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Performance Evaluation of Laboratory Scale Vegetated Vermifilter for Domestic Wastewater: A Review

Vaishnavi Sanjay Angathekar[1], Yashwant Mohan Patil[2]

[1]*Student, Rajarambapu Institute of Technology, Islampur, Sangli, Maharashtra, India*
[2]*Professor, Rajarambapu Institute of Technology, Islampur, Sangli, Maharashtra, India*

Abstract – *Earthworm's body works as a biofilter and have been found to remove BOD, COD, TDS, and TSS by general mechanism of ingestion, biodegradation, and absorption through body walls. Two lab-scale vertical flow vermifilter are to be designed, one aided with only canna indica and filter media and second with canna indica and Eisenia Foetida (earthworms) along with filter media.. The experimental phase is to be continued for 6 weeks with a hydraulic loading rate of 0.65 m^3 $m^{-2}day^{-1}$. Various parameters such as BOD, COD, Dissolved oxygen (DO), Total nitrogen and phosphorous (TN and TP), pH, Organic load, Growth of Canna indica and bed clogging.*

***Abbrevations*:**

BOD – *Biological Oxygen Demand*

COD - *Chemical Oxygen Demand*

DO – *Dissolved Oxygen*

HLR – *Hydraulic Loading Rate*

VF - *Vermifilter*

MAVF - *Macrophyte Assisted Vermifilter*

PFF – *Peak Flow Factor*

***Key Words*: Domestic Wastewater, Vermifilter, Aerobic Treatment, Low Cost Treatment, Organic Waste, Hydraulic Loading Rate(HLR), BOD, COD, , Canna Indica, Eisenia Foetida**

1. INTRODUCTION

A Vermifilter basically consists of worms in addition to gravel and sand media used in conventional filter for wastewater treatment. It is also called as Vermi-digestor or Lumbrifilter. Nearly 80% of the water supply used by the society returns as municipal wastewater in the sewer system as sewage. Vermifiltration of wastewater using waste eater earthworms is a newly conceived novel technology. There is no sludge formation in the process which requires additional expenditure on landfill disposal. This is also an odour-free process and the resulting vermifiltered water is clean enough to be reused for farm irrigation and in parks and gardens. Many developing nations cannot afford to construct and maintain costly STP's. They need more options for sewage treatment at low-cost. In both developed and developing world, at least for new developments, centralized sewage treatment system may not fulfill sustainable wastewater management requirements in future due to ever increasing demand. Individual households or a cluster of homes can treat their domestic wastewater at source in a decentralized manner so as to reduce the burden (BOD and COD loads) on the sewage treatment plants (STP's) down the sewer system.

2. Literature Review

2.1 Sinha R. K., Bharambe G. and Bapat P., 2007

Removal of high BOD and COD loadings of primary liquid waste products from dairy industry by vermi-filtration technology using earthworms.

Brewery and milk dairy wastewaters which have very high BOD and TSS loadings e.g. 6780 mg/L & 682 mg/L respectively from brewery and 1,39,200 mg/L & 3,60,00 mg/L respectively from the dairy industry. Earthworms removed the high BOD loads by 99 % in both cases and TSS by over 98 %. But the hydraulic retention times (HRTs) in case of brewery wastewater was 3-4 hours and 6-10 hours for the dairy wastewater. An important observation was that although the BOD, COD and the TSS of wastewater were also considerably removed by the control system (devoid of earthworms) it never worked for longer time and frequently got choked. The organic solids in the wastewater accumulated as peat in the soil layer and also attracted heavy 'fungal infection'. It became un-operational after sometimes. In the vermifiltration system the earthworms constantly fed upon the solids and the fungus and never allowed the system to be choked and become un-operational.

2.2 Sinha Rajiv K., Bharambe Gokul and Chaudhari Uday, 2008

Vermifiltration of sewage obtained from the Oxley Wastewater Treatment Plant in Brisbane, Australia.

The experiment was carried out in a 220 L capacity 'vermicomposting bin' with provisions for dripping wastewater from the top and collecting the filtered water at bottom through an outlet. Vermifilter bed was prepared by organizing pebbles at bottom of the bin and about 30 cm layer of soil on top in which worms were released. A control bin was also organized which had pebbles and soil bed but no earthworms. The pebbles and soil (with microbes) can also be expected to contribute in the filtration of wastewater.

