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Utilizing *Eisenia fatida* for Treatment of Domestic Wastewater

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Abstract: In the present study, earthworm species *Eisenia fatida* has been used for treating and reclaiming the domestic wastewater (sewage). For this purpose, a field scale vermifilter was designed and constructed, from which the domestic wastewater was allowed to pass through. The performance of the vermifilter was assessed by evaluating the physico-chemical and microbiological characteristics of the effluent. The study revealed that presence of earthworms in the vermifilter bed can efficiently remove pollutional parameters like biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (TDS) from the wastewater and at the same time, concentration of dissolved oxygen is increased / improved. More significantly, the pathogenicity is reduced in terms of total coliforms and faecal coliforms. The combination of earthworms with microorganisms proves to be very supportive in fighting against the organic matter and pathogens present in wastewater, as the earthworms are best known for their waste management capacity. They assist in maintaining the aerobic conditions in wastewater with their famous burrowing action.

Keywords: Domestic wastewater, vermifilter, BOD, COD, total coliforms, faecal coliforms.

I. INTRODUCTION

With the onset of industrialization and urbanization, a huge impact of wastewater generation on environment has already been observed and reported from decades (Arora et al., 2016). It has been reported that due to tremendous discharge of wastewater or sewage which finds their way to nearby streams, lakes and rivers tend to pollute the water bodies and making the water unfit for drinking and other purposes. Untreated sewage encompasses a large portion of biodegradable organic matter which is not only high in BOD, COD, solids, less in DO but it also carries numerous disease causing pathogenic microorganisms that causes detrimental effect on human health (Arora et al., 2014). The untreated sewage or wastewater from industrial or other sources has received scientific attention over the last decade due to the presence of pathogens. The discharge of untreated sewage in surface and subsurface water courses is most important sources of contamination of water resources and its treatment has become an important health issue.

Even though numerous solutions have been adopted for the treatment of wastewater but among all the technologies it has been found that vermifiltration is more effective and a newly confined novel technology. Vermifiltration is a low cost, odourless and non-laborious intensive method of wastewater treatment and do not occupy large area for the treatment facility to set up.

Vermifiltration is also known by the term ‘lumbrifiltration’. It is an extension of vermicomposting of solid waste management and is an engineered natural system, which is based on the symbiotic relationship between earthworms and microorganism (Das et al., 2015). Vermifilter also called vermidigester is a type of wastewater treatment biofilter or trickling filter but with the addition of earthworms to improve the treatment efficiency. In the vermifilter system, microbes perform biochemical degradation of waste material while earthworm degrade and homogenize the material through muscular actions of their foregut and add mucus to the ingested material, therefore increasing the surface area for microbial action.

II. MATERIALS AND METHODS

Vermifiltration is a known biotechnological aerobic process of treatment of wastewater which is carried out with the use of epigenic earthworms as a mean of treating wastewater and it has been increasingly regarded as an environmental friendly wastewater technique. The dissolved and suspended solids get trapped on top of the vermifilter bed and proceed by earthworms and fed to the soil microbes which are immobilized in the vermifilter. This technology has been reported efficient in removing solids and liquid organic wastes from the wastewater through the action of earthworms. Earthworms have 600 million years of experience as waste and environmental managers managing bio-waste including

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human waste, soil and land on earth. They are burrowing animals and form tunnels by literally eating their way through the soil and their distribution in soil depends on factors like soil moisture, availability of organic matter and pH of the soil. An optimum temperature of 20˚-25˚C is needed for their proper functioning. They can increase the hydraulic conductivity and natural aeration of the organic particle by granulating the organic particles in to smaller particle (Anusha & Sundar, 2015).

A. *Experimental Setup*

In the present study, the treatment efficiency of vermifilter for domestic wastewater has been evaluated and compared for efficacy.

The work is carried out by analyzing important physico-chemicals parameters like TDS, DO, BOD, COD and microbiological parameters like total coliforms and faecal coliforms.

In order to achieve the objectives, a field scale vermifilter of cube shape having dimensions of 1 m^3 was set up at Dr. B. Lal institute of Biotechnology campus area, Jaipur, India for domestic wastewater. The schematic diagram of vermifilter is shown in FIGURE 1.

