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Research Article

Performance of A Pilot-Scale Vermifilter for the Treatment of A Real Hospital Wastewater

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Abstract

In this study, the performance of a pilot-scale vermifilter (VF) for the treatment of hospital wastewater using the earthworm species Eisenia fetida was evaluated. The earthworms' gut acts as a bioreactor and can ingest the wastewater solid and liquid organic wastes and expel these as vermicompost. A pilot-scale vermifilter was installed and operated for 133 days in one of hospitals in Hamadan city; the designed system was fed with the influent passed through coarse and fine grillage and the sedimentation tank of the hospital's sanitary collection system. In order to study the efficiency of the system, the variations of pH value, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and total suspended solids (TSS) were measured. In addition, a conventional geofilter (GF) without Earthworm was used as the experimental control. The vermifiltration caused a significant decrease in the levels of COD (75%), BOD_5 (93%), and TSS (89%) as well as neutralized pH in the wastewater. Also, these contents in the geofilter were observed to be 65%, 71%, and 71%, respectively. The vermifiltration technology can, therefore, be applied as an environmentally friendly method for hospital wastewater treatment.

Keywords: Hospital Wastewater, Vermifiltration, Eisenia Fetida

1. Introduction

Approximately over 80% of the water supply consumed by society returns as domestic wastewater. Sewage treatment plants (STPs), usually, are not suggested because of high establishment and running cost and many developing countries cannot afford the construction of the STP. Besides, huge quantities of different kinds of wastewaters like sanitary and hospital sewages and excess sewage sludge are generated annually (1, 2).

Hospital wastewaters are important in terms of both quantitative and qualitative issues. Domestic per capita water consumption is approximately 100 to 200 liters per person, but it is by far higher in hospitals, ie, 350 to 1400 liters per bed. Wastewater, particularly hospital wastewater, contains various materials like pathogens, organic matters and radioactive materials, heavy metals, and pharmaceutical wastes. Discharge and entrance of untreated wastewaters into the environment, in particular the surface and the underground waters, can cause serious health hazards to human. Thus, it is imperative that hospital wastewaters be treated effectively. Considering the characteristics of these kinds of wastewaters including their high contents of nutrients and organic load and the limited available space of hospitals, some systems that have high performance efficiency are entirely essential. Although activated sludge systems are known for hospital wastewater treatment, their operation and maintenance are somewhat challenging. Besides, they cannot meet effluent standards (3, 4). Hence, developing processes that are ecologically safe and efficient and require relatively low costs, energy, and space is completely vital (2, 5).

Currently, vermifiltration is a promising economical method, particularly in developing countries, which combines biological technologies and ecological methods for treating different sewages (6, 7). The utilization of earthworms in wastewater or sludge treatment is called verminbiofiltration. It was first advocated by Prof. Jose Toha at the University of Chile in 1992 (1, 7). Also, Sinha et al. (8) reported that earthworms' gut works as a biofilter; they can reduce biological oxygen demand (BOD_5) level by over 90%, chemical oxygen demand (COD) level by 80 to 90%, total suspended solids (TSS) level by 90 to 95%, and turbidity from wastewater. Vermifiltration of wastewater by means of waste-eater earthworms is a low energy-consuming and beneficial process and has distinct advantages as compared with conventional wastewater treatment systems like activated sludge, trickling filters , aerated lagoons, and rotating biological contactors (RBCs). These conventional systems are highly energy intensive and their equipment and operation are very costly. It should be noted that the main upside of wastewater vermifiltration is the consumption of low energy; moreover, there is no formation of sludge in the case of this process. Naturally, there is no problem with any foul odor (9, 10). The vermifiltered water is almost crystal clear, nearly sterile, neutral in pH and, also, becomes a nutritive "organic fertilizer" rich in NKP (nitrogen 2 to 3%, potassium 1.85 to 2.25%, and phosphorus 1.55 to 2.25%) and other nutrients as the worms release them into water over the process (8, 10). To our best knowledge, this technology has been used to treat wastewater from small communities and effluents from some industries like dairy, herbal medicines and so on. Therefore, in the present study, we investigated the performance of the vermifilteration process for the treatment of a real hospital wastewater. Furthermore, the removal efficiencies of BOD and COD loadings from hospital wastewater by the verminfiltration technology using earthworms were studied.

