Vermifiltration Technique: A Review

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Abstract : Now a days waste water treatment processes are costly, need more space for the construction of treatment plant & use of chemical for the treatment. We need some more options at low cost, space saving and eco-friendly techniques. Centralized treatment involve problem of high cost collection, treatment & disposal of wastewater which needs for small scale decentralized eco-friendly alternative treatment options Vermifiltration is one of the ecofriendly, low cost, chemical free technique used to treat the wastewater using the Eiseniafetida earthworm species. The present paper review describes the vermifiltration mechanism for removal of various pollutants from wastewater such as pathogen, organics and nutrients. In addition to this, effect of various parameters on treatment process like feeding mode, hydraulic loading rate, earthworm density, filter media, organic carbon source, etc. have been discussed briefly.

***IndexTerms* - Vermifilteration, Biochemical Oxygen Demand(BOD), Chemical Oxygen Demand(COD), Total Solids(TS), Total Suspended Solids(TSS), Total DissolvedSolids(TDS), Earthworms, Eiseniafetida, Waste Water(WW), wastewater treatment, Ingestion**

I. INTRODUCTION

The generation & treatment of waste water creats health issue in the developing countries due to the inadequate treatment facilities. Our water resources are getting polluted due to discharge of untreated waste water. Most of the population in rural areas ofdeveloping nations depends upon the treatment systems that are comparatively low costs, energy, and maintenance considered as better for the treatment of rural domestic wastewater [1, 2].

In rural area many technologies have been developed for the treatment of domestic wastewater, including soil infiltrationtrenches, constructed wetlands, vegetation-based wastewater treatment and vermifiltration[3,4, 5, 6]. Among these technologies, the vermifiltrationis the most effective technology as other technologies are restricted to ample occupying area [7]. A revolution in vermiculture studies (rearing of useful earthworms species) for sustainable development &multiple uses in environmental protection [8-10].The role of earth-worms is known as “fertility improvers”, “waste managers”, & “soil managers and “plant growth promoters” for long time. But some new discoveries about their role in “wastewater treatment”, “contaminated soil remediation”

In Vermifiltration technology.Earthworm's body works as a “biofilter”& various species of earthworm are used .It has been found that through this technology removal of 5 days BOD (BOD5), COD, total dissolved solids (TDS), and the total suspended solids (TSS) 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. In vermifilter technology, the earthworms increase the population of soil microorganisms[11]. For small city & town vermifilteration can be good option for decentralized treatment of wastewater. It has been reported that efficiency of vermifiltration technology is same as activated sludge process [12].In this process there is no sludge formation which requires additional cost on landfill disposal. Moreover it is an odor-free process and the vermifiltered water can be reused for irrigation purpose& in park, gardenexcept drinking purpose.

II. FACTORS AFFECTING EARTHWORM

Hydraulic retention time: It is how much time taken by waste water to pass through vermifilter bed in which earthworms in habits. The efficiency of vermin processing will be more if wastewater remain in contact with earthwarm for longer time. Slower discharge of wastewater on filterbed, maximum HRT can be achieved which leads to slower percolation into the bed. By increasing the depth of filter bed we can increase the HRT. (Sinha et al. 2008).The optimal HRT of a vermifiltration system can be determined on the basis of concentration of the organic pollutants .However, in some cases, the optimal HRT ranged from six to nine hours for sewage wastewater (Xing et al., 2005). Due to the differences of HRT between some studies, it is important to consider that the optimal HRT may vary with design of the vermifiltration system.

