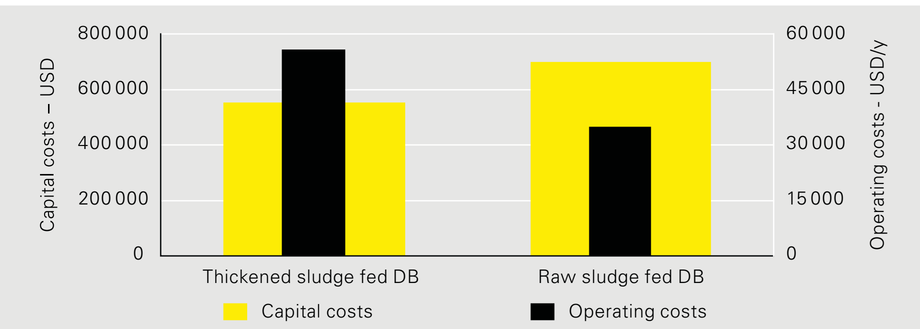

Figure 3: Capital and operating costs of the two feeding options (for a 100 m^3/d plant; raw sludge-fed drying beds (DB) designed for 100 kg TS/m^3/y; thickened sludge-fed drying beds designed for 300 kg TS/m^3/y).

[1] United Nations (2005): The Millennium Development Goals Report.
[2] Cofie, O.O., et al. (2006): Solid-liquid separation of faecal sludge using drying beds in Ghana: Implications for nutrient recycling in urban agriculture. Water Research, 40(1): p. 75–82.
[3] Vodounhessi, A., von Munch, E. (2006): Financial challenges to making faecal sludge management an integrated part of the ecosan approach. Case Study of Kumasi, Ghana. Water Practice and Technology, 1(2).
[4] Gning, J.B. (2008): Evaluation socio-économique de la filière des boues de vidange dans la région de Dakar, Master degree thesis, Institut Supérieur de l'Environnement, Dakar, Senegal.
[5] Heinss, U., Larmie, S.A. and Strauss, M. (1998): Solids Separation and Pond Systems for the Treatment of Faecal Sludges in the Tropics. Eawag/Sandec, Dübendorf, Switzerland, p. 17.