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The Use of Vermifilteration in Wastewater Treatment: A Review

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Abstract—*Today, the biggest problem is scarcity of water which is vital for survival of living things, so the different methods are being adopted to recycle the wastewater. Many authors investigated may aspects of the utilization of earthworms in land improvement and environmental management. Vermifilteration is one of the cheaper, environmentally sustainable as well as communally acceptable treatment. The vermifiltration technology is the treatment of municipal and nontoxic industrial wastewater, purification and disinfection for their reuse. It is also known as a term lumbrifilteration . It is a technology to process organically polluted water using earthworms. It is emerging wastewater treatment technology designed for a wide range of municipal and industrial applications. Vermi Filter (VF) serves as an efficient reactor with advantages of high pollutant removal rate, low reactor volume required and unique capability of removing solids and nutrients together. The performance of VF which is based on various components such a biofilm growth, filter media and its size and aeration system. This method is widely used due to its simplicity ease in construction of filter. This paper summarize the research by various authors who investigated many aspects of utilization of earthworms.*

1. INTRODUCTION

Today, The global scientific community is searching for a technology to reduce the waste in such a manner that it should be economically cheaper, environmentally sustainable and socially acceptable. The technologies based on earthworms are self-promoted, self-improved and self-enhanced, low or no-energy requiring zero-waste technologies, easy to construct, operate and maintain .

Vermifiltration technology may remove chemical and biological contaminants (pathogens) in a single facility. The performance of vermifilter (VF) is controlled by an ecosystem of living organisms (earthworms and microorganisms), which helps in biodegradation of organic matter in wastewater. It 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 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 benefits of earthworms in recycling liquid or solid organic residues have already been highlighted (for instance: White, 1996; Hertle et al., 2002; Sinha et al., 2002; Bajsa et al., 2003; Taylor et al., 2003; Bouch´e and Soto, 2004; Hughes et al., 2007).. We all know that the earthworm is farmer's friend. But the truth is that earthworm is soil's cultivator. The earthworms have the ability to support the growth of plants and they can increase the fertility of the soil. The present paper reviews the research work done on various aspects involved in various uses of vermifilteration.

1.1 Biology of earthworm

Earthworms are very sensitive to touch, light and dryness. Worms can tolerate a temperature range between 5ºC to 29ºC. A temperature of 20ºC to 25ºC and moisture of 50–60 percent is optimum for earthworm function (Hand, 1988). Earthworms are long, narrow, cylindrical, bilaterally symmetrical, segmented animals without bones. The body is dark brown, glistening and covered with delicate cuticle. They weigh about 700–1400 mg after 10 weeks. They have a muscular gizzard which finely grinds the food such as fresh and decaying plant debris, living or dead larvae etc.(Edwards, C.A. and J.R. Lofty, 1972.)

In India, so far, 509 species, referable to 67 genera and 10 families, have been reported (Kale,1991). Earthworm is a hermaphrodite, both male and female reproductive organs are present in every single earthworm but self-fertilization does not generally occur. A pair of earthworm lay 100 eggs or cocoons within 3 to 6 months.(Ismail 1997) Cocoons resemble the shape of coriander seeds. Thorn like structure will be protruding from the 2 sides of cocoon. At first it appears in white color as growth proceeds, it becomes black colored. Young worms will come out within 2 to 3 weeks. 3 to 4 young worms will come out from one egg. They will attain the stage of reproduction within 6 weeks.(Stephenson,1930) In this stage a new growth structure called clitellum's will develop on the surface of earthworms.(Edwards 1972)Earthworms reproduce through bisexual reproduction. They can be useful as animal feed. Usually the life span of an earthworm is about 3 to 7 years depending upon the type of species and ecology. The Earthworm populations depend on both physical and chemical properties of the soil, such as temperature, moisture, pH, salts, aeration, and texture, as well as available food, and the ability of the species to reproduce and disperse .So the Utilization of earthworms may be as an ecologically sound, economically viable and socially acceptable technology.

2. SOME EXPERIMENTAL STUDIES

1) Sinha et, al., (2008 a) studied the vermifiltration of sewage obtained from the Oxley Wastewater Treatment Plant in Brisbane, Australia. They also studied the vermifiltration of brewery & dairy wastewaters. 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 (BOD5) 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) Sinha et, al., (2007) also studied the vermifiltration of brewery and milk dairy wastewaters which have very high BOD5 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 BOD5 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.

