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Treatment of Hospital Wastewater through Vermifiltration unit

Neha Verma[1] and Ashok K. Ghosh[2]

[1]Department of Botany, A. N. College, Patna,
[2]Bihar State Pollution Control Board, Patna, India
Email id: nehavipul15@gmail.com

ABSTRACT

A huge amount of water is consumed in hospitals. Consequently, considerable amount of hospital wastewater is generated and cannot be released without treatment because such water carries so many pathogens and harmful toxic substances. There are so many methods for treatment of wastewater, vermifiltration technique is one of them. Vermifiltration is one of the cheaper, environmentally sustainable, and acceptable treatment processes. In this study, earthworm's species *Eisenia fatida* has been used for the treatment of hospital wastewater. The gut of the earthworm acts as a bioreactor. Earthworm can ingest the solid and liquid organic wastes and eject them as vermicompost. Wastewater analysis was done by vermifilter collected from Mahavir Cancer Sansthan & Research Center and PMCH, Patna. Efficiency of the system, variations of pH value, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BODs), Total suspended solid (TSS), and Turbidity were measured in this study. A significant decrease in the level of BODs, COD, TSS, Turbidity, and neutralized pH of water was found using vermifiltration. Vermifiltration technology can be applied as an environment friendly method for the treatment of hospital wastewater. It also reduces the environmental risk.

Keywords: Vermifiltration (VF), Hospital wastewater from Mahavir Cancer Sansthan & Research Center (HWW1), Hospital wastewater from PMCH (HWW2), Vermiaqua of Mahavir Cancer Sansthan & Research Center (VA1), Vermiaqua of PMCH (VA2).

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INTRODUCTION

Treatment of hospital wastewater is very crucial because it creates both the qualitative and quantitative issues. Hospital wastewater contains so many materials like drug metabolites, chemical materials, pharmaceutical ingredients, pathogens, disinfectants and organic matters (Pauwels and Verstraete 2006). Consumption of water for domestic purpose is approximately 100-200 lit/person but in hospital consumption of water is approximately 350-400lit/bed i.e. the water consumption rate in hospital is so higher than the domestic consumption (Ghobadi et. al 2016). Entrance and discharge of untreated hospital wastewater in the environment (especially in soil and water) causes serious health problems for human beings and other organisms (Jones et. al 2001). Thus, it is very important that the hospital wastewater should be treated effectively before discharging into municipal collection system (Suarez et. al 2009).

Establishment and running cost of Sewage Treatment Plants (STP) are very high, so developing countries can't afford the construction and maintenance of the STP unit. Beside this large quantity of sanitary and sewage sludges are also generated annually (Tomar et al. 2011 & Kumar et al. 2014). Hence, it is necessary to develop a suitable method which can remove these pollutants (Carballa et al. 2004). Considering the characteristics of these types of wastewater, various processes are used for the treatment of wastewater, but these are expensive, time consuming, space consuming and different chemicals are used. Biological measures are more suitable than the chemical and physical treatment methods for the treatment of these kinds of wastewater. To overcome these types of problems a new technique has been introduced, which is low cost and ecofriendly. For this purpose, earthworms are introduced in the filtration system and known as vermifiltration system. Vermifiltration is a new approach towards wastewater treatment. This system is all natural, save money, time, energy, space and eliminate use of chemicals. Vermifiltration is an environment and economic friendly technology when compared to other biological processes like: fixed activated sludge treatment, septic tanks, rotating biological contactor, trickling filters etc. (Ansola G. et al. 2003, Zhang D. Q. et al. 2012). Vermifiltration process is an appropriate small-scale way to treat wastewater. Technically, it is a synergistic and symbiotic action of earthworms and microorganisms, where earthworms integrated with organic pollutants which is present in wastewater and increasing surface area that is suitable for the microbial activity and further degradation (Tomar P. et al. 2011, Arora S. et al. 2016 and Samal K. et al. 2017). Professor Jose Toha (Lat

