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Relevance of vermicomposting in present era in organic waste valorization and bioremediation: An urgent need in environmental protection

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ABSTRACT

The environment friendly and economically affordable technology for the treatment of biodegradable solid waste is vermicomposting. Earthworms are used in the vermicomposting process to turn biodegradable organic waste into vermicast, which resembles humus. The end result of the vermicomposting process, which involves the cooperation of earthworms and bacteria, is vermicompost. The ecology is seriously threatened by the rate at which solid garbage is being produced around the world. If adequate precautions are not implemented, biodegradable contaminants will bring about an unpleasant odour and unclean situation. By minimising the negative consequences of garbage, this technique turns the waste into valuable manure. Vermicompost is a top-notch organic fertiliser that helps in organic farming and also has pest-repelling qualities. In the present paper production of vermicompost, role of earthworm in preparing composting and use of vermicompost in heavy metal removing from water bodies, chelating of contaminants in soil, influence in plant growth and development and pest and disease prevention abilities have been highlighted.

1. Introduction

Increased population rate and rapid urbanization leads to a proportionate increment in global waste generation which is estimated to be 1.3 billion metric tons approximately at present and the amount is expected to get doubled by 2025 (Samal *et al*., 2019). Of the total solid waste generated majority are of organic in origin. Therefore, management of wastes is a global concern and the management system is directly proportional to environmental and socio-economic factors, that's why majority of the developing countries are unable to avail updated technologies for safe disposal of waste due to economical barrier. The mostly used waste management technologies are composting, landfilling, combustion, waste to energy conversion, etc and some of them adversely affects environment. Landfill dumping leads to ground water contamination and release of higher amount of greenhouse gases. Carbon dioxide and other dangerous gases are released in large quantities during the combustion process. Besides use of sewage sludge as fertilizer on agricultural land again release some toxic chemicals to the plants and thus causes soil contamination and also affects activities of useful soil microbes. Therefore, the most beneficial methods of solid waste management are recycling, and reuse. For this, one of the practical and environmentally benign method for turning commercial and household trash into high-quality compost is vermicomposting. Earthworms are added to organic waste during the vermicomposting process, when they progressively transform the garbage into vermicompost, which is a humus-like substance which is black in colour and odourless. Vermiculture refers to the large production of earthworms in garbage, while vermicomposting refers to the use of earthworm technology to valuable waste management (Bhat *et al*., 2018). Besides vermicompost are preferred to be the soil medicine and is utilised extensively for crop production. It enhances plant

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productivity, soil health, and the possibility for disease resistance. Numerous reports back up the idea that adding vermicompost to soil could boost the yield of a variety of crops and plants (Biswas *et al*., 2021; Biswas *et al*., 2022).

2. Role of earthworm in vermicomposting

Earthworms and gut microbes work together during vermicomposting to break down the organic waste into tiny bits. By using their muscles, earthworms break down bigger organic particles into smaller ones in the first stage, and then the gut bacteria break down the newly generated smaller particles in the second step. The microbial breakdown process is accelerated by the smaller particles' greater surface area, which is employed as a microbe attachment site. The biodegradable waste is broken down by microorganisms in the second stage. Carbon dioxide and water are the last by-products of aerobic decomposition. The variety of bacteria that break down trash and the material's biodegradability are key factors in the waste degradation process. The rate of decomposition increases if the waste materials are readily biodegradable. The organic matter is digested by earthworms and builds up inside of them. The composting bed becomes more porous as a result of earthworm burrowing activity, allowing ambient oxygen to seep into the filter bed. In composting beds, aerobic conditions predominate and promote the growth of aerobic microorganisms. Water and nutrients disperse everywhere on the bed because of its porous texture. Earthworms secrete mucus and coelomic fluid, which combine with organic materials and start the degrading process when it is damp. Additionally, earthworms function as a buffering agent and maintain a pH of 7 in the composting bed. Earthworms alter the makeup of trash, reducing organic carbon content and the C:N ratio while preserving macro- and micronutrients (Bhat *et al*., 2018). Because it reduces the toxicity of the three wastes, earthworm bioconversion of industrial wastes and sludges is beneficial (Bhat *et al*., 2018). Heavy metals in industrial sludges can be detoxified by chloragocyte cells and the bacteria that live in earthworm guts (Srivastava *et al*., 2005). The various types of earthworms applied for waste recycling and vermicomposting have been presented in Table 1.