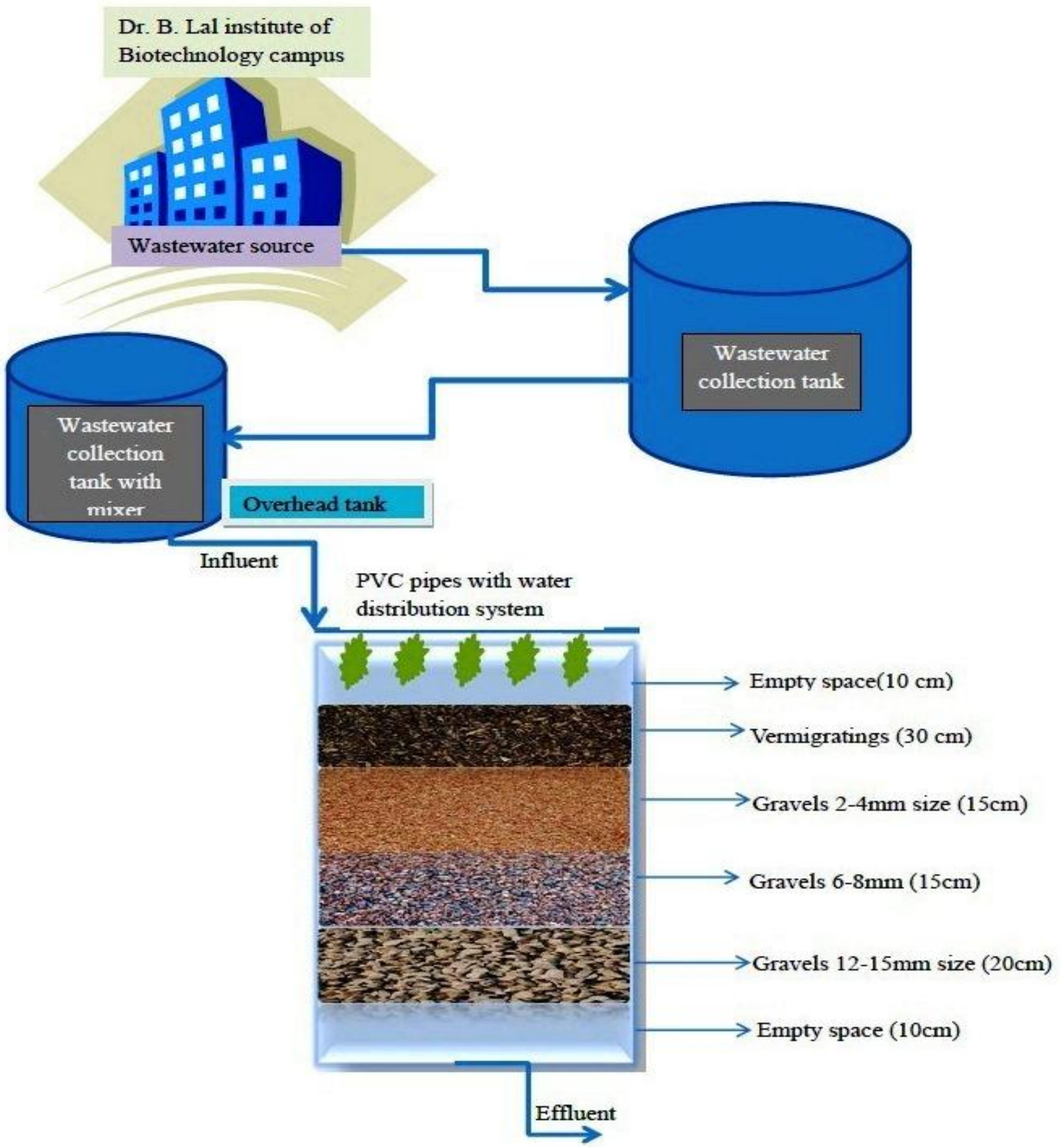

FIGURE 1: Schematic view of Vermifilter tank

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B. *Design Setup for Vermifilter*

Wastewater contains large fractions of organic as well as inorganic components which must be treated before it is dispose of in order to protect the environment as well as health of living organisms. Keeping this concern in mind, a wastewater treatment plant was setup at the institute campus. A large storage tank of 500 L capacity was installed which finds its way to overhead tank of 300 L capacity with continuous agitation. The wastewater gets collected and stored first in the 500 L capacity large storage tank. Then it is pumped in to overhead tank of 300 L tank, where a continuous agitation was provided for proper mixing of wastewater which avoids the settling of organic waste at the bottom of the tank.

The vermifilter was designed and installed based upon various parameters like filter media, hydraulic loading rate (HLR), hydraulic retention time (HRT), stocking density (SD), and the species of earthworm inoculated in the vermifilter.