e) of the University of Chile, Chile, was among the pioneer scientists of world to work on this innovative technology for wastewater treatment by earthworms in 1992 (Wang, Yang, Lou, & Yang,2010). It is a self-regulated, automated, cost-effective, no noise pollution, low electricity, sludge free, maintenance free disinfected and detoxified process. This technology fulfills all the necessary nutrients which is required for irrigation in agriculture. Actually, earthworm's body functions as a bioreactor having physical, bio-degradation and chemo-degradation process combined together and make the earthworm's body as a biofilter that absorbs pollutants from wastewater and reduces BOD, COD, TDS, TSS and Turbidity. VF reduces 95% BOD5, 85% COD, 90-92% TDS, 95% TSS & Turbidity and 99% fecal coliforms from wastewater (Sinha et al, 20012). It also reduces 93% BOD5, 65% COD, 89% TSS and average pH value was 7.24 from hospital wastewater (Ghobadi et al. 2016). Vermifiltration is capable of treating hospital wastewater because it reduces 90% COD and 90% BOD_5 from hospital wastewater (Shokouhi et al. 2020). Vermiaqua is almost crystal clear, neutral in pH, nearly sterile and also a nutritive organic fertilizer, rich in 2 to 3% Nitrogen, 1.85 to 2.25% Potassium and 1.55 to 2.25% Phosphorus i.e. NPK (Sinha et al, 2008 & Sinha et al, 2010). This technology has been used for the treatment of wastewater from sewage, small communities and industries like, gelatin, dairy, herbal medicines etc. Vermifilter may better reduce the environmental risk of antibiotics which is present in hospital wastewater (Shokouhi et al. 2020). Vermifiltration technology helps the reuse of wastewater water in the society. Due to the highly nutritious properties it becomes useful for irrigation, with the use of which also saves water and fertilizers (Kumar and Ghosh 2019). As vermifiltered water is highly nutritive, odor free, pathogen free, chemical free, neutral in pH and sterile, so it is used for washing in homes, vehicals, institutions, toilet flushing, irrigation in farms and gardens, and also for industrial uses (Sinha et al. 2012).

In this study, we investigated the performance of vermifilteration process for the treatment of hospital wastewater and the removal efficiency of COD, BOD_5, TSS and Turbidity from the hospital wastewater.

MATERIAL & METHODS

Vermifiltration bed was made up of gravels of different sizes, sand and garden soil. 1.5 kg earthworms were added in garden soil which was Purchas from local market.

1.Designing and preparation of Vermifiltration unit

VF unit was designed for the treatment of hospital wastewater. For this purpose, plastic drum of 80 l was taken. It was filled with 25 cm of large size gravel, 25 cm of middle and 25 cm of small size gravel. It was followed by 25 cm of sand. The top layer of about 35 cm was consist of garden soil. In topmost soil 5kg dry cow dung and 1kg crop straw were added. After 2weeks 1.5kg earthworms were added on the top layer of soil bed known as vermibed. Different materials of vermifilter unit was shown in fig. 1. Dry leaves were added at regular interval as a food supplements for earthworms. Two weeks were given to the earthworms to settle in the soil bed to adjust in the new environment before the experiments. VF could run after the stabilization phase. The upper part of drum was connected with influent (hospital wastewater) container having water controller knobs for the adjustment of poured down of wastewater at the speed of 10 ml per minute upon the top layer of the drum (vermibed) and the lower part of drum was connected to the effluent (filtered water) container through a water pipe for the collection of vermiaqua. All containers were assembled on the movable iron rack as shown in Fig 2.

Fig. 1: Different materials used for the fabrication of vermifilter bed.

Fig. 2: Vermifiltration unit assembled on the movable iron rack

2. Preparation of Control

In control Earthworms were not released except that all the arrangements of layers were as it is vermifilter bed.

