Technology Transfer – Forage Plants Used in Faecal Sludge Dewatering Beds in Sub-Saharan Africa

In collaboration with the Asian Institute of Technology (AIT), Bangkok, Eawag has previously demonstrated that constructed wetlands, especially in Thailand, offer a viable solution for the treatment of faecal sludge. However, since the characteristics of sludge vary widely from one region to another, appropriate indigenous plants had to be identified so as to ensure successful operation of these facilities. Doulaye Koné[1] and Ives Kengne[2]

In urban areas of developing countries, especially in those of sub-Saharan Africa, on-site sanitation systems predominate over sewered alternatives. Since area-wide sewerage is not affordable, they will play an important role in excreta disposal for decades to come. Unfortunately, the gap in knowledge on low-cost and efficient treatment options is one of the main factors leading to the uncontrolled discharge of untreated faecal sludges (FS) into drains, water bodies and open land spaces. This improper practice is at odds with ecological principles, as the faecal sludge contains high concentrations of pathogens and pollutants impairing public health and the aquatic environment. In Cameroon as in other sub-Saharan countries, eutrophication of lakes and streams is significant, and diseases linked to poor water and sanitation management remain burning issues. Faecal sludges contain extremely high pathogen concentrations responsible for the elevated endemic rate of excreta-related diseases, especially among children [1].

Development of efficient and low-cost methods for separation of the solid and liquid fraction is a key requirement for sustainable management of faecal sludge. This step is essential to avoid hygienic problems and allow the recovery of resources or energy [2, 3]. If well managed, vertical-flow constructed wetlands (VFCW) could be efficiently used to tackle the lack of treatment options in Africa.

[1] Eawag/Sandec
[2] University of Yaoundé I, Department of Plant Biology, Water Research Unit
The authors acknowledge the support received from the **Swiss National Centre of Competence in Research (NCCR) North–South:** Research Partnerships for Mitigating Syndromes of Global Change, co-funded by the Swiss National Science Foundation (SNF) and the Swiss Agency for Development and Cooperation (SDC). Additional support was also provided by the **International Foundation for Science (IFS, Sweden, grant W4115/1).**
Contact: doulaye.kone@eawag.ch

Vegetation and operation

Experiments, conducted on a yard-scale at the University of Yaoundé I, Cameroon, over the last three years, aim at assessing the effects of FS application on the performance of the system in order to determine the factors likely to affect its sustainability (Photo 1). Faecal sludges were applied weekly on beds vegetated either with antelope grass *(Echinochloa pyramidalis)* or papyrus *(Cyperus papyrus)*. This allows the solid phase to be retained on the surface of the filtering matrix, where it undergoes mineralisation, while the liquid phase is drained out of the system for further treatment. Prior to sludge application, young shoots or fragments of *E. pyramidalis* stems with at least one internode and old fragments of rhizomes of *C. papyrus*, weighing 300 to 350 g (fresh weight), were allowed to grow for six weeks in a media saturated with raw domestic wastewater.

System performance

For six months, the sludge loads were gradually increased by a mixture of FS from traditional pit latrines, septic tanks and public toilets delivered by emptying trucks to reach nominal solid loading rates of 100, 200 and 300 kg TS (total solids)/m^2/yr. Faecal sludges, stored in two tanks (1 cm^2 each), were stirred prior to each loading. This gradual SLR (sludge loading rate) increase was performed to avoid withering of the macrophytes due to the application of rapid and large amounts of pollutants, and to master all the adverse conditions that could hamper the experiments. The beds were subsequently fed at nominal loading rates for another six months at one application per week, except in E. pyramidalis beds whose FS application was interrupted for one month during plant harvesting and regrowth. SLRs were derived from TS content of the raw sludge prior to each application. Since the TS contents were constant, the hydraulic sludge load applied to the beds was determined each time according to the following equation:

$$\text{Hydraulic load (l)} = \frac{C1}{C2} \times \frac{1}{52}$$

with: C1 = annual loading rate (kg TS/m^2/yr)
C2 = TS content of each newly delivered raw FS by the mechanical emptiers (kg/L)

Based on the results obtained, both indigenous plants were found suitable for dewatering of highly concentrated FS in tropical regions at 100 kg TS/m^2/yr. Indeed,

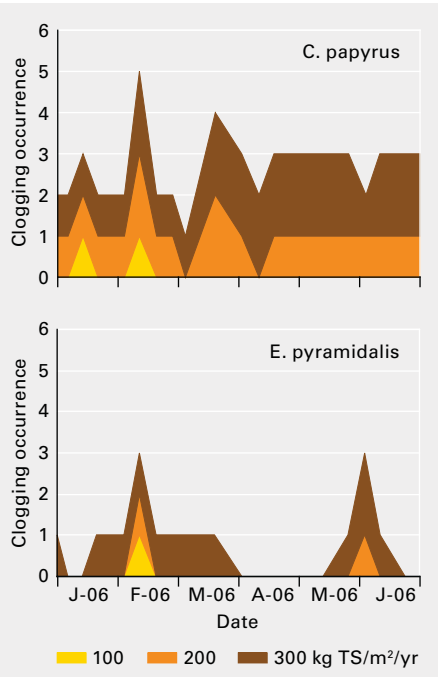

Figure 1: Occurrence of clogging events in the different beds as a function of the solid loading rates applied.

