



## VERMIFILTRATION AS A VIABLE AND SUSTAINABLE WASTEWATER TREATMENT PROCESS: A NOVEL BIOFILTER TECHNOLOGY

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**Abstract:** One of the most promising approaches to address the worldwide water crisis is wastewater treatment and utilization. Vermifiltration is a novel wastewater treatment method that involves using composting earthworms to remediate contaminated water. It is considered as an innovative technology that offers a long-term strategy for wastewater treatment with simultaneous sludge reduction and remediation. The treatment capacity parameters by vermifilter of wastewater has a strong association with earthworm activity. It's a biofilter in which the earthworms breakdown the suspended particles trapped on the filter bed, decompose organic matter via enzymatic activity, and aerate the system through burrowing action while removing pathogens. The present review focuses on vermifiltration and the mechanisms underlying it, as well as the current situation of the technology for the treatment and reutilization of pollutants produced in domestic and industrial fields.

**Keywords:** Biofilter, Bioremediation, Earthworms, Vermifiltration, Wastewater treatment.

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### INTRODUCTION

Rapid depletion of natural resources and increased anthropogenic activities have resulted in several environment related complications including biodiversity threats (Prakash and Verma, 2022). Water consumption and emissions from various operations introduce harmful foreign matter (pollutants) into the aquatic environment, rendering water unsafe for consumption (Kalal *et al.*, 2021). Aseptic conditions and issues arise as a result of the

entrance of contaminants such as organics and nutrients such as eutrophication and low dissolved oxygen (DO). Water contamination arises when untreated sewage and industrial effluents are discharged into surface water bodies (Goel, 2006) that badly influences the aquatic biota including fishes (Prakash and Verma, 2020, 2021; Verma and Prakash, 2021).

Water-borne infections are spread by exposure to contaminated water caused by sewage pathogens



discharged into surface water. Due to water scarcity and pollution caused by human activities, it is necessary to treat and reuse treated effluent for industrial, agricultural, and non-potable uses. Proper waste management not only reduces the organic load at the site of generation, but also minimizes downstream environmental and public health problems caused by nitrogen leaching into soil and groundwater, which can lead to eutrophication, soil acidity, and groundwater pollution (Galloway *et al.*, 2003).

Poor wastewater management results in a reduction of ecosystem services and economic prospects, climate change due to effluent emissions of methane and nitrous oxide, which have higher global warming potentials than carbon dioxide, and the spread of 'dead zones' affecting fisheries, livelihood, the food chain, and health due to water-borne diseases. Untreated wastewater reuse in agriculture can affect soil pH, increase organic compounds, salinity, nitrogen, metals, and new contaminants, and change the structure and activity of microbial communities (Jaramillo and Restrepo, 2017).

In order to obtain cost-effective clean (disinfected and detoxified) water for farm irrigation, and domestic and industrial applications, our society requires automated, self-regulating, low-electricity, no-sludge, and maintenance-free wastewater treatment plants. Water recycling is a significant aspect of their economic and environmental progress. Coagulation, flocculation, sedimentation, filtration, disinfection, adsorption, and biodegradation are just a few of the physical, chemical, and biological processes that are currently being used to set up cost-effective wastewater treatment plants all over the world to ensure complete sterilization of wastewater. Biological treatment is gaining social acceptance around as a result of deficiencies in existing physical and chemical treatment technologies (Degrémont, 1991). The scientific community around the world is working on the ways to reduce pollution that are both economically and environmentally viable, as well as socially acceptable.

Earthworm belongs to class Oligochaeta of phylum Annelida, which is the first phylum of

eucoelomate animals (Verma and Prakash, 2020). The earthworm is nocturnal and burrowing animal having antioxidant property and biomarker potential (Deswal *et al.*, 2020; Singh and Fatima, 2022). The technologies based on earthworms are self-promoted, self-improved, and self-enhanced, requiring very little energy and producing zero waste. They are also simple to design, operate, and maintain (Bobade and Ansari, 2016).

Vermifiltration is one of the sustainable technologies that has gained popularity in recent years for treating wastewater using earthworms. This method reduces organic waste in the wastewater by a massive amount (Singh *et al.*, 2021). Vermifiltration is a wastewater treatment process is low-cost, odorless, and labor-intensive (Sinha *et al.*, 2007). It is a new technique based on vermicomposting and wastewater treatment using bio-filtration and linked growth systems. The vermifiltration technology covers all of the requirements for the reuse of treated water in society, and because of the high nutritional characteristics (rich in NKP) of vermicompost, it is more helpful for irrigation in agriculture, saving vast amounts of groundwater and fertilizers for farmers (Kumar and Ghosh, 2019).

