Waste water treatment using vermifiltration technique at institutional level

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ABSTRACT

In recent days many developing nations cannot afford to construct and maintain costly wastewater treatment plants. They need more options for wastewater treatment at low cost. In both developed and developing nations, centralized sewage treatment system may not fulfill sustainable wastewater management requirements in future due to ever-increasing demand. Therefore in the present study an attempt is made to know the efficiency of vermifilter and non-vermifilter as decentralized treatment for parameters pH, removal of Biological oxygen demand and chemical oxygen demand. In this study waste water is treated using vermifilter containing earth worms and the results are compared with waste water treatment by non-vermifilter, for the treatment of domestic wastewater. The domestic waste water is collected from boy’s hostel kitchen of SJBIT. The performance of vermifiltration unit using the earthworm, for wastewater treatment was studied. The average removal efficiencies of the vermifilter were as follows: chemical oxygen demand (COD) 65%; Biological oxygen demand (BOD), 92%; Total dissolved solids, 90%; Total suspended solids, 88% and Turbidity 93.2% after the Study. From the experiment data it was found that percentage reduction in concentration of BOD and COD in vermifilter was more efficient than non-vermifilter. During the process of vermifiltration, there was no sludge formation in the process and was also an odor-free process and the resulting vermifiltered water was clean enough to be reused for farm irrigation and gardens. Thus, earthworm activities had significant relationship with treatment efficiency of parameters by vermifilter of wastewater.

Key words: BOD, COD, Vermifiltration, Decentralization

INTRODUCTION

Vermifiltration has a great potential which adapts the traditional vermicomposting to a passive wastewater treatment. Earthworm body works as bio-filter which widens the microbial metabolism by increasing their population. Effluent resulted will be extremely rich in nutrition and can be reused as earthworms are versatile waste eaters and decomposers. It also grinds,
aerate, crush, degrade the chemicals and act as biological stimulator. Microbial and vermi processes will simultaneously work by treating the wastewater using earthworms. Microbial activity will be stimulated and accelerated by earthworms through developed aeration and also by improve the soil microbe population (Sinha et al. 2008). This treatment has additional advantage as absence of sludge formation compared to traditional treatment. Vermitechnology is found to be suitable for decentralized treatment of wastewater. Diverse experiments had been carried out on vermifiltration and found it highly efficient in removing Chemical oxygen demand (COD), Biochemical oxygen demand (BOD) and suspended solid (SS) and some N and P. Foul odouring during processing was also found to be lacking (Hughes et al. 2011; Sinha et al. 2008). The objective of the proposed work is to investigate the treatment of wastewater using Vermifiltration technique and to compare the vermifilter and non-vermifilter units.

MATERIALS AND METHODS

Collection of Earthworms

Young specimens of Earthworms, weighing 139 ±0.009 mg live individual weights, were obtained from composting unit maintained at temperature of 25°C in cow manure located in Hunsemarada Palya – Sai Temple, Bangalore.

Fig. 1 Collected earthworms

Preparation of bed material for Earthworms

In the top most layer of the filter system, bed material placed in which Earthworms were released. The bed materials consists of pure garden soil, saw dust and cow dung. Soil and sawdust were mixed at a volume ratio of 3:1. Sawdust was added as a bulking agent because it has been shown to improve soil permeability and enhance earthworm growth and survival. Cow dung was added to provide nutrients of earthworms during acclimatization period of the experiment.

