Potential of filter-vermicomposter for household wastewater pre-treatment and sludge sanitisation on site

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Abstract Septic tank systems have been widely used to separate and digest solid matter in the household wastewater for a long time. However, they contaminate groundwater with pathogens and nutrients and deprive agriculture of valuable nutrients and soil conditioner from human excreta. Compared with septic tank systems the filter–composter (Rottebehaelten), which usually consists of an underground monolithic concrete tank having two filter beds at its bottom or two filter bags that are hung side by side and used alternately at intervals of 6–12 months, is an efficient component for solid–liquid separation, pre-treatment and collection/storage of solid matter in household wastewater. The solids are retained and decompose in the filter bags or on the filter bed while the liquid filters through. However, because of the high moisture content of the retained solids decomposition is slow. Therefore, secondary treatment of the retained solids is required for sanitisation. The breakthrough was the combination of vermicomposting with the filter-composter system. Relatively dry and stable retained materials were obtained in the filter bags in about 3 months only. No secondary treatment is required as the human excreta will be converted to vermicastings, which are hygienically safe and can be reused as soil conditioner. Therefore, further development of the filter–composter with vermicomposting is worthwhile, especially the aspects of sanitisation of the faecal matter and its reuse as a soil conditioner.

Keywords Filter-composter; household wastewater; sludge sanitisation; vermicomposting

Introduction
The challenge in the 21st century remains to produce enough food to meet the needs of the increasing population while preserving and enhancing the natural resource. The extensive use of chemical fertiliser and overcropping cause land degradation. Also the production of chemical fertiliser is energy intensive, draws on very limited fossil resources and causes environmental problems. Therefore, nutrients and organic matter present in household wastewater should rather be reused instead of discharging them into the water body in order to minimise the production of mineral fertiliser as well as to avoid polluting the water body. Deficiencies of centralised wastewater management systems for nutrient recovery and public health have been well documented (Otterpohl et al., 1997). Even the advanced technologies, which are not affordable for most of the population, discharge large amounts of nutrients present in wastewater to the aquatic environment, where they are lost for ever and cause severe problems. Those nutrients, which are captured in sludge are often contaminated with heavy metals such as cadmium (Cd) and organic compounds such as PCB (polychlorinated biphenyl), which pose potential toxic risks to plants, animals and humans (Metcalfe and Eddy, 1991). Therefore, large amounts of sewage sludge are disposed of in landfills or incinerated. Only a smaller part is applied to agricultural land.

Compared to the centralised systems, decentralised wastewater management systems have many benefits (Wilderer, 2001; Otterpohl, 2001). The most important benefits are: there is no need to lay sewers for the transportation of sewage as in the centralised
treatment plant; construction, maintenance and operation of sewers are very costly parts of sanitation systems; and there is far less dilution of sewage than in the centralised system, which creates possibilities to reuse treated wastewater and nutrients. Therefore, decentralised wastewater treatment technologies will play a significant role, if they are low-cost and allow reuse. In this paper the limitations and potential of some of these technologies are discussed.

**Septic tank systems and their limitations**

Septic tank systems have been used to collect household wastewater, settle out the solids and anaerobically digest them to some extent for a long time. Most of the people in urban and peri-urban areas of Asia, Africa and Latin America and peri-urban areas of industrialised countries use septic tank systems. Even in the USA, 25 per cent of the houses are served by septic tanks (Crites and Tchobanoglous, 1998). However, they cause pollution, i.e. nutrients and pathogens seeping from these systems contaminate groundwater and nearby surface water. They cannot destroy pathogens, and deprive agriculture of valuable nutrients and soil conditioner from human excreta. Moreover, they require expensive tanker-trucks to pump and transport the sludge deposited at the bottom of the tank off site, often far away. In large cities, transportation distances are normally long, since suitable sites for treatment and disposal can mostly only be found at the outskirts of cities. Transportation of relatively small faecal sludge volumes (5–10 m³ per truck) through congested roads over long distances in large urban agglomerations is not suitable, neither from an economical nor from an ecological point of view (Montanero and Strauss, 2000).