3)Meiyan Xing, JianYang, Yayi Wang, Jing Liu, Fen Yu studied Reduction and stabilization of sewage sludge during the clarification of municipal wastewater was synchronously shown to be improved significantly in a pilot-scale vermifiltration using an epigeic earthworm

Eisenia fetida. The present study aimed to select a better filter media suited to vermifiltration performance by the comparisons of sludge yields, the characteristics of the by-products of vermifiltration-vermicast and the abrasions of earthworms between ceramsite and quartz sand. It was observed that the sludge yield of the CVB (Ceramsite Vermibed) ranged from 0.07 to 0.09 kg SS/kgCODremoved at ambient temperature of 4–29 ◦C, representing 81% and 50% lower than that of the SVB (Quartz Sand Vermibed) and other reduction systems mentioned in this study. In addition, the sludge morphology variations described that the vermicast sludge from the CVB was more completely digested by earthworm than that of the SVB. The abrasions of the body wall of the earthworms in the CVB depicted less injured than that of in the SVB. So the ceramsite as filter media was better suited for the vermifiltration than the quartz sand.

4) Jian Yang, Chunhui Zhao, Meiyan Xing , Yanan Lin studied enhancement stabilization of heavy metals (Zn, Pb, Cr and Cu) during vermifiltration of liquid-state sludge. Significant enhancement of organics degradation in sludge caused an increase of heavy metal concentrations in VF effluent sludge. However, the analysis of heavy metal chemical speciation indicated earthworms made unstable fractions of heavy metals transformed into stable fractions. Further investigation using principal component analysis revealed that transformations of heavy metal fractions were mainly due to the changes in sludge physico-chemical properties of pH, soluble chemical oxygen demand and available phosphorus. The bioassay of earthworms indicated that only zinc was accumulated by earthworms because the unstable fraction was its main chemical speciation. Furthermore, risk analysis demonstrated that earthworm activities weakened heavy metal risk due to the formation of stable fractions although their total concentrations increased. These results indicated that earthworms in vermifilter had a positive role in stabilizing heavy metals in sewage sludge.

5) Xiaowei Li, Meiyan Xing , Jian Yang, Yongsen Lu studied the Vermifiltration is an alternative and low-cost technology for stabilizing excess sludge from domestic wastewater treatment plants. The biofilm properties of a vermifilter (VF) with earthworms, Eisenia fetida, for domestic wastewater sludge (DWS) treatment were studied. A biofilter (BF) without earthworms served as the control. VF biofilms had lower levels of suspended solids (SS), volatile SS, C, H, N and S contents, protein-like groups, and total viable cell numbers and larger humic acid-like fractions and protease, dehydrogenase, lipase, and amylase activities compared with BF biofilms. VF Furthermore, biofilms featured richer diversity in their microbial community and more populations of Proteobacteria than BF biofilms. The relationships between organic matter and microbial eco-physiological indices in VF biofilms were significantly different from those in BF biofilms. Overall findings indicated that earthworm presence remarkably decreases organic matter contents and microbial biomass and improves microbial enzyme activities and the community structure of VF biofilms.

6) Sudipti Aroraa, Ankur Rajpala, Tarun Kumara, Renu Bhargavaa & A.A. Kazmia studied the Pathogen removal during wastewater treatment by vermifiltration. The experimental phase continued for 10 weeks, starting after the initial stabilization phase of one week. Significant organic matter degradation and coliform removal were observed during vermifiltration of domestic wastewater. It was observed that vermifilter (VF) reduced biochemical oxygen demand and chemical oxygen demand by 84.8% and 73.9%, respectively.

7) Luth, Paul Robin,Philippe Germain, Marcel Lecomte , Brigitte Landrain , Yinsheng Li , Daniel Cluzeau studied the Earthworm effects on gaseous emissions during vermifiltration of pig fresh slurry. Treatment of liquid manure can result in the production of ammonia, nitrous oxide and methane. Earthworms mix and transform nitrogen and carbon without consuming additional energy. The objective of this paper is to analyse whether earthworms modify the emissions of NH_3, N_2O, CH_4 and CO_2 during vermifiltration of pig slurry.