Design of vermifilter system - Bench Scale Reactor

The vermifilter and the formation of vermifilter bed

A laboratory model of vermifilter system was designed in which arrangement has been made to supply the wastewater from top as well as collect the treated wastewater from the bottom of the system (Fig. 2). The wastewater was fed by gravity flow and with the help of
sprinkler. The sprinkler arranged in such a way that the fed wastewater circulated uniformly on filter bed. Since it is on laboratory scale, it is referred to as a Bench Scale Reactor. The body of the reactor was made of PVC drum. The present model has been designed so as to treat 40 liters of wastewater per day. This unit designed based on. They have considered rectangular shape filter unit of $40 \times 40$ m$^2$ of area. A cylindrical shaped Vermifiltration Filter unit (40 cm in diameter 40 cm in depth) was designed, so as to reduce the area of application of wastewater. The depth of 40 cm has been divided into 4 parts in which gravel, sand and soil bed for earthworm were placed from bottom layer to top. The vermifilter system contained about 25 kg of gravels with a layer of a garden soil on top. The garden soil and sawdust were mixed at a volume ratio of 3:1. This formed the vermifilter bed. The system has provisions to collect the filtered water at the bottom which opens out through a pipe fitted with tap. The system consists of bottommost layer and was made of gravel aggregates of size 16-20 mm and it fills up to the depth of 10 cm. Above this lies the aggregates of 10 mm sizes filling up to another 10 cm. On the top of this, 10 cm layer of 5 mm aggregates mixed with sand. The topmost layer of about 10 cm consists of soil bed in which the earthworms were released. The inoculated earthworms i.e., Indian blue worms was at an initial earthworm density of 75 gm. The worms were given around one week settling time in the soil bed to acclimatize in the new environment. A cylinder shaped vermifilter that was naturally ventilated was equipped with a 16mm polypropylene pipe with holes to ensure uniform distribution of the influent and a set of pipes inserted to provide aeration. A layer of net of wire mesh was placed below the layer of soil bed to allow only water to trickle down while holding the earthworms in the soil bed because it can crawl down to filter materials.

Experimental procedure and operation of the reactor

Around 45 liters of wastewater was kept in PVC drum. These drums were kept on an elevated platform just near the vermifilter unit. The PVC drums had tap at the bottom to which a sprinkler system was attached. The sprinkler system consisted of simple 16mm polypropylene pipe with holes for trickling water that allowed uniform distribution of wastewater on the soil bed.
surface (vermifilter bed). Wastewater from the drums flowed through the irrigation pipes by gravity. The wastewater percolated down through various layers in the vermifilter bed passing through the soil layer inhabited by earthworms, the sandy layer, and the gravels and at the end was collected from the bottom of the system. Next day this treated wastewater from both systems were collected and analyzed for BOD, COD, pH, turbidity and the TSS. During operation the surface loading of the wastewater was adjusted to 0.32 m$^3$/m$^2$.d (i.e., 40 liters per day for the system area), and the wet to dry time ratio was 1:3. These approaches prevented the blockage of the soil layers and sustained the penetrability of the ecofilter. The entire volume of the synthetic wastewater was applied in continuous operation mode through polypropylene pipe with holes to ensure uniform distribution of the influent. The polypropylene pipe was placed on the upside of the vermifilter surface, 15 cm from the top layer of vermifilter. The same operational procedure was repeated for the control unit/ non-vermifilter unit for reference and comparison. To start up the non-vermifilter, seeding was adopted using less polluted wastewater to develop microbial film layer on the filter bed, this will help to degrade the organic matter content. The seeding was done for duration of 7 days before starting actual wastewater feeding. After seeding, the actual procedure was repeated as same as vermifilter operation.

**Determination of Hydraulic Loading Rate (HLR)**

Previous studies have primarily focused on the use of vermifilter or its combined processes in the treatment of different types of wastewater, and the related factors contributing to its efficiency in removing pollutants. However, neither study has focused on the vermifiltration on continuous mode of operation and the capacity of earthworms to treat the wastewater. In batch process, wet to dry time ratio 1:3 has been used (each cycle included wastewater flow for 1 h, retention for 3 h) if the system has to work without choking and clogging.

Hydraulic loading rate can be calculated by:

$$HLR = \frac{V_{ww}}{A \times t}$$

$V_{ww} =$ Volumetric flow rate of wastewater (m$^3$); $A =$ Area of soil profile exposed (m$^2$); $t =$ 1day.