It has to be noted that occasionally problems with broken septic tanks occur leading to infiltration of nearly untreated wastewater. It is reported that there are 22 million septic system sites in the USA issuing contaminants such as bacteria, viruses, nitrate, phosphate, chloride, and organic compounds into the environment (Jenkins, 1994). According to the EPA, states of the USA reported septic tanks as a source of groundwater contamination more than any other source, with 46 states citing septic systems as sources of groundwater pollution (Figure 1) and nine of them to be the primary source of groundwater contamination in their state.

![Number of states reporting source](https://iwaponline.com/wst/article-pdf/55/7/65/439561/65.pdf)

**Figure 1** Reported sources of groundwater contamination in the United States (Jenkins, 1994)
The incomplete anaerobic decomposition in septic tanks results in unpleasant odour that spreads into the surroundings. Many households often add chemicals into septic tanks to reduce odour. These chemicals have adverse effects on the decomposition process and ultimately on the environment (Gray, 1989).

Because of the above mentioned drawbacks septic tank systems are not a suitable component for household wastewater pre-treatment. Compared to the septic tank systems, the conventional filter-composter (Rottebehaelter) that has been increasingly applied in Germany, Austria and Switzerland for domestic wastewater pre-treatment is an efficient component for solid–liquid separation, pre-treatment (dewatering to a certain extent) and collection/storage of solid matters in household wastewater (Otterpohl, 2001; Gajurel et al., 2003a). In the following section its benefits and limitations are discussed.

**Conventional filter-composter systems and their benefits and limitations**

The conventional filter-composter consists of an underground monolithic concrete tank having two filter beds at its bottom or two filter bags that are hung side by side and used alternately at intervals of 6–12 months (see Figures 2 and 3).

It is watertight and structurally sound in order to avoid entering of extraneous groundwater into it and leakage of the filtrate into the groundwater, which would cause groundwater pollution. The top opening is covered by a prefabricated concrete slab and provided with ventilation so that air can enter. A shutter for changing the filter bag or emptying treated material, adding bulking agents such as straw, bark, etc. into the retained materials, inspection and cleaning is provided on the covering of the tank.

The influent is discharged into one of the two filter beds or filter bags retaining solid materials while draining the liquid. The principal role of the filter medium (filter bed or filter bag) is to cause a clean separation of particulate solids of the influent with no additional energy consumption. The filter medium is designed to recover a valuable solid product. Therefore, attempts are made to create a surface deposition of the solids in a recoverable form. When the influent is discharged into the filter bed or filter bag a filter cake is formed at the bottom. Its depth increases during the filtration due to deposition of solid material on its surface.

Results of the investigation in different conditions showed that the filter–composter system has a high potential for retaining and dewatering solid materials containing valuable nutrients and carbon. These retained materials are far more dewatered and less offensive than septic tank sludge that has to be treated in centralised treatment plants. However, the retained materials in the filter–composter still had a moisture content above 80% which is too high for composting of retained materials that have low structural stability (Gajurel et al., 2003b). Therefore, retained materials were only slightly decomposed and still contained pathogens.
The retained materials in the filter–composter, on the one hand have a high moisture content and, on the other hand have poor structure and a low carbon(C):nitrogen(N) ratio for composting. Therefore, the moisture content, structure and C:N ratio of retained materials should be maintained at an optimal level for composting. This can be achieved by adding straw or wood scrapes. Fibrous or bulky material such as straw or wood chips or wood scrapes can absorb relatively large quantities of water and still maintain their structural integrity and porosity as well as C:N ratio. Relatively dry and stable retained materials were obtained in the filter-composter by adding a sufficient amount of structural materials (barks or wood scrapes) after one year. However, temperature was low in the filter–composter, not more than 2–5°C above the ambient temperature. Therefore, secondary treatment is required in order to eliminate pathogens further. It is also not very realistic to expect users of this system to add structural material every couple of weeks as our research has shown.

