# Treatment of Sewage by Vermifiltration: A Review

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Abstract**: A centralized treatment facility often faces problems of high cost of collection, treatment and disposal of wastewater and hence the growing needs for small scale decentralized eco-friendly alternative treatment options are necessary. Vermifiltration is such method where wastewater is treated using earthworms. Earthworm's body works as a biofilter and have been found to remove BOD, COD, TDS, and TSS by general mechanism of ingestion, biodegradation, and absorption through body walls. There is no sludge formation in vermifiltration process which requires additional cost on landfill disposal and it is also odor-free process. Treated water also can used for farm irrigation and in parks and gardens. The present study will evaluate the performance of vermifiltration for parameters like BOD, COD, TDS, TSS, phosphorus and nitrogen for sewage.**

**Keywords: Vermifiltration, Earthworms, Wastewater, Ingestion, Absorption**

## Introduction

Due to the increasing population and scarcity of treatment area, high cost of wastewater collection and its treatment is not allowing the conventional STP everywhere. Hence, cost effective decentralized and eco-friendly treatments are required. Many developing countries can"t afford the construction of STPs, and thus, there is a growing need for developing some ecologically safe and economically viable onsite small-scale wastewater treatment technologies. [24] The discharge of untreated wastewater in surface and sub-surface water courses is the most important source of contamination of water resources. Most of the population living in rural and urban areas of developing nations depends upon onsite systems for the treatment of domestic wastewater. The treatment systems that require comparatively low costs, energy, and

maintenance are better for the treatment of rural domestic wastewater. [20, 21] Many solutions have been adopted for the treatment of domestic wastewater especially in rural areas, including constructed wetlands, soil infiltration trenches, vegetation-based wastewater treatment and vermifiltration[(3, 7, 10, 26]. Among these technologies, Vermifiltration is one such an alternative treatment technology; where in organically polluted wastewater can be treated using earthworms.

Vermifiltration of wastewater using earthworms is a newly conceived technology. Earthworm"s body works as a „biofilter" and they have been found to remove the 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, the earthworms propel and facilitate up the microbial activity by increasing the population of soil microorganisms. [31]

Vermifiltration needs no external energy, except pumping. Because of this it can be very useful for small communities, colonies and villages. Vermifiltration is more dependable than various other wastewater treatment technologies like constructed wet land, stabilization pond and other common technologies because these technologies need more area as compared to vermifiltration. [30] It has further been reported that vermifiltration process has equal efficiency to the activated sludge process. [15]
There is no sludge formation in the process which requires additional expenditure on landfill disposal. This is furthermore an odor-free process and the resulting vermifiltered water is clean enough to be reused in parks and gardens and for farm irrigation.

**Vermifiltration System**

*Earthworms*

The earthworms have around 600 million years of experience in waste and environmental management. Charles Darwin called them as the „unheralded soldiers of mankind,‟ and the Greek philosopher Aristotle called them as the „intestine of earth,‟ meaning digesting a wide variety of organic materials including the waste organics, from earth. [4, 18]
Earthworms are long, cylindrical, narrow, bilaterally symmetrical, segmented animals without bones. The body is dark brown, glistening, and covered by all of delicate cuticle. They weigh around 1,400–1,500 mg after 8–10 weeks. On an average, 2,000 adult worms weigh 1 kg and one million worms weigh approximately 1 ton. Usually the life span of an earthworm is practically 3–7 years depending upon the type of species and the ecological situation. Earthworms nourish millions of „nitrogen-fixing‟ and „decomposer microbes‟ in their gut. They have „chemoreceptors‟ which help in search of food.

The distribution of earthworms in soil depends on factors like availability of organic matter, soil moisture and pH of the soil. They develop in different habitats especially those which are dark and moist.

As worms breathe through their skin significant ventilation of air in soil medium is necessary. They can tolerate a temperature range between 5 and 29$^{O}$C. A temperature of 20–25$^{O}$C and moisture of 60–75% are optimum for good worm function. [8]
Earthworms are bisexual animals and multiply literally rapidly. Given the optimal conditions of temperature, moisture, and feeding materials earthworms can multiply by 28, i.e. 256 worms every 6 months from a single individual. The total life cycle of the worms is closely around 220 days. They produce 300–400 young ones within this life period. [8]

Earthworms are very sensitive to light, touch, and dryness. Low temperature is not a big problem for them as the high temperature. Their movement is significantly slowed down in winter, but heat can kill them instantly.