Results showed that the earthworms removed BOD loads of sewage by over 99 % at hydraulic retention time (HRT) of 1-2 hours. Average COD removed from the sewage by earthworms is over 50 %. COD removal was not very significant, but at least much higher than the control. Earthworms also removed the total suspended solids (TSS) from the sewage by over 90 %.

2.3 Li Y. S., Robin P., Cluzeau D., Bouche M., Qiu J. P., Laplanche A., Hassouna M., Morand P., Dappelo C. and Callarec J.,2008

Vermifiltration as a stage in reuse of swine wastewater: monitoring methodology on an experimental farm.

A pilot associated with a swine facility (piggery) with 66 swine was developed to treat diluted manure, produce earthworms and vermicompost, and reduce air pollution. The earthworm population increased by 30% in 4 weeks, indicating the acclimation of the earthworms. A reduction in ammonia emission was observed of about 50% for the whole system. Higher water (+100%), carbon (+70%), and total nitrogen (+80%) gaseous losses were observed compared to conventional breeding on a slatted floor. The vermifilter removed about 85% of the C and 65% of the N in the swine excretion (related to 2 seventh of total excretion because of 2 days/week sprinkling).

2.4 Li Y.S., Xiao Y.Q., Qiu J.P., Dai Y.Q., Robin Paul., 2009

Continuous village sewage treatment by vermifiltration and activated sludge process.

In this study, a larger vermifilter was designed to treat the sewage on village scale for long-term operation. Filter material composition was optimized by a half year experimentation. The treatment effects of vermifiltration were also compared with traditional activated sludge process for the same influent sewage. The results showed that the designed vermifiltration system could continuously treat the sewage produced by more than 100 inhabitants per day. COD, BOD and SS concentration in outflow were rather stable despite the fluctuation of hydraulic loading rate and organic input during one year test. The comparative test showed that the treatment efficacy of vermifiltration was similar as activated sludge process. Generally, this vermifiltration system has practical application value for village sewage treatment.

2.5 Merlin G. and Cottin N., 2009

Performance of a compost biofilter containing earthworms to treat cheese whey.

The main goal of this study was to follow up pollutant removal performance after more than one year of operation. During the experiment, cheese whey loading varied from a few litres to 40 L m−2 d−1. For COD and BOD, 80–88% of the loading mass and 70–80% of nitrogen and phosphorus was removed. In this experiment, the treated effluent could not meet the standards for discharge into rivers, but was a very effective and simple pretreatment. It is essential to maintain the aerobic condition in the biofilter. Alternating phases of feed and rest seem to be fundamental to maintain aerobic conditions within the filter bed and to mineralize the organic matter, and this should be taken into account for the design of the process and the number of units.

2.6 Sinha R. K., Agarwal S., Chauhan K., Chandran V. and Soni B. K., 2010

Vermiculture technology: Reviving the dreams of Sir Charles Darwin for Scientific Use of Earthworms in Sustainable Development Programs.

Vermiculture technology is emerging as an 'environmentally sustainable', 'economically viable' and 'socially acceptable' technology all over the world. Vermi-composting Technology (to manage most organic wastes); Vermi-filtration Technology (to treat municipal & several industrial wastewater); Vermi-remediation Technology (to treat & clean up contaminated lands); Vermi-agro-production Technology (to produce chemical-free organic foods by worms & vermicompost); Vermi-industrial Production Technology (to produce valuable industrial raw materials from worms). Wastes are degraded by over 75% faster than conventional systems and compost produced are disinfected, detoxified, richer in nutrients & beneficial soil microbes; BOD loads & TSS of wastewater is reduced by over 95%; PAHs from contaminated soils are removed by over 80% in just 12 weeks; and crops growths are promoted by 30-40% higher as compared to chemical fertilizers. Earthworms are both "protective" & "productive" for environment and society.

2.7 Xing M., Li X. and Yang J.,2010

Treatment performance of smallscale vermifilter for domestic wastewater and its relationship to earthworm growth, reproduction and enzymatic activity.