The filter–composter system in combination with sorting toilets, which separate urine and faeces at source, is more effective to recover high levels of nutrients as urine contains most of the soluble nutrients (Otterpohl, 2001). It was found in the Lambertsmuehle pilot project that considerably large amounts of nutrients were separated from the human excreta with this combination of sorting toilets and faecal matter pre-treatment in the filter–composter (Wupperverband, 2003).

**Filter-vermicomposter and its potential**

Compared to composting by adding bark or wood scrapes in the retained materials, combination of vermicomposting as performed, for example, in Australia (Bajsa et al., 2003) with the filter–composter system is a highly efficient technique for processing the retained matters in the filter–composter. Vermicomposting is the process in which organic materials are converted into humus using earthworms that break down the organic materials. The worms maintain aerobic conditions in the mixture, ingest solids, convert a portion of the organics into worm biomass and into respiration products, and expel the remaining partially stabilised matter as discrete material (castings). The worms and the microorganisms act symbiotically to accelerate and enhance the decomposition of the organic matter (Loehr et al., 1988). The end product, a decomposed faecal matter (earthworm faeces or “castings”), consists of very finely structured, uniform, stable and aggregated particles of humified organic material, with excellent porosity, aeration
and water holding capacity, rich in available plant nutrients, hormones, enzymes and microbial populations (Appelhof, 1997). Thus this product is valuable, marketable and a superior plant growth medium (Aranda et al., 1999). Moreover, pathogens cannot survive the vermicomposting process (Werner and Cuevas, 1996; Edwards et al., 2002).

The processing of organic materials by worms occurs most rapidly at temperatures between 15°C and 25°C, at a moisture content of 70 to 90% and pH of 6.5–7.5 (Edwards, 1995). Outside these limits, worm activity and productivity, and thus the rate of waste processing, falls dramatically. The retained materials in the filter–composter offer an optimal range of moisture content, temperature and pH for worms. Results of the pilot scale experiments showed that relatively dry and stable retained materials can be obtained in the filter bags in about 3 months only, without adding structural material but including toilet paper at temperatures around 18 to 20°C. Also, operation is far easier as no structural material has to be added, only once every half year the flow has to be directed to the other filter and worms have to be added to the now idle bag.

Vermicomposting is an effective process to sanitise faecal materials. The final product is hygienically relatively safe as the human excreta will be converted to vermicastings. The typical analysis of the vermicast of wastewater sludge in Australia revealed that pathogens such as enteric viruses, parasite eggs and bacteria such as E. coli have been reduced to safe levels for use in the garden (Bajsa et al., 2003). However, there are very few data available so far. Therefore, further investigation is required to find out if pathogens can survive during the vermicomposting of retained materials in filter–composters.

Conclusion
In a well functioning filter–vermicomposter system, solid–liquid separation, sludge storage, dewatering and vermicomposting can be achieved in one unit with two chambers or bags. It can be implemented where people use flush toilets. Therefore, the septic tank systems can be replaced by the ecologically and hygienically advantageous filter–vermicomposter for household wastewater pre-treatment. In many cases there is no need to construct a new tank, since the existing tank can be modified, if the tank is watertight at least at the bottom where the filtrate is collected. The filter–vermicomposters are most beneficial when they are integrated in resources management sanitation (source control) for rural and peri-urban areas where local post treatment and reuse is possible. This has ecological, economic and hygienic benefits. Last but not least, the filter–vermicomposter system should be tested in pilot projects adapted to respective regional socio-economical conditions. For example, regional specific worms should be used that can easily adapt to the respective environment and are regionally available at low cost.

It has to be stated that because maintenance is a crucial factor, removal and handling of the retained material has to be improved. In addition, proper procedures of further treatment and usage should be established. The loss of water head does make it more appropriate for sites with a good gradient; otherwise an additional pump may be required to pump the filtrate collected at the bottom of the filter–vermicomposter for final treatment of the filtrate.

References


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