2. Materials and Methods

2.1. Vermifilter Design

This study was carried out on a real hospital wastewater treatment plant in Hamadan which utilizes an extended aeration activated sludge system. A pilot-scale vermifilter (VF) was designed for the treatment of the wastewater. A schematic diagram of the VF system has been shown in Figure 1. Since the average ambient temperatures of 26 to 28°C are the most suitable for performing the experiments, the months of May to July 2015, which have the same weather, were selected. The VF reactor (with dimensions of 40 $\times$ 40 $\times$ 120 cm) was made of Pyrex glass material; the reactor had an empty space of 10 cm at the top for the aeration purpose. The VF consisted of four parts: bed material, earthworms, wastewater distributor, and drain system. The filter bed contained four layers with the bottommost layer (supporting layer) made up of cobble stone of size 10 to 50 mm and filled up to the depth of 20 cm. On top, there was a layer of detritus (3 to 10 mm) and filled up to another depth of 30 cm. Another layer of sand (100 to 800 μm) was introduced with a depth of approximately 30 cm. The topmost layer (active layer) was then made up of 30 cm of garden soil-earthworm. The earthworms were given two weeks for settling in the soil bed to acclimatize in the new environment before the experiments. After the stabilization phase, the VF was allowed to run for 17 weeks continuously with a constant hydraulic loading rate (HLR) of 1 $m^3 m^{-2} d^{-1}$ (6, 11). The raw wastewater was passed through coarse and fine grillage and the sedimentation tank, and then was stored in a distribution tank, and was finally taken as the inflow of the vermifilter. In order to achieve homogeneous raw wastewater, distribution shower bath nozzles were used for the VF. The treated water after the vermifiltration was collected at the bottom of the VF. The physical and chemical characteristics of the influent of the vermifilter were COD 227 - 461 mg/L, BOD_5 145 - 300 mg/L, TSS 190 - 260 mg/L and pH 6.8 - 7.15.

2.2. Control Kit Without Earthworms: The Geofilter

A control kit (exact replica of the VF kit but devoid of earthworms) was, also, organized for the comparison and the assessment of the precise role of the earthworms as biofilters. Where the geological and microbial systems work together is called a "geofilter".

2.3. Earthworms

Long-term studies on vermiculture have illustrated that the Eisenia fetida, having high reproductive capability and good applicability in high water-containing environment, can be considered as a suitable choice for vermitreatment (8, 12). Therefore, it was selected as a test species. The number and the population density (biomass) of earthworms in soil are important factors influencing the performance of the wastewater treatment system (10). On the initial and final day of the experiments, earthworms were counted and biomass was measured to find the percentage changes in the earthworm's biomass.

2.4. Water Sampling and Analysis

Influent and effluent samples collected weekly were analyzed for different physic-chemical parameters: pH, COD, BOD_5, and TSS as explained in the Standard Methods (13); COD was determined using the potassium dichromate method, whilst BOD_5 was measured by the standard oxidation procedure after 5 days at 20°C and TSS was measured using the method 2540 D (APHA 1995). The pH values were detected by using a digital pH meter (Hach, USA).

The final removal efficiency was calculated for each parameter by Equation 1:

$$\text{percentage reduction } (\%R) = \frac{(c_i - c_0)}{c_i} \times 100 \qquad (1)$$

2.5. Statistical Analysis

Microsoft Excel 2013 was used to carry out statistical analyses and draw the Figures.

3. Results and Discussion

3.1. pH Variations in Different Parts of the System

The average pH values of the influent and effluent were around 6.94 and 7.24, respectively. However, the average pH value of the effluent geofilter also improved to 7.11 but