A vermifilter system packed with quartz sands and ceramsite was studied for domestic wastewater treatment. Results showed that good performance of vermifilter was achieved and removal rates were COD (47.3 – 64.7%), BOD (54.78 – 66.36%), SS (57.18 – 77.90%), TN (7.63 – 14.90%), and NH4-N (21.01 – 62.31%), respectively. An increase in hydraulic loading led to a decrease in treatment efficiency and adult earthworm abundance. Earthworm enzymatic activities had significant correlation with treatment efficiency of COD and BOD by vermifilter. Thus an important relationship exists for earthworm population dynamics and enzymatic activities with COD and BOD removal rates of domestic wastewater by vermifilter.

2.8 Kharwade M. and Khedikar I. P., 2011

Laboratory scale studies on domestic grey water through vermifilter and non-vermifilter.

Domestic grey water was passed through vermifilter and non-vermifilter. Domestic grey water was collected from the two storied building (house-1) and four storied building (house-2). The percentage of reduction in concentration of BOD in vermifilter ranges from 85 to 93 % while in non-vermifilter it was found to be 72 to 80 % at 2-3hr of detention time. The percentage of reduction in concentration of COD in vermifilter ranges from 74 to 80%. COD reduction was greatly affected by detention time. The percentage reduction in concentration of Suspended Solid ranges from 70 to 80% while in non-vermifilter it was found to be 60 to 70% at 2-3hr of detention time. Suspended solids from greywater are obtained and it is not much affected by detention time.

2.9 Liu J., Lu Z., Zhang J., Xing M., Yang J.,2013

Phylogenetic characterization of microbial communities in a full-scale vermifilter treating rural domestic sewage.

In this study the focus was on optimizing filter depth on sludge reduction in a four-stage vermifiltration during the course of treating excess sludge continuously. The results indicated that when the filter depth exceeded 75 cm, though the fourth stage can further advance the sludge reduction, its contribution for the total sludge reduction was lower than 10%. The earthworm activities attributed to aerobic bacteria being preferentially selected in the system, positively supporting the organic decomposition. As far as economic cost and process performance are concerned, a 75-cm vermifilter was recommended to efficiently and economically achieve the required standard for sewage sludge reduction and stabilization.

2.10 Sharma M.K., Kazmi A.A.,2014

Effect of physical property of supporting media and variable hydraulic loading on hydraulic characteristics of advanced onsite wastewater treatment system.

A laboratory-scale study was carried out to investigate the effects of physical properties of the supporting media and variable hydraulic shock loads on the hydraulic characteristics of an advanced onsite wastewater treatment system. Hydraulic loadings were based on peak flow factor (PFF), varying from one to six, to simulate the actual conditions during onsite wastewater treatment. The system showed a very good hydraulic efficiency, between 0.86 and 0.93, with the media of highest porosity at the hydraulic loading of PFF ≤ 4. At the higher hydraulic loading of PFF 6 also, an appreciable hydraulic efficiency of 0.74 was observed. The system also showed good chemical oxygen demand and total suspended solids removal efficiency of 80.5% and 82.3%, respectively at the higher hydraulic loading of PFF 6.

2.11 Kumar Tarun, Rajpal Ankur, Bhargava Renu and Hari Prasad K.S., 2014

Performance evaluation of vermifilter at different hydraulic loading rate using river bed material.

In this study the potential of vermifilter using river bed material with application of wastewater at different hydraulic loading rates for the treatment was evaluated. In addition, a comparative study was performed with vermifilter containing the earthworm species (Eisenia fetida) parallel to a geofilter (without earthworms). The wastewater was applied to the vermifilter and geofilter at four different hydraulic loading rates of 1.5, 2, 2.5 and 3.0 m3 m−2 d−1. Among these, optimum results were observed in case of hydraulic loading rate 2.5 m3 m−2 d−1. For this hydraulic loading rate, the removal efficiency of biochemical oxygen demand, total suspended solids and total dissolve solids with vermifilter were 96%, 90% and 82%, while in geofilter it was observed 70%, 79% and 56% respectively. The riverbed material was found to be better as a media in vermifilter for better growth of earthworm biomass.

2.12 Wang L., Guo Z., Che Y., Yang F., Chao J., Gao Y. and Zhang Y., 2014

The effect of vermifiltration height and wet: dry time ratio on nutrient removal performance and biological features: and their influence on nutrient removal efficiencies.