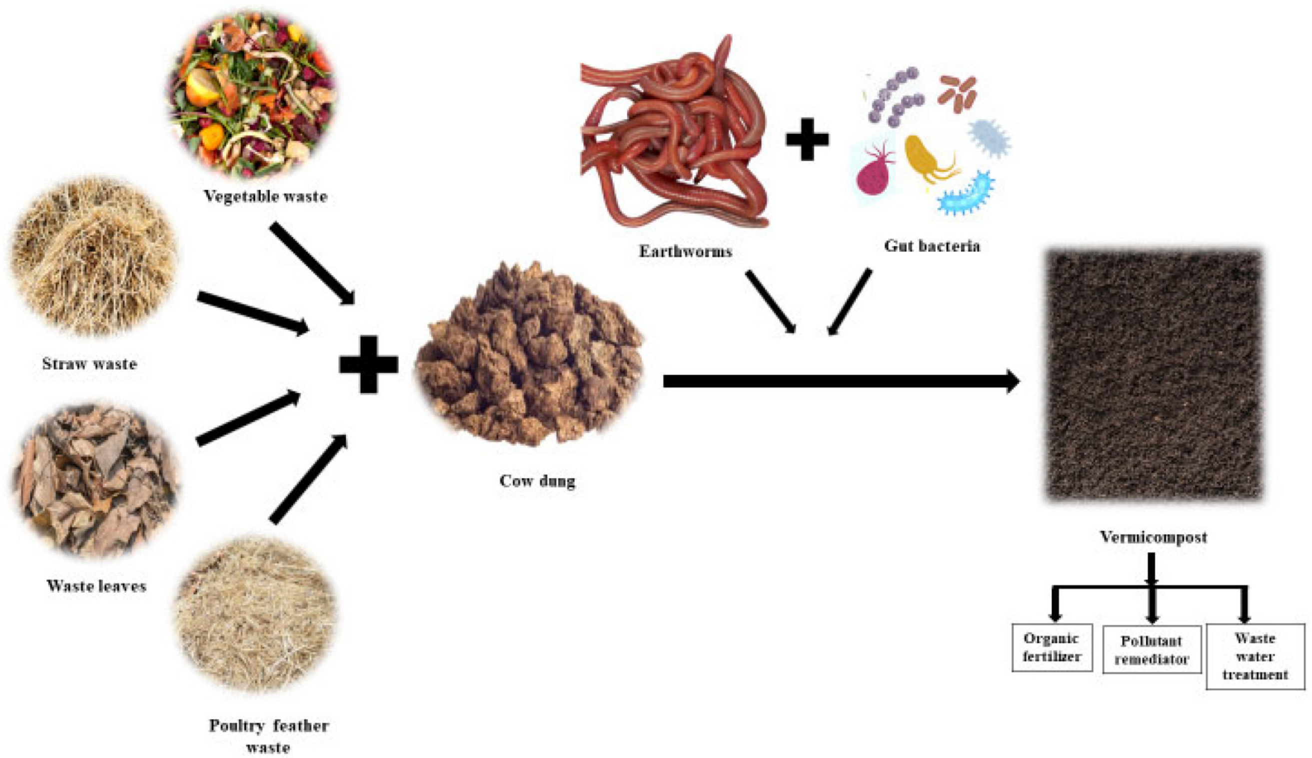

Figure 1: Scheme of vermicomposting.

Table 1
Biological criteria to classify earthworms used for waste management.