**Table 1: Niche Diversification in Earthworms**

| Earthworm species | Weight adult worm(g) | Temperature tolerance ($^{o}c$) | Moisture tolerance (%) | Active phase | Distribution |
|---|---|---|---|---|---|
| Eudrilus eugeniae | 1.5-2.5 | 18-35 | 20-40 | Throughout the year | Tropical Africa and south America |
| Eisenia fetida | 0.3-0.7 | 15-30 | 20-40 | Throughout the year | Temperate regions of Europe, north America, India |
| Perionyx excavatus | 0.8-1.2 | 8-30 | 30-50 | Throughout the year | Tropical countries |
| Dichogaster bolaui | 0.04-0.07 | 20-28 | 20-30 | July- October | Tropical countries |
| Dicogaster affinis | 0.04-0.07 | 20-28 | 20-30 | July- October | Tropical countries |
| Drawida barwelli | 0.2-0.5 | 20-30 | 40-50 | August-November | Tropical countries shade essential for establishment |
| Lampito mauritii | 0.8-1.5 | 18-28 | 20-40 | June-august | Plains of Indian penninsula |

**Table 2: The Use of Vermifilter for Treatment of Sewage**

| Sr. No. | Types of wastewater | Earthworm species | Organics removal (%) | Nutrient removal (%) | Bed material and size | HLR ($m^3/m^2d$) | HRT (hour) |
|---|---|---|---|---|---|---|---|
| 1 | Sewage | Eisenia fetida | BOD 98,COD 45,TSS 90 | - | pure soil, sand(10-12mm), gravel(7.5, of 3.5-4.5) | - | 1-2 |
| 2 | Synthetic sewage | Eisenia fetida | COD 83.6 | TN 63, TP 86.7, $NH_3$-N 70.5 | Cobblestones (6-10 cm),soil, sawdust | 0.2 | 48,72,96 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Urban wastewater | perionyx sansibaricus | COD 80-90, TSS 88.6,TDS 99.8 | $No^{-}_{3}$ 92.7, $Po^{3-}_{4}$ 98.3 | surface vegetation, soil, dried leaves, sawdust, small stones (5-7cm), : large stones (10-15 cm) | - | 1 |
| 4 | Sewage | Eisenia fetida | BOD 98, COD 70, TDS 95 | - | garden soil, sand, aggregates (3-5,7-8 cm) | - | 2 |
| 5 | Rural domestic sewage | Eisenia fetida | BOD 78, COD 67.6, TSS 89.8 | $NH^{+}_{4}$ 92.1 | Ceramsite (3-5 mm) | 4.2 | - |
| 6 | Synthetic wastewater | Eisenia fetida | BOD 96, COD 90, TDS 82 | - | Vermicompost, riverbed material (6-8 mm), sand (1-2mm),gravels (10-12.5mm) | 1.5,2,2.5,3 | - |
| 7 | Urban wastewater | Eisenia fetida | BOD 98.5, COD 74.3, TSS 96.6 | $NH^{+}_{4}$ 99.1 | Vermicompost, quartz sand, gravel (40mm) | 2.6,1.3,0.8,0.6 | 2,4,6,8 |
| 8 | Synthetic wastewater | Eisenia fetida | BOD 70-81, COD 59-72, TSS 55-75 | - | Vermicompost, sand (2-4mm),riverbed material, wood coal, glass balls, mud balls, gravel (10-12.5mm) | 1.5 | - |

**Removal of BOD and COD**

BOD means the amount of dissolved oxygen that is required by aerobic bacteria to breakdown organic pollutants in wastewater. Earthworms significantly degrade the wastewater organics by enzymatic actions whereby the earthworms worked as biological catalysts resulting in faster biochemical reactions hence high BOD removal in the vermifilter. These indicate the major difference between vermi-degradation and microbial degradation.

COD means the chemical decomposition of organic and inorganic pollutants in wastewater which cannot be biologically removed. COD removed by earthworms was not as significant as the BOD removed; nevertheless, the COD amount removed was still practically higher than that removed by the microbial system. This was apparently because the enzymes in the gut of earthworms helped in the degradation of many of those chemicals which could not be decomposed by microbes.

Sinha et al. found the BOD and COD removal efficiency of 98% and 45%, respectively for sewage. Manyuchi et al. reported the use of vermifilter to treat sewage wastewater and the removal efficiency of BOD and COD were 98% and 70%, respectively. Tomar et al. also reported that a vermifilter removal efficiency of COD was 80-90% for urban wastewater. Xing et al. reported that a pilot scale vermifiltration removal efficiency for BOD and COD 54.7-66% and 47.3-64.7%, respectively.

