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Evaluation of vermifiltration process using natural ingredients for effective wastewater treatment

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ABSTRACT

The present investigation focused on the evaluation of vermifiltration process using different natural ingredients as a media. The vermifilter was evaluated using different natural ingredients viz river bed material, wood coal, glass balls, mud balls and employing *Eisenia fetida* as an earthworm species. The complete study was carried out for 90 days. The average COD removal for different material i.e. river bed material, wood coal, glass balls and mud balls was found as 72.3, 64.6, 61.5 and 59.8% while average BOD removal was observed as 81.2, 74.5, 72.7 and 70.9%, for respective filter media. Similarly, the total suspended solid removal was observed as 75, 64, 59 and 55%, respectively for above mentioned different media. The river bed material revealed maximum reduction of indicator organisms like total coliform (3.6 ± 0.90 log unit), fecal coliform (3.4 ± 0.67 log unit), fecal streptococci and *Escherichia coli* (2.5 ± 0.51 log unit). At the end of the run vermicompost obtained through vermifiltration process as a byproduct were found to be rich in nitrate (31.2 ± 5.9 mg/L), phosphate (18.1 ± 4.6 mg/L) which could be exploited in sewage farming.

1. Introduction

The wastewater generation and its treatment has become an important health issue in the developing countries due to the inadequate treatment facilities (Singh et al., 2014). The discharge of untreated sewage in surface and sub-surface water courses is the most important source of contamination of water resources. Most of the population living in rural and urban areas of developing countries depends upon onsite systems for the treatment of domestic wastewater. The treatment systems that require relatively low costs, energy, and maintenance are preferable for the treatment of rural domestic wastewater (Sharma et al., 2014; Sharma and Kazmi, 2014). The numerous solutions have been adopted for the treatment of domestic wastewater specially in rural areas, including constructed wetlands, soil infiltration trenches, vegetation-based wastewater treatment and vermifiltration (Cuyk et al., 2001; Ham et al., 2007; Kaoru et al., 2010; Sinha et al., 2008). Among these technologies, the vermifiltration has represented its efficacy as other technologies are restricted to large occupying area (Kumar et al., 2014). In addition, the vermifiltration has the potential which separates wastewater solids by allowing wastewater to be gravity-fed over the filtration material. During vermifiltration process, the earthworm acts as bio-filter that reduces the unwanted organic waste from the wastewater (Manyuchi et al., 2013). It is the most promising economical method for treating point and diffused sources of domestic wastewater. In vermifilter, the earthworms stimulate and accelerate the microbial activity by increasing the population of soil microorganisms (Sinha et al., 2008).

The present study is concerned with evaluating the effect of different filter media as a vermifilter bed on the performance of vermifilter. For this purpose, the vermifiltration experiments were conducted using four different easily available and cost effective natural ingredients as a filter media. Xing et al., (2011) studied the health of earthworms and change in final characteristics of treated sludge from vermifiltration using ceramsite and quartz sand material. In their investigation ceramsite material was found to be relatively better media for the process with better characteristics of sewage sludge and health of earthworms. The earlier studies have also shown the use of converter slag–coal cinder as suitable media for vermifiltration process (Wang et al., 2010). However, their study was limited to the analysis of nutrients removal like ammonia nitrogen, phosphorous and organic contaminants. Despite recent advancement, vermifiltration is still in its infancy and needs a better media that could bridge different issues like

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pollutant removal, nutrient behavior and earthworm biomass (health of earthworms).

The present investigation deals with evaluation of effect of different filter media viz river bed material (VFR), wood coal (VFC), glass balls (VFG), mud balls (VFM) on vermifiltration. The effectiveness is monitored by the removal of various pollutants and pathogen removal.

2. Materials and methods

2.1. Experimental design

The experimental set up was placed in the solid waste laboratory of Civil Engineering Department, Indian Institute of Technology (IIT) Roorkee. For study, four sets of reactor were taken for evaluation purpose. Four different types of media were used as a vermifilter bed material like river bed material, wood coal, glass balls and mud ball in triplicates. Each reactor consisted of plastic container having cross sectional dimension of 250 mm × 200 mm and depth 300 mm. The top layer was 100 mm thick matured vermicompost (worm-bed). The second, third and fourth layers from top were taken as 6–8 mm studied media as mentioned in objective (50 mm thick), 2–4 mm sand (50 mm thick) and 10–12.5 mm gravel (50 mm thick) respectively. The specification and arrangement of different layer is illustrated in Table 1. Only second layer was changed with different media (river bed material, wood coal, glass balls and mud balls) in all reactors which acts as a vermifilter bed and plays a major role during treatment process. The porosity of different media is represented in Table 2. The wastewater was applied from the top side of reactors under gravity. To collect the wastewater a 350 l storage tank was kept at certain height from the reactor that act as an overhead tank. In addition to this for maintaining hydraulic loading rate at constant level a 30 l constant head tank was employed. For uniform distribution of wastewater, a 0.5 in. glass pipe with 1.5 mm diameter hole was provided as a distributer on the top side of vermifilter bed for uniform distribution. Fig. 1 shows the schematic view of lab-scale vermifilter. Each vermifilter was inoculated with 150 earthworms (*Eisenia fetida*) based on the stocking density of 10,000/cum of vermifilter bed. A constant hydraulic loading rate of wastewater, around 1.5 $m^3/m^2/d$, was maintained in all reactors during study period. The complete study was carried out for 90 days. Prior to analysis a 20 days acclimatization period were provided to the reactors.