The vermifilter beds consist of:-

- A filter bed of different layers
- A wastewater storage tank for influent mixer installed in the overhead tank of 500 L capacity to constantly mix the influent before it is allowed to pass through the wastewater sprayer.
- An overhead tank for maintaining the constant head, tank of 300 L capacity for wastewater to be fed by gravity.
- A collection system to collect the effluent.

The treatment of the wastewater was accomplished with the different layers in the vermifilter reactor. The vermifilter bed comprises of 5 layers (total depth- 100cm) of packed filter media of different sizes of gravels and vermicompost layer. At the top, an empty space of 10 cm is provided for aeration. Also at bottom an empty space of 10 cm is provided for collection of the effluent samples. The first layer comprises of mature vermigratings (earthworm + vermicompost) of 30 cm depth in which the earthworm species of *Eisenia fetida* were inoculated with stocking density of 10,000 worms/m^2. The second layer comprises of 2-4 mm fine gravel size with 15 cm depth followed by third layer of 6-8 mm medium gravel size with 15cm depth. The fourth layer comprises of large gravel with 20 cm depth. The domestic wastewater was collected from the institute campus itself. The wastewater was introduced in to the vermifilter system through perforated PVC pipes of 1.5 mm diameter with hydraulic loading rate of $1m^3/m^3$/day.

The experiments were performed during the month of March 2017 through June 2017. Initially, 15 days were considered as acclimatization period for earthworms to adjust to the new surrounding environment. The starting of the vermifiltration process was initiated by seeding wastewater in batch mode for 3hrs/day and later, after acclimation and configuration, the hydraulic retention time was found to be 8hrs/day at room temperature. The treated effluent samples were collected once in every week by grab sampling technique. The basic design setups are depicted in Table I.

TABLE I Design setup for the Vermifilter bed

Parameter	**Values**
Volume of the Vermifilter System	1m* 1m * 1m
Hydraulic Loading Rate (HLR)	$1m^3/ m^2$ / day
Hydraulic Retention Time	8 hrs
Stock Density	10,000 worms/m^3

The various design parameters of the filter bed are tabulated in Table II.

TABLE II Design Parameters for the Vermifilter bed

Layer from Top to Bottom	**Filter materials**	**Particle Size**	**Depth**
Free space (For aeration)	-	-	10 cm
Layer – 1	Vermigratings & Earthworms	600 - 800 µm	30 cm
Layer – 2	Fine Gravels	2 - 4 cm	15 cm
Layer - 3	Small Gravels	6 - 8 cm	15 cm
Layer – 4	Large Gravels	12 - 15 cm	20 cm
Free Space (for collection of effluent samples)	-	-	10 cm

The following FIGURE 2 shows earthworm species of *Eisenia fetida* which was used during the experimental work.

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FIGURE 2: Species of *Eisenia fetida* used during the experiment

III. RESULTS AND DISCUSSION

For the evaluation of performance efficiency, a field scale vermifilter was installed in the institute campus of Dr. B. Lal Institute of Biotechnology (BIBT), Jaipur for the treatment of domestic wastewater. The filter was operated continuously and monitored daily for a period of 6 months from February to July, 2017. The study specially focuses on the physico-chemical and microbiological parameters removal efficiency during the process of vermifiltration.

A. *Physico-Chemical Contaminants Removal*

For the evaluation of performance efficiency for domestic wastewater, some important physico-chemical parameters like electrical conductivity, total dissolved solids, BOD, COD and DO were performed and analysed.

The average electrical conductivity (EC) value for the influent and effluent was found as 2720.8 ± 271.4 µs/cm and 2354.5 ± 437.8 µs/cm as shown in GRAPH 1. An average decrease in EC was observed. During the treatment, the influent average TDS was observed as 1382.5 ± 191.5 ppm which decreased slightly in the effluent as 1190.9 ± 232.3 ppm as shown in GRAPH 2. The TABLE III shows the variations in EC and TDS.