Earthworm category	Representatives	Characteristic features
Anecic	*Lumbricus terrestris*, *L. friendi*, *L. polyphemus*	They are of large size having light pigmentation with moderate reproduction rate and long life cycle. They generally live inside deep soil layer and are thus deep burrower, however, are not much efficient in waste recycling. They are phytogeophagous and for feeding they use litter and soil andexcrete organo-mineral faeces.
Endogeic	*Aporrectodea caliginosa*, *A. rosea*, *Octolasion cyaneum*, *Allolobophora chlorotica*	They are of medium size having low or no pigmentation with low reproduction rate and medium life cycle. They live mostly in upper layer of soil and burrow up to 10-30 cm representing medium burrowing capacity. Some species engaged in vermicomposting. They are geophagous and for feeding they use organic matter of soil and excrete organo-mineral faeces.
Epigeic	*Eisenia fetida*, *Lumbricus rubellus*, *Perionyx excavatus*, *Eudrilus eugeniae*	They are of small size, highly pigmented with high reproduction rate and short life cycle. They are most efficient species for vermicomposting. They preferably live between 3-10 cm having very much low burrowing capacity. They are phytophagous and for feeding they use leaf litter and animal excreta and excrete holorganic faeces.

By using *Eisenia fetida* as a vermicomposting agent, it is possible to significantly alter the bacterial composition and diversity while also reducing the toxicity and overall concentration of heavy metals. Different digestive enzymes, such as cellulase, amylase, phosphatase, protease, mannase, and lipase, are released by microbes and the gut of earthworms to aid in the breakdown of different organic matter components, such as starch, lignin, cellulose, and hemicellulose. Earthworms release proteins and a variety of nitrogenous compounds, which enhance the nitrogen content in the compost bed. In the compost bed, the nitrogenous molecules that are released mineralize and become available to the plants. By burrowing, casting, grazing, and dispersing earthworms alter the biochemical and physical characteristics of trash (Samal *et al.,* 2019). The vermicomposting method involves two stages: (1) During the active phase, earthworm digestion alters the physical and microbiological properties of waste materials. (2) During the maturation phase, earthworms leave the compost's matured layer and go to the new, undigested layers. The density of earthworms, species, pace of trash consumption, and method all affect how long the active phase lasts. Due to a variety of gut-related activities, the physical and biological features of organic waste in the earthworm stomach changed. The earthworm consumes partially decomposed organic waste, eliminates harmful microorganisms, adds helpful gut microbes, and ultimately pushes the digested materials to the surface of the soil as vermicast. The dynamics of the microbial population entirely alter in this manner. Old bacterial species that were present in the materials which the vermicomposting process consumed vanishe, while new bacterial species proliferated.

Some of the bacterial species associated with vermicomposting are *Aeromonas hydrophila*, *A. caviae*, *Sphingobacterium* sp., *Azospira* sp., *Bacillus subtilis*, *Flavobacterium* sp., *Fluviicola* sp., *Myroides* sp. and others. By secreting enzymes, *Aeromonas hydrophila* accelerates the breakdown of organic material. Protein hydrolysis is carried out by Saprospiraceae, which also utilises amino acids as a source of carbon and energy. In the process of the anaerobic food chain, proteins are broken down to CH_4 and CO_2. *Sphingobacterium* sp. has been discovered to breakdown steroidal oestrogens and aromatic chemicals like methylbenzene, pyrene, and phenanthrene. Fluviicola aid in the digestion of sludge. Delta-proteobacteria have been found to break down other microorganisms (such as bacteria and yeast) by secreting a variety of hydrolytic enzymes, including amylase, lipase, proteases and enzymes that break down cell walls. *B. subtilis* create a range of enzymes that can break down a range of natural substrates, and induce the creation of beneficial biofilms. *Aeromonas caviae* have the ability to create biofilms, break down organic materials, and convert nitrate to nitrite. Flavobacterium N_2O should be released by improving the denitrification process. Myroides species producing emulsifying agents will aid in the biodegradation of proteins (Samal *et al.,* 2019).