Hydraulic loading rate: It is quantity of wastewater applied on filter bed per unit time per m2 area. Higher hydraulic rate could reduce the treatment efficiency (Sinha et al. 2008).For adsorption, transformation, and reduction of contaminants wastewater required a certain contact time with the biofilm which grew and attached to the filter media to allow.The rate of infiltration depend upon the substrate characteristics like pore size distribution and pore size, method of effluent application, substrate morphological characteristics including structure, texture, bulk density and clay mineralogy [13].Wang et al. [14] found that at a HLR of 1 m/d in an integrated system consisting of *Phragmitesaustralis & Eiseniafetida* COD, nitrogen and phosphorous removal efficiency were more than 90 % and Zhao et al. [15] observed synthetic wastewater using *Acoruscalamus*plant species in a vermifiltration system at HLR of 0.056 m/d and COD, nitrogen removal were 86.7 % and 85.6 %, respectively. Kumar et al. [16] used varying HLR of 1.5, 2.0, 2.5 and 3.0 m/d and found 2.5 m/d as the optimum HLR for domestic wastewater treatment in vermifilter. Removal efficiency of BOD5, TSS and TDS were reported as 96%, 90% and 82%, respectively at optimum HLR

Feeding mode: Different feeding mode like continuous, batch, intermittent process influence the oxygen diffusion & transfer, oxidation-reduction conditions in filter bed, hence affect the treatment efficiency. Generally, lower redox potential leads to less effective removal of aerobic pollutant in continuous mode than batch and intermittent flow mode [17]. Arora et al. [18] reported mean removal efficiencies of BOD and COD were 84.8% and 73.9%, respectively in the continuous mode of a vermifiltration system. Sinha et al. [19] concluded in a continuous vermifilter COD and BOD treatment ranged from 70 % to 95 %. Li et al. [20] also observed the significant COD, BOD and TSS removal in a continuous onsite vermifiltration system. Intermittent feed involves feeding water with periodic flood and drain to improve redox conditions &achieve subsurface aeration [21]. There are many advantages of intermittent feed over others. Intermittent operation encourage DO availability for the growth of aerobic bacterial which enhances the biodegradation process. Secondly, periodic resting might be adopted as a passive method for removing the surplus biomass and restoring the hydraulic capacity. Thirdly, during the process of pollutant removal, the produced gases such as N2, CO2, CH4 and N2O will congest in and clog the soil pores, thus reduce the infiltration capacity(22,23,24]. Therefore, intermittent operation encourage the gases escaping from the systems

Earthworm stocking density and mixed culture plant : Population of earthworms (stocking density) in a vermifiltration system affect various physiological processes such as respiration rate, reproduction rate, feeding rate and burrowing activity. At higher population densities, cocoon production per earthworm is reduced, growth rate is decreased and mortality is increased. Dominguez [25] has reported that, at higher population densities earthworm grow slowly with a lower biomass, even when the physical conditions were ideal &identical. Therefore, when establishing a vermifiltration system, it is essential to maintain optimum earthworm density to obtain maximum population growth and reproduction in shortest possible time. Sinha et al. [26] reported that a relatively high number of earthworms (at least 15,000-20,000 worms/m3) in vermifilter should be inoculated. Arora et al. [27] used 1000 worms/m3 in a vermifiltration system to remove organics & pathogens. Xing et al. [28] inoculated 40g/L Eiseniafetida to treat liquid state sewage sludge.

Filter media: Substrates provide a suitable growing medium for microorganism, earthworm, and plant. Through sorption processes tt interacts directly with contaminants (mostly phosphorus) and allows successful movement of wastewater [29]. Large sized media should not be used which leads insufficient surface area of the top coarse layer for the growth of biofilms. Likewise, small grains can provide a higher specific surface area for biofilm establishment; whereas, the narrower pore diameters may result in bridging of surface accumulations and pore occlusion. The survival of earthworm also depends on filter media.Filter media previously utilized for vermifilter are ceramsite, slag-coal cinder, mud balls, quartz sand, glass balls, river bed material, wood coal, etc. [30, 31,32]. Wang etal. [33] used converter slag-coal cinder as vermibed. Average treatment efficiency of BOD, COD, phosphorus and NH4+-N were 98.4 %, 78.0 %, 62.4% and 90.3 %, respectively. Arora et al. [32] and Kumar et al. [31] investigated that the river bed material was the most excellent media for vermifilter.

