International Proceedings of Chemical, Biological and Environment Engineering
Volume of IPCBEE (2016)
DOI: 10.7763/IPCBEE. 2016. V94. 17

Performance Efficiency and Design Criteria of a Peat System for Treating Septic Tank Effluents

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Abstract. The performances of vertically loaded peat biofilters treating septic tank effluent were studied at laboratory scale. The average removal rates were 28, 17, 49, 18, 39, and 27% for magnesium, zinc, iron, phosphate, nitrate, and biological oxygen demand (BOD) respectively. With such removal rates, the final effluent will satisfy Kuwait's Environment Protection Authority (EPA) standards for reuse in agricultural irrigation. An interesting observation on the removal of iron, manganese, zinc, and phosphate is that they follow a breakthrough curve, unlike BOD and chemical oxygen demand (COD). This phenomenon suggests that peat tend to adsorb these species and that peat filter design is limited by the breakthrough behavior displayed by these elements. The design parameters were extracted as: the maximum hydraulic surface loading rates of 2.183 $m^3/m^2/d$, maximum BOD loading per module 3.13 g/d or 0.218 $kg/m^2/d$, breakthrough time in days according to phosphate 10–20 days.

Keywords: Insitu wastewater treatment, septic tank effluent reuse, peat filters.

1. Introduction

Reliance on treated wastewater has proved effective in irrigation in Kuwait [1], and the opportunity is available to out-scale the experience to reclaim wastewater generated at households and similar sources insitu, a subject that has received scanty attention so far. The major objective in doing so is to avail an inexpensive source of water for insitu reuse and inadvertently reduce the risks associated with wastewater disposal and improve water use efficiency.

The use of peat filters as an on-site secondary treatment system where land restricts treatment will result in necessary improvements to a greater number of septic tank systems. Peat is an abundant resource in Kuwait and can be used in low-cost, low-maintenance wastewater treatment systems for single houses and small facilities [2], [3]. Its ability to treat the wastewater from larger multiple house developments has not been widely reported in literature. All laboratory column studies have shown peat to be a potentially excellent filtration media for the treatment of septic tank effluent [2], [3]. Peat filters have been used for the treatment of a variety of waste streams including septic tank effluent (STE) [4]-[7]. Peat filters have been studied for their removal efficiencies related to metals [8], oily emulsions [9], pathogens and viruses [10], biochemical oxygen demand [4], [11], and odors [12].

Although peat filters provide an opportunity for on-site wastewater reuse, including both wastewater and gray water, they have only been studied for use as a tertiary treatment method for wastewaters for over 40 years [13], [14]. Most work on the treatment of settled sewage or septic tank wastewaters has been laboratory studies [2], [3]. Accordingly, peat filtration has been underused for domestic wastewater treatment, especially in areas where inadequate subsurface percolation exists and for small group systems.

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Peat biofiltration provides physical filtration combined with strong adsorption capabilities, and it also creates a microbial ecosystem similar to that found in other fixed film reactors [15]. Like other filter media, the peat fibres support a diverse range of both heterotrophic and autotrophic bacteria, mesofauna (Protozoa, Rotifera) and higher forms, in particular oligochates [16]. Peat filter media are available commercially in different forms, either as peat moss or more commonly as fibrous peat which is normally used for water and wastewater treatment. Milled peat is rarely used as it readily ponds [16]. Fibrous peat has been widely used as a filter medium in the treatment of a variety of wastewaters including sewage [17], combined sewer overflows [18], storm water and road runoff [19] and landfill leachate [17]. Fibrous peat is also employed in the on-site treatment of septic tank effluent [20] and has been used for the treatment of septic tank effluent from schools [21], [22].

The aim of this study is to evaluate the treatment efficiencies of vertical peat filters for the treatment of septic tank effluents and to extract peat filter design and operational parameters to facilitate scale-up and in-situ application.