3. Biology and Ecology of Earthworm

Earthworms are cylindrical, long, narrow, segmented animals without bones, tubular bilaterally symmetrical and measuring a few centimetres in length. Their body is glistening and dark brown in colour. It is covered with delicate cuticle. Earthworm's body consists of 70-80% of high-quality lysine (rich protein on a dry weight), 14% fats, 3% ash, and 14% carbohydrates (Gerard 1960 and ARRPET 2005).

Earthworms are burrowing animals. They form tunnels by eating their way through the soil. Soil moisture, presence of organic matter and pH of soil are the factors for the distribution of earthworms in the soil. Earthworms occur in diverse habitats, especially in dark and moist conditions. They are generally absent or rare in soil, with a coarse texture and high clay content, or soil with pH<4 (Gunathilagraj 1996). Generally, earthworms are tolerant to moderate salt salinity in the soil. But, some species like tiger worms (*E. fetida*) have been found highly salt tolerant (Satchell 1983).

Proper ventilation of air in the solid medium is necessary because worms breathe through their skin. Worms can tolerate a temperature ranging between 5^0C and 29^0C. For a good worm function, a temperature of 20^0C -25^0C and moisture of 60-75% is required. Earthworms multiply very rapidly, as they are bisexual animals. Each worm ejects a lemon-shaped 'cocoon' after copulation, where sperm enters to fertilize eggs. Up to 3 cocoons per about 10-12 tiny worms emerge. Studies show that worms double their number at least every 60-70 days. Earthworms can multiply by 2^8, (i.e. every 6 months 256 worms were developed from a single individual) if given the optimal conditions like moisture, temperature, and feeding materials. To produce a huge biomass of worms in a short time, each of 256 worms multiplies in the same proportion. Life cycle of worm is about 220 days. They produce 300-400 young worms within this life period (Hand 1988). An adult can attain reproductive capability with 8-12 weeks of hatching from the cocoon. Red worms take 4-6 weeks to become sexually mature, and earthworms continue to grow throughout their life (Sinha et al. 2012).

Earthworms are very sensitive to light, touch, and dryness. Low temperature (cold) is not a problem for them when compared to high temperature (heat). Their activities are slowed down in winter but heat or high temp. can kill them instantly. Worms are not very sensitive to offensive smell, as they love to live and feed on cattle dung and even sewage sludge. However, offensive smell can persevere for a short duration in any environment, where worms are active. Worms arrest all foul odors created by killing pathogens and anaerobes (Sinha et al. 2010).

4. Selection of Earthworm's species

Eisenia fetida is used as a test species for vermitreatment because it has good applicability and high reproductive capability in a high-water containing environment. It has been also highly salt tolerant in nature (Sinha et al. 2008).

5. Sampling of Hospital Wastewater

Sampling was done in pre-treated BOD bottle (washed with nitric acid) from Mahavir Cancer Sansthan & Research Center (MCSRC) (HWW1) and Patna Medical College and Hospital (PMCH) (HWW2), Patna, Bihar. Collected hospital wastewater was directly poured into the pre-treated influent container and left for filtration through vermifilter bed. After filtration the filtered water (vermiaqua) was collected into the pre-traeted effluent container. Vermiaqua was transferred to the pre-treated BOD bottle and stored at room temperature as shown in Fig.3

Fig. 3: Collected samples of control (C) (left), Hospital wastewater (HWW1 & HWW2) (middle) and Vermiaqua (VA1 & VA2) (right).

6. Physico-Chemical and Biological analysis of Hospital Wastewater and Vermifiltrate (Vermiaqua)

Influent and effluent samples were collected monthly and analyzed different physico-chemical and biological parameters: pH, COD, BOD_5, TSS, Turbidity and E. coli test. The pH values were measured by Electrometric method, by using microprocessor-based pH meter (ESICO, model no.- 1012). BOD5 was determined by Titrimetric Method, after 5 days at 20°C, COD was determined by using the Open Reflux Method, TSS was measured by using 2540 D method (APHA 1995) and Turbidity was measured by Turbidity the tube method. Biological parameter was analysed by Coliform vials.