Organic carbon source: Biological wastewater treatment process depends on types of organic carbon sources which is required for microbial activity. Low C/N ratio in the influent might leads to the low nutrient removal efficiency. Different substances like saw dust, rice straw, dried leaves, etc. have already been applied in vermifilter. The C/N ratios vary between different systems, depending on the wetland configurations, nitrogen composition, plantation and types of wastewater to be treated.

Temperature: Growth of Microbial and its metabolic process strongly depends on temperature. At higher temperature microbial activity will be higher due to rapid metabolism and at lower temperature restrict the biological activity and lead to accumulation of organic matter [34, 35].The optimum temperature range for earthworms is 15-30^{0}C. In extreme conditions, earthworms go to deeper layers of the soil for protection For nitrification and denitrification activity in soils the optimal temperature varies between 20-30^0 C. Wang et al. [36]observed the performance of vermifilter fed synthetic wastewater over the course of one year. Both COD and NH3-N removal efficiency during the summer and autumn were found to be more than 95 % and 85 %, respectively. Arora and Kazmi [37] also investigate the effects of seasonal temperature with a special attention for pathogen removal in vermifilter taking spring, winter, autumn, and summer into consideration. The study showed that higher BOD (88-95 %) and COD (70-80 %) removal was achieved during the spring and autumn period when the mean temperature was 25-27^{0}C. However, during summer, the indicator bacteria removal was maximum by 99.9%, *Salmonella* reduction by 96.9% and *Escherichia coli* by 99.3%.Nivalaetal. [38] found higher organics removal performancesduring summer (60-97 %), compared to winter (44-88 %) in an aerated horizontal flow wetland system

pH : The pH of the wastewater influences the survival and activity of worms. Vermifiltration systems have been found to stabilise the acidic or basic wastewater (Hughes et al., 2007). In a study by Hughes et al. (2007), it was also found that the earthworm species *E. fetida* and *E. andrei*, can survive pH values between 6.2 and 9.7, with juvenile impairment at both higher and lower pH levels.

Presence of Sodium chloride in waste water : It is observed that high level of sodium chloride is toxic for the worm species which reduce the efficiency of treatment..(Pathania et al. 2013)

Earthworm selection: Generally EiseniaFetida is widely used species of earth worm for vermifilteration (Pathania et al 2013).

III. BOD, COD & PATHOGEN REMOVAL

BOD and COD removal : Various Researches had been carried out for the treatment of wastewater from rural and urban areas including industries. The removal parameters review in different areas are given below.

Lakshietal 2014 reported removal efficiency of BOD, COD, TDS & TSS were 92%, 65%, 90% & 88% respectively at institute level. It was reported that there was no formation of sludge &odour. Kharwadeetal 2011 reported BOD,COD, SS removal efficiency of 85-93%, 74-80% & 70-80% respectively for domestic grey water (Nagpur). Meiyanetal 2010 found COD removal efficiency 81.3%, for rural domestic sewage.Chaudhry 2006 found BOD & COD removal efficiency of 98-100% & 45% respectively for municipal waste water. Li etal found BOD, COD & SS removal efficiency of 89.3%,83.5% & 81.3% respectively for sewage. LIFE 2005 found BOD,COD& SS removal efficiency 97%,75% & 94% respectively for domestic waste water.

Sinha et al. [39] investigated removal efficiency of BOD, COD, TDS and TSS were > 90 %, 80-90 %, 90-92 % and 90-95 %, respectively for domestic wastewater treat by vermifilter. while treating domestic wastewater using *Eiseniafetida*Arora et al. [40]found the BOD and COD removal efficiency of 75.9 % and 66.7 %, respectively,. Xing et al. [41] also found a pilot scale vermifilter removal efficiency for COD, BOD, SS could reach up to 47.3-64.7 %, 54.7-66 % and 57-77.9 %, respectively. Wang et al. observed COD, BOD, SS removal efficiency 83.5 %, 81.3 % and 93.7 %, respectively as they used a circular vermifilter to treat domestic wastewater for one year.

