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Design and Suitability of Modular Vermifilter for Domestic Sewage Treatment

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ABSTRACT

In recent days many developing countries cannot afford to construct, operate and maintain sewage treatment plants. Centralized sewage treatment system may not fulfill sustainable wastewater management in future, due to ever-increasing demand. A low cost sewage management system will be a prime demand by the people. In this study an attempt is made to know the efficiency of vermifilter as decentralized treatment system with reference to parameters like pH, turbidity, total solids, removal of biological oxygen demand and chemical oxygen demand. Sewage is being treated using vermifilter containing earth worms and the results are compared with non-vermifilter for the treatment of domestic wastewater.

Keywords: Sewage, Vermifiltration, earthworms, cost effective.

INTRODUCTION

Vermifiltration of wastewater using waste eater earthworms is a newly conceived novel technology. Sewage generation and treatment has become a worrisome issue in India. 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.

Nearly 80% of the water supply used by society returns as municipal waste water in the sewer system as sewage. Sewage may carry hazardous content and very high loadings of organic matter referred as BOD (biological oxygen demand) and COD (chemical oxygen demand) and solids - both dissolved and suspended solids. Sewage has to be treated to reduce the organic loads before discharging into the environment (rivers and oceans). Aerobic bacteria will consume more dissolved oxygen (DO) from the river/ ocean water to decompose this organic material thereby depleting the DO values.

More than 70% of our fresh water bodies are polluted today (MoEF, 2009). Besides rapidly depleting groundwater table, the country faces another major problem on the water front - groundwater contamination - a problem which has affected as many as 19 states (MoEF, 2009). Multiple sources have been identified to be responsible for this situation. Discharge of untreated sewage in surface and sub-surface water courses is the most important water polluting source in India. Out of about 38000 million liter per day of sewage generated treatment capacity exists for only about 12000

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million liters per day (CPCB, 2009). One should also note that while the industrial sector only accounts for three per cent of the annual water withdrawals in India, its contribution to water pollution, particularly in urban areas, is considerable (MoEF, 2009).

Grey water

Water is an essential and rare source required for socio-economic development but fresh water sources are now in declining situation. The consumption of water goes on increasing due to change in mentality of people. In any household level, there are mainly two sources of wastewater is considered i.e. grey water and black water. Grey water is originated from various locations i.e. kitchen, bathroom, laundry, cloth washers, bath tubs and black water is generated from toilets. Untreated grey water should not be useful for toilet flushing as well as for gardening. Untreated grey water can be treated by simple way - collecting grey water, piping and dispersing. It may include fine/course screening or filtering to remove particulate matter, disinfectants to remove pathogens and last to the storage tank. Potential health effects also related with grey water treatment. If untreated grey water get stored for more than 8-10 hours, bacteria which are presents in grey water will grow fast that is harmful to human health. Due to long storage of grey water create nuisance of mosquitoes, odor which will face to the nearby areas. Maximum amount of grey water gets used without any treatment for irrigation purpose. Grey water formation totally depends on availability of water, habits of people as well as locality.

Grey water reuse offers various advantages which will help to save money by water authorities on clean water supplies as well as sewage flow and public water demand of potable water. This helps to reduce the load on wastewater disposal systems. According to United States Environmental Protection Agency, grey water can be used untreated or it can be treated to varying degrees to reduce nutrients and disease causing micro-organisms (Victor G. Nganga et al, 2012). In summer, winter and rainy season, water usage is considered nearby 50-53 lit/person/day, 60-64 lit/person/day and 70-75 lit/person/day respectively. These values shows water used by occupants in rainy season is more than other seasons.

