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Review Article

Solid Garbage Treatment: Issues and Challenges

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Abstract

The escalating volume of solid waste due to rapid urbanization, population growth, and industrialization poses significant environmental and public health challenges. Improper disposal of solid waste, especially organic and municipal garbage, leads to pollution of soil, air, and water, causing a surge in health risks and ecosystem degradation. Traditional waste management practices are often inefficient, expensive, and time-consuming. Composting and vermicomposting have emerged as eco-friendly, cost-effective, and sustainable alternatives for organic waste management. Vermicomposting, which employs earthworms to decompose organic waste into nutrient-rich compost, has shown potential in improving soil fertility, reducing pathogenic microbes, and recycling essential nutrients like nitrogen, phosphorus, and potassium. Various organic wastes such as agricultural residues, municipal waste, animal dung, and market garbage have been effectively treated through vermicomposting using species like Eisenia fetida and Eudrilus eugeniae. This review emphasizes the technological, environmental, and agricultural benefits of vermicomposting in transforming biodegradable solid waste into valuable compost, promoting sustainable waste management practices, and enhancing agricultural productivity.

Introduction

Solid garbage treatment: Issues and challenges

Modern eras have plagued the global population with new problems due to industrialization and simultaneous population explosion with their ever increasing needs and expectations. Pollution has become the main concern and challenge to the mankind [1]. The call of pollution is caught from all junctions of the world, which is the major threat in our life [2]. The habitations of both human and animals generate huge load of organic wastes and their decomposition products that affect the quality of soil, air and water detrimentally. The term pollution is derived from the Latin term pollutionem, is the sense to defile or make dirty [3]. Pollution causes adverse changes in physical, chemical, and biological features of air, land and water, which affects human life, living circumstances and cultural resources quite exponentially mainly due to the rapid industrial development. Though the contamination by natural procedures is known, the man made pollution poses a real danger to the mankind [4].

Waste treatment is a much demanding issue in all countries, especially in developed nations. Domestic litter from municipal areas, deprived of correct planning, leads to a major source of pollution [5]. Organic wastes, which are manufactured in large amounts all over the world, create major environmental and disposal problems. These materials result in unpleasant odor, and utilization of huge amounts of productive or fertile land for discharging these wastes are often a basis of pollution of ground waste [6]. The waste constituents of road side trash originates from households as well as other industrial utilities are not well defined due to their heterogeneous nature of constituents and these materials are often having varying physical, chemical and biological properties. Besides, the unpredictable loads of these solid wastes exceed the capacity that the corporation can maintain or safely process [7]. The waste accumulation has amplified concurrently with the rapid growth in residential colonies, fast food outlets, vegetable merchants, fruit yards and other customer outlets in respective areas. Garbage is also dumped in huge plastic bags that obstruct the traffic and they pose persistent problems due to their non degradative nature and lack of technologies to convert them in to environmental friendly safe products [8]. Says that the amount of large solid litter has been slowly growing and its management and removal is a main social and environmental problem as well as a major challenge. Much of the bio-solid wastes are highly infectious as they contain an array of pathogenic microorganisms. Their disposal into the environment without prior disinfection causes health and environmental risks.

In light of growing concerns over environmental degradation and unsustainable waste disposal methods, there is an urgent need to develop effective, scalable, and environmentally-friendly strategies. This review aims to assess the current practices in vermicomposting and solid waste management and to explore its potential to alleviate the challenges faced by urban and rural populations. Additionally, integrating innovative, low-cost biological approaches with policy support can help improve adoption in both household and industrial contexts. By compiling research insights and case studies, this article intends to provide a comprehensive resource for academics, policymakers, and practitioners in the waste management sector.

Aim of the study

The primary objective of this review is to explore the challenges associated with solid garbage treatment and evaluate the role of vermicomposting as a sustainable solution for organic waste management. The study aims to consolidate research findings and provide a comprehensive understanding of how vermicomposting contributes to environmental sustainability, waste reduction, and soil enrichment.

Composting

The management of bio solid wastes is gaining importance for not only providing clean and healthy environment but also enhancing the primary productivity through soil quality improvement. Composting is the widely accepted process for the recycling of organic wastes, avoiding the drawbacks associated to the direct land application of raw wastes or poorly stabilized materials, toxicity and pathogenicity [9]. Composting is coined from the Latin word 'compositum' meaning mixture. It is defined as the biodegradable process carried out over a mixture of substrates by the microbial community under aerobic conditions in the solid state. Composting facilitates the biological transformation of the organic matter into a well-stabilized product through the fast succession of microbial populations under aerobic conditions. The process results in mineralization of organic matter to carbon dioxide as well as transformation of organic matter into humic substances, an indicator of soil fertility [10].

The exothermic process generates energy in the form of heat, resulting in an increase of the temperature in the mass. A spontaneous process, therefore, is passing through a thermophilic phase, preceded and followed by two mesophilic phases. During the process of composting, there is an initial release of phytotoxins, intermediary metabolites, ammonia, etc. At the end of the process, this phytotoxicity is completely overcome by the metabolism of toxic constituents by organisms present in the composts and the final product is beneficial to plant growth. The composting process leads to the final production of carbon dioxide, water, minerals, and stabilized organic matter (compost). The process starts with the oxidation of easily degradable organic matter and this initial phase is called decomposition. The next phase is called stabilization that includes both the mineralization of slowly degradable molecules and more complex processes such as the humification of ligno-cellulosic compounds.

