DECENTRALIZED WASTE WATER TREATMENT BY VERMIFILTRATION USING RIVER BED MATERIAL

RenuBhargava
Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttrakhand, India
Telephone: +91-1332-285458; Fax: 01332-273560
E-mail: renbhfce@iitr.ernet.in; renubhargi@gmail.com

JyotiVerma
Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttrakhand, India
E-mail: jyotiverma2009@gmail.com

K.S. Hari Prasad
Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttrakhand, India
Telephone: +91-1332-285405; Fax: 01332-273560
Email: suryafce@iitr.ernet.in

Tarun Kumar
Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttrakhand, India
Telephone: +91-1332-285495
E-mail: vrma.tarun@gmail.com

Abstract

Rural sewage treatment is now paid more and more attention in India. The high cost of wastewater collection and wastewater (WW) treatment is not permitting the conventional sewage treatment plant in small areas, so cost effective decentralized and eco-friendly treatments are needed. Vermifiltration needs no external energy (except pumping), is low cost, and produces no sludge; hence vermifiltration can be very useful for small communities, colonies and villages. The present study was carried out to get optimum Hydraulic loading rate (HLR) for vermi filter to achieve the requisite quality of effluent. In the present study, there were two reactors and these reactors were in triplicates. One set of the reactors (vermifilter) was inoculated with earthworms (*E.fetida*) and other set contained only filter material without earthworms (geofilter).The laboratory model consisted of plastic containers filled with the filter materials in four layers: gratings at the top and then gravel of two different sizes in two layers and supporting layer of larger size gravels. The wastewater was applied to the filters at four rates: 1.5, 2, 2.5 and $3.5 m^3/m^2/d$. The effluent from vermifilters and control were analysed for physico-chemical and biological parameters. Maximum removal of organic matters in vermifilters was at $2.5\ m^3\ m^{-2}\ d^{-1}$. At this rate, BOD, COD, TSS and TDS removal was 96%, 89%, 90%, 82% respectively. The treated effluent and vermicompost both were rich in nitrate, phosphate and hence both could be used in agriculture.

Keywords: Vermifiltration, Vermi filter, decentralized wastewater treatment, Hydraulic Loading Rate (HLR)

1. Introduction

Due to increasing population the natural resources are exhausting which fosters the wastewater reuse planning and emphasizes on the decentralized wastewater treatment, especially in rural areas where high cost wastewater (WW) collection and treatment does not permit the conventional sewage treatment plants. Decentralized wastewater treatment involves the collection, treatment, disposal and reuse of sewage from individual homes, clusters of homes and isolated communities at or near the point of generation (Li *et al* 2009, Tchobanoglous 2003). Vermifiltration has the great potential in this direction which adapts the traditional vermicomposting to a passive wastewater treatment. In vermifiltration earthworm body works as a bio- filter and extends the microbial metabolism by increasing their population. The resulting effluent becomes highly nutritive and can be reused for irrigation purpose. Earthworms are versatile waste eaters and decomposers. They promote the growth of 'beneficial decomposer bacteria in domestic wastewater and acts as aerator, grinder, crusher, chemical degrader and biological stimulator. The two processes-microbial process and vermi-process simultaneously work in the treatment of domestic wastewater using earthworms. Earthworms further stimulate and accelerate microbial activity by increasing the population of soil microorganisms and also through improved aeration (Sinha *et al.* 2008). There is no sludge formation which requires additional expenditure on its disposal in conventional treatment. The various investigators have found that the vermitechnology has potential for the decentralized treatment of wastewater. On small to pilot scale level various studies has been carried out on vermifiltration and it is tend to be a potential method for sewage treatment, with high removal rates of Chemical oxygen demand (COD), Biochemical oxygen demand (BOD) and suspended solid (SS) as well as some ability to remove N and P (Sinha *et al.* 2008). The pH of treated wastewater is measured neutral. Also no problem of any foul odour during the processing (Hughes *et al.* 2011; Sinha *et al.* 2008). The present paper deals with the treatment of wastewater by vermitechnology where river bed material is used as filter media.

2. Material and method

The experimental set up was placed in the solid waste laboratory of Civil Engineering Department of IIT Roorkee. In this study two set of reactors were taken, one is vermifilter and another is geofilter. Both were taken into triplicates. The reactors consisted of plastic container having dimension of 255 mm x 300 mm x 300 mm. Four layers of material were used in both units. The top layer was facilitated with gratings (5 cm thick) and second layer from top was gravel having size from 6 to 8 mm (10 cm thick) and the third layer consisted of gravel having size of 1 to 2 mm (5 cm thick) and the bottom layer that acts as a supporting layer, facilitated with gravel having size of 10 to 12.5 mm (5 cm thick). All the gravels used were river bed materials. Earthworm species *Eiseinia Fetida* was used for this study. Each of vermifilter was inoculated with 270 earthworms based on the stock density of 12,000/cum of filter-bed.