Vermifilter

Wastewater treatment involves physical, chemical and biological methods to remove unwanted material in contaminated water so that it can be used for a fit purpose. Vermifiltration is increasingly becoming popular as an environment friendly and cheap way of treating wastewater Vermifiltration technology uses earthworms as bio-filters in waste water treatment, whereby the earthworms feed on the organic pollutants in the wastewater. These results in reduced biological oxygen demand (BOD), chemical oxygen demand (COD), total soluble solids (TSS), and total dissolved suspended solids (TDS) and turbidity by over 80%. Additionally, a vermicomposting, which is a bio-fertilizer, is produced at the end of the process. Furthermore, the earthworm microbial activity found effective to remove heavy metals present in sewage. The Vermifiltration process is facilitated by the earthworm activity whereby they act as bio-filters reducing the unwanted organic waste loading in the wastewater. Additionally, the soil and gravel particles employed as part of the vermifilter bed contribute to the filtration and cleaning of the sewage wastewater by adsorption of the organic impurities on their surfaces. The Vermifiltration process is therefore a combined action of the earthworms as well as the soil, sand and gravel particles. The Vermifiltration technology was proposed as an alternative sewage wastewater treatment method in developing countries that face wastewater treatment challenges. This treated water has been recommended for use in irrigation purposes. This was to provide an alternative wastewater treatment method due to the challenges being faced in operating wastewater treatment plants as well as the replacement of equipment costs that are being faced in developing countries. The vermifilter used in this technology is integral to the development of the new high-value treated water and the replacement of existing chemical-based wastewater treatment processes. The proper selection and design of the vermifilter determines the optimal commercial process and the corresponding capital investment hence the need of a proper vermifilter design.

MATERIALS AND METHOD

The present work consists

1. Sewage generation scenario and estimation.
2. Design of modular vermifilter.
3. Suitability of vermifilter for domestic sewage.

Sewage Generation Scenario and Estimation

For a 10 storied building consisting of 4 cubical per floor of 5 members per flat, 20 liters of grey water discharge will be there per day per flat. Accordingly 3000 liters per day will be grey water generation. The vermifilter unit is divided into two parts each of capacity 1500 liters per day per filter. The grey water is fed by gravity flow in such a way that fed gray water is circulated uniformly on vermifilter bed.

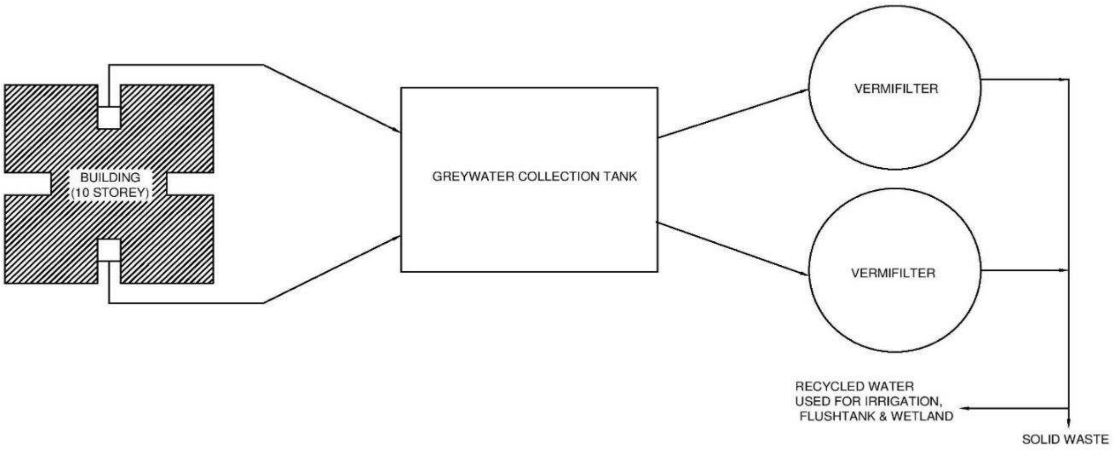


Figure1. *Layout plan of Vermifilter*

Design of Modular Vermifilter

Filtration is the process where total solids are supposed to remove. In the multitasking era the unit which can utilize for multiple objectives in sewage treatment will be most reasonable. The present work elaborate multi objective filtration. The vermifilter unit will perform not only filtration but also will regulate BOD, COD, turbidity and pH.

Determination of Hydraulic Loading Rate (HLR)

Previous studies have primarily focused on the use of vermifilter or its combined processes in the treatment of different types of wastewater, and the related factors contributing to its efficiency in removing pollutants. However, neither study has focused on the Vermifiltration on continuous mode of operation and the capacity of earthworms to treat the wastewater. In batch process, wet to dry time ratio 1:3 has been used (each cycle included wastewater flow for 1 h, retention for 3 h) if the system has to work without choking and clogging.

Hydraulic loading rate can be calculated by: HLR = V waste water / A x t

V_{ww} = Volumetric flow rate of wastewater (m^3); A = Area of soil profile exposed (m^2); t = 1day.