The vermifiltration of municipal wastewater has been accomplished with a variety of earthworm species (Sinha *et al.*, 2010; Ghatnekar *et al.*, 2010). The earthworm body acts as a biofilter in the vermifiltration process, increasing the microbial population and enhancing microbial metabolism. Earthworms are waste eaters and decomposers with a wide range of abilities. They act as aerators, grinders, crushers, chemical degraders, and biological stimulators in domestic wastewater, encouraging the growth of 'beneficial decomposer bacteria'. Vermifiltration is a process in which earthworms and microorganisms function together to consume and biodegrade contaminants in wastewater. Vermifiltration is capable of treating sewage wastewater by removing higher levels of biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS), as well as nitrogen and phosphorus (Hughes *et al.*, 2007; Sinha *et al.*, 2008; Ghatnekar *et al.*, 2010).

Earthworms will stimulate and expedite microbial activity by improving the soil microbe population as well as developing aeration (Sinha *et al.*, 2008). The addition of earthworms to traditional wastewater treatment biofilters was a significant advancement, as it generated a new method of biological reaction by expanding food chains, transferring energy, and moving mass from the biofilm to the earthworm (Xing *et al.*, 2010). This procedure is also odor-free, and the resulting vermifiltered water is suitable for agricultural irrigation as well as in parks and gardens. These systems no doubt create wastewater of up to secondary quality (Suthar, 2012). Vermifiltration has the potential to provide a low-cost and efficient means of treating domestic wastewater, particularly with high biological contaminants, to a set standard and can be easily implemented in developing nations (Manyuchi *et al.*, 2019).

#### **VERMITECHNOLOGY**

Vermitechnology consists of 2 main components: vermiculture and vermicomposting. It is a simple natural process of waste degradation in which certain earthworm species are used to improve the waste transition process and provide a superior final product (Nayak *et al.*, 2013; Sonowal, 2014). The vermicomposting technique has been used to handle a variety of wastes, including food waste, biodegradable waste, industrial waste, and so on (Bhat *et al.*, 2017, 2018). Earthworms and vermicompost can be sold to balance the expense of water treatment while also reducing the quantity of manure applied to farmland. Vermifiltration is a brand-new technology that is based on actual findings of vermicomposting and wastewater treatment using biofiltration and growth systems.

As a part of a technological improvement to vermicomposting procedures, reactors are converted into trickling filters filled with solid matter and inhabited by earthworms and microorganisms. In this approach, they work as trickle bed bioreactors, through which liquid wastes flow at a rate that allows for continuous biotreatment rather than the discontinuous treatment that vermicomposting creates. The combined action of earthworms and microorganisms in vermicomposting

significantly improves the breakdown and stability of sludge.

Earthworms act as mechanical blenders in the vermicomposting process, comminuting organic matter and changing its physical and chemical status, gradually lowering its C:N ratio, increasing the surface area exposed to microorganisms, and making it more favorable for microbial activity and further decomposition (Domínguez *et al.*, 2000; Ghatnekar *et al.*, 2010). Microorganisms have been identified as an important source of nutrition for worms in the vermiculture field (Pathma and Sakthivel, 2012). Compared to other biological technologies, vermiculture processes have 100-1,000 times higher 'value addition'. Accessing earthworms from vermiculture farms is one-time cost in any vermiculture method since the earthworms multiply quickly, resulting in a large population of worms that promotes and enhances the activity (Sinha *et al.*, 2008). As a result, earthworms are the stars of this technology, performing the majority of the tasks. Vermifiltration technology, among all other advanced green technologies, is an effective and innovative green technology that includes earthworms inside a biofilter to assist remove impurities, particularly organics and pathogens, using indigenous microorganisms. The vermifiltration technique combines primary (removal of grit, silt, etc.), secondary (biological degradation and nutrients removal), and tertiary (nutrients recovery) treatment technologies into a single unit (Arora and Saraswat, 2021).