**Determination of volume of earthworm biomass**

The density of earthworm biomass required for the treatment of wastewater can be calculated by

Density of earthworm biomass $Vs = \pi r^2 h$

$Vs = \pi * 0.2^2 * 0.1$

$= 0.0125$ m$^3$

$= 12.5$L

There initial biomass of worms needed $= 12.5 \times 12.5$

$= 156.25$gms

**Determination of number of holes to be considered in Longitudinal and Lateral direction**

Total area of perforation $= 0.2\%$ of filter area

$= 0.002 * 0.1257$

$= 0.00024$ m$^2$

Total area of laterals $= 2 * $ total area of perforation

$= 2 * 0.00024$

$= 0.00048$m$^2$
Assuming 1mm diameter perforation
No of perforations in longitudinal direction = 5 nos.
No of perforations in lateral direction = 4 in each side

Results

The different types of experimental work done to determine the performance evaluation of vermifilter and non-vermifilter for the treatment of wastewater have been presented. The results of the test conducted to know the characteristics of wastewater have been represented in table 4.1 of this chapter. During the whole experimental period, the vermifiltration unit and Non-vermifiltration unit were fed with domestic wastewater.

Characteristics of wastewater

<table>
<thead>
<tr>
<th>Description of the parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Odor</td>
<td>Unpleasant</td>
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<tr>
<td>Temperature</td>
<td>25°C</td>
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<tr>
<td>Total solids</td>
<td>720 mg/L</td>
</tr>
<tr>
<td>Total Dissolved solids</td>
<td>390 mg/L</td>
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<tr>
<td>Total Suspended solids</td>
<td>340 mg/L</td>
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<tr>
<td>pH</td>
<td>8.22</td>
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<tr>
<td>Turbidity</td>
<td>125 NTU</td>
</tr>
<tr>
<td>Biological oxygen demand</td>
<td>219.45 mg/L</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>288 mg/L</td>
</tr>
</tbody>
</table>

Table. 1 Characteristics of waste water

Experimental results of the vermifilter and non-vermifilter units

Both the experimental units—one with earthworms (vermifilter unit) and the other without (non-vermifilter unit/control unit) were constantly observed for symptoms like foul odor, smooth percolation of wastewater through the soil bed, and appearance of the upper layer of soil bed. The vermifilter unit was also observed and monitored for the agility and movement of the earthworms, its growth, and health conditions. Any toxicity in the wastewater might adversely affect the earthworm’s population in the soil bed. There was very little or no problem of any foul odor with the vermifilter unit throughout the experimental study. However, foul odor was observed emanating from the control unit. Wastewater percolated smoothly into the soil bed in the vermifilter unit throughout the experimental study while in the control unit it was constantly choking after few smooth run down of wastewater. The earthworms in the vermifilter bed were agile and healthy and achieved good growth throughout the period of study. They
appeared to be increasing in number and were much developed at the end of the study, after about 3 weeks.

A [ACW] - Actual wastewater
B [TWW] - Treated wastewater from vermifilter unit
C [HWC] - Hazy water from control or non-vermifilter unit

Results of vermifilter performance for detail parameters

<table>
<thead>
<tr>
<th>Date</th>
<th>Odor</th>
<th>pH</th>
<th>BOD in mg/L</th>
<th>COD in mg/L</th>
<th>Turbidity in NTU</th>
<th>TDS in mg/L</th>
<th>TSS in mg/L</th>
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</thead>
<tbody>
<tr>
<td>November</td>
<td>Influent</td>
<td>8.22</td>
<td>7.15</td>
<td>219.45</td>
<td>39.48</td>
<td>82.00%</td>
<td>111</td>
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<tr>
<td>November</td>
<td>Effluent</td>
<td>8.15</td>
<td>7.10</td>
<td>219.45</td>
<td>29.40</td>
<td>86.6%</td>
<td>108</td>
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<tr>
<td>November</td>
<td>%R</td>
<td></td>
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Results of Non-vermifilter performance for detail parameters