3. Wastewater composition

The synthetic wastewater composed of molasses, urea, KH_2PO_4 to give the ratio of COD/N/P as 300/10/1 (Seetha *et. al.*, 2010). 0.02 mg/L of $MgSO_4$ was also added to this wastewater. The stock solution of wastewater was prepared**.** Initial characteristics of wastewater were COD 447.7±10 mg/L, BOD 260±5 mg/L, pH 8.2, NO_3-N 10.5±1 mg/L, TP 8.1±2 mg/L, TSS 588±50 mg/L, TDS 976±50 mg/L.

4. Sampling and analysis

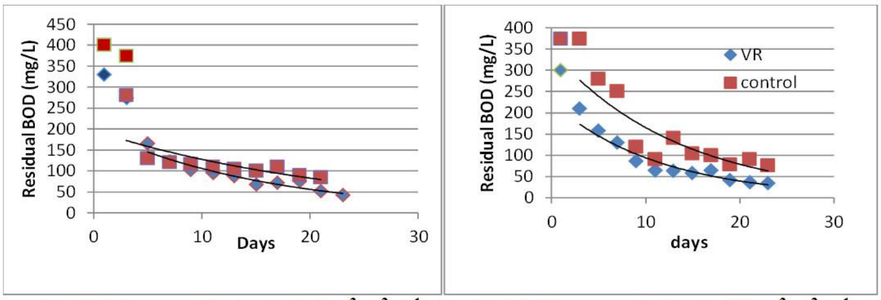
After application of wastewater from the top of the reactors, effluent was collected at the bottom of the reactors. Samples were collected daily. The average of the results of three vermi-filters (VR) and control was used for plotting graphs and calculations. Treated wastewater was analysed for BOD, COD, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), nitrate nitrogen (NO_3-N), pH and total phosphate (TP). All the parameters were analysed according to the standard methods for the examination of water and wastewater (APHA, 2005).

5. Result and discussion

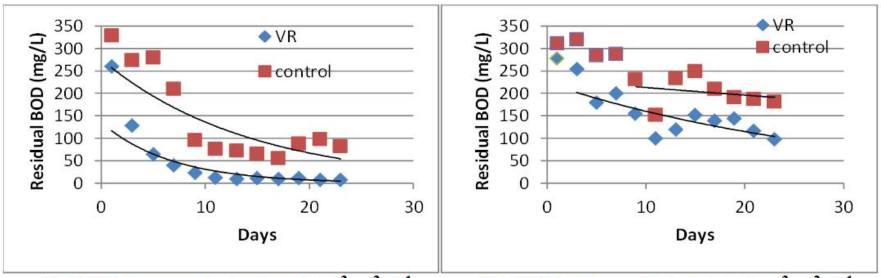
5.1 Characteristics of effluent

5.1.1 BOD and COD

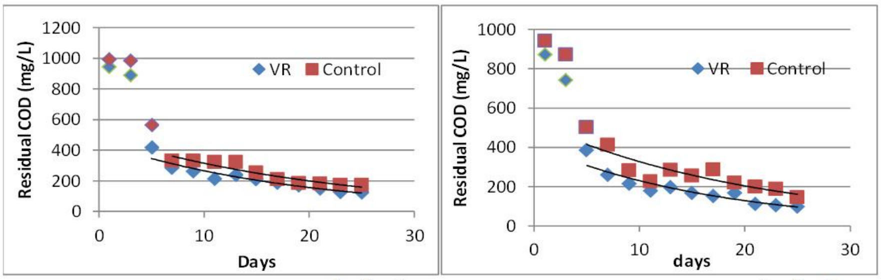
BOD and COD of effluent decreased in all the reactors at all rates. BOD removal for vermifilter was 83%, 86%, 96%, 62% while for geofilter, it was 67%, 70%, 68% and 30% at 1.5, 2, 2.5 and 3.5 $m^3m^{-2}d^{-1}$ hydraulic loading rate (HLR) respectively. Fig.1 (a) to 1(d) shows residual BOD.



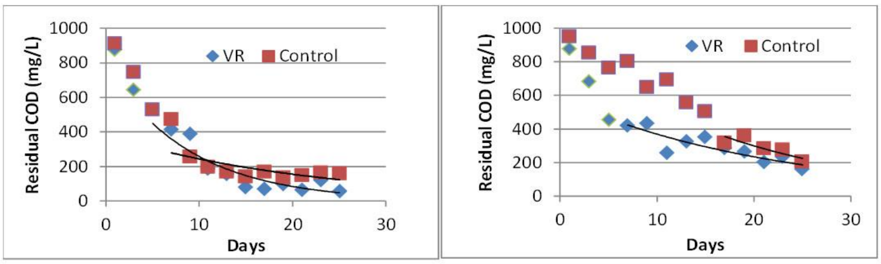
(a) BOD removal at rate 1.5 $m^3m^{-2}\ d^{-1}$ **(b) BOD removal at rate 2.0 $m^3m^{-2}\ d^{-1}$**



(c) BOD removal at rate 2.5 $m^3m^{-2}\ d^{-1}$ **(d) BOD removal at rate 3.5 $m^3m^{-2}\ d^{-1}$**



(e) COD removal at rate 1.5 $m^3m^{-2}\ d^{-1}$ **(f) COD removal at rate 2 $m^3m^{-2}\ d^{-1}$**