2.2. Wastewater composition

The wastewater was prepared in the laboratory by dissolving molasses, urea and KH_2PO_4 to give the ratio of COD/N/P as 300/30/1 (Seetha et al., 2010) such that it simulates actual domestic wastewater of medium strength (Tchobanoglous et al., 2003). The influent had total chemical oxygen demand (COD) 480 ± 21 mg/L, total biochemical oxygen demand (BOD) 330 ± 15 mg/L, BOD/COD ratio 0.69 ± 0.02, dissolved biochemical oxygen demand (dBOD) 296 ± 19 mg/L, dissolved chemical oxygen demand (dCOD) 419 ± 25 mg/L, dissolved oxygen (DO) 3.2 ± 1.1 mg/L, total dissolved solids (TDS) 587 ± 162 mg/L, total suspended solids (TSS) 230 ± 36 mg/L, ammonia nitrogen (NH_4^+-N) 48.5 ± 11.4 mg/L, total phosphorus (TP) 5.2 ± 1.6 mg/L and pH of 7.3 ± 0.06. For initializing the growth of microbial population the synthetic sewage was seeded with 1% domestic wastewater to mimic the actual sewage.

The microbial quality of the synthetic domestic wastewater was quite consistent with an average concentration of TC, FC, FS and *E. coli* observed as $3.16 \times 10^5 \pm 1.58 \times 10^4$, $7.94 \times 10^4 \pm 1.26 \times 10^3$, $7.94 \times 10^3 \pm 1.58 \times 10^3$ MPN/100 ml and $1.26 \times 10^4 \pm 6.31 \times 10^3$ CFU/100 ml respectively, throughout the study period.

Table 2
Porosity of different media used in study.

S. No.	Media	Size (mm)	Porosity (%)
1	River bed material	6–8	35
2	Wood coal	6–8	45
3	Glass balls	6–8	40
4	Mud balls	6–8	43

2.3. Data collection and analysis

The collected influent and effluent samples were analyzed for biochemical oxygen demand (BOD, dBOD), chemical oxygen demand (COD, dCOD), nitrogen (NH_4^+-N, NO_3-N), pH, TP, TDS and TSS. All the parameters were analyzed according to the Standard Methods for the examination of water and wastewater (APHA, AWWA and WEF, 2005). The earth-worm biomass was also monitored on the initial and final day of experiment. The final removal efficiency was calculated as the percent removal for each parameter, which was determined using following equation:

$$R = \left(1 - \frac{C_e}{C_i}\right) \times 100 \quad (1)$$

where C_i and C_e are the influent and effluent concentrations measured in mg/L.

All the samples were assayed for microbial analysis and their enumeration was carried out for indicator organisms like total coliform (TC), faecal coliform (FC), faecal streptococci (FS) and *Escherichia coli* (*E. coli*). Enumerations of indicator organisms were carried out weekly. The concentration of TC, FC and FS were enumerated by Multiple Tube Fermentation Technique (APHA, AWWA and WEF, 2005) while E. coli was enumerated by serial dilutions of the sample plated on MacConkey Agar medium and incubated in an inverted position for 24–48 h at 37 °C.

2.4. Statistical analysis

All results being reported in study are the means of three replicate. One-way analysis of variance (ANOVA) was performed to measure the difference among different days for each physico–chemical parameter of wastewater using SPSS® statistical package (Window Version16). The probability levels used for statistical significance were $p < 0.05$ for the tests. Tukey's HSD (honestly significant differences) test was also performed as a post hoc

Table 1
Description of the filter bed layers for vermifilter.

Layers from top	Description of layers	Description of material in vermifilter	Size of material	Depth (mm)
Layer 1	Active layer	Matured vermicompost	600–800 μm	100
Layer 2	Active layer	Media (river bed material/wood coal/glass balls/mud balls)	6–8 mm	50
Layer 3	Third layer	Sand	2–4 mm	50
Layer 4	Supporting layer	Large gravel	10–12 mm	50