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Natural systems treating greywater and blackwater on-site: Integrating treatment, reuse and landscaping

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ABSTRACT

With increasing water scarcity, reuse of water is becoming increasingly more attractive. Moreover, in large parts of the world centralized sewerage is still not available. In this paper we discuss a solution for treatment and reuse of source segregated domestic wastewater. The blackwater fraction is treated in an evapotranspiration tank (TEvap) system, whereas the greywater fraction is treated by a compact setup including a grease trap, sedimentation tank and two constructed wetlands. Results of both systems, obtained during a 400-days trial in a 9-person household in Campo Grande-MS, Brazil, are presented. Results show that it is possible to introduce an ecological and low-cost alternative to conventional septic tank solutions, to manage both greywater and blackwater at household level, enabling the development of green areas, improving microclimate and allowing for the reuse of grey water and the nutrients present in black water. The TEvap system was essentially maintenance free, but the constructed wetlands did require attention, to prevent clogging of subsystems.

1. Introduction

Domestic sewage, according to its origin and composition can be segregated into greywater, originating from sinks, shower, bath, kitchen and laundry activities (Morel and Diener, 2006) and blackwater, originating from the toilets (water, urine, faeces and toilet paper). The blackwater is what contains the main part of organic load and the pathogens, and even though produced in less volume as greywater, poses the biggest contamination risk, thus needing to be subject to adequate treatment.

Source segregation is an important step towards simplification of domestic sewage treatment, enabling reuse of greywater and treatment of blackwater in more compact and decentralized systems (Otterpohl, 2001). Greywater, representing about 70% of domestic sewage, has a great potential for reuse, due to its availability and its low content of pollutants, when compared to mixed sewage (Hernández Leal et al., 2007), specially concerning pathogens. When considering separate household and blackwater treatment, aspects like required area, construction costs, and operation and maintenance become matters of concern. The segregation of greywater and blackwater, no matter the environmental and health related benefits, is generally considered an extra expense at first sight. To stimulate domestic wastewater segregation, effective and low-cost systems should be developed or optimized.

Constructed wetlands (CWs) are considered an ecological treatment alternative and are the most common system used for decentralized greywater treatment (Paulo et al., 2009). The main reasons for their use are technical simplicity combined with high treatment capacity, good bacterial elimination rates, and high load flexibility, without the need of operational skills or energy (Platzer et al., 2007). More complex systems are necessary for blackwater treatment though, in order to reduce the pathogens, organic material and nutrients contained. The evapotranspiration tank (TEvap) is a simplified treatment system, which can be used for blackwater treatment at household level. Hardly any scientific publications are available about this kind of system though; so most information was obtained either from personal communications or unpublished results. The TEvap is a soil and plants based system, presented as an alternative for conventional treatment systems, consisting of an impermeable rectangular tank, filled with layers of different substrates and planted with fast growing, high water consumption plants. In literature, the zero discharge willow system (Gregersen and Brix, 2001), which is also an evapotranspiration-based system, is the most comparable technology. However, the novelty of the TEvap is the anaerobic chamber inside the tank where the wastewater is received. This chamber allows the solids to settle and to be partially digested, avoiding clogging of the tank media. Additionally, the tiles and gravel used (or any other coarse material) serve as filtering material and support for biofilm formation, which allows

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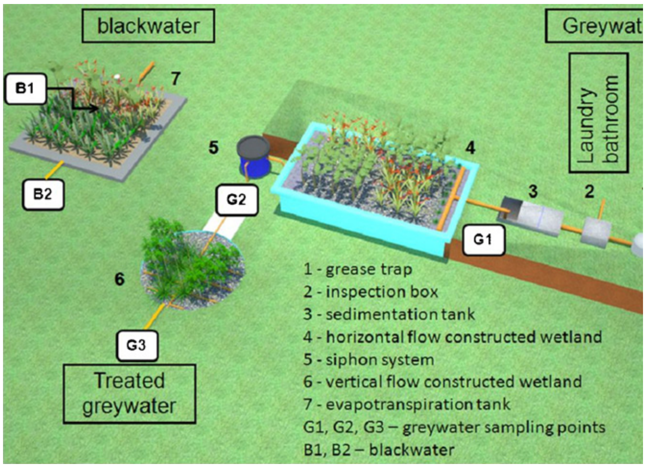

Fig. 1. Schematic drawing of the setup.