Substrates for composting

The common biochemical catabolic activities of microbes of composting utilizes the following biogenic substrates of plant, animal, or microbial origins and they originate from biological activities such as photosynthesis, consumer biomass etc. Usually, plant materials such as lignin, cellulose, and hemicelluloses (xylan, pectin and starch) etc make up the highest amounts, while animal tissues (glycogen and collagen) or microbial components (murein and chitin) are only minor fractions of any mixture, but usually are the most nutrient-rich fractions [11]. Among these mixtures, certain constituents such as lignin and collagen are highly resistant to degradation and may take longer duration for composting than the materials rich in other substances [12,13] and the collagen degradation becomes time consuming process if the fibrous protein cross links with humic substances [12].

Importance of vermicomposting

Various physical, chemical and microbiological methods of disposal of organic or bio solid wastes are currently in use. However, these methods are not only uneconomical but also time consuming. Therefore, there is a necessity to find out cost-effective alternative method of shorter duration. In this regard, vermicomposting has been reported to be a viable, cost-effective and rapid technique for the efficient management of the organic solid wastes [14]. Vermicomposting is a biotechnological procedure, wherein earthworms are utilized to transform the organic litters into humus like substance known as vermicompost. Certain earthworm types are able to consume wide ranging diversity of organic litters from sewage sludge, animal trashes, and agricultural remains, domestic and industrial wastes that widely vary with waste constituents. Under the optimal conducive composting conditions of heat and moisture, earthworms maintain an aerobic environment and ingest organic waste constituents and egest a humus-like material that is more homogeneous than organic trashes or raw materials utilized [15]. During the transit of material through worms' gut, some important plant metabolites like NPK present in the organic waste are converted into such chemical forms bioavailable to plants. The activities of earthworms in this procedure are physical and biochemical. Physical activities comprise fragmentation, turnover and aeration. Biochemical activities comprise of enzymatic digestion, nitrogen enrichment, and carriage of inorganic and organic resources [16]. In this procedure, significant proportion of plant nutrients such as nitrogen, potassium, phosphorus and calcium exist in insoluble forms in waste constituents which are transformed by microbial activities into soluble chemicals that can be more readily utilized by plants as nutrients than those in the parental substrate forms [17].

Vermicomposting differs from conventional composting because the organic material is processed by the digestive systems of earthworms. The egested casts can be used to improve the fertility and physical characteristics of soil and potting media. In this process, the earthworms actively participate in the degradation of organic matter through physical and biochemical means. Physical participation in degrading organic substrates results in fragmentation, thereby increasing the surface area of action and aeration. Conversely, biochemical changes in the degradation of organic matter are carried out by microorganisms through enzymatic digestion, enrichment by nitrogen excrement and transport of inorganic and organic materials. The earthworms contribute significantly in the recycling of organic waste and production of organic manure with high humic contents, which are helpful in maintenance of soil structure, aeration and fertility [18]. The efficient bioactive substances present in the humic acid fertilizer can enhance physiological metabolism, growth, yield of crops, seed germination etc and these features are not possessed by ordinary fertilizer [19]. Applying humic acid fertilizer can also effectively increase the anti-drought and anti-frigidity potential of crops, and prevent underground plant diseases, insect pests and pathogenic bacteria.

Agricultural waste resources

Animal and municipal garbage changes the soil appeal, including pH, bulk density, conductivity, water stock capacity and increased the proportion of organic carbon content Khaleel, et al. 1981 [20]. Edwards, et al. [21] has evaluated the growth of Perionyx excavatus (earthworm) population with different types of organic wastes and observed that the maximum reproduction occurred in cattle and sewage mud at 25 °C. Besides, it was also reported that a similar growth pattern was also obtained while using anaerobic digested sewage waste, and cattle solid waste.

Solid waste administration is not an easy task in the existing scenario, due to enormous growth of population, fast urbanization and lifestyle of the people that make huge quantity of solid produced every day [22,23] conveyed that earthworms such as Eisenia fetida were used for solid agricultural and household solid garbage treatment, and it provided an employment for community with recycling of energy. Vermicompost derived from cattle manure was studied for its efficiency using Petroselinum crispum Mill, and the result suggested that vermicompost improved the yield, leaves, and the plant height [24].

To address the nutritional needs of the growing population, vermicompost practices in agro industry has been adopted to manage and process huge bio-solid wastes generated from human habitats. Managing the agro waste using E. eugenic resulted in reduction of cadmium toxicity in the soil besides enriching P, K, Na, Ca and nitrogen nutrient contents of the soil [25]. The uncontrolled and mismanagement of municipal solid waste (MSW) from urban area consumed high cost for disposal and this could be managed with economical, ecofriendly and sustainable vermicomposting methods.