TABLE III Variations in Electrical Conductivity and Total Dissolved Solids

Days	Electrical Conductivity (µs/cm)		Total Dissolved Solids (ppm)	
	Influent	Effluent	Influent	Effluent
1	2469	2522	1232	1248.5
7	2446	2587	1220	1292
14	3110	2440	1550	1216
21	3170	2563	1850	1453
28	2967	2150	1478	1072
35	2694	2925	1344	1462
42	2844	2574	1421	1287
49	2764	2617	1382	1308
56	2539	2422	1269	1211
63	2463	1550	1231	775
70	2463	1550	1231	775
Average	2720.8	2354.5	1382.5	1190.9
SD (Standard Deviation)	271.4	437.8	191.5	232.3

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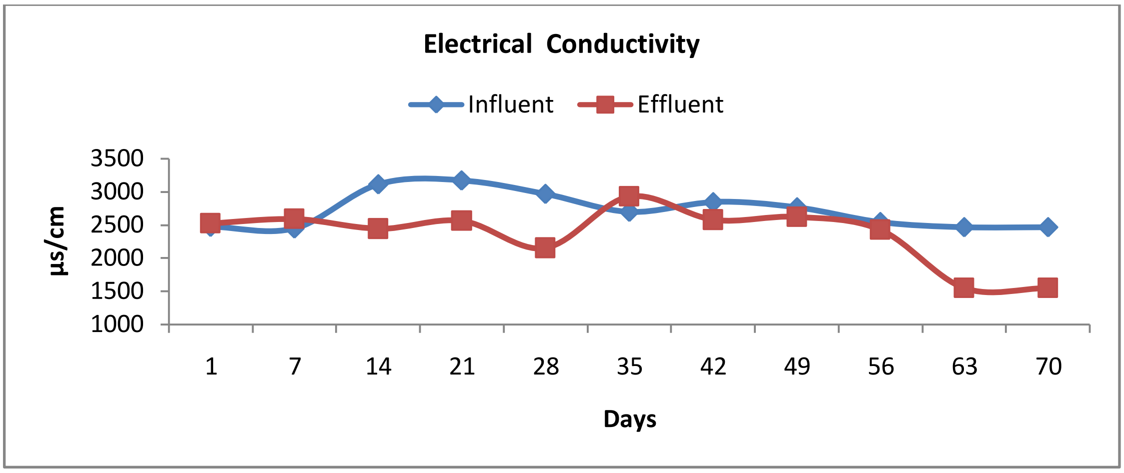
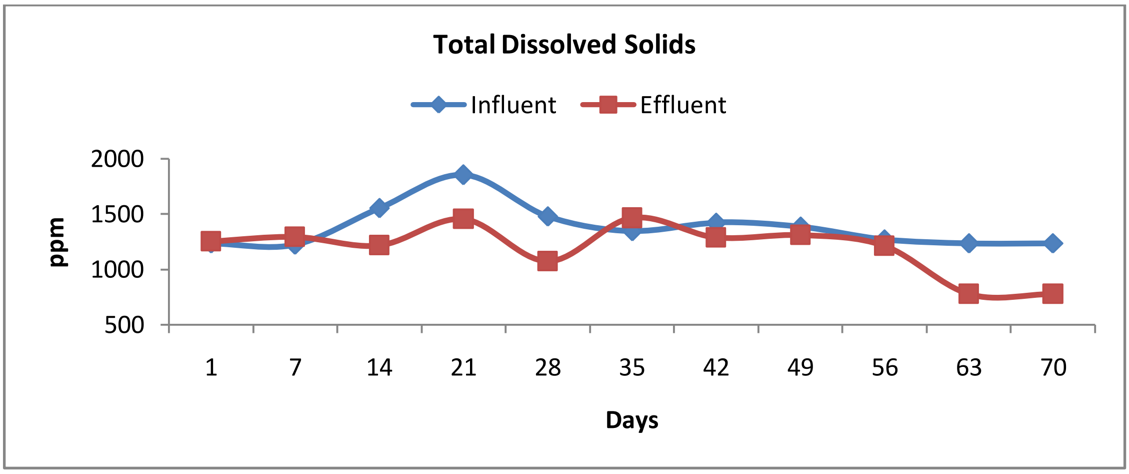
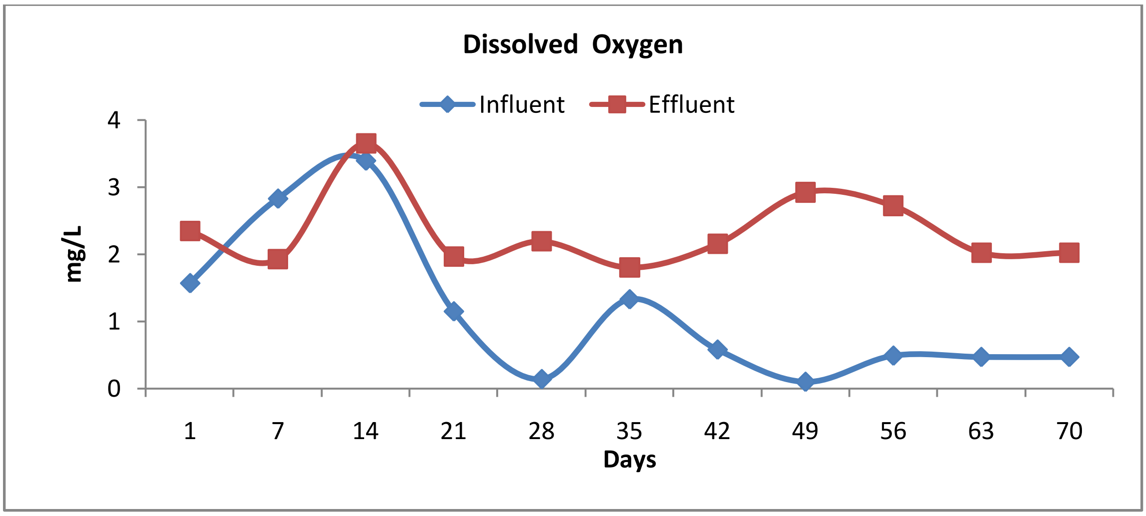