The two filters were made up of cylindrical DN200-PVC pipes and were filled with 10 cm gravel, 20 cm sand and 30 cm fine sawdust from bottom to top. Two hundred Eudrilus eugeniae earthworms were inoculated to one of the filters and the other was used as a control unit. Analysis were done for ammonium (NH4+), nitrate (NO3-), nitrite (NO2-), orthophosphate (PO43-), Chemical Oxygen Demand (COD), Total suspended solids (TSS), Dissolved Oxygen (DO), pH, and Temperature. The contribution from each filter medium layer in the removal of pollutants from the concentrated greywater treatment by vermifiltration was studied for 7 months. When the performances of the respective layers of the vermifilter and control unit were compared, there was no significant differences (>0.05) except for COD and DO concentrations but with a slightly less average effluent concentration of nitrate and orthophosphate in the control unit. To conclude, major removal of NH4+, NO3-, NO2-, PO43-, COD and TSS were occurred at the fine sawdust layer.

2.13 Jiang L., Liu Y., Hu X., Zeng G., Wang H., Zhou L., Tan X., Huang B., Liu S. and Liu S., 2015

The use of microbial-earthworm ecofilters for wastewater treatment with special attention to influencing factors in performance: a review.

This paper provided an overview of the research activities on the use of microbial-earthworm eco-filters (MEEs) for removing pollutants from various wastewater throughout the world. However, the long-term effective treatment performance and sustainable operation of this system still remain a challenge since the treatment performance would be affected by design parameters, operational conditions, and environmental factors. The design parameters and operational conditions of MEEs include earthworm species and load, filter media type, hydraulic loading rate, nutrient load, packing bed height, chemical factors and temperature. Lastly, this review highlighted the further research on these issues to improve performance and sustainability of MEEs.

2.14 Nahid Ghobadi, Reza Shokoohi, Ali Reza Rahmani, Mohammad Taghi Samadi, Kazem Godini, and Mohammad Reza Samarghandi; 2016

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

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. The vermifiltration caused a significant decrease in the levels of COD (75%), BOD (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.

2.15 Lourenco N. and Nunes L. M.,2017

Optimization of a vermifiltration process for treating urban wastewater.

A small-scale vermifiltration process comprising single stage, and four-stage vermifilter (VF) systems. All reactor modules were made of PVC with a total volume of 25 L using vermicompost as the filtering material and quartz sand and gravel as the inert filter. System performance was assessed by the removal efficiencies of BOD, tCOD, sCOD, pCOD, TSS and NH4 +. In the earthworm study, four abundances were evaluated: 10 g L−1 (W10), 20 g L−1 (W20), 30 g L−1 (W30) and 40 g L−1 (W40). In the four-stage VF the earthworm abundance evaluated was 20 g L−1. W20 proved to be the optimal treatment condition with efficiencies for BOD, tCOD, pCOD, TSS and NH4 + of 97.5%, 74.3%, 91.1%, 98.2% and 88.1%, for a pCOD/tCOD ratio of 0.20. The four-stage sequential VF promoted a decrease of BOD (98.5%), tCOD (74.3%), pCOD (86.7%), TSS (96.6%), and NH4 + (99.1%). Results indicate that sequential VF systems can significantly improve treatment efficiencies when compared to single stage VF.

2.16 Kundan Samal, Rajesh Roshan Dash, Puspendu Bhunia, 2017
Performance assessment of a Canna indica assisted vermifilter for synthetic dairy wastewater treatment.

Two lab-scale vertical flow vermifilter were designed, one aided with Canna indica (MAVF) and the other without it (VF), but Eisenia fetida was inserted in both the systems. Removal efficiencies of BOD were 80.6% for MAVF and 71% for VF, while for COD it was 75.8% and 66.1%, respectively. TSS removal for MAVF and VF was found to be 84.8% and 73.8%, respectively, but TDS removal was insignificant in both the filters. . MAVF removed 42.6% TN, and effluent NH4 +-N concentration in MAVF and VF were as low as 8.4mg/L and 13.2mg/L, respectively. However, TP concentration in effluent increased gradually may be due to the actions of phosphorus solubilizing microorganisms (PSM) and phosphatase enzymes secreted by earthworm. Growth characteristics of C. indica and E. fetida were also observed during the experimental period. The performance of MAVF was found to be superior to VF with high longevity.