Sandec

Photo 1: Pilot beds of the VFCW developed for the FS dewatering study in sub-Saharan countries.

bed clogging, the main operational problem encountered in such a system, rarely occurred at this loading rate (Fig. 1). The average dry matter content for this SLR amounts to ≥ 30 % prior to each weekly application. However, at ≥ 200 kg TS/m^2/yr loading rate, clogging occurrence was higher in the *C. papyrus* beds than in those of *E. pyramidalis* (Fig. 1). These results contrast with the operational loading rates of less than 80 kg TS/m^2/yr generally applied in Europe and North America [4, 5], but lie within the range of previous work conducted in Thailand [6]. Pollutant removal efficiencies, based on average differences in input and output fluxes, revealed that beds vegetated either with *C. papyrus* or *E. pyramidalis* performed relatively well for solids, nutrients and organics, irrespective of the solid loading rates applied, with removal rates often higher than 78 % (Table 1). Despite these good removal efficiencies, the percolate concentration in pollutants remained relatively high. These percolates will need to undergo further treatment in constructed wetlands or waste stabilisation ponds to comply with reuse standards for unrestrictive agriculture.

A comparison of the growth characteristics of the plants in constructed and natural wetlands indicate that both macrophytes adapted and developed relatively well when loaded with faecal sludge. As a result of FS applications, shoot numbers at harvesting were two to four times higher in dewatering beds despite their short period of growth. Indeed, their density at harvesting varied from 260 to 400 and from 56 to 150 shoots/m^2 for *E. pyramidalis* and *C. papyrus*, respectively. Cross-surveys of their density in natural wetlands revealed an average of 89 and 24 shoots/m^2 for *E. pyramidalis* and *C. papyrus*, respectively. This significant growth rate can be attributed to the availability of sufficient nutrients, especially nitrogen and phosphorus contained in faecal sludge. An important development of the aerial parts of antelope grass was noted in the beds, thus requiring frequent harvests to allow a regrowth of new shoots from the rhizomes. Shoots growing from the rhizomes are expected to create enough tubular spaces during wing movement, and enhance FS dewatering rather than the growth of shoots from the aerial internodes. A potential annual harvest of at least 150 dry tons/ha of this highly prized local forage plant can be obtained if harvested thrice a year. Severe signs of plant wilting were nevertheless observed when loaded with FS exhibiting high salinity (15 mS/cm), such as those from public toilets, especially when the infiltration rate was slow. Monitoring of the effects of salinity on the growth and nutritive value of the antelope grass is currently being conducted.

Parameters	Average Removal Efficiencies
TVS	95.4 – 98.9
TS	90.2 – 95.8
NTK	89.5 – 95.7
NH4	77.6 – 90.9
COD	97.8 – 99.2

Table 1: Pollutant removal efficiencies of the VFCW for FS dewatering.

Extensive rhizome growth, as well as weak and slow culm regrowth were identified as potential factors limiting the use of *C. papyrus* for FS dewatering when loaded at more than 100 kg TS/m^2. Easy regrowth of *Echinochloa* shoots was observed from the fragments of stems remaining in the beds after the harvest of shoots by cuttings. As regards the operational conditions of the sludge treatment plant, this could be an interesting aspect pleading in favour of the use of this macrophyte. Indeed, easy regrowth could result in a time and money saving factor.

At least 2000 tons of fresh weight/ha/year biosolids can be accumulated on top of the beds. These biosolids can be considered as mature compost even without being subjected to the classic mesophilic, thermophilic and maturation phase for their stabilisation. Indeed, their C/N ratio was equal to 11, a value close to that generally found in mature composts. Furthermore, the humification indices obtained, especially the degree of polymerisation of 3.7, was higher than that found in other mature co-composts [7]. The biosolids also exhibited high nutrient contents with total N and P_2O_5 accounting for up to 2 and 2.3 % DM, respectively. Nevertheless, helminth eggs remained relatively higher (79 eggs/g TS on average) than the WHO guidelines of less than 1 helminth egg/g TS for unrestricted agricultural use, thus requiring longer storage periods or co-composting to obtain a safer product.

The findings of this research were considered an added value pleading for the development of this ecotechnology in Africa. Indeed, besides the primary goal of using the VFCW to tackle the lack of affordable FS treatment options, the harvested macrophytes (antelope grass) could be used as fodder for sheep and goats. The high mineral content of the produced biosolids could also serve as organic soil amendment, reduce the need for fertilisers by local farmers and generate funds to sustain the system if properly managed.

[1] World Health Organization (2006): Guidelines for the safe use of wastewater, excreta and greywater. Vol. 4, WHO, Geneva.

[2] Koné, D. (2007): Excreta and Wastewater Management Contributing to Cities' Economic Development. A Paradigm Shift. Sandec News, 2007. No. 8, 8–9.

[3] Koné, D. and Strauss, M. (2004): Low-cost options for treating faecal sludge (FS) in developing countries: challenges and performance. In: Proc. of 9th Int. Conf. on Wetland Systems held in Avignon, France, Sept. 26–Oct. 02. IWA & ASTEE, Vol. 1, 213–220.

[4] Kim, B.J. and Smith, D. (1997): Evaluation of sludge dewatering reed beds: A niche for small systems. Water Science and Technology, 35(6):21–28.

[5] Nielsen S. (2005): Sludge reed beds facilities – Operation and problems. Water Science and Technology, 51(9), 99–107.

[6] Koottatep, T., Surinkul, N., Polprasert, C., Kamal, A.S.M., Koné, D., Montangero, A., Heinss, U., and Strauss, M. (2005): Treatment of septage in constructed wetlands in tropical climate: lessons learnt from seven years of operation. Water Science & Technology 51(9), 119–126.

[7] Jouraiphy, A., Amir, S., El Gharous, M., Revel, J.-C., and Hafidi, M. (2005): Chemical and spectroscopic analysis of organic matter transformation during composting of sewage sludge and green plant waste. International Biodeterioration & Biodegradation 56(2):101–108.