GRAPH 1: Variation in Electrical Conductivity of Domestic Wastewater



GRAPH 2: Variation in TDS of Domestic Wastewater

The average dissolved oxygen concentration in influent was observed as 1.14 ± 1.09 mg/L which increase slightly in effluent as 2.34 ± 0.55 mg/L as shown in GRAPH 3. Lower DO in effluent indicate that the wastewater is not fit to dispose in the nearby water sources and also unfit for irrigation purpose.



GRAPH 3: Variation in Dissolved Oxygen (DO) of Domestic Wastewater

The average biochemical oxygen demand (BOD) of influent and effluent was found as 237 ± 74 mg/L and 31 ± 3. BOD removal efficiency of vermifilter was found as 86.91 % considering few initial days of acclimation period as shown in

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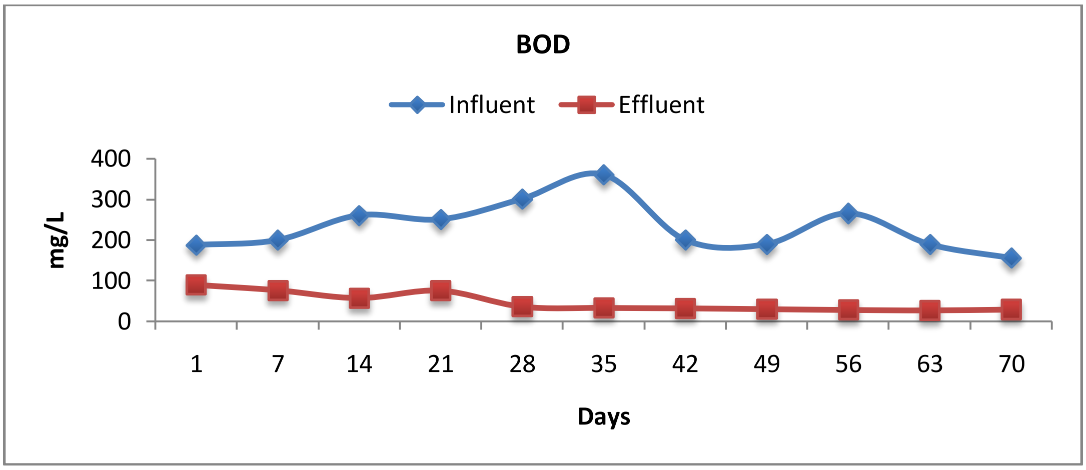
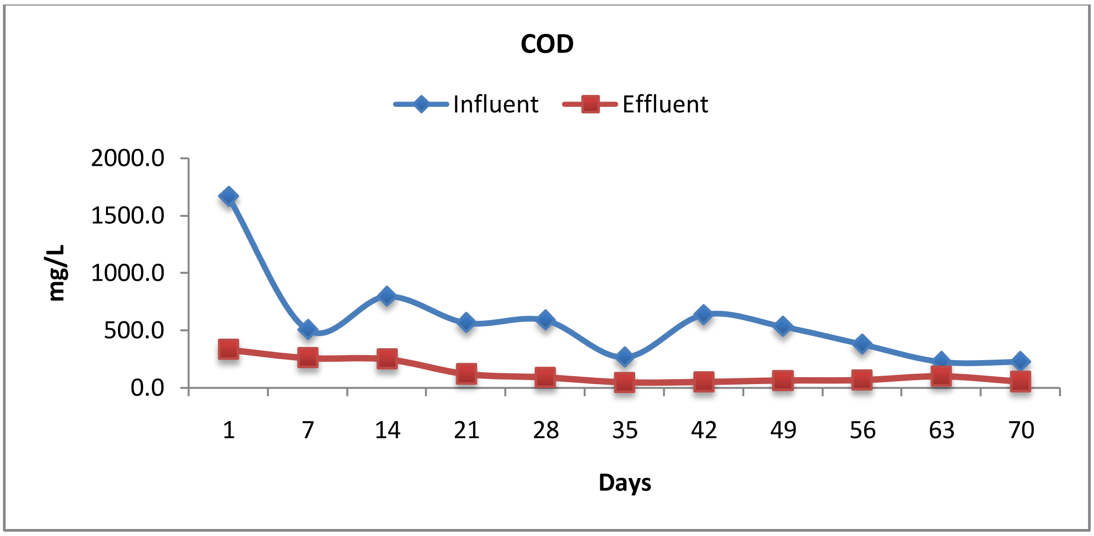
GRAPH 4. Similarly the concentration of COD decline from 425.7 ± 173 mg/L in influent to 71.1 ± 27 mg/L in effluent which shows that about 83.29 % get reduced by the activity of earthworms as shown in GRAPH 5 respectively. This result indicates that microbes play an important role in enhancing the biodegradation through their burrowing action. Variations in BOD and COD values during the treatment are shown in TABLE IV & GRAPHS 4 and 5.