According to Xing et al,earthworms enable transformation of organic materials from insoluble forms to soluble forms that are available for further degradation by microorganisms, which leads to enhance the overall decomposition and enzymeactivities. Earthworms also get their nourishment from microbes, where as microbial activity is stimulated by the casts produced by worms. These are often enriched with different macro and micro nutrient sand contain more active microbial communities; henceenzymeactivity isgreater in the casts of the earthworm than inuningested material .

Reference [42] studied the effluent management from household liverstock by the use of earthworm which contain very heavy loads of BOD, TDSS, nitrogen & phosphorous. The worms produced clean effluents and also nutrient rich vermicompost. Using vermifilteration technology reference [43] studied the treatment of domestic waste water & found that removal efficiency of BOD, COD SS & TDSS were more than 70-80. Reference [44]studied the treatment of municipal wastewater in a pilot plant for wastewater of 1000 inhabitants and found that the BOD load was removed by 99%, TSS by 95%, VSS (volatile suspended solids) by 96%, nitrogen (N) by 89% and phosphorus (P) by 70%. A pilot study on vermifiltration of sewage was made by [45] at Shanghai Quyang Wastewater Treatment Facility in China. The earthworm bed size was 1 m (long) × 1 m (wide) × 1.6 m (high), which was composed of granular materials and earthworms. The density of worm's number was kept at about 8000 worms/sqm. The raw sewage average chemical oxygen demand (COD) was 408.8 mg/L, 5 days biological oxygen demand (BOD5) was 297 mg/L & suspended solids (SS) was 186.5 mg/L. The hydraulic retention time varied from 6 to 9 hours and the hydraulic loading from 2.0 to 3.0 m3/ m2.d) of sewage. The removal efficiency of COD ranged between 81-86%, the BOD5 between 91-98%, and the SS between 97-98%.

Reference [46] studied the vermifiltration of sewage obtained from the Oxley Wastewater Treatment Plant in Brisbane, Australia. 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 was over 50%. Although the COD removal by vermifiltration system was not significant like BOD, it was still higher than the value of COD removed by the control system without worms. Reference [47] also studied brewery and milk dairy wastewaters in Brisbane. From brewery industry having very high BOD56780 mg/L and TSS l682 mg/L and from dairy industry 1,39,200 mg/L & 3,60,00 mg/L respectively. In both case BOD removal was up to 99% & TSS removal was up to 98%. But the hydraulic retention times (HRTs) was 3-4 hours in case of brewery wastewater and 6-10 hours in case of the dairy wastewater. Currently Reference [48]are working for "fruit juice processing industry" wastewater in Brisbane. The fruit juice wastewater contain very high BOD, COD, TSS and TDS. The removal efficiency of 5 days biological oxygen demand (BOD5) was 99.77%, chemical oxygen demand (COD) 95.89%, total suspended solids (TSS) 91.57%, total dissolved solids (TDS) 97.27%, and the turbidity 95.38%.

Pathogen removal and microbial dynamics in vermibed :

The pathogens reduction (FC, TC, FS, salmonella, *E. coli*) in vermifiltration processes is mainly due to the action of intestinal enzymes secreted in the earthworm's body wall Theearthworm intestine &gizzard work as a 'Bio-reactor'. They ingest the food materials, cull the harmful microorganisms and deposit them mixed with minerals and beneficial microbes as 'vermicasts' on the top layer. Earthworms release coelomic fluids from their body cavity (coelom) that have antibacterial properties and destroy all the pathogens present in wastewater). Earthworms devour on the pathogens found in the wastewater and promote the development of some bacteria and fungi, which are capable of producing antibiotics that kills the pathogens.