Dar and Dar [26] reported that, municipal waste from 17 wards of Ganderbal district affected the environment and caused water borne ailments due to poor waste treatment. Adopting of vermicomposting, complete degradation of wastes was achieved within 35-42 days and the resultant manure was rich in high NPK content besides reducing the manpower to process the raw waste.

Vermicomposting technology

Ramesh, et al. [27] has reported that pollution increased due to organic waste from day to day activities and adopting vermicomposting yielded compost manure with desirable physical, chemical and nutritional properties suitable for horticulture Westerman and Bicudo [28].

Atiyeh, et al. [29] studied the effects of humic acids formed during the breakdown of organic wastes by earthworms (vermicomposting) on plant growth and it was observed that the treatment resulted in productivity of plants such as increase in plant heights, leaf areas, shoot and root dry weights. The plant growth properties of composts were due to hormone-like activity of humic acids from the vermicomposts or could have been due to plant growth hormones adsorbed onto the humates.

Kaviraja Sharma [30] stated that a composting study was performed with two types of earthworms (Lampito mauritii and Eisenia fetida) for solid garbage treatment. The obtained composts have variations in their nutrient values such as total organic carbon, carbon and nitrogen, Kjeldahl nitrogen, electrical conductivity and total potassium and weight of the solid waste. In this study, Lampito mauritii exhibited desirable nutritional properties when compared to the composting process of Eisenia fetida.

Organic wastes increased the microbial biomass-carbon content in soil and the microbial BC and BN (Biomass nitrogen) was positively correlated with organic C content [31]. The degradable organic waste and their safe disposal is a big concern all over the world. The sustainable energy in renewing the soil is a challenge by providing sustainable environment and enhancing soil vermicompost to enrich the water stock capacity, nutrient and most importantly in developing plants to exhibit resistance against pests and diseases. Earthworms can facilitate these functions and they serve as "nature's plowman" and serve as a nature's gift to yield good humus that is the greatest valuable material to fulfill the nutritional wants of crops [32].

Ansari [33] described that waste treatment is a complicated problem in developing countries and has used grass clippings wastes as renewal energy by utilizing cow fertilizer enriched with *E. fetida*. The initial raw material was 210 kg and the final weight of the compost was 120 kg and the conversion rate of bioenergy was observed to be 57%. Aalok, et al. [34], studied the maintenance of solid litters by using three different earthworms such as *E. eugeniae*, *E. fetida* and *Perionyx excavates* and found that the bulk mass of municipal solid waste volume (MSWV) was reduced to about 65, 55 and 40%, respectively. In this study, it was reported that pH, electrical conductivity, nitrogen, phosphorus, potassium, calcium, and magnesium concentration were increased in the resultant compost manure. Another study conducted by Pattnaik and Reddy [35] indicated that the nutrient values of vermicompost was higher when using *E. eugeniaethan E. fetida* and *P. excavatus*.

Vermicomposts and characteristics

Earthworm is one of the chief resources for eco-friendly method for the treatment of solid garbage. A greenhouse test was performed with vermicompost from (1) Raw dairy dung with tobacco residue; (2) Yard leaf; (3) Sewage sludge + rice hull; (4) Sewage sludge + yard leaf, and (5) raw dairy dung were estimated in tomato seedling. It was observed that all these methods yielded compost with desirable nutritional properties and bioconversion ratio [36].

Nair, et al. [37] stated that kitchen waste was thermo-composted for 9 days and transformed as vermicompost in 2.5 months. The vermicomposting is a powerful tool for bulk discount of waste as well as pathogen free vermicompost. Vermicomposting is a significant technique of transforming organic garbage into nutrient rich dung through earthworms without reducing the population of useful bacterial flora that facilitated microbial composting.

Though conventional bio-composting methods such as microbial composting and vermicomposting are able to degrade bio-wastes through thermophilic and non-thermophilic mechanisms respectively, individually they suffer several demerits. Though vermicomposting is efficient in decomposing plant wastes as well as contributing desired soil fertility attributes, the process suffers certain demerits such as the inability to degrade the animal wastes effectively, high pathogenic microbial load and long duration process. On the other hand, microbial based thermal composting is effective in rapid decomposition of solid matter by thermal elevation due to intense metabolism of thermophilic microbes resulting in reduction in the pathogenic microbial load to a great extent. However, the microbial composting process has the limitation to produce bio-fertilizer of high humic content due to their reduced efficiency in processing vegetable wastes. A paradigm shift in transforming these bio-wastes to fertile resources with improved primary productivity by synergizing the desired features of microbial degradation and vermicomposting is feasible. It is reported that the combination of these methods in two-phased manner is expected to reduce the duration of complete decomposition of biosolid matters against the methods when performed separately [38].

Researchers reported that vermicomposting yielded high content of NPK, carbon, nitrogen, beneficial micro-organisms and growth hormones [39]. Pathma and Sakhivel [40] stated that vermicompost is a procedure of non-thermophilic, bio-oxidative procedure with the combined assistance of earthworm and microbes.

Dalal [41] stated that biological waste was transformed as vermicompost wherein the process resulted the reduction of waste volume by 65%.