The experiment used mesocosms of around 50 L, made from a vermifilter treating the diluted manure of a swine house. Three levels of slurry were added to the mesocosms, with or without earthworms, during one month, in triplicate. Earthworm abundance and gas emissions were measured three and five times, respectively. There was a decrease in emissions of ammonia and nitrous oxide and a sink of methane in treatments with earthworms. We suggest that earthworm abundance can be used as a bioindicator of low energy input, and low greenhouse gas and ammonia output in systems using fresh slurry with water recycling.

8) The research was conducted at the Piggery Experimental Station of Guernévez, Saint Goazec, France from October 2009 to November 2009. In this site, a vermifilter 48 m^2 in area and 0.5 m in height is in use since 2007. Most earthworms are Eisenia andrei (Bouché) and Eisenia fetida (Savigny). It was designed according to the conclusions of Li et al. (2008). It recycles the wastewater of a piggery with 30 sows with 4–6 flushings per day (800 L water per flushing). Wood chips are added twice a year, and the vermicompost is progressively removed. The wastewater goes through a screen, a vermifilter, a settling tank, and four levels of lagooning and constructed wetlands, until it reaches a storage basin that accumulates rainwater in winter to compensate for summer evaporation. The water is pumped back from the storage basin to flush the piggery. The compositions of the liquids at thevarious levels are given in Morand et al. (2009).

9) Longmian Wanga, Feihong Guo, Zheng Zheng, Xingzhang Luo, Jibiao Zhang studied the Enhancement of rural domestic sewage treatment performance, and assessment of microbial community diversity and structure using tower vermifiltration. The performance of a novel three-stage vermifiltration (VF) system using the earthworm, Eisenia fetida, for rural domestic wastewater treatment was studied during a 131-day period. The average removal efficiencies of the tower VF planted with Penstemon campanulatus were as follows: chemical oxygen demand, 81.3%; ammonium, 98%; total nitrogen, 60.2%; total phosphorus, 98.4%; total nitrogen, mainly in the form of nitrate. Soils played an important role in removing the organic matter. The three-sectional design with increasing oxygen demand concentration in the effluents, and the distribution of certain oxides in the padding were likely beneficial for ammonium and phosphorus removal, respectively. The microbial community profiles revealed that band patterns varied more or less in various matrices of each stage at different sampling times, while the presence of earthworms intensified the bacterial diversity in soils.

10) The acute toxicity tests assessed the toxicity of two common sodium salts found in household products namely: Na_2SO_4 and NaCl, (Patterson, 1998). Sodium carbonate another common sodium salt in household products has been previously found to have a relatively low toxicity (Edwards and Arancon, 2004). The concentrations of Na_2SO_4 used in the test were 0 (control), 2.17, 10.87, 21.75, 43.50, 108.75 and 217.49 mmol/kg. The concentrations of NaCl used in the test were 0 (control), 4.35, 10.87, 108.74 and 21.47 mmol/kg of substrate. Each concentration had three replicates and 10 adult worms with clitellum were added to each container 24 h after each sodium salt had been added and homogenised into the substrate. The worm species E. fetida was used as the test species. The species is the most widely used vermifiltration species (Taylor et al., 2003) and vermicomposting species (Edwards and Arancon, 2004). It is also the species most commonly used in the OECD acute toxicity test (Davies et al., 2003).

11) Zhalo et al.(2010) studied Two sets (each has three parallel reactors) of cylindrical filters were set up, one set was the vermifilters with an initial earthworm density of 32 g/L (fresh weigh basis) while the conventional biofilters (BF)

without earthworms were used as the control. Each filter (diameter of 30 cm and depth of 90 cm, made of perspex) had a work volume of 49.5 L and packed with ceramsites (10–13 mm in diameter). A layer of plastic fiber was placed on the top of the filter bed to avoid the direct hydraulic influence on the earthworms and ensure an even influent sludge distribution. The earthworms, Eisenia fetida,used in this study were purchased from a farm in Yancheng city,China. The influent sludge was withdrawn from the secondary sedimentation tank of a municipal WWTP in Shanghai, China. The hydraulic load of the two sets of filters was kept at 4 m/d, and the organic load of the influent sludge was at the range of 1.38–1.51 kg-VSS/(m3d). After passing through the filter bed, the sludge entered into a sedimentation tank. These filters were operated continuously for 8 months to investigate their performances on heavy metal stabilization after about 30 days of acclimation.