**Removal of TDSS**

A total dissolved and suspended solid means the organic and inorganic pollutants which are either suspended or dissolved in the wastewater.

These solids which were trapped build up over time as sludge in a normal filter and choke the system which then ceases to function properly. However, in the vermifilter bed these bio-solids were consistently ingested by the earthworms and expelled as vermicompost. Therefore there was no choking and discontinuous functioning of the vermifilter bed.

Manyuchi et al. reported the use of vermifilter to treat sewage wastewater and the removal efficiency of TDSS by 95%. Tomar et al. also reported that a vermifilter removal efficiency of TSS and TDS were 88.6% and 99.8% for urban wastewater. Xing et al. reported that pilot scale vermifiltration removal efficiency for TSS was 57-77.9%. Kumar et al. studied the efficiency of vermifilter to treat sewage wastewater and its results suggested that vermifiltration decrease TDS by 82%.

**Removal of nitrogen and phosphorus**

Nitrate is a significant indicator of water pollution and its high concentration in freshwater bodies accelerate eutrophication problem. There are further plenty of nitrifying and denitrifying microbes present in the intestinal gut of earthworms. Due to burrowing movement of earthworms, atmospheric oxygen diffused into vermibed which enhance the nitrification process and supports creating a microenvironment for growth of aerobic nitrobacteria. Also worm casts aerate the influent and this aeration accelerates the nitrification of ammonia.

Wang et al. reported 70.5% $NH_3$-N and 63% TN removal for synthetic sewage treatment in vermifilter. Tomar et al. treated urban wastewater in a vermifilter and it remove 92.7% $NO^-_3$. Liu et al. confirmed maximum 92.1% $NH_4^+$-N removal in 180 days experimentation while treating rural domestic sewage. Bajsa et al. has reported that earthworms secrete polysaccharides, proteins, and other nitrogenous compounds, and mineralize the nitrogen available in wastewater to make it available to the plants as nutrients.

Phosphorous removal completely depends on vermifilter bed material sorption capability, surface area and size. Besides that, chemical reaction like ligand exchange reaction, complexation and precipitation play an important role. The activities of earthworms and associated microbes in vermifilter bed encourage rapid phosphate mineralization in the system generating increased concentration of TP in the effluent.

Wang et al. reported 86.7% removal of TP from synthetic sewage in vermifilter. Tomar et al. treated urban wastewater in a vermifilter and it remove 98.3% $PO_4^{3-}$.

**Advantages of vermifiltration**

i. Vermifiltration treatment is low energy dependent and has distinct advantage over all the conventional biological wastewater treatment systems- the 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.
ii. In the vermifilter process there is 100% capture of organic materials, the capital and operating costs are less, and there is high value added end product (vermicompost).
iii. sludge is discharged in the vermifilter bed as excreta (vermicompost) which is useful soil additive for agriculture and horticulture
iv. There is no foul odor as the earthworms arrest rotting and decay of all putrescible matters in the wastewater and the sludge.
v. Large quantities of worm biomass will be available as food for the cattle, poultry, and fish farming, after the first year of vermitreatment.
vi. It can utilize waste organics that otherwise cannot be utilized by other technologies.
vii. Achieve greater utilization of waste materials that cannot be achieved by other technologies.

**Conclusion**

This paper describes the basic mechanism of vermifilter and vermifilter was found to be suitable technique for highly efficient treatment technology for wastewater. This is also a good alternative treatment for decentralized onsite treatment. Earthworms are protective and productive organisms and they play a significant role in breaking pollutants and aerating filter bed. Vermifiltration process driven by the earthworms likely to become more vigorous and efficient with time as the army of worms grows. It further keeps the system thoroughly aerated with plenty of oxygen available for aerobic decomposer microbes. The treated effluent had higher value of nitrate and phosphate concentration which is best suited for sewage farming or horticulture. No sludge was produced and the organic matter and solids present in the wastewater were consumed by earthworms transforming these into valuable vermicompost. This vermicompost can be used as manure as it is having good content of nitrogen and phosphate. Still there are some limitation of vermifilter like vermifilter cleaning process, heavy metals removal, wastewater feeding mode, and saline water treatment. Hence in order to make vermifilter efficient and sustainable more research related to optimum wastewater feeding mode, cleaning mechanism, integration with other technologies and other more efficient earthworm species is required.

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