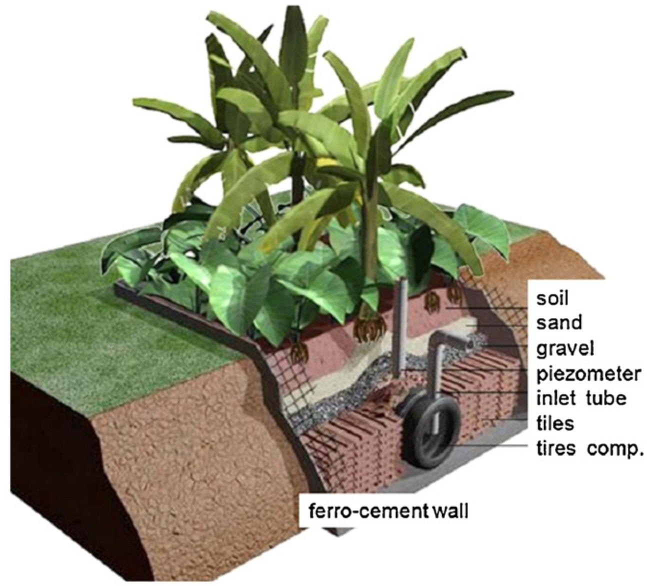

Fig. 2. Cross-sectional view of the evaporation tank (TEvap).

TEvap to be considered a 2 in 1 system. The blackwater enters the system through a reception chamber at the bottom of the tank, and then permeates through layers of bricks and rocks. In this lower part of the TEvap anaerobic digestion of the effluent occurs. When the water level in the system rises, the upper layers, of gravel and sand, also become flooded, until the water level reaches the top layer, of soil, from where capillary forces, wind and heat, as well as uptake by plants' roots causes elimination of the water by evapotranspiration, while the nutrients are removed by incorporation in the biomass of the plants. Except from few occasions of severe hydraulic overloading, no effluent leaves the system normally. Use of TEvaps at household level might avoid overloading sewage treatment works and reduce the pollutant load discharged into streams and rivers as a result of insufficient (partial) treatment of sewage. The use of planted systems in urban areas might also contribute to an increase in biodiversity, local production of food and ornamental plants and landscaping, as well as contribute to an improvement of the microclimate in neighbourhoods.

The aim of this work was to give a general view of a system, implemented at household level, for treating greywater (a hybrid constructed wetland system) and to introduce the evapotranspiration tank (TEvap) for blackwater. The focus here was to illustrate the complete system and give indications on the stability of a hybrid constructed wetland system with a non-common configuration and to present information on the behaviour of physico-chemical, bacteriological and parasitological parameters of an evapotranspiration tank.

2. Materials and methods

The system was implemented in a 9 persons-household, located in Campo Grande, MS, Brazil (54°39′W, 20°31′S). A schematic view of the complete system is shown in Fig. 1.

2.1. Blackwater system

The system conceived for blackwater treatment was an evaporation tank (TEvap). The design was based on unpublished information and personal communications from permaculture practitioners. The suggested size was 2 m^2 per person. The household had 2 bathrooms and the TEvap was built to attend 2 persons, although the number of persons using the bathrooms could vary seasonally. The TEvap was built with ferrocement, embedded 1 m deep into the soil, with 2 m width and 2 m length. The border was 10 cm above level field, to avoid flooding by rainwater. In the centre of the tank a linear compartment ("tube") was built of car tires, with spaces between them, so that the effluent could flow through. The inflowing blackwater was directed into this compartment, around which a layer of tiles (45 cm) was laid, above which the following layers were placed: coarse gravel (10 cm; ϕ from 4.8 to 9.5 mm; porosity of 0.50), sand (10 cm; ϕ from 0.15 to 4.75 mm) and soil (35 cm). In the top (soil) layer, plants and trees were planted: 3 banana trees (*Musa cavendishii*), distributed along the centreline of the tank, and *Xanthosoma sagittifolium* (popularly known as Taioba) and *Canna* species (popularly known as Beri) each occupying half of the remaining space. Fig. 2 shows the general layout of the tank. A piezometer, installed in the inlet part of the tank, permits access to the tires compartment, allowing for sampling (sampling point B1) and water level measurement. A water meter (multi-jet, Actaris®, Brazil) was installed to monitor the volume of water used daily for toilet flushing. Precipitation (rain), humidity and temperature were also monitored. An overflow was installed 18 cm below the soil surface, in the top layer. In case of overflow, i.e., when not all water entering the system as effluent or rainfall could be evaporated by the plants, the drained effluent would be directed towards an inspection box (sampling point B2) and then passed on to an infiltration trench. No operation and maintenance was required during the experimental period, except for trimming the plants in the rainy season.

In order to better understand the system dynamics related to physical–chemical and bacteriological aspects, 10 samples were collected from the evaporation tank, at points B1 and B2. Samples were taken over a period of 8 months. Parameters analysed were: pH, conductivity, turbidity, chloride, alkalinity, dissolved oxygen (DO), chemical and biochemical oxygen demand (COD and BOD), total and ammonium nitrogen (TN and NH_4–N), total phosphate (TP), total coliforms, and *Escherichia coli* (*E. coli*). Total and thermotolerant coliforms were analysed from Taioba leaves collected from inside and outside of the tank in the 7th month of the experiment. From the samples collected inside the tank, peeled stalks and whole plants, including leaves (washed in chlorine solution) were also analysed. In the 7th month of experiment, the following samples were taken for parasitological tests: faeces from the householders (toilet users), soil from inside and outside the tank, samples from