#### **VERMIFILTRATION**

Vermifiltration of wastewater using waste-eating earthworms is a promising technology that has recently been developed. Vermifiltration technology (VFT) has the potential to be the most cost-effective and odor-free sewage treatment procedure available, with efficiency, economy, convenience, and decentralization potential. For optimum results, vermifiltration of any wastewater should begin with a large number of earthworms- at least 15,000-20,000 worms per cubic meter (cum) of soil in the vermifilter bed (Sinha *et al.*, 2008). A vermifilter is a type of aerobic treatment system that consists of a biological reactor with a medium that filters

organic matter from wastewater. The most popular applications for vermifilters are sewage treatment and agro-industrial wastewater treatment (Furlong *et al.*, 2014). Researchers from the University of Chile first proposed vermifiltration in 1992 as a low-cost, long-term solution for decentralized sewage treatment in rural areas (Xing *et al.*, 2010). Vermifiltration, which treats wastewater with epigeic earthworms, is becoming a more ecologically friendly wastewater treatment method (Trivedy, 2007; Kharwade and Khedikar, 2011).

Edwards (1998) reported that five earthworm species (*Dendrobaena veneta*, *Eudrilus eugeniae*, *Perionyx excavatus*, *Perionyx hawayana*, and *Eisenia fetida*) have the greatest capacity for organic waste digestion. During vermifiltration, the earthworms function as biofilters removing organic debris from the wastewater (Manyuchi *et al.*, 2013). The use of earthworms and aerobic bacteria in the treatment of wastewater is known as 'vermifiltration' (Sinha *et al.*, 2009). Earthworms, various sized gravel layers, and soil bedding compose the vermifiltration system. Water is equally dispersed throughout the biofilter surface during vermifiltration. The number of earthworms in the vermifiltration bed is a very good indicator of how well it worked during the duration. Earthworm numbers are predicted to rise rapidly from the initial population if the vermifiltration bed provides a favorable environment (Manyuchi *et al.*, 2019).

Since no sludge is produced in vermifiltration, it does not require additional expenditure for its disposal, whereas traditional treatment technologies such as the activated sludge process, sequencing batch reactor (SBR), an upflow anaerobic reactor (UASB) can produce a large amount of sludge, which requires additional treatment before disposal (Kumar *et al.*, 2014). *Eisenia fetida*, an exotic epigeic species has been found as a potential option to break down the organic content of wastewater (Li *et al.*, 2009). The vermifiltered water (vermiaqua) becomes highly nutritious, pathogen-free, odor-free, chemical-free, and pH-neutral, making it acceptable for all non-potable uses such as

cultivation, toilet flushing, and washing in households, institutions, and industry (Sinha *et al.*, 2012). *Eisenia fetida*, *Lumbricus rubellus*, *Eudrilus eugeniae*, and *Eisenia andrei* are among the earthworm species used in vermifiltration, with a filter bed made up of soil, compost, and cow dung accessible for degradation of organic pollutants in the earthworm active zone (Xing *et al.*, 2011; Singh *et al.*, 2019).