2. Methodology

Peat holding columns were made of chemically nonreactive plexi-glass materials. A spray nozzle was used to spray water on top of the peat media. Plexi-glass tubes fitted at the bottom of the tank were used to drain out the seeped through (treated) wastewater. The inflow was from a domestic septic tank effluent line. This effluent gets primary treatment in an anaerobic septic tank.

Before its application to the media, the septic tank effluent (STE) was oxygenated by bubbling natural air through for 10 to 15 h. Fig. 1 shows the schematic of the assembled systems of the peat columns.

Multiple columns were used to operate more than one test simultaneously. The storage tank contained enough liquid capacity to provide for 24 h inflow to the operating columns. The inflow rate into the columns was on an average 31.44 l each day. The dimensions of the columns are shown in Fig. 1. The columns were a 12 x 12 cm square. However, the peat height of 1m and the height of 45 cm sand support under the peat were constant for all columns. Peat media of 10.6 kg was used for each column. The columns stood vertical to facilitate gravitational flow of liquid through the media.

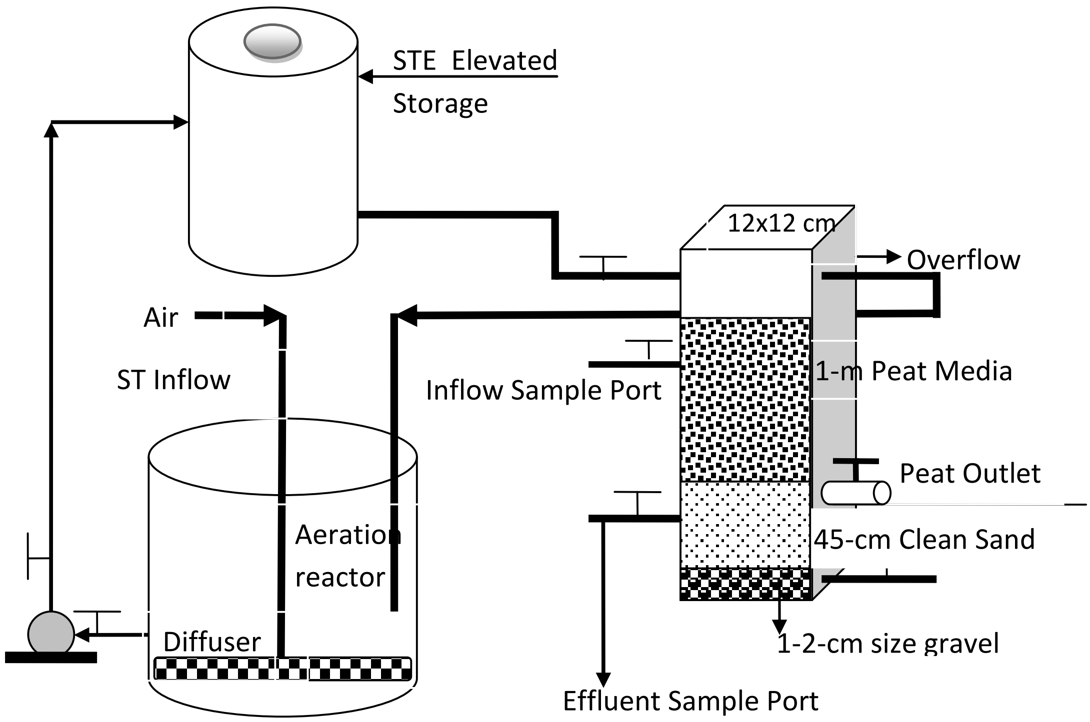

Fig. 1: Schematic diagram of peat adsorption and absorption system.

All laboratory tests were performed in the Sulaibiya Wastewater Laboratory at the Kuwait Institute for Scientific Research (KISR). The laboratory analyses were performed according to standard methods [23].