Determination of Volume of Earthworm Biomass

The density of earthworm biomass required for the treatment of wastewater can be calculated by

Density of earthworm biomass Vs = $PI*r^{2*}h$
= $PI * 0.675^2 * 0.2$
Vs = $0.286\ m^3$
= 28.6L

There initial biomass of worms needed =28.6X28.6
= 817.96gms

Determination of Number of Holes to be considered in Longitudinal and Lateral direction

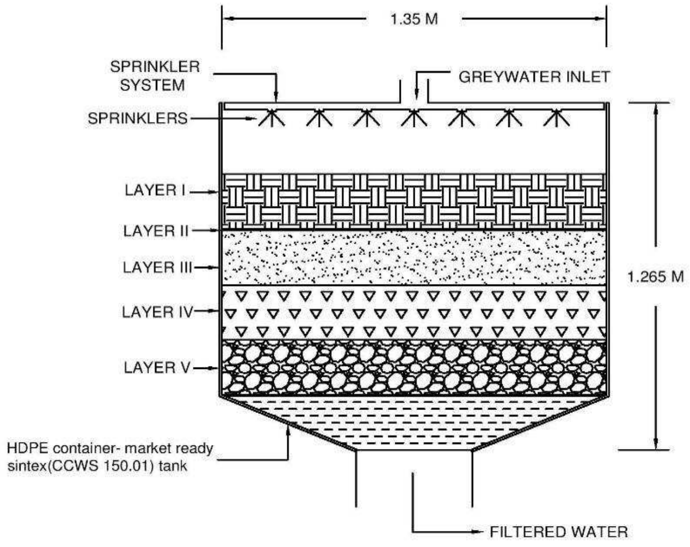
Total area of perforation = 0.2% of filter area
= $0.002 * PI*0.675^2$
= $0.00286\ m^2$

Total area of laterals = 2 * total area of perforation
= 2*0.00286
= $0.00572m^2$

Assuming 3mm diameter perforation
No of perforations in longitudinal direction = 5 nos.
No of perforations in lateral direction = 4 in each side

The Vermifilter and the Formation of Vermifilter Bed

The assembly of vermifilter is composed of HDPE container – a market ready Sintex® (CCWS 150.01) tank of capacity of 1500 lit. The present model has been designed so as to treat 400 liters of wastewater per day. This reactor as a Vermifiltration unit of 1350 mm in diameter 1265 mm in depth has been designed. The depth of 1265 mm has been divided into 4 parts in which gravel, sand and soil bed for earthworm were placed from bottom layer to top. The assembly consist about 35 kg of gravels with a layer of garden soil on top. The proper mixture of garden soil and sawdust at a volume ratio of 3:1 has been adopted- forms vermifilter bed. The system has provisions to collect the filtered water at the bottom which opens out through a pipe fitted with tap. The system consists of bottommost layer and was made of gravel aggregates of size 16-20 mm and it fills up to the depth of 20 cm. Above this lies the aggregates of 10 mm sizes filling up to another 20 cm. On the top of this, 20 cm layer of 5 mm aggregates mixed with sand. The topmost layer of about 20 cm consists of soil bed in which the earthworms were released. The inoculated earthworms i.e., Indian blue worms was at an initial earthworm density of 75 gm. The worms were given around one week settling time in the soil bed to acclimatize in the new environment. A cylinder shaped vermifilter that was naturally ventilated was equipped with a 16mm polypropylene pipe with holes to ensure uniform distribution of the influent and a set of pipes inserted to provide aeration. A wire net was placed below the layer of soil bed to allow only water to trickle down while holding the earthworms in the soil bed because it can crawl down to filter materials.



Layer I

Soil Bed + Earthworms (20cm)

Layer II

Net wire mesh

Layer III

Sand + 5mm aggregate

Layer IV

10 to 16 aggregate (20cm)

Layer V

20 mm aggregate (20cm)

Figure2. *Schematic Diagram of Vermifilter showing different layers*

This reactor was kept on an elevated platform liter bed. A layer of net of wire mesh was placed below the layer of soil bed to allow only water to trickle down while holding the earthworms in the soil bed because it can crawl down to filter materials.

RESULTS AND DISCUSSION

The results of the test conducted to know the characteristics of wastewater have been represented in table.1. During the whole experimental period, the Vermifiltration unit and Non-Vermifiltration unit were fed with domestic wastewater.