Percentage reduction for each parameter was calculated by the equation no. 1

$$\% \text{ reduction } (\%R) = \frac{(ci - c0)}{ci} \times 100$$

(1)

Where, Ci = influent and C0 = effluent

RESULT & DISCUSION

A. Variation in the pH value

The average pH value of the Hospital wastewater 1 (HWW1) was 6.44 & Hospital wastewater 2 (HWW2) was 6.35 whereas the pH value of effluent vermiaqua (VA 1) was 7.19 & vermiaqua (VA 2) was 7.16 respectively. However, the average pH value of control was 6.71, but the pH value of effluents was as higher as control. Result shows that the pH value of influents (Hospital wastewater) was neutralized by the activity of earthworms as shown in Fig. 4.

B. Removal of Biochemical Oxygen Demand (BOD_5)

The average BOD_5 value of influent HWW1 was 279.16 mg/l and HWW 2 was 300.16 mg/l whereas the average BOD_5 value of effluent VA 1 was 15.98 mg/l and VA 2 was 15.9 mg/l and control was 38.82 mg/l respectively as shown in Fig 5. The result showed that earthworms present in the vermifilter bed removed approximately 94-95% BOD_5. Here, the BOD_5 value of effluent was lowest, which shows that the higher BOD_5 removal takes place in effluent (vermiaqua). Higher BOD_5 removal takes place due to the symbiotic activities of earthworms and microorganisms present in vermifilter bed.

C. Removal of Chemical Oxygen Demand (COD)

The result showed that average COD value of HWW1 was 274.83 mg/l and HWW 2 was 275.00 mg/l whereas the average COD value of VA 1 was 129.91 mg/l and VA 2 was 131.58 mg/l respectively as shown in Fig. 6. The COD value of control was 218 mg/l. The findings showed that 52-53% removal of COD takes place. This may be due to the biological, chemical, and physical process and co-effect of earthworms and microorganism's activity, as well as the redox reaction of the organic matters (Wang et a. 2011). Also, can be responsible to the enzymes present in the intestine of earthworms, many of which contribute to the degradation or deterioration of chemicals that would not otherwise be decomposed by microorganisms (Manyuchi 2013).

It should be reported that the removal of COD was less than that of BOD5 because earthworms are mainly responsible for the bio-degradation of organic wastes compared to inorganic wastes (Ghobadi et al.2016).

D. Removal of Total Suspended Solid (TSS)

Results indicated that the average TSS value of influent HWW1 was 383.25 mg/l and HWW 2 was 380.91 mg/l whereas the average TSS value of effluent VA 1 was 28.08 mg/l and VA 2 was 29.58 mg/l and control was 168.66 mg/l respectively as shown in Fig. 7. The results showed that removal of TSS was 92%. The value of vermiaqua was as lower as control due to the presence of earthworms. They trapped suspended solids on the top of the vermifilter bed and eat up by them. They convert these wastes into vermicompost, due to which vermifilter bed did not choke and work regularly (Sinha et al., 2008 & Dhadse et al., 2010).

E. Removal of Turbidity

Result showed that the average turbidity of HWW1 was 111.33 NTU and HWW 2 was 109.58 NTU whereas the average turbidity of effluent VA 1 was 4.69 NTU and VA 2 was 5.00 NTU and control was 13.62 NTU respectively as shown in Fig. 8. Here, the value of VA was less than the value of control. The average reduction in turbidity by earthworm's action was 95-96%. It appears that the designing of filtration system (gravels, sand and soil) plays an important role for the removal of turbidity.

Histogram of average values of pH, COD, BOD_5, Total suspended solids (TSS) and Turbidity before and after the treatment was shown in Fig. 9.