Initial soaking of the column takes 5-8 h. After the soaking period, effluent starts flowing out at the bottom exit of the column. An effluent sample was collected of the initial effluent flow and was analyzed in the laboratory for the concentration of the target specie. Every 24 h, the effluent was sampled and analyzed until it was found that the specie in the inflow and outflow were approximately at same level. When it occurred, it was assumed that the peat filter had reached a steady state and breakthrough had taken place.

3. Results and Discussion

Peat is partially fossilized plant material and is complex in its structure with lignin and cellulose as its major constituents. The lignin in particular bears polar functional groups such as alcohols, aldehydes, ketones, acids, phenolic hydroxides and esters that are involved in chemical bonding. This complex nature makes peat an excellent adsorbent for both metals and polar organic molecules, including volatile organic compounds, pesticides and oils [24]-[26]. The sorptive capacity of the medium is limited, so that the removal rate of recalcitrant organic and inert compounds will eventually decline as the adsorption sites become permanently used. Peat is also highly absorbent and is able to retain significant quantities of water, which ensures long retention time within the filters, enhancing microbial oxidation in particular [27].

3.1. Process Efficiency

As can be seen from Fig. 2, the removal rates of pollutants in the peat filter system shows an average reduction in the concentrations of pollutants ranging between 20 and 50%. The average removal rates were 28, 17, 49, 18, 39, and 27% for magnesium, zinc, iron, phosphate, nitrate, and biological oxygen demand (BOD) respectively. With such removal rates, the final effluent will satisfy Kuwait's Environment Protection Authority (KEPA) standards for reuse in agricultural irrigation [ref].

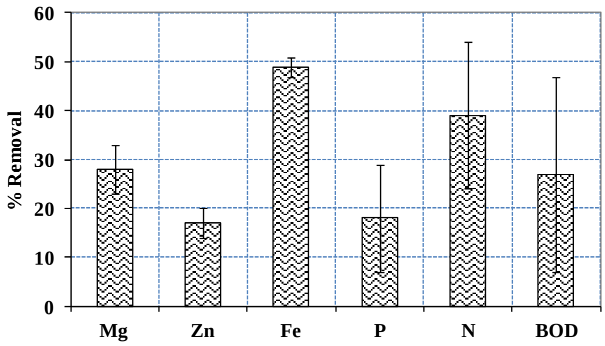

Fig. 2: Peat column removal efficiency for magnesium (Mg), zinc (Zn), iron (Fe), phosphorous (P as PO_4), nitrogen (N as NO_3), and 5-day biochemical oxygen demand (BOD).

As an indicator of filter media stability, the pH remained in the neutral range, although Fig. 3 shows minor reduction in effluent pH in the two experiments shown.

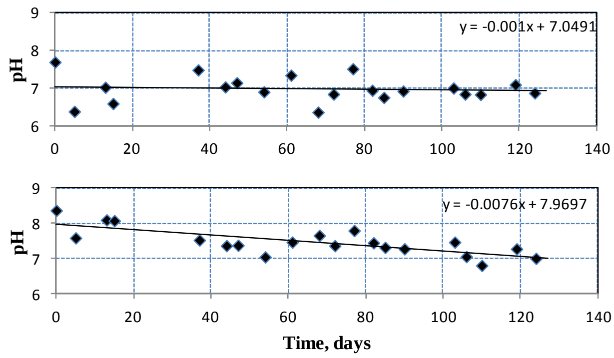

Fig. 3: Effluent pH Variation during two typical experiments.

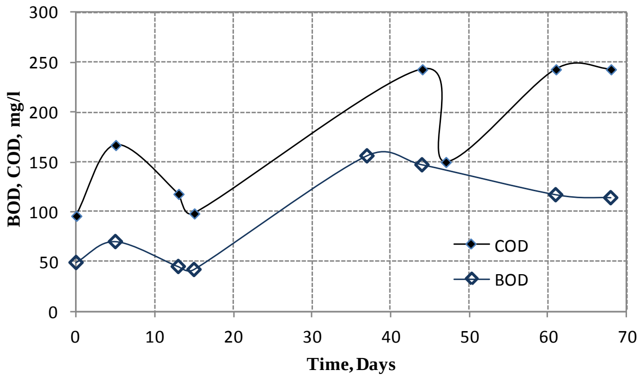

Fig. 4: BOD and COD effluent concentrations during column experiments.