Characteristics of wastewater

Table1. *Characteristics of waste water*

Description of the parameter	Value
Odor	Unpleasant
Temperature	25^{o}c
Total solids	720 mg/L
Total Dissolved solids	390 mg/L
Total Suspended solids	340 mg/L
pH	8.22
Turbidity	125 NTU
Biological oxygen demand	219.45 mg/L
Chemical oxygen demand	288 mg/L

Experimental Results of the Vermifilter and Non-Vermifilter Units

Both the experimental units – one with earthworms (vermifilter unit) and the other without (non-vermifilter unit/control unit) were constantly observed for symptoms like foul odor, smooth percolation of wastewater through the soil bed, and appearance of the upper layer of soil bed. The vermifilter unit was also observed and monitored for the agility and movement of the earthworms, its growth, and health conditions. Any toxicity in the wastewater might adversely affect the earthworm's population in the soil bed. There was very little or no problem of any foul odor with the vermifilter unit throughout the experimental study. However, unpleasant smell was emanating from the control unit. Wastewater percolated smoothly into the soil bed in the vermifilter unit throughout the experimental study while in the control unit it was constantly choking after few smooth run down of wastewater. The earthworms in the vermifilter bed were agile and healthy and achieved good growth throughout the period of study. They appeared to be increasing in number and were much developed at the end of the study, after about 3 weeks.

Results of Non - Vermifilter Performance for Detail Parameters

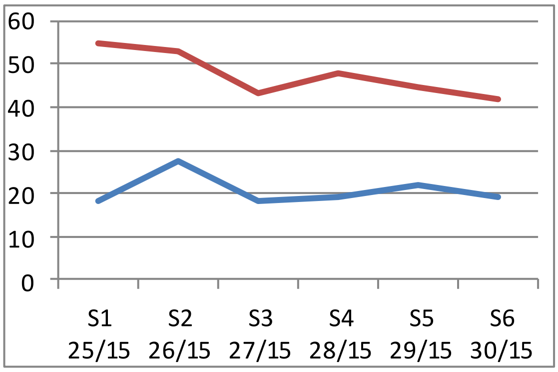
Date	Odor		pH		BOD in mg/L			COD in mg/L			Turbidity in NTU			TDS in mg/L			TSS in mg/L		
April	**I**	**E**	**I**	**E**	**I**	**E**	**% R**	**I**	**E**	**% R**	**I**	**E**	**% R**	**I**	**E**	**% R**	**I**	**E**	**% R**
25/13	Unpleasant	odorless	8.22	7.5	219.45	54.86	75	288	144	50.17	125	26	79	380	102	73.16	340	78	77.06
26/13	Unpleasant	odorless	8.15	7.4	219.45	53.13	75.76	288	136	52.77	118	25	78	390	98	74.87	360	68	81.11
27/13	Unpleasant	odorless	8.48	7.8	216.36	43.27	80.38	283	128	55.55	120	22	82	360	87	75.83	330	56	83.03
28/13	Unpleasant	odorless	8.15	7.4	228.54	47.99	79.00	290	133	54.15	135	28	79.25	400	104	74	380	68	82.12
29/13	Unpleasant	odorless	8.5	7.6	220.50	44.45	79.84	285	134	53.98	128	26	79.70	380	94	75.26	370	70	81.08
30/13	Unpleasant	odorless	8.22	7.5	219.45	41.70	80.99	288	130	54.86	125	25	80	390	97	75.13	340	68	80

Results of Vermifilter Performance for Detail Parameters

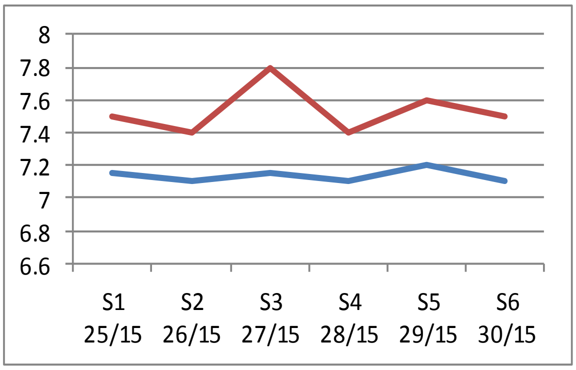
Date	Odor		pH		BOD in mg/L			COD in mg/L			Turbidity in NTU			TDS in mg/L			TSS in mg/L		
Mar	**I**	**E**	**I**	**E**	**I**	**E**	**% R**	**I**	**E**	**% R**	**I**	**E**	**% R**	**I**	**E**	**%R**	**I**	**E**	**% R**
25/15	Unpleasant	odorless	8.22	7.15	172.2	18.33	89.35	248	91	63.3	142	8	94.36	380	55	85.53	340	46	86.47
26/15	Unpleasant	odorless	8.15	7.1	185.45	27.40	85.22	253	98	61.26	148	10	93.24	376	48	87.23	360	42	88.33
27/15	Unpleasant	odorless	8.48	7.15	177.36	18.37	89.64	241	93	61.41	151	9	94.04	360	40	88.88	350	34	90.28
28/15	Unpleasant	odorless	8.15	7.1	176.54	19.37	88.91	257	95	63.03	145	9	93.79	367	56	84.74	380	38	90.00
29/15	Unpleasant	odorless	8.5	7.2	182.50	22.05	87.92	239	94	60.66	153	12	92.15	369	53	85.64	345	44	87.25
30/15	Unpleasant	odorless	8.22	7.1	175.45	19.34	88.9	238	97	59.24	157	11	94.26	366	46	87.43	340	34	90.00