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<th>Date</th>
<th>Odor</th>
<th>pH</th>
<th>BOD in mg/L</th>
<th>COD in mg/L</th>
<th>Turbidity in NTU</th>
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<tr>
<td>November</td>
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<td>7.20</td>
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<td>November</td>
<td>%R</td>
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I- Influent E- Effluent %R- Percentage reduction
I - Influent E- Effluent %R Percentage reduction

Results of the experiment clearly showed that the performance of earthworms in the degradation of organic materials present in the vermifilter bed. The contributions of earthworms in the percentage removal of all analyzed parameters are shown. The removal efficiency of parameters analyzed were improved 24.38%, 25.86%, 17.06%, 25.26%, 35.47% of COD, BOD, Turbidity, TDS, TSS respectively by the presence of earthworms.

Variation in pH value of treated wastewater

Results indicated that the pH value of raw wastewater is almost neutralized by the earthworms in the vermifilter unit. The pH value of treated wastewater without earthworms also improved but it was not consistent throughout the experiment.

Turbidity removal

Results indicated that the average reduction in turbidity by earthworms is over 96% while that without earthworms in the control unit is also significantly high and over 80%. It appears that the filter media of the unit also plays very important role in turbidity removal by adsorption of suspended particles on the surface of the soil, sand and the gravels. Turbidity of treated wastewater is affected by HLR.

Removal of total suspended solids

Results showed that the earthworms can significantly remove the suspended solids from the wastewater by over 88%, which in the control unit (where geological and microbial system works together) is over 60% only.

Removal of total dissolved solids

Total suspended solids (TSS) and total dissolved solids (TDS) showed drastic reduction during bio filtration (control) and vermifiltration process. The total reduction in TDS content was about 95% in vermifiltration unit and that was significantly higher than total removal in control unit, i.e. 75%. Results thus clearly suggested the capability of earthworms to remove solid fractions of wastewater during vermi-biofiltration processes. The control (bio-filtration) unit showed a gradual removal of TDS during treatments process while in vermifiltration unit TDS removed sharply during initial stages of the experiment thereafter; the removal process was more or less steady till last observation. The difference between both units could be due to difference in biological components and working capabilities of both units.

Removal of Biochemical oxygen demand (BOD5)

BOD is also an important indicator of organic load of wastewater. The BOD load in effluents from control unit and vermifiltration unit was significantly lower than initial levels, but vermi-biofiltration showed more removal efficiency than control unit. Results show that the earthworms can remove BOD (BOD5) loads by over 92%. BOD removal in the control unit (where only the soil, sand and microbial system works) is just around 78%.
Removal of Chemical oxygen demand (COD)

Results showed that the average COD removed from the wastewater by earthworms is over 65% while that without earthworms is just over 52%. COD removal by earthworms is not as significant as the BOD, as but at least much higher than the microbial system. Again, the enzymes in the gut of earthworms help in the degradation of several of those chemicals which otherwise cannot be decomposed by microbes.

Variations of parameters in vermifilter

**pH**

**BOD**

**COD**

**TURBIDITY**

**TDS**

**TSS**

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<th>Date</th>
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<th>% reduction of COD</th>
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<td>9.5</td>
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<th>BOD</th>
<th>% reduction of TSS</th>
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Variations of parameters in non-vermifilter

CONCLUSION

Vermifiltration is a logical extension of soil filtration which has been used for sewage silviculture (growing trees). From the experimental data it was found that vermifilter is more efficient than non-vermifilter in efficiency of removal of BOD, COD as well as solids. Results of vermifilter technology are most cost effective, odor free for treatment with efficiency, economy and potential decentralization. When compared to the acceptable value for BOD in
treated waste water is 1-15mg/l, COD is 40-70mg/l and pH is 7.0. The values obtained from the experimental are well within the limits, shows vermicompost system has good performance in treatment of waste water. It is seen from experiment, reduction of waste water characteristic was greatly facilitated by addition of sawdust to the soil, which could enhance the porosity of soil. This laboratory scale study may allow extension of methodology to applications like controlling water pollution in rural areas. The earthworm production, growth, breed & survive in the moist environment is very well was observed during the process of experiment.

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