Lim, et al. [42] stated that vermicomposting is a process, in which earthworms are utilized to transform organic materials into humus-like material named as vermicompost. Vermicompost have high nutrient content than other methods of composting as vermicomposting improves soil fertility physically, chemically and biologically. Vermicompost treated soil has good aeration, bulk density and water stock capacity besides improving agricultural yields due to rich in preferable plant nutrient contents. Though vermicompost helps to enhance the plant growth, high quantity of vermicompost may affect the development of plants due to the presence of soluble salts in vermicompost. The quantity of compost with respect to nutrient contents and pH can be optimized for obtaining better yields when applied on to the fields. Gomez-Brandon and Dominguez [43] described that large scale of solid litters was transformed rapidly as a valuable fertilizer with low price and the rapid transformation and the quality of the composts could be correlated with the gut bacterial flora.

Managing market waste through vermicomposting

Vermicomposting can be suggested as a better method of solid waste treatment, which is one of the major challenges today. Lokeshwari and Swamy [44] conducted a vermicomposting study using municipal, agricultural and mixed solid wastes along with sewage sludge in different proportions such as 0%, 10%, 20% and 30% respectively with the sewage sludge. It was reported that pre-aerobic decomposition for 20 days followed by vermicompost reduced the overall time required for composting (30 days), when compared to windrow composting, which requires about 80 days obtaining the final product. Chemical analysis of the vermicompost samples showed the significant decrease in carbon content and good amount of N, P and K contents in the final composts.

Mane and Smita [45] carried out on the proper utilization of agriculture waste from the market yard through vermicomposting and obtained the nutrient rich organic manure. For composting, the African species of earthworms i.e. Eisenia fetida and Eudrilus eugenae were selected for the study. The crops cultivated using the composts resulted in higher yields than the ones grown with just cow manure.

Kizilkaya, et al. [46] stated that earthworms played a significant role in organic garbage treatment through vermicomposting; the vermibed was equipped in diverse combination by using sewage sludge amended with hazelnut husk and cow dung. After preparation, *E. fetida* was introduced into vermibed and their compost was studied on Triticum aestium; and the compost induced the development of plant when compared to control. Sujatha and Bhat [47] reported the field efficacy using vermicompost over the chemical fertilizers. It was observed that the pH, organic carbon, phosphorus, nitrogen and potassium were increased significantly when compared to chemical fertilizer.

Ansari and Hanief [48] reported that vermicomposting of grass, water hyacinth and a combination of grass with water hyacinth were successful and the final compost yields were about 30%. The final compost material had the beneficial microorganisms such as Actinomycetes, Azotobacter, Nitrobacter, Nitrosomonas and Aspergillus that were responsible for enhanced plant productivity much more than what would be possible from the mere conversion of minerals into more readily available forms of nutrients for the plant's growth.

Fauziah and Agamuthu, [49] reported that the bioremediation of organic garbage into valued product through vermicomposting using *E. fetida*, wherein about 40-50% of waste was transformed as vermicompost. The water stock capacity of vermicompost was 25% (wt) and total organic content was 12%.

Procedure for vermicomposting

A vermibed with the following diverse ratio of agriculture waste and cattle fertilizer was reported by Suthar, [50] (1) Equal weight of (Penniseum typhoides and Sorghum vulgare) + sheep manure (1:2 ratio), (2) Vigna radiata + Triticum aestivum+ cow dung (1:1:2 ratio), (3) Mixture of the above plants + cow dung (1:1 ratio), and (4) Cattle shed manure for renewal of energy through vermicompost. All the composts were rich in N (97.3% to 155%), P (67.5% to 123.5%), K (38.3% to 112.9%), and Ca (23.3% to 53.2%), and showed reduction in organic Carbon (20.4% to 29.0%).

Disposal and treatment

Ansari and Sukhraj K [51] stated that organic garbage comprising of grass clippings and water hyacinth were effectively processed by bio dung composting followed by vermicomposting for 60 days duration using *E. fetida*. The method not only destroyed the pathogenic microbes but also reduced the waste by more than 60%.

Gurav and Pathade [52] stated that the temple organic litters with cow dung and biogas digester slurry were decayed for the duration of 30 days at 30° C. Then, *E. eugeniae* was introduced into the decomposed waste at 25 °C and the moisture content was 80%.

Beohar and Srivastava [53] conducted comparative study between exotic and indigenous epigeic Eisenia foetida (exotic) and anaecic species Lampito mauritii (indigenous)) respectively. They used two species of earthworms for the evaluation of their efficacy in vermicomposting of poultry waste. Vermicomposting of poultry waste took 90 days of time, resulted in significance difference between the two species in their performance and compost quality in respect to pH, electrical conductivity, organic carbon, organic matter, nitrogen, phosphorus, potassium, Ca, Mg and weight loss of poultry waste.