3. Gap Analysis

Previously, there has been a paramount research using vermifilter for treatment of various types of wastewater, but there has been little research on MAVF as well as VF for treatment of domestic wastewater. Various parameters will be studied during this comparative study to suggest the best possible decentralized treatment process for domestic wastewater.

4. Objectives

a) Critical evaluation of current physical and biological systems of greywater treatment reported in literature with reference to their applicability to Indian conditions.

b) Design and development of pilot scale vegetated vermifilter for domestic wastewater treatment.

c) Performance evaluation studies of wastewater parameters between two designed pilot schemes.

i) Biological Oxygen Demand (BOD)

ii) Chemical Oxygen Demand (COD)

iii) pH

iv) Temperature

v) Dissolved Oxygen (DO)

vi) Total solids (TS)

d) Cost-benefit analysis of designed pilot treatment systems.

5. Material and Procedure

5.1 Earthworm - Vermifilter is to be inoculated with earthworms **Eisenia fetida** to achieve a stocking density of 10,000 worms/m3 in worm active layer **(Arora et al., 2014; Kumar et al., 2015)**. E. fetida is an epigeic earthworm species, which lives in organic wastes and requires high moisture content, adequate amount of organic matter, a suitable bedding material for proper growth and development. It is being used widespread in the existing vermifiltration system and also proven of its potential for processing of municipal solid waste and wastewater treatment **(Sinha et al., 2008).**

5.2 Plant - Organic compounds are degraded both aerobically and anaerobically by the heterotrophic microorganisms in the macrophyte based filter depending on the oxygen concentration in the bed. Those oxygen can be provided by diffusion, convection and oxygen leakage from the **C. indica** roots into the rhizosphere **(Vymazal, 2007).** They strongly enhance filtration processes by consumption, digestion and assimilation of high rates of organic solids retained in the bed matrix through passage of wastewater **(Arora et al., 2016; Wang et al., 2011)**

5.3 Procedure –

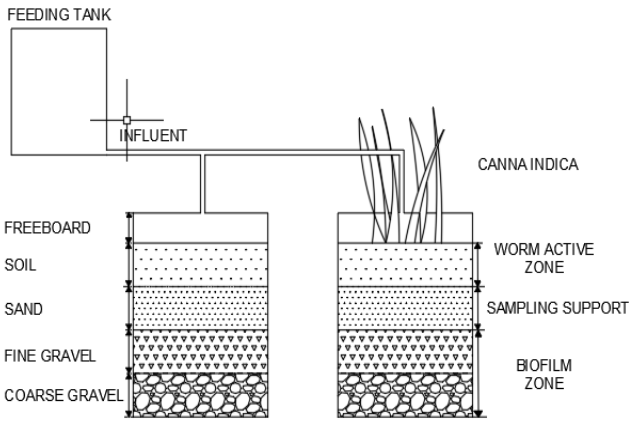

Fig. 1: Schematic Diagram of Experimental Arrangement

The experimental set-up consists of two cylindrical PVC containers erected in laboratory. The filter bed is to be filled with four layers (from top to bottom). Top layer or worm active layer consisted of vermicompost and garden soil in the ratio of 1:3 by volume. The second, third and fourth layers from the top will be taken as washed sand , 6–8 mm fine gravel and 10–12mm coarse gravel respectively.

The complete study is to be carried out for 56 days (7 weeks)and prior to analysis a 15 days acclimatization period will be provided to both the reactors. A constant hydraulic loading rate of wastewater, around 0.65m3 $m^{-2}day^{-1}$ is to be maintained in both reactors by gravity flow.

6. CONCLUSIONS

The filter media and other material required for the fabrication and erection have been finalized from extensive literature survey.

After the completion of process and logging of results, this work will provide an opportunity to explore the efficiency and sustainability of an integrated system consisting of C. indica and E. fetida particular to Domestic Wastewater.

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BIOGRAPHIES

Vaishnavi S. Angathekar, UG Student, Department of Civil Engineering, Rajarambapu Institute of Technology, (RIT) Rajaramnagar, Sangli, Maharashtra, India.

Yashwant M. Patil, Professor, Department of Civil Engineering, Rajarambapu Institute of Technology, (RIT) Rajaramnagar, Sangli, Maharashtra, India