3. VERMIFILTERATION

Vermifiltration was first advocated by the late Professor Jose Toha at the University of Chile in 1992 (Wang, Yang, Lou, & Yang,2010). It also known by the term lumbrifiltration, is a relatively new technology to process organically polluted water using earthworms. It is an extension of vermicomposting for solid waste first developed wastewater streams with high organic content In the vermi-biofiltration system, suspended solids are trapped on top of the vermifilter and, after getting processed by the earthworms, are fed to the soil microbes immobilized in the vermifilter. Dissolved and suspended solids (organic and inorganic get trapped by adsorption and stabilization through complex biodegradation processes which occur in the “living soil” inhabited by earthworm and the aerobic microbes. Intensification of soil processes and aeration by earthworms and the resultant soil stabilization makes the filtration system effective, while reducing the overall space requirement compared to a conventional filtration system. In general, inoculated earthworms in vermibeds accumulate many organic pollutants from its ambient soil environment, passive absorption through the bodywall and also intestinal uptake during the passage of soil through the gut . Successful attempts have also been made to create a reactor set-up with the use of aquatic worms, though reported treatment efficiencies (particularly removal of solids) vary a lot Vermifiltration of wastewater using waste eater earthworms is a newly conceived novel technology. Earthworms’ body works as a ‘biofilter’ and they have been found to remove the 5 days’ BOD (BOD5) by over 90%, COD by 80–90%, total dissolved solids (TDS) by 90– 92%, and the total suspended solids (TSS) by 90–95% from wastewater by the general mechanism of ‘ingestion’ and biodegradation of organic wastes, heavy metals, and solids from wastewater and also by their ‘absorption’ through body walls. There is no sludge formation in the process which requires additional expenditure on landfill disposal. This is also an odor-free process and the resulting vermifiltered water is clean enough to be reused for farm irrigation and in parks and gardens. They create aerobic conditions in the waste materials by their burrowing actions, inhibiting the action of anaerobic microorganisms which release foul-smelling hydrogen sulfide and mercaptans. Modifications of the vermifilter have been proposed and examined. They have been integrated into constructed wetlands and have also been triplicated to further improve the final effluent quality.

4. FILTERATION

Removal of suspended solids by filtration plays an important role in the natural treatment of groundwater as it percolates through the soil. It was also a major partof most water treatment. Groundwater that has been softened or treated through iron and manganese removal will require filtration to remove floc created by coagulation or oxidation processes. Since surface water sources are subject to runoff and do not undergo natural filtration, it must be filtered to remove particles and impurities.

4.1. Filteration Process

The filter used in the filtration process can be compared to a sieve or micro-strainer that traps suspended material between the grains of filter media. However, since most suspended particles can easily pass through the spaces between the grains of the filter media, straining was the least important process in filtration. Filtration primarily depends on a combination of complex physical and chemical mechanisms, the most important being adsorption. Adsorption was the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials.

4.2 Filter Media

A filter media is one of the main components in the system to achieve effluent quality requirements. The filter media has a noticeable influence on the hydraulic characteristics on oxygen-substrate transfer rate. Therefore, the selection of a suitable media is critical part in filteration process, to enable the effluent quality reached the regulated standard. In any system, there are two types of filter media; floating media such as plastic media and polystrene pellets and sunken media such as ceramics, zeolite and sand. The filter media provide a large surface area per unit volume to maintain a high amount of active biofilms and variety of microbial population. The media also allows the reactor to act as a deep, submerged filter and incorporate suspended solids removal. The selection of filter media to enable the required effluent standard quality for ammonia removal is depending on some factors which is media type and sizes. It has been found that the characterization of filter media is required to determine their suitability for biofilm growth and attachment.

5. CONCLUSION

Various papers regarding the use of Eisenia fetida in vermifilteration summarize the various aspects of earthworm utilization in filteration. It is concluded that vermifilter is more efficient in efficiency of removal of BOD, COD as well as suspended solids. 5 days BOD (BOD5) remove by over 90%, COD by 80–90%, total dissolved solids (TDS) by 90– 92%, and the total suspended solids (TSS) by 90–95%

Vermifilteration is oddourless Sustainable, effective and cheapest method of effluent treatment for wastewater.

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