Shamini and Fauziah [54] investigated the possibility of treating selected organic wastes via vermicomposting using formulated microbial cocktail consisting of Bacillus weihenstephanensis, Bacilluspumillus, Pseudomonas alcaligenes, Flavobacterium johnsoniae, Staphylococcus hominis and Bacillus licheniformis. The microbial consortium enhanced the efficacy of the vermicomposting in terms of degradation of wastes at faster rates. This enabled a reduction of 50% carbon content which was converted to nitrogenous products. This was not achieved when vermicomposting was performed without the aid of microbial consortium.

Subbulakshmi and Thiruneelakandan [55] stated that solid waste was transformed as vermicompost through aerobic conversion and the product had been used for enhancing the soil fertility and also acted as a plant development promoter. The nutrient values of vermicompost (N, P, K, Ca and Mg) were increased when compared to farm yard fertilizer. Lim, et al. [56] stated that soybean husk and papaya garbage were combined in diverse ratio for waste treatment with *E. eugeniae*. Amongst the various ratios, 1:1 ratio was the best mixture for vermicompost. All the nutrient contents such as Ca, K, Mg, and P value were increased while C: N ratio decreased after 63 days.

Mahanta, et al. [57] reported that the effect of rice yield and plant development was evaluated by using vermicompost from rice straw, Eichhornia crassipes, Ipomoea carnea, and their mixed biomass, were augmented with microbial inoculants of Azotobacter chroococcum, Azospirillum brasilense, and Pseudomonas fluorescens. Among them, Ipomoeacarnea derived vermicompost was higher in nitrogen content and microbial population than the other earthworms. The highest plant development was observed due to A. chroococcum followed by enrichment with A. brasilense. Nutrient contents in plant and organic C, N, P, and K in post-harvest soil were also significantly enhanced through the application of enriched vermicomposts.

Majlessi, et al. [58] reported that vermicompost was moderately phytotoxic to cress seeds. The maturity of compost was evaluated by Solvita test and the CO2 released from microbial activity was suitable for vermicompost.

The improper handling of organic waste creates environmental pollution and this in turns results in the inability in using them as a renewable energy source. Earthworm and housefly maggots can be used for sustainable organic waste management. Both of them are able to transform the organic garbage into valuable materials (vermicompost) [59]. Anastasi, et al. [60] analyzed the microbial diversity of compost (plant debris) and vermicompost (plant and animal garbage with action of earthworm) and found out that the higher numbers of microbes were recorded in vermicompost than the conventional compost and the increment of microbes in vermicompost could be attributed to effective lignin degradation.

Vermicomposting by *E. eugeniae*

Punde and Ganorkar [61] stated that organic waste on exposure to sunlight for 5 - 10 days removed the pathogenic organisms and toxic gases. Decomposition of cotton took 20-25 days whereas for other organic wastes, it was 5-10 days. The following 8 different combinations of pre-digested materials utilized as raw materials for vermicomposting by *E. eugeniae*: Soil + cow dung (0.5:1); Soil + vegetable waste (1:1); Cow dung + vegetable waste (1:1); Cow dung + rice husk (1:1); Food waste + cow dung (4:1); Cloth waste + cow dung (3:10); Sugarcane waste + cow dung (1:1); and Paper + cow dung, and all the treatments were performed in soil bed. Among these processes, vermicompost materials derived by waste combinations 3, 5 and 7 showed higher NPK values at 45 days analysis.

Mujeebunisa, [62] reported that the growth of *E. eugeniae* was evaluated on different vermibeds with mixture of cow manure. Different waste constituents such as leaf litter, vegetables, coffee seeds, and flowers were dried for 5- 6 days. Then, the dried wastes were pre-digested using cow dung with 1:1 ratio and individually maintained for microbial activity up to 21 days. After the earthworms were presented into vermibed, the results showed that vegetable and flower waste with cow dung exhibited significant growth of earthworms.

Eudrilus eugeniaewas used for municipal solid litter management wherein, the litter was transformed into vermicompost within 30-32 days and about 60% of volume was reduced in the process. Solid garbage treatment is a large problem in our country; the garbage can be transformed into useful material (vermicompost) by using earthworm for the use as a fertilizer [63] . Kumari [64] stated that the vermicompost process was completed with diverse ratio of (1) Soil + cow dung; (2) Soil+ vegetable waste + fruit waste; (3) Soil + vegetable waste + fruit waste + cow dung; (4) Soil+ paper waste+ cow dung and their composts were examined for TP, TK, TOC, TKN, and C: N parameters. The heat of compost during the process was observed to be between 21-25 ° C, and TP (0.11-0.25%), TK (0.19-0.55%), TKN% (0.33-0.77%), TOC (8.03-22.3%), pH (5.9-6.1) and C: N (10.78-31.68%) was recorded 0-45 days of composting.

Paper waste comprising rich carbon and low nitrogen content of cow dung was utilized as mixture in diverse ratio 1:1 (paper+ cow dung); 2:1 (paper + cow dung); and3:1 (paper + cow dung). Among the combinations, 1:1 ratio was best one, and the compost was collected up to 65 days excluding 15 days pre-digestion. All the nutrition parameters such as total nitrogen (%), phosphorus (%) and potassium (%) were decreased whereas the pH and C: N ratios were decreased within the duration of 0-65 days. It was also found that there is an increase in the quantity of worms, cocoons and the body weight of worms. The overall weight of the waste was reduced to more than 50%, and the final weight of compost was 1350 g [65].