The effluent BOD and chemical oxygen demand (COD) are shown in Fig. 4. Although the concentrations seem to oscillate, an overall average reduction has been observed, as reported in Fig. 2. A mixed action of adsorption, absorption, particle entrapment, and anaerobic bio-activity was expected to take place in the reduction of BOD_5 in the peat media. Hence, the reduction should not be exclusively accounted for adsorption and absorption in case of BOD removal in the column. Average, maximum, and minimum reductions in BOD were found to be 27, 51, and 8% respectively, with average liquid detention of 11 h in the column.

An interesting observation on the removal of iron, manganese, zinc and phosphate is that they follow a breakthrough curve, unlike BOD and COD, as shown in Fig. 5. This phenomenon suggests that peat tend to adsorb these species and that peat filter design should follow the breakthrough behavior displayed here in case these elements are of significance.

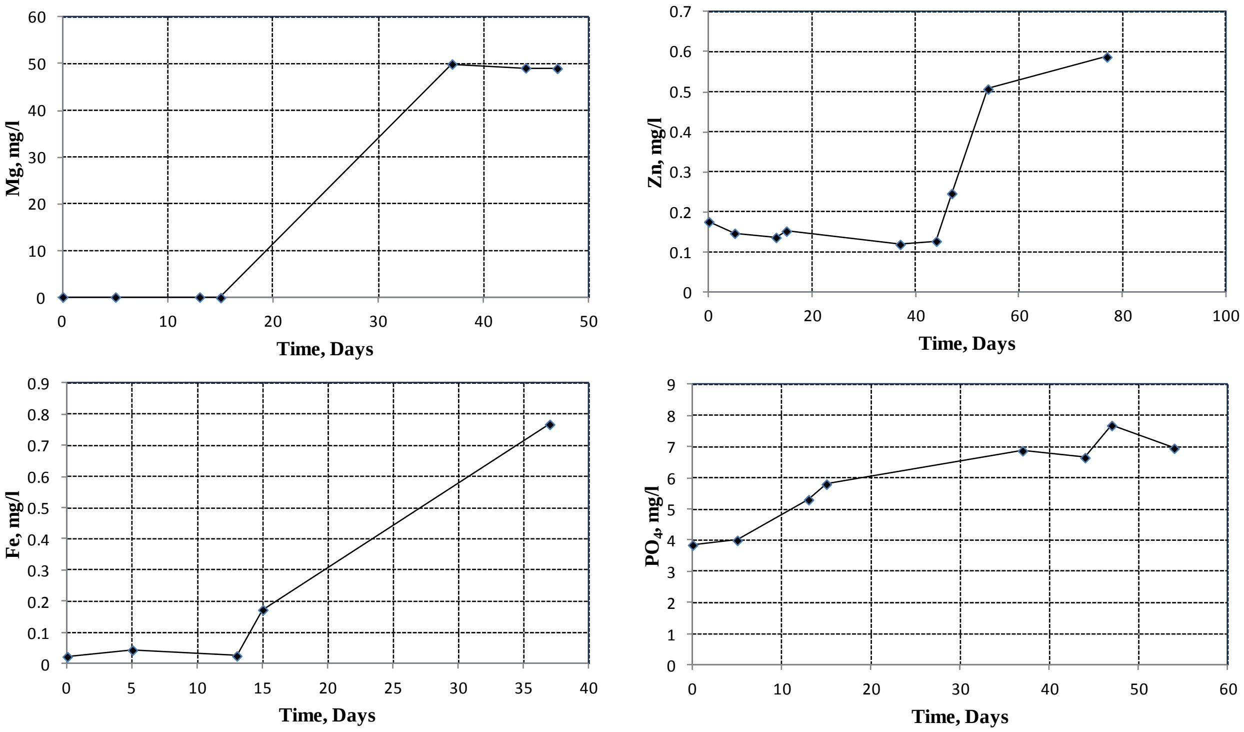

Fig. 5: Column breakthrough curves for Mg, Fe, Zn, and PO_4.