I – Influent; E – Effluent; %R - Percentage reduction

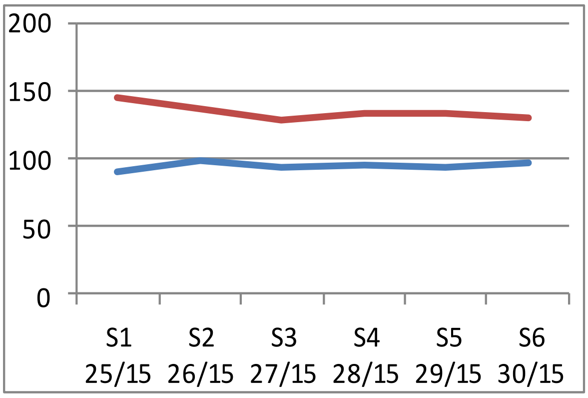
Graphs



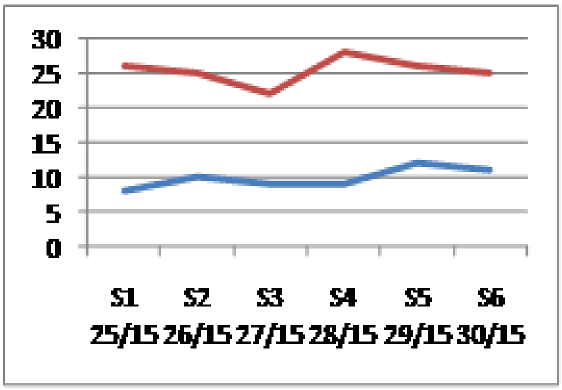
Graph1. *BOD values (mg/L) comparison*



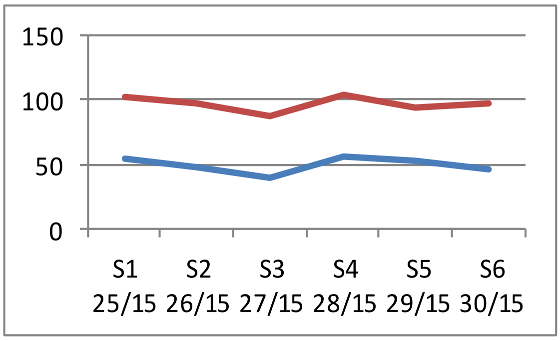
Graph2. *PH values comparison*



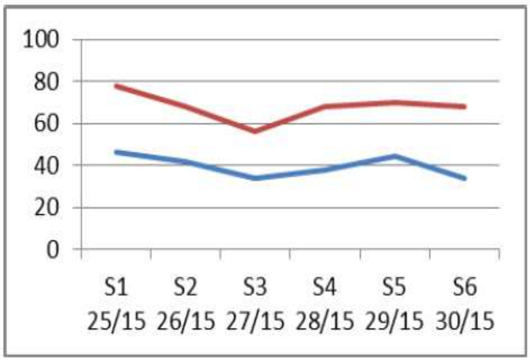
Graph3. *COD values (mg/L) comparison*



Graph4. *Turbidity values (NTU) comparison*



Graph5. *TDS values (mg/L) comparison*



Graph6. *TSS values (mg/L) comparison*

——— *Non Vermifilter* ——— *Vermifilter*

CONCLUSION

The performance of earthworms in the degradation of organic materials present in the vermifilter bed. The contributions of earthworms in the percentage removal of all analyzed parameters are shown. The removal efficiency of parameters analyzed were improved 24.38%, 25.86%, 17.06%, 25.26%, 35.47% of COD, BOD, Turbidity, TDS, TSS respectively by the presence of earthworms.

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