Treating bio-degradable wastes

Ravindran, et al. [66], reported that Eudrilus eugeniae has been utilized for vermicompost production. The waste of solid state fermented (SSF) and submerged (SmF) state fermented TFL was combined with cow dung and plant material. Microbes play an important role in vermicompost process. The compost has phytohormones, Indole 3-acetic acid, Gibberellic acid, and Kinetin. Maximum quantity of plant hormones exist in vermicompost products due to earthworm and microorganisms. The vermicompost obtained from different ratios of raw materials viz., (1) Mushrooms, media waste, cow manure, and vegetable wastes, (2) Mushrooms media waste, cow manure and leaf litter and (3) Mushrooms, media waste, cow manure, vegetable wastes and leaf litter. All the above vermicomposts produced higher yield of cabbage than inorganic fertilizer [67]. Hussain, et al. [68] reported that vermicomposting was a waste recycling method which increased the N and P levels by microbial action. Different combinations of vegetable wastes, rice straw and cow dung were used as the raw materials for compost production by *E. fetida* and *P. excavatus*. The compost derived from *E. fetida* was shown to have reduced total organic carbon, and increased pH neutrality, and NPK availability, and microbial population. It was also identified two N-fixing strains of Kluyvera ascorbata as an effectual bio-fertilizer candidate to accelerate the composting process. Moreover, both N-fixing and P-solubilizing strains of Serratia and Bacillus were isolated from earthworm gut. All the isolated strains have effectively enhanced the soil health and eased up the crop development via serving as bio-fertilizers.

Our nation (India) alone produces 3000 million tons of degradable waste/year, and the waste comes from domestic sources [69]. Improper management by dumping solid garbage in a region may pollute water and soil. Most of the waste is managed by incineration and composting. The biodegradable waste was transformed as manure (vermicompost) by earthworm composting for counteracting the ecological as well as for the economic reasons. The solid waste was transformed as vermicompost through using *E. fetida*. The compost rich in nitrogen, phosphorous and potassium improves the soil structure, fertility, and water stock capacity for high yield [70].

Dhimal, et al. [71] described that Zoo wastes were regarded mostly as animal dungs, garbage and litter; and they were transformed as compost through earthworms with minimal time span when compared to conventional composting. The resultant compost had huge microbial content, and optimal organic matter content, moisture content, nitrogen, phosphorous, potassium and (Carbon:Nitrogen) C: N value for agricultural productivity.

Eisenia fetida was utilized for biodegradable solid garbage treatment and it was an eco-friendly waste treatment method producing heat. As he suggested that small scale (individual house) waste treatment was easiest way for solid management and was economically viable. Also the pH of the raw waste was lower than compost. The compost had higher carbon, phosphorus and nitrogen ratio than raw litter [72]. Vermicompost is a sustainable way to manage the livestock excretes. While using earthworm which breaks the dung effectively renders it recyclable as it contains high amount of nutrient and microbial biomass for plant growth. Compost is a significant tool for eco-friendly waste treatment [73].

Kaouachi [74] stated that the olive waste was transformed as vermicompost through E. andrei. The gained vermicompost have enhanced NPK, calcium, magnesium, sodium and required EC and C/N ratio. This is eco-friendly method for olive waste treatment.

Sumi, et al. [75] reported that solid garbage treatment was one of the large ecological problems. The residual waste of anthropogenic origin pollutes aquatic and terrestrial ecosystem, if not properly disposed. A quantity of solid litters was categorized as biodegradable and such wastes were altered into ecological safely products through microbial composting, vermicomposting, biogas plant, etc; Vermicompost induced gas germination, high microflora, high NPK content, flowering and fruiting duration of plants than the control(conventional composting). It was suggested that vermicompost was a simple, cost efficient andsimple technique of waste treatment with low maintenance.

Benefits of vermicomposting

Kumar, et al. [76] conveyed that few of the Indian cities were addressing the environmental problem due to solid waste through compost methods. The solid waste makes numerous problems, especially in the rainy season, as it blocks the water. In many ways, solid waste could be handled viz., incineration, composting, gasification, refuse derived fuel (RDF). The organic solid was pulverized and transformed into vermicompost and economically the value was 9.36 lakhs / year. Sequeira and Chandrashekar [77] stated that household waste of food, paper, vegetable waste and garden (grass and leaves) were combined with cow dung and alone were utilized for vermibed and Eudrilus sp., the compost is composed of helpful microbial community of bacteria, fungi and actinomycetes and Pseudomonads, P- solubilizers and N2 fixers were increased in vermicompost.

Nidoni and Math [78] described that plant, paper, cow dung and milk sludge were used for raw materials for composting by using *E. eugeniae*. After composting, the materials were analyzed for NPK and others at 30 and 45 days compost. The pH, electrical conductivity, organic carbon, nitrogen, phosphorus, and potash, carbon: nitrogen, copper and zinc were within the limit when compared to standard. It is an important technique to manage the solid garbage into valid materials in eco-friendly manner.