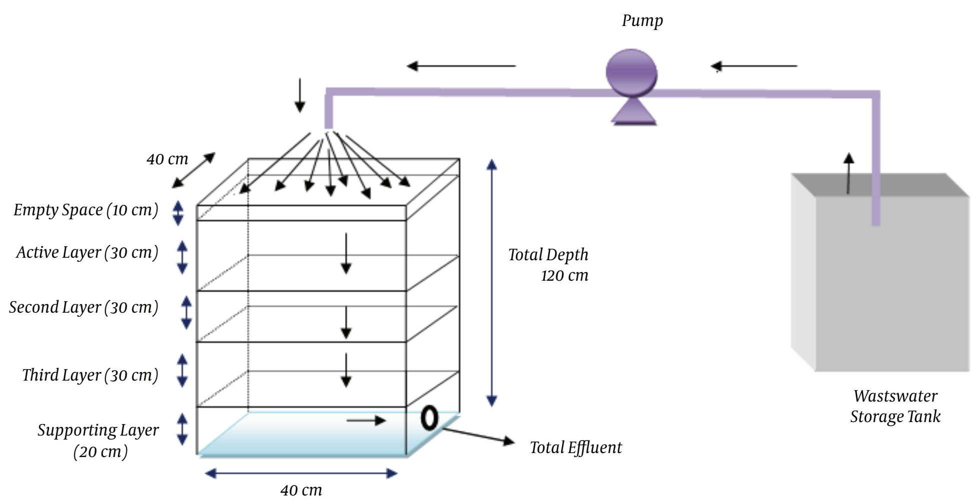

Figure 1. Diagram of the Pilot-Scale VF System used in this study

not as high as that in the vermifilter. The results indicated that the pH value of the influent of the vermifilter bed was almost neutralized by the earthworms. In-built pH buffering ability by raising the pH value can be assigned to earthworm mediated quick mineralization of organic fractions of the wastewater (1).

3.2. COD Removal

The findings showed that both geofilter and vermifiltration could treat the COD load by 75 to 65%, respectively (see Figure 2A). This could be because of the physical, chemical, and biological processes and the synergistic effects of earthworms and microorganisms, including the adsorption of small particle organisms, colloid-size organisms, and organic molecules, as well as the oxidation-reduction of the organic matters and the activity of earthworms (6). In addition, this can be attributed to the enzymes in the gut of earthworms contributing to the degradation of several of those chemicals which otherwise could not be decomposed by microbes (1, 14). The COD level of the effluent declined gradually in geofilter during the treatment processes while, in vermifiltration system, it reduced rapidly after four weeks. Xing et al. have recently studied the treatment of domestic wastewater by means of vermifiltration; they claimed the content of COD reduced by 47 to 58% (15). Also, Sinha et al. reported an 80 to 90% reduction in COD by using vermifiltration in order to treat wastewater originating from a dairy industry under a pilot-scale project (16).

3.3. BOD5 Removal

The results showed that the earthworms in the VF removed BOD_5 loads by approximately 93% whilst the control geofilter bed indicated a 71% decline in BOD_5 (Figure 2B).

Higher BOD_5 removal in VF is attributed to the symbiotic activity of earthworms and aerobic microbes accelerating and enhancing the decomposition of organic matters (2). It should be pointed that the removal of COD was observed to be lower than that of BOD_5 which could be attributed to the fact that earthworms are mainly responsible for the biodegradation of organic wastes as compared to inorganic wastes (17).

3.4. TSS Removal

The results showed that the TSS of the effluent was significantly low both in vermifilter and geofilter, illustrating that the earthworms were capable of removing significantly TSS from the wastewater by over 89%: 71% in the geofilter (Figure 3). This could be attributed to the difference in biological components and working capabilities of the both reactors. Suspended solids are trapped on top of the filter; later, through the filter bed SS accumulates over time as "sludge" in a normal bio-filter and chokes the system which, in turn, ceases the operation of the system. However, in the VF bed, these solids are constantly eaten up by earthworms and excreted as finer particles as vermicompost. This clearly indicated why the VF bed did not choke and work smoothly (8, 14, 18).

Li et al. (2009) reported the use of a VF to continuous village sewage treatment in pilot scale; the results showed that COD, BOD_5, and SS in sewage could be efficiently removed by the VF. The mean removal rates of COD, BOD_5, and SS were, respectively, 83.5, 89.3, and 89.1% (19).