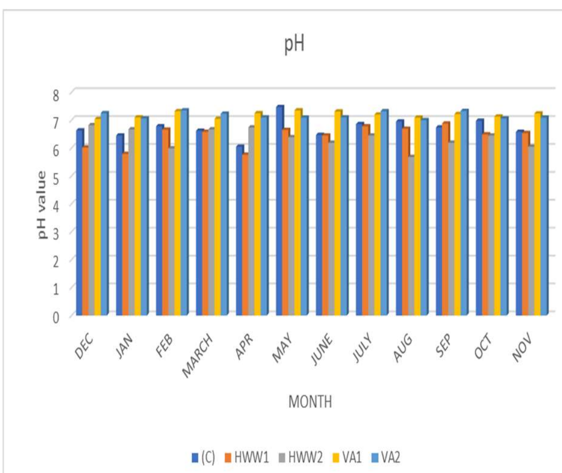

Fig. 4. Graphic representation of pH.

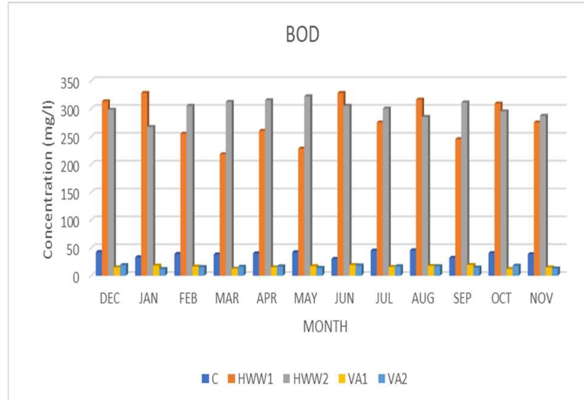

Fig. 5. Graphic representation of BOD_5

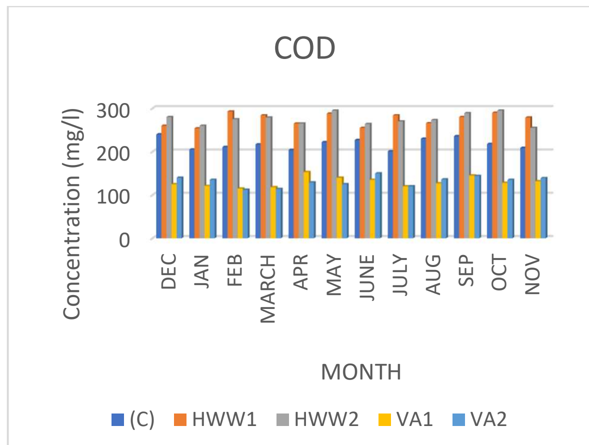

Fig. 6. Graphic representation of COD

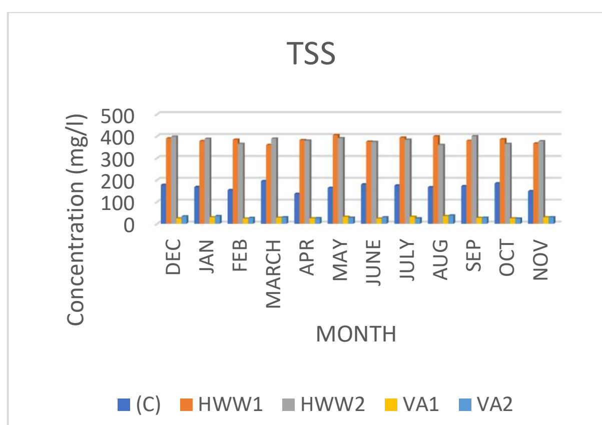

Fig. 7. Graphic representation of TSS

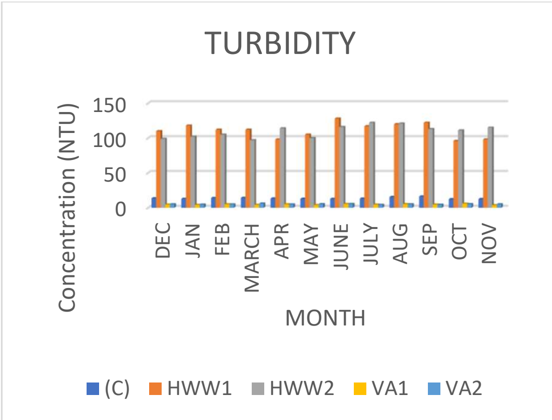

Fig. 8. Graphic representation of Turbidity

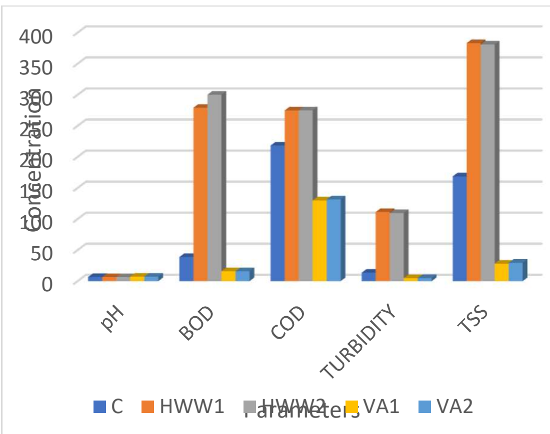

Fig. 9. Graphic representation of average values of pH, COD, BOD_5, Total suspended solids (TSS) and Turbidity before and after the treatment.

Significance and advantages of Vermifiltration:

• Vermifiltration (VF) is a low energy dependent and better than all other biological wastewater treatment systems like Trickling Filters, Activated sludge process and Rotating biological contactors (B. P. jatin 2018).

• These biological wastewater treatment systems using large amount of energy, costly for installation and operation and don't give any type of income. But VF is a low-cost operating system. In this process 100% capture of organic materials take place and the end product i.e. vermicompost is also used (Sinha et al. 2008).

• Earthworms decompose organic materials present in the wastewater and known as 'Sludge digester'. They discharge sludge in the vermifilter bed as vermicompost, which is useful for soil. It is used as nutritive plant food for agriculture and horticultures (Hughes et al. 2005).

• VF is free from pathogens because earthworms eat up all pathogens like bacteria, fungi, nematodes, protozoa etc. found in wastewater and sludges. They secrete some chemicals (coelomic fluid) which arrest all microbes that causes rotting and they have anti-bacterial properties (Pierre et al.1982). Earthworms also encourage the activity of some bacteria and fungi which produce antibiotics and kill the pathogenic organisms present in the waste biomass. They make the medium almost odorless and sterile, thus VF is an odorless system (Sinha et al. 2008).