Albasha, et al. [79] stated that kitchen waste with the mixture of cowdung, the predigestion was carried out in 15 days. The best dung was gained in kitchen waste + cowdung (1:1), than Kitchen waste + cowdung (2:1) and Kitchen waste + cowdung (3:1) ratio. The pH value was reduced when duration of compost collection day increased (0-60 day), total nitrogen (%), phosphorus (%), potassium (%) and carbon: nitrogen ratio were increased considerably.

Paul [80] studied different types of waste such as canteen waste, kitchen scraps, non-toxic solids and household garbage's were decayed for a period of 30 days, and after 30 days, cow dung slurry was combined with decamped materials and introduced in *E. fetida*. After few days, the waste dumped material was transformed as compost and were utilized for crop production with income. Mammals produced many tones of manure daily, and improper management caused increase in GHG (Greenhouse gas) emission and environmental pollutions. Nandy, et al. [81] analyzed that the vermicompost for microbial content showed that the compost contained rich organic matter and microbial population.

Sadasivuni, et al. [82] has stated that India has recyclable organic biomass of 0.7 and 0.8 million tons/year. The author specified that potential usage of areca nut and cocoa waste had been used for income with using technology without ecological effects known as vermicompost having greater nutrient than compost which also restored the soil fertility considerably. The vermicompost treated potato plant had higher phenol content compared to that of the control. The treatment reduced the efficacy of transformation of ingested and digested food also affect the carbohydrate and protease of the larvae and pupae [83] .

Londhe and Bhosale [84] stated that solid waste was handled by converting it as composting, in an environmental friendly manner without producing any kind of risk to environment. They evaluated T1, soil + cow dung, (0.5:1), T2, Soil + vegetable + fruit waste (1:1), T3, Soil + agricultural waste + cow dung (1:1) and T4, Soil + paper waste + cow dung (1:1) ratio and showed increased N level. All the compost materials increased the nutrient potash and nitrogen contents.

Nag, et al. [85] stated that organic solid garbage was 5-75% in religious areas of Patna, Bihar; it was managed and transformed as valued materials by *E. fetida* and *E. eugeniae*. The results presented that NPK were increased with increase in the duration. The results also showed an increase in C/N ratio. Carbon% was decreased with increasing duration of composting period.

Amaravathi and Reddy [86] conveyed that municipal solid garbage was transformed as compost by *E. fetida* and for *P. excavatus*. The best environmental conditions were (temperature, moisture, pH, EC) required for vermicomposting. In the early stage, the temperature was high and it was reduced during the process and also the pH was high while cow dung and soil were added for microbial and earthworm growth. Also the author concludes that *P. excavatus* is superior to *E. fetida*.

Baki, et al. [87] informed that 100% of food garbage was reduced within 7 days as vermicompost through *E. eugeniae*; it contains high nutrient content of N, P, and K.

Karmakar, et al. [88] evaluated the result of vermicompost alone, chemical fertilizer and 50 manure +50 fertilizer and control on rice field. They found that vermicompost also showed good growth and provided maximum nutrient to tested plants.

Jain [89] Jain V, et al. [89] observed that organic solid management was a major problem of many cities in developing countries. Enormous quantity of waste with poor maintenance was known as environmental contamination. In India most of pilgrims, produced enormous quantity of waste during the festival. The flower garbage was huge in some of the main regions in Jaipur and Rajasthan temples. The flower garbage was transformed as vermicompost with combination of cattle dung and using *E. fetida*. The garbage was transformed as vermicompost by more than 50%. The compost was at 25°C, 8.0 pH, 1-2mm particle size, moisture 60% and the bulk density were at acceptable limit. Also compost condensed the EC, C: N ratio, C: P ratio and increased in N, P.K, Ca, Mg, and sulphur. The vermicompost utilized as manure for tomato plant cultivation improved the growth parameters such as stem diameter, height, leaf number, length of roots, yield/plant.

Vermicomposting of organic wastes and its usefulness

The Samanea saman (rain tree) is native to northern South America and the leaves contain 22-27% crude proteins. In some Asian countries, rain tree is grown as a green fodder supplement for goats, sheep and cattle. A 5 year old tree can produce 550 kg of green forage. Rain tree is easily identified through its characteristic umbrella-shaped canopy [90]. When grown in open, the tree typically achieves 15-25 m in height with a canopy diameter broader than the tree. Rain tree is regarded as a shade tree for avenue planting along streets, in parks, public grounds, and other spacious areas. It is too large for home gardens in city areas but is suitable for smallholdings in rural areas with acceptable space for the trees to develop their impressive crowns. Trees also yield multiple products–edible pods, leaf litter for mulching and composting as well as additional livestock feed, nectar for honey bees, wood for crafts and construction–that can be used in rural economies. Leaves are interchangeably organized along twigs and have a noticeable swelling (pulvinus) at petiole base; stipules exist and threadlike; the leaf blades are twice-even-pinnately compound, organized in 2-6 pairs of pinnae, each pinna bearing 6-16 diamond shaped leaflets, shiny green above, dull and finely hairy beneath, 2-4 cm long and 1-2 cm wide, the apical leaflets largest. During dry periods, trees are semi-deciduous, dropping their leaves for a little period which causes enormous quantity of waste to the atmosphere. These kinds of wastes are also handled through the vermicomposting method.