IV. ADVANTAGES & LIMITATION OF VERMIFILTERATION TECHNOLOGY

Advantages of vermifilteration technology over conventional wastewater treatment technologies

1) Low Energy Requirement :In Vermi-filtration technique energy requirement is low as compared to other coneventional wastewater treatment system like "Activated Sludge Process", "Trickling Filters" and "Rotating Biological Contactors" which are highly energy intensive, costly to install and operate and do not generate any income. In the vermifilter process there is high value added end products e.g. vermifiltered "nutrient rich" water which can be used for farm irrigation and vermicompost retrieved from the vermifiltered beds.

2) No Formation of Sewage Sludge and No Foul Odor :The major advantage of vermifiltration system is that there is no formation of "sewage sludge". The worms decompose the organics present in the wastewater and also devour the solids (which forms the sludge) synchronously. There is no foul odor as the earthworms arrests rotting and decay of all putriciblematters in the wastewater and the sludge. Earthworms feed readily upon the sludge components, rapidly convert them into vermicompost, reduce the pathogens to safe levels and ingest the heavy metals

3) Disinfected and Detoxified :Treated Water for Reuse :Vermifiltered wastewater is free of toxic chemical &pathogens and it is suitable for "reuse" as water for farm irrigation& other non-potable uses. The worms devour on all the pathogens (bacteria, fungus, protozoa & nematodes) in the medium in which they inhabit. They have the tendancy to bio-accumulate high concentrations of toxic chemicals in their tissues and the resulting wastewater becomes almost chemical-free.

Vermifilteration limitations

During the implementation on the field most of the researches have focused on vermifilter operation, the limitation of the vermifilter are the following.

I) Vermifilter cannot be operated in floating mode or in submerged condition. Earthworm can not survive. It was observed that during day time movement of earthworm are restricted because sun heat dries out their skin and paralyzes them, they cannot breath and eventually die, which affects the treatment process. Therefore surface should be covered or the filter bed should be kept away from sunlight.

II)Earthworms can not survive high hydraulic loading or direct impact of rain because whole body is made of soft muscular part [49]. During high hydraulic load, soil void fills up with water & saturated [50]. Due to this in middle & bottom layer of filter earthworms casting &burrowing activity reduces.So, oxygen transfer through diffusion process to the bed material is limited. So bottom layer become dead zone &only top layer is favourable for the habitation of earthworms. Which reduce the treatment efficiency.

III)vermifilter can not treat Saline and sodic water (NaCl contained) because it creates osmotic imbalance within earthworm body and arrests neurosecretory activity [51,52]. Indirectly, it reduces reproduction rate of worms, biomass & survival. Similarly, wastewater which containheavy metals cannot be treated efficiently.

(IV)Due to rapid increase of earthworm population, stability of vermifilter can not sustain longer. After certain time due to lack of food & space, health condition & growth rate may be affected badly, which may directly reduce treatment process.

(V)There is no proper methodavailable for the cleaning of vermifilter. Proper attention is required while segregate worms from the bed material because they may injure or die due to improper handling.

(VI)Vermifilters chocked frequently so this system fail to work continuously for longer time due to deposition of excess solid on top layer & formation of sludge on the surface. Height of Vermifilter is a major factor.iffavourable condition is not maintained, earthworm activities are limited to certain centimeter.

V. CONCLUSION

Vermifiltration is one of the efficient technology for the removal of BOD, COD, TSS, SS as compared to the other conventional techniques. The end product of this technique is vermicompost which can be used as a soil conditioner. There is no formation of sludge. vermifilter uses no chemicals, the system is all natural.

it can be installed as primary, secondary or tertiary treatment unit. But when the pollutants load of wastewater will be very high, then it should be used as tertiary treatment unit only. Contaminant removal process are majorly biological; i.e. microbial degradation or transformation process. Earthworms are protective and productive organisms and they play a major role in fragmenting pollutants and oxygenating filter bed. There are some limitation also. The study of potential harmful micro-organisms before and after the treatment is also desirable, as most of the wastewater contains harmful pathogens and there is need to analyse them before the treated water can be reused or discharged..

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