• Less electricity is required for operating this system.

• For the construction, installation, and operation of Vermifilter bed no more materials are required because it is a very simple and affective filtration system.

• Chloragogen cells present in the gut of earthworms mainly accumulate heavy metals. They bioaccumulate Mercury (Hg), Manganese (Mn), Cadmium (Cd), Lead (Pb), Zinc (Zn), Calcium (Ca), Iron (Fe) and Copper (Cu) (Sinha et al.2008). Several studies have been found that organochlorine pesticide and residues of polycyclic aromatic hydrocarbons present in the medium in which earthworms grow and feed, can also accumulated or degraded by them (Ireland M. P. 1983).

• Vermicast is a nutritive food for plants. They are rich in NPK nutrients. Earthworm's feces contain 1.16% nitrogen (N), 1.34% potassium (K) and 1.22% phosphorus (P). They also secrete proteins, polysaccharides, and nitrogenous compounds like nitrates, ammonium and mucoproteins (Xing et al. 2005).

• After the first year of vermitreatment, a large quantity of worm's biomass will be used as pro-biotic food which is good source of essential amino acids- methionine and lysine for cattle, poultry and fish farming (B. P. jatin 2018).

CONCLUSION

The current study indicates that the vermifiltration unit provides a good system for the treatment of hospital wastewater. The vermifiltration system was successfully operated at low cost, occupied very less space, without using electricity, order free process and worked continuously for a long time. The vermiaqua of hospital wastewater resulted a significant decrease in COD, BOD_5, TSS, Turbidity and neutralized the pH value. Result of present study indicates that vermifiltration is a suitable technique with high performance.

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