3. Waste management and bioremediation efficacy of vermicompost

3.1. Heavy metal removal from water bodies

Vermicompost is found to associated with the release of heavy metals. Several reports support the fact. For the total removal of Cd^{2+}, Cu^{2+}, chromium (as $Cr_2O_7^{2-}$), Ni^{2+}, and Zn^{2+} from synthetic aqueous solutions and galvanoplastic effluents, Jordao *et al.,* (2002) packed glass columns with sufficient amounts of vermicompost and observed the satisfying results. When Matos and Arruda (2003) used vermicompost to treat chemical laboratory effluents, they were able to successfully adsorb Cd^{2+}, Cu^{2+}, Pb^{2+} and Zn^{2+}. Vermicompost was utilised by Jordao *et al.* (2010) to remove Fe^{2+} and Al^{3+} from artificial aqueous solutions as well as from industrial wastewaters coming from a mineral processing facility. Another explanation for the prevalence of unspecific adsorption can be found in the parallels between the charge densities for Zn^{2+} and Cu^{2+} as well as Pb^{2+} and Cd^{2+}. This is in addition to the significant excess of negative charges in the vermicompost structure. When Kaushik and Garg (2003) used *Eisenia fetida* for the composting of textile sludge, they found that the resultant vermicompost had 25% less Cr and 11.5-38.2% less Zn. When employing cow dung as a bulking agent, Gupta *et al.* (2007) found a considerable reduction in Pb^{2+}, Cd^{2+}, and Cu^{2+} in the final vermicompost produced from water hyacinth. Domnguez-Crespo *et al.* (2012) discovered a dramatic reduction in Ni and Zn in the final vermicompost after composting sewage sludge using *Eisenia fetida*.

3.2. Removal of contaminants from soil

Vermicompost have been used to successfully lower the amount of a herbicide called 3-(3,4- dichlorophenyl)-1,1-dimethylurea, or diuron, that is present in soils (Fernandez-Bayo *et al.,* 2008). As a result of diuron's ($C_9H_{10}C_{l2}N_{2O}$) acceptable polarity and high affinity for the hydrophilic groups of vermicompost, this compound is distributed throughout several strata of modified soils. Similar to this, Fernandez-Bayo *et al.,* (2007) investigated the impact of vermicompost on imidacloprid ($C_9H_{10}ClN_5O_2$) pesticide mobility in numerous Spanish soils. Vermicompost was accountable for the considerable retention of imidacloprid, as seen for diuron, which was expected from polarity considerations (Fernandez-Bayo *et al.,* 2008).

3.3. Use of vermicompost for plant growth and productivity

Vermicompost is suitable for plant growth because it is rich in microbial floraincluding bacteria, fungi and actinomycetes. Additionally, vermicompost contains hormones and enzymes that promote plant growth and inhibit plant diseases. Numerous researchers have noted that the final vermicompost made from cow dung, paper mill sludge, and sewage contains significant amounts of humic chemicals, which are crucial for plant development and growth (Bhat *et al.,* 2018). Figure 2 represents the nutritional content of vermicompost as explained by Biswas *et al.* (2022). After establishing a symbiotic interaction between fungus and the roots of sorghum, Gutierrez-Miceli *et al.* (2008) observed a considerable boost in plant development when fertilizers produced from leachates of vermicompost containing sufficient amount of potassium, nitrate, and phosphate were administered to sorghum cultures. Biswas *et al.* (2021) applied CFPH (Chicken feather protein hydrolysate) amended vermicompost for yield improvement of tomato plants. Biswas *et al.* (2022) applied vermicompost in combination of egg shell dust for cultivation of Capsicum and observed satisfying results. Zhao *et al.* (2017) used chicken manure vermicompost for cultivation of cucumber (*C. sativus*) on sandy loam soil and observed higher fruit yield and quality under continuous cropping conditions. Similarly, vermicompost produced with combination of rice waste, rice husk ash and coconut fiber when applied for tomato (*Lycopersicon* sp.), the yield was higher compared to the controls and other treatments (Truong *et al.,* 2017). The NPK uptake, plant height, leaf area, shoot weight, eardiameter, weight of the husked and unhusked ears and weight of the husked ear per plot all significantly increased with VC application for sweet corn (*Zea mays*) production. The impact increased as VC concentration increased (Muktamar *et al.,* 2017). Similarly, when Lemon grass (*Cymbopogan flexuosus*) was grown with VC made from cow dung, plant waste, and lemongrass waste, the plants' height, tillernumber, herb yield, and oil content all rose (Sasikala *et al.,* 2016). The ability of VC made from industrial cassava waste to affect maize (*Zea mays*) development and as soil conditioners to improve salt-affected soils was evaluated. In comparison to the control, VC displayed higher plant height and more total dry matter of maize (Oo *et al.,* 2015). *Phaseolus vulgaris*, a bean plant, was grown with a mixture of cow manure, wheat straw and melon waste amended with VC. VC increased plant height, number of pods, leaf area, grain dry weight, length, volume, dry weight of roots, pod dry weight, number of grains, dry weight of biomass, and nodule number (Gardezi *et al.,* 2013). Comparative research was done to see how well tomato (*Lycopersicon esculentum*), bell pepper (*Capsicum anuum*) and strawberry (*Fragaria* spp.) cultivation responded to VC made from food and recycled paper waste, cow manure and inorganic fertiliser. When compared to inorganic fertiliser, VC increased the growth and productivity of each of the species under study (Arancon *et al.,* 2003).