Vermicomposting is also used for treating the animal wastes. The quantities of minerals differ in treatment groups, and this can contribute to variations in growth and multiplication rate of earthworms in the diverse animal manures, which result in a differential pattern of uptake of the nutrient for their body synthesis and subsequent release of the remaining minerals in a mineralized form. The carbon content of cattle manure decreased during vermicomposting indicating a higher mineralization of organic matter. However, the N content of cattle dung has been augmented in process of vermicomposting. This shows that the augmented microbial activity continues outside the gut in the casts and results in an increased mineralization rate of organic N and consequent further increase in concentration of nitrogen substances [91]. The vermicompost from olive cake reduced the environmental effect of amended soil [92]. In the present scenario, waste treatment is an important task worldwide due to management cost and environmental pollution. Lack of organic content in agro ecosystem, necessary to re-use the organic energy for enhancing soil to strong cultivation with minimizing the fertilizer, water, for that cow manure, pomegranate meal + sawdust, cow dung + potato waste pomegranate + potato waste, Cow manure + pomegranate metal, and cow manure+ pomegranate metal+potato waste for preparing vermibed for vermicompost among the combination with cow manure with pomegranate meal + saw dust and potato waste. The pomegranate meal enhanced the conductivity of soil and organic content and also soil pollution was reduced [93].

With the increasing population, there is a need for fertile lands to cultivate many plants for agriculture. Mentha arvensis plants were cultivated in salt stressed situations in controlled and field conditions. The fungi Glomus aggregatum and Exiguobacterium oxidotolerans with vermicompost enhanced plant growth. The study also concluded that multimicrobial inoculations together with vermicompost as effectual bio-fertilizers for M. arvensis cultivation [94]. Xu, et al. [95] stated that vermicompost had difficult effects on the antioxidant enzyme actions of plants grown in high salinity and the composts enhance the salinity stress of the plant. The organic waste of industrial sewage sludge and municipal solid waste compost were combined with cultivated soil. Both treatments amplified the organic matter, microbes, but decreased water holding capacity in industrial waste [96].

Aali, et al. [97] conveyed that indiscriminate use of synthetic chemicals directs to numerous problems in our ecosystem and also affects the non-target organism. For agricultural industry garbage like sheep manure, pomegranate peels, spent mushroom compost either singly or double, triple or fourfold chopped corn, sugar beet pulp and sawdust were utilized as raw substantial for vermibed. The gained compost condensed the electrical conductivity by raising the pH and NPK levels of treated land. It also acts as a fertilizer.

Masullo [98] reported that waste materials were processed by anaerobic condition initially followed by transformation by vermicomposting. While vermicompost is applied in the field, it reduced the irrigation frequency, eliminated the requirement of chemical fertilizer and induced the plant growth. The vermicompost from sewage sludge, wood chips and the mixture with biochar induced the higher reproductive rate (cocoon, juveniles) and reduced the Zn and Cd contents [99] Maji, et al. [100] reported that humic acid rich vermicompost induced the plant height, fresh weight, and dry weight with increase in the density of beneficial soil micro flora.

Wang, et al. [101] evaluated digestion of chicken fertilizer and kitchen waste by acid digestion and buffering (4 volatile fatty acids) with vermicompost biochar and vermicompost. It was found that chicken fertilizer and kitchen waste were digested with the assistance of vermicompost and vermicompost biochar. Acid-buffering of biochar played an important role on enhancing the anaerobic digestion. Overall, the vermicompost biochar played a key role in digestion of chicken fertilizer and kitchen waste.

Vermicompost and beneficial microflora

The vermicompost, an end product of the vermicomposting process is rich in microbial content. The total microfloral population however is less in vermicompost than the substrate from which it is obtained. The substrate or wastes generally contain some pathogenic microbes and during vermicomposting procedure, earthworms neutralize these harmful microbes. Earthworms stabilize organic remaining's and decrease pathogenic bacteria and other human pathogens [102]. [103] reported a 90% elimination of fecal coliforms and 100% elimination of helminths from sewage mud and water hyacinth after vermicomposting. The part of microbes by earthworms in decay of organic matter and particularly in humification process is well known [104]. Earthworms play a significant role in soil biology by serving as natural bioreactor to harness the helpful soil microflora and abolish the soil pathogens. Microorganisms normally flourish in earthworm casts and it has been suggested that they especially fungi, establish a nutrient pool for earthworms [105]. Suthar [106] reported that worm cast of L. mauritii and *E. eugeniae* polyculture showed significantly amplified the microbial action than L. mauritii monoculture.

Summary

This review updates the various researches made in vermicomposting mediated solid waste management. The techniques and processes used by the different vermicompost procedures are reviewed and presented. Also, various bio-degradable and other bio-solid waste treatment methods are described that have relevance on the research presented in the thesis.

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