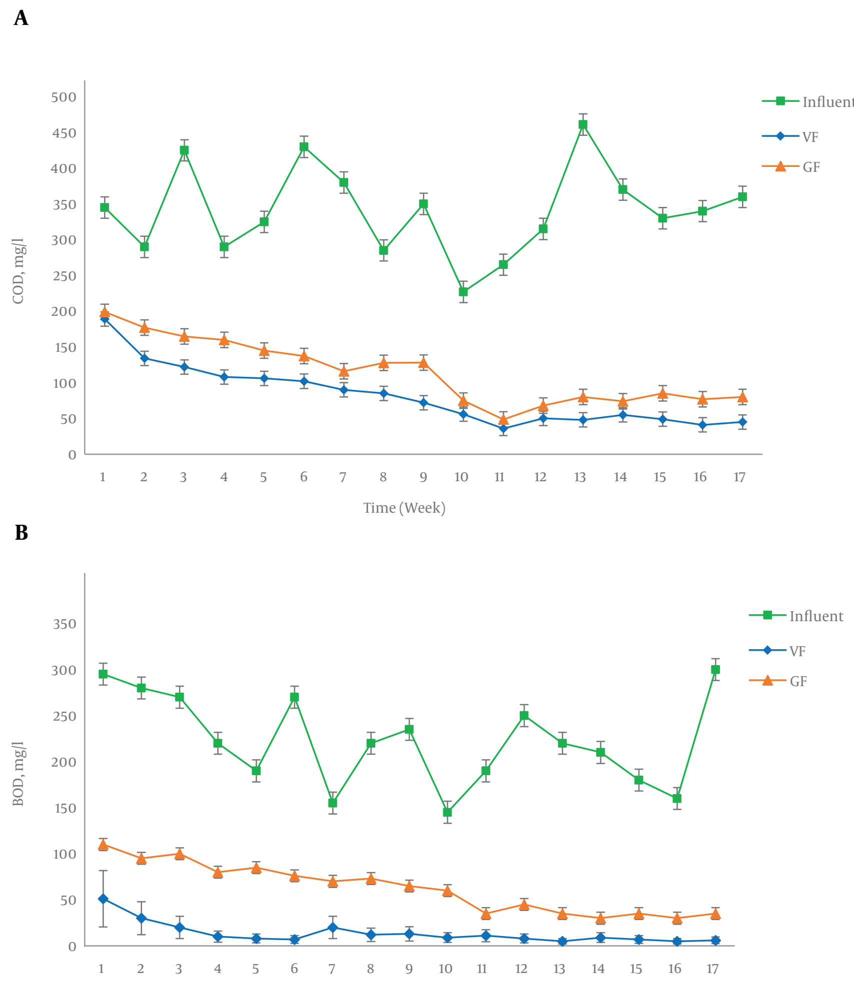

Figure 2. Variation in A, COD and B, BOD with Time During Treatment Period

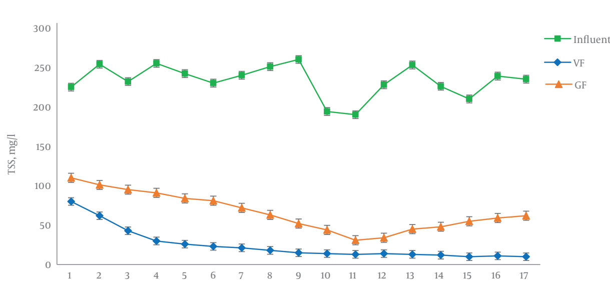

Figure 3. Variation in TSS and with Time During the Treatment Period

COD, BOD_5, and TSS parameters in influent fluctuated irregularly and intensively during the test period (Figure 4). However, these parameters in the influent after VF were relatively steady. This showed the ability of the VF to resist the organic load fluctuation.

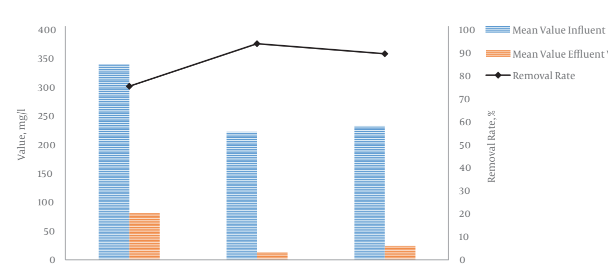

Figure 4. Mean Values of Chemical Analysis in Wastewater from Vermifiltration

3.5. Earthworm's Growth Rate Characteristics

In the beginning, the worm population (species E. fetida) was 480 (weighed 270 g) in the VF (a stocking density of 10 000 worms/m^3 of VF bed). At the end of the experiments, the population of earthworms increased to 670, showing a 28% increase. The earthworm biomass increased significantly by 33.9%. This clearly indicates that vermifiltration, via E. fetida, can be utilized for hospital wastewater treatment.

4. Conclusion

The current work provides an opportunity to explore the efficiency of a vermifiltration system for the treatment of hospital wastewater. The designed vermifiltration system was capable of working continuously in long-term periods, despite the fluctuation of organic input in wastewater. The bottom line is that the vermifilteration system is a very suitable alternative in order to treat hospital wastewaters. This is a notable advantage of vermifiltration. The vermifiltration of hospital wastewater resulted in a significant decrease in BOD_5, COD, and TSS and the pH of the wastewater was neutralized. The Vermifiltration technology can, therefore, be applied as an environmentally friendly technique for the treatment of different effluents, particularly hospital wastewaters. Although the results from the present study clearly indicated that the vermifiltration is an appropriate technique with high performance for hospital wastewater, further detailed studies are still required.

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