Kõiv et al. [17] recorded significantly higher BOD, COD, and nitrogen removal in vertical peat systems compared to horizontal systems, which is the case we investigated here. They also observed that, in both systems, the removal of total phosphorus declined after six months of operation; a result that can be foreseen from the effluent breakthrough behavior for few elements in our system (Fig. 5).

Ammonia and nitrate removal is shown in Fig. 6. As can be seen, their removal improves with time indicating the development of nitrification and denitrification processes in the peat filter.

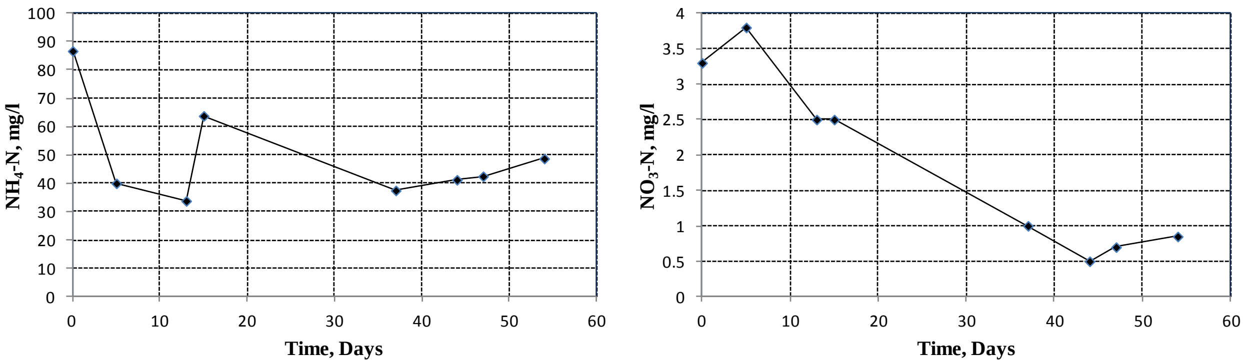

Fig. 6: Ammonia nitrogen and nitrate nitrogen effluent concentration during column experiments.

3.2. Design Parameters

On average it was possible to achieve the aforementioned removal rates using the columns as described in the methodology section. The main objective of treating the septic tank effluent was that their BOD and nutrients were higher than allowable limits for reuse, and therefore, when extracting design parameters, we considered the following three parameters only:

1. Maximum hydraulic surface loading rates of 2.183 $m^3/m^2/d$.
2. Maximum BOD loading per module 3.13 g/d or 0.218 $kg/m^2/d$.
3. Breakthrough time in days or hours according to phosphate 10–20 days.

4. Conclusions and Recommendations

From the results of this laboratory study, it is clear that peat filter can be used to refine septic tank effluents and enable reusing these effluents in-situ. Specific conclusions are as follows:

1. Peat filter efficiency is limited by the breakthrough behaviour displayed by Fe, Mg, Zn, and PO_4 removal curves.
2. The design parameters were extracted as: the maximum hydraulic surface loading rates of 2.183 $m^3/m^2/d$, maximum BOD loading per module 3.13 g/d or 0.218 $kg/m^2/d$, breakthrough time in days according to phosphate 10–20 days.

In order to further research the findings of this study, we recommend testing a pilot filter using the design parameters listed earlier and study its efficiency and economics.

5. Acknowledgements

The authors would like to thank the Kuwait Institute for Scientific Research (KISR) and the Kuwait Foundation for the Advancement of Sciences (KFAS) for funding the study.

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