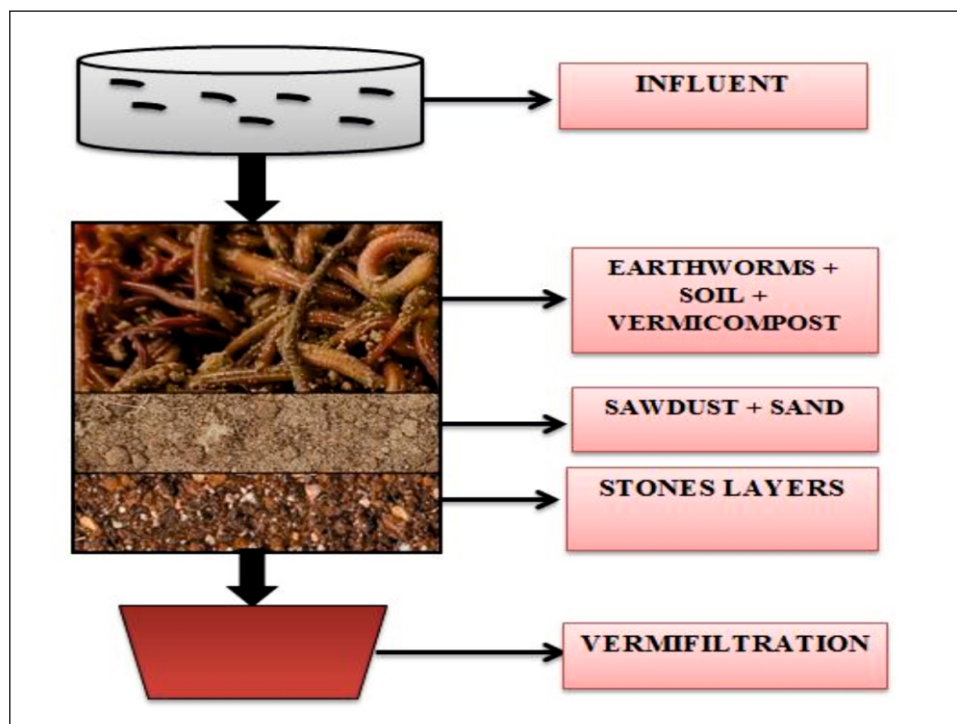
#### VERMIFILTRATION MECHANISM

Under the influence of suitable environmental circumstances, the mechanism of the vermifiltration process is completely dependent on the working efficiency of earthworms and microorganisms. Vermibed and earthworms are the two most important components of the vermifiltration system. When used together, both components play a significant role in pollution removal. Vermibed is a key component of the vermifiltration system that has a significant impact on wastewater pollution abatement. The permeable vermibed aids in the filtering of wastewater and the trapping of solids, which are then eaten by earthworms and expelled as small particles with improved specific surface area and uptake capacity (Sinha *et al.*, 2008). The basic technique of macrophyte-assisted vermifiltration has progressed into environmentally acceptable wastewater treatment and recycling possibilities. The earthworm consumes the particulates on the filter bed and turns them into humus (Sinha *et al.*, 2008; Singh *et al.*, 2017).

A microbial layer builds in the filter media as a result of the reduced porosity, which stimulates earthworm development by providing a food resource via sorption from wastewater (Liu *et al.*, 2013; Singh *et al.*, 2017; Wang *et al.*, 2010a, 2010b). The growth of microorganisms is aided by filter media, which then undergoes further treatment. The earthworm's grinding activity contributes to the filter media's overall specific surface area. As particles percolate through the filter media, they are trapped and stabilized by complicated bioprocesses in the active layer (Fig. 1).

Dissolved wastewater components travel further down in the profiles, where these are adsorbed





**Fig. 1: Vermifiltration Process.**

onto the surface matrix of the media and digested by earthworm-released enzymes and bacteria in a symbiotic relationship. Earthworms and microorganisms work together to change the physicochemical characteristics of wastewater (Arora and Saraswat, 2021).

#### **THE MECHANISM OF EARTHWORM ACTION IN VERMIFILTRATION TECHNOLOGY**

In the vermifiltration technology, the two processes-microbial and vermiprocess-work together. The biodegradation process is aided by microbes found in earthworm gut and enzymes found in secreted coelomic fluid. The vermifilter unit's sand and pebble layers also provide an ideal environment for aerobic microbial growth. Earthworms and aerobic microorganisms discharged from their guts absorb and stabilize contaminants in wastewater.

Vermifilters have a large specific area of up to 800 square meters per gram of soil and a voidage of up to 60%. Suspended particles are deposited on the surface of the vermifilter, where they are degraded by earthworms and fed to soil bacteria immobilized in the filter (Komarowski, 2001). Adsorption traps dissolved and suspended organic and inorganic particles, which are then stabilized via complicated bioprocesses in the

'living soil' populated by earthworms and aerobic bacteria.

#### **FUTURE PERCEPTION**

In developing countries, vermifiltration is the preferred method of treating wastewater. Instead of sludge, vermifiltrated purified water can be used for irrigation, and vermicompost can be used as a bio-filter. Vermifiltration's ability to remediate both domestic and industrial waste has been thoroughly proven. Vermifiltration experiments with genuine sewage and industrial effluents will help determine the efficiency of organic, nutrient, and pathogen extraction. Studies on the effects of symbiotic associations or mixed earthworm species on the removal of impurities from wastewater are necessary. The *Eisenia fetida* earthworm and the various natural substances work together to efficiently treat wastewater. The actual value of this technology is the ability to start decentralized and small-scale urban initiatives or industry-specific programs. Engineering institutes can assist in the effective design and operation of reactors, resulting in faster clean water restoration and the generation of vermicompost and earthworms.

#### **CONCLUSION**

Vermifiltration treatment of wastewater is a viable treatment technique and significant for

maintaining aquatic life and developing environmentally friendly technology. The presence of earthworms facilitates microbial degrading activity in the vermifiltration technique, which is an extension of soil filtration. This technique does not introduce any further toxic chemical substances into the environment, is reasonably straightforward to monitor, and can be easily adapted to meet local demands. Vermifiltration of wastewater with waste-eating earthworms is a brand-new concept. It's a long-term solution based on the interactions of earthworms and microorganisms. Due to its low cost and environmentally benign characteristics, it has paved new ground for wastewater treatment all over the world. As a result, it could be considered an interesting eco-innovation in wastewater treatment.

#### CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication.

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