TABLE IV Variations in Dissolved Oxygen (DO), BOD and COD

Days	DO (mg/L)		BOD (mg/L)		COD (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
1	1.57	2.34	187	89	1664	330.7
7	2.83	1.92	199	76	504	257.3
14	3.396	3.65	260	57	794	247.3
21	1.15	1.96	250	75	564	117.3
28	0.14	2.19	300	36	587.3	87.3
35	1.33	1.8	360	33	264	44
42	0.58	2.15	200	32	634	47.3
49	0.1	2.92	189	30	530.7	60.7
56	0.49	2.72	265	28	377.3	64
63	0.47	2.02	189	27	224	97.3
70	0.47	2.02	155	29	224	50.7
Average	1.14	2.34	237	31	425.7	71.1
SD	1.09	0.55	74	3	173.0	27.0



GRAPH 4: Variation in Biochemical Oxygen Demand (BOD) of Domestic Wastewater



GRAPH 5: Variation in Chemical Oxygen Demand (COD) of Domestic Wastewater

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B. *Pathogen Removal Efficiency*

The pathogen performance of vermifiltration for domestic wastewater treatment is given in TABLE V. The average value of total coliform (TC) and faecal coliform (FC) in the influent was 4.7 ± 0.7 MPN/100 mL and 3.6 ± 0.2 MPN/100 mL. The concentration of TC and FC decreased up to 2.5 ± 0.9 MPN/100 mL and 1.1 ± 0.1 in the effluent. Therefore the results show that 99% of TC and FC was removed respectively during treatment of domestic wastewater treatment. Previous studies have shown that the actions of the intestinal enzymes in the earthworm are responsible for the pathogen removal efficiency in the vermifiltration (Arora et al., 2014). The possible reason for the pathogen removal may be due to antimicrobial activity of the microorganisms against other pathogens. Also Sinha et al., (2008) reported that the earthworm release coelomic fluid from its body cavity, having antibacterial properties which may inhibit the growth of other pathogens. Other factors affecting the pathogen removal efficiency in vermifiltration includes property of filter media to retain pathogens during filtration (Arora et al., 2014).

TABLE V Efficiency of Pathogen Removal (MPN/100 ml)

Parameters	Influent (average ± sd)	Effluent (average ± sd)	Log removal
Total Coliform (log scale)	4.7 ± 0.7	2.5 ± 0.9	2.2
Faecal Coliform (log scale)	3.6 ± 0.2	1.1 ± 0.1	2.5

IV. CONCLUSION

It has been observed that in treatment of domestic wastewater, the removal efficiency of BOD and COD were 86.91 % and 83.29 % respectively. So it can be concluded that the vermifiltration system is very efficient in treating the domestic wastewater. Also vermifiltration of wastewater should be started with higher numbers of earthworms, at least 15,000- 20,000 worms per m^3 of soil to attain good results.

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