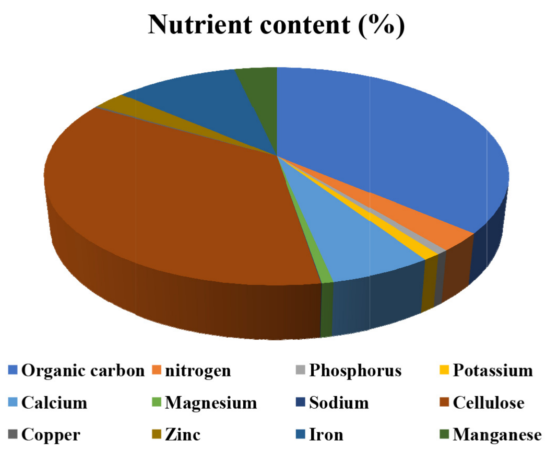

Figure 2: Nutritional profiling of vermicomposting (Biswas *et al*., 2022).

3.4. Role of vermicompost on pests and disease control

Plant disease is efficiently controlled by adding organic amendments to soils with low levels of organic matter and microbial activity (Pathma and Sakthivel, 2012). Thermophilic compost has been shown to have disease-suppressing capabilities against a variety of phytopathogens, including *Rhizoctonia*, *Plasmidiophora brassicae*, *Phytopthora*, *Gaeumannomyces graminis*, and *Fusarium*. As organic supplements increase the microbial population and variety, microbial conflict may be one of the potential causes of disease suppression. Traditional thermophilic composts only support a limited number of microbes, whereas non-thermophilic vermicomposts are abundant sources of microbial diversity and harbour a considerable number of antagonistic bacteria, acting as efficient biocontrol agents and assisting in the eradication of diseases brought on by soil-borne phytopathogenic fungi (Pathma and Sakthivel, 2012) Insect pests, plant parasitic nematodes and a wide variety of microbiological illnesses can all be suppressed by VC, according to numerous research. Szczech (1999) and Szczech and Smolinska (2001) showed a notable decrease in the infection caused by *Phytophthora nicotianae* and *Fusarium lycopersici* in tomato cultivated on soil that had been modified with VC. According to Arancon *et al*. (2005), *Pseudococcus* spp., *Myzus persicae* and *Peiris brassicae* infections are much less common in tomato, pepper and cabbage plants cultivated in VC modified media. Infestations of *Acalymma vittatum*, *Manduca quinquemaculata* and *Diabotricaun decempunctata* in cucumber and tomato plants planted in pig dung VC were reduced, according to Yardim *et al*. (2006).

4. Conclusion

Without proper treatment, industrial pollutants and solid organic wastes may pollute the soil and other wildlife, posing serious health risks. According to the findings of numerous authors, vermitechnology is a useful method for reducing the toxic effects of industrial wastes and solid organic wastes. In vermitechnology, earthworms and microorganisms work together to reduce organic waste and produce the final vermicompost, which has the best physicochemical and biological properties since it has been stabilised and finely split. The majority of research also showed that the vermicompost's end product may function as an appropriate medium for plant growth since it has a higher concentration of soil enzymes and growth hormones. Earthworm activity results in the production of vermicompost, which is high in macro- and micronutrients, growth hormones, vitamins, and enzymes like amylases, proteases, cellulose lyases, lipases and chitinases as well as immobilised microflora. Vermicompost is the best organic supplement for improvement of plant growth and development and output in general. Without harmful consequences towards the environment, it can enhance the crop production rate and shield them from harmful pests. Vermicompost application accelerated growth, enhanced plant nutrition and enhanced fruit and seed quality.

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