(g) COD removal at rate 2.5 $m^3m^{-2}\ d^{-1}$ **(h) COD removal at rate 3.5 $m^3m^{-2}\ d^{-1}$**

Figure 1**:** BOD and COD variation during vermifiltration

At HLR 2.5 $m^3m^{-2}d^{-1}$ maximum COD and BOD removal were observed as 89% and 96% respectively. There was an increase in BOD and COD during initial period of experiments because of dissolution of organic matters present in gratings. However COD removal was less as compared to BOD removal because earthworms are mainly responsible for biodegradable waste as compared to inorganic waste (Sinha et. al 2008). Similar results were obtained by other researchers (Rajpal *et. al.*, 2012)

5.1.2 TP and NO_3-N

TP and NO_3-N increased in effluent of all reactors at all rates. Maximum increase in nitrate nitrogen and total phosphate was observed at 2.5$m^3m^{-2}d^{-1}$. Nitrate nitrogen increased from 10 mg/L to 34, 39, 45 and 40 mg/L in VR and in geofilter it increased to 20, 20, 24, 18 mg/L at various HLR 1.5, 2, 2.5 and 3.5 $m^3m^{-2}d^{-1}$ respectively during test period.

Total phosphate concentration in the effluent increased from 8.1 mg/L to 26.5 (225% increment), 30.5 (275% increment), 32.5 (300% increment), and 12.5 mg/L (53% increment) during 1.5, 2, 2.5 and 3.5 $m^3m^{-2}d^{-1}$ respectively within test period. During vermifiltration, nitrate and phosphate concentration increased in effluent because of the enzymes and microbes present in the guts of earthworms.

5.1.3 TSS & TDS

TSS and TDS both reduced during vermifiltration. In the initial period of experiments, TSS and TDS increased because of dissolution of minerals. TDS removal in VR was 70%, 76%, 82% and 62% while in control it was 42%, 49%, 56% and 25% at various HLR 1.5, 2, 2.5 and 3.5 $m^3m^{-2}d^{-1}$ respectively. TSS removal in VR was 57%, 77%, 90% and 35% and in control 30%, 37%, 45% and 20% at HLR 1.5, 2, 2.5 and 3.5 $m^3m^{-2}d^{-1}$ respectively within test period. Earthworms ingest solid particles of wastewater and excrete them as finer particles. These finer particles trapped in the voids of VR and caused high removal efficiency of TSS and TDS from wastewater (Sinha *et.al*, 2008). There was maximum TSS and TDS removal at HLR 2.5 $m^3m^{-2}d^{-1}$ within test period in VR. Nitrate nitrogen and total phosphate was increasing in the effluent, though TDS was decreasing the reason for low TDS is that the organic dissolved solids are removed in the process.

5.1.4 TOC

In vermifilter, TOC removal was found to be 72%, 77%, 83% and 54% at various HLR 1.5,2, 2.5 and 3.5 $m^3m^{-2}d^{-1}$ respectively. Minimum TOC observed within test period (83% removal) at HLR 2.5 $m^3m^{-2}d^{-1}$. Earthworms and microbial activity increased the decay rate of organic matter during vermifiltration process. This was due to increased carbon consumption in metabolic activity as well as CO_2 emission in the VR (Rajpal *et. al* 2012).

5.1.5 pH

The pH of the effluent from both reactors was more than the influent. The pH of effluent of VR and control, obtained at the end of treatment process in each run was between 6.5 & 8.0. The difference between control and vermi-filter for pH could be related to earthworm mediated rapid mineralization of organic fractions of wastewater (Rajpal *et. al.*, 2012).

5.1.6 Earthworms biomass

At the end of the 25 days, the earthworm biomass increased slowly in both VR. The increase in weight of earthworm biomass during the vermifiltration period varied between 7.4% and 20.7%. Maximum growth of earthworms was at hydraulic loading rate 2.5 $m^3m^{-2}d^{-1}$ during which earthworms increased to 326.

5.1.8 Mass and quality of compost (grating)

The vermicompost was dark brown (towards blackish) in colour and homogeneous after 25 days of earthworm activity. TP and nitrate nitrogen concentration decreased in the compost at the end of each run. From this again it proved that dissolution of organics took place from compost to wastewater. In VR, dissolution also took place but due to enzymatic action of earthworms in these reactors TP and nitrogen content was continuously increasing in the compost which finally became as vermicompost. For HLR 2.5 m^3m^{-2} d^{-1} TP and TN were 70.8 mg/l and 286.4 mg/l.

6. Conclusion

From the present study vermifiltration is found to be suitable technique for decentralised wastewater treatment. In this study the optimum HLR of 2.5 m^3m^{-2} d^{-1} was found in vermi filter for the test media (naturally occurring river bed material). The BOD, COD, TSS, TDS were reduced by 96%, 89%, 90% 82% respectively at optimum rate. In this system, no sludge was produced. On the other hand vermi compost was produced which can be used as fertilizer. The organic matter present in wastewater was consumed by earthworms converting it into value added vermi compost. The treated effluent had higher value of nitrate, phosphate which is best suited for sewage farming or horticulture.

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