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Management of waste water using hydrophytes and contributing towards vermicomposting

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Abstract
In recent years the disposal of wastes from domestic, agricultural and industrial sources has severely affected our ecosystem. Primarily, the untreated effluents are released to water bodies, making them unfit for any use. Water crisis seen across the globe has to be dealt in a priority basis. Reusability of water can be a suitable alternative to circumvent this alarming situation. Nevertheless with the help of several scientific tools waste water may be converted to usable form, but it is interesting to note that some plants also have the ability to remove pollutants from water bodies. This process of removing pollutants from waste water with the help of plants is called Phytoremediation extensively. There are some specific hydrophytes exists that decreases the toxicity level in the water bodies. The breakthrough benefit of phytoremediation process is largely due to its cost effectiveness and eco-friendly approach. The biggest add-on advantage of this process is the reuse of hydrophytes for vermicomposting resulting in enhanced soil fertility. Phytoremediation can be pulled up along with the vermicomposting scheme so that the entire process can contribute for sustainable agricultural practices. This review primarily highlights the process of phytoremediation and its applicability in the vermicomposting process for usability in the agricultural sector.

Keywords: phytoremedistion, hydrophytes, vermicomposting, earthworms, microorganisms

Introduction

An Overview on Vermicomposting

Vermicomposting is a kind of composting in which certain species of earthworm are used to enhance the process of conversion of organic waste to produce utilizable end product. Various studies have revealed that the earthworm like *Eisenia fetida* fed with *Azolla* sp. shows remarkable reproduction and growth. It also points to the fact that *Azolla* vermicomposting may be an efficient way of converting *Azolla* into a product that has a value such as vermicompost which is used locally as a rich nutrient in agriculture as organic fertilizer. Consequently, weed harvests of *Azolla* fed by *Eisenia fetida* are transformed in vermicast that can be used as manure by people who have farm fields and vegetable gardens. The functioning and service of the ecosystems are influenced by aquatic plants but these plants acts as threat if excessively present. The various anthropogenic activities results in building-up of nutrients in aquatic ecosystems with massive growth of the weeds and various adverse effects associated with them. Effective weed management is difficult to manage in several aquatic systems. The most common methods used to control and manage aquatic weeds are habitat manipulation, biological, chemical and mechanical removal of weeds. Such processes, however, can be highly upsetting, detrimental to the environment and inefficient. On the other hand, a wide variety of harvested weeds can be converted to a healthy, rich in nutrients called vermicompost by different species of earthworms. Among the various aquatic weeds, water orchids (*Eichhornia crassipes*) are the most widely vermi-composted weeds, using various species of earthworm. *Eisenia fetida* is the most widely used species among the different species of earthworm used for vermicomposting aquatic weeds. Vermicomposting is a highly efficient eco-biotechnological method that turns biotic waste into a highly nutritious material suitable for the cultivation of sustainable agricultural ecosystems (Fig. 1). In conjunction with recovery of organic substances and low input nutrient depletion, a wider use of water-based vermicompost weeds can solve their management and disposal problems in horticulture.

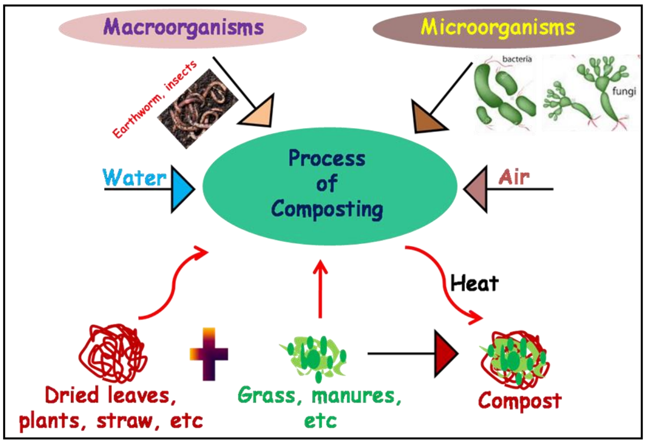

Fig 1: Process Flow Diagram of Composting

Environmental Factors Affecting Vermicomposting

Biotic factors

Distinct biotic factors, includes earthworm stocking densities, microorganisms, enzymes etc., which influence vermicomposting.

Earthworms stocking density

Efficiency of vermicomposting decreases with overcrowding of worms. Optimum density and feed are important parameters for a good and productive vermicomposting system. Earthworm population (stocking density) affects several physiological processes in a vermicomposting system such as respiration rates, reproduction rates, feed rates and burrowing activity. The growth rate of *E. fetida* was faster at high stocking density, but biomass gain per worm was faster at lower stocking densities, whereas earthworm attains sexual maturity earlier at higher stocking densities [1]. They also noted highest growth rate in 100 per cent cow dung at all stocking densities as compared to other wastes containing textile mill waste water sludge. They reported that a worm population of 27-53 worms per kg of feed was found to be the most favourable stocking density. An increase in mortality due to higher population densities, a decrease in cocoon production and a decrease in growth rate [2]. In contrast, the growth of *Eisenia andrei* decreased significantly when stock-densities were increased [3]. The stocking density of 1.60 kg / worm / m^2 at a feeding rate of 1.25 kg feed/kg worm/day is the optimal combination [4]. Therefore, it is important to maintain the best earthworm density, in order for the development of vermicomposting systems to achieve maximum population growth and early reproduction.

Microorganisms

Earthworm is regarded as natural bioreactors which multiply along with micro-organisms and provides the condition required for the decomposition of biodegradable waste. In order to ensure the disintegration of organic waste under optimal environmental conditions, microorganisms naturally populate in organic waste material. The composition of the microorganism communities of a vermicomposting system depends on its composition. The interplay of earthworms and vermicomposting microorganisms stabilises organic matter [5]. Earthworms use organically produced substrates to satisfy protein or nitrogen needs, however the population of earthworms' casts were almost equal or higher than the original substrate population [6]. In addition to mineralizing complex substances into available form for plants, micro-organisms also synthesize biomass active substances. Earthworms ingest organic substrates in vermicomposting, but not every microorganism is killed in the gut [7]. Sporal germination is actually facilitated under favourable conditions of earthworm guts and it may increase vermicompost's microbial biomass [8]. It also indicates that earthworm-microbe relationship favours the recycling of organic waste through vermiculture. Vermicomposting of press mud from a sugar factory using *Eudrilus euginie* and observed that vermicomposting involves bioxidation and stabilization of organic material through interactions between earthworms and micro-organisms [9]. Vermicompost produced the joint action of earthworm and microbes contain nutrients in the available form with increased microbial activity. Earthworm mucus significantly enhanced the humidification and decomposition of vermicomposting materials and even promotes microbial activity and the growth and increase community diversity in vermicomposting system. Earthworms prime the symbiotic gut microflora with secreted mucus and water to increase their digestion of ingested organic matter and release of assimilable metabolites [10]. The microorganisms and earthworm act symbiotically to accelerate and enhance the decomposition of organic matter and consequently humification and mineralization takes place as a result of which nutrients becomes available to plants.

Enzymes

Chemically very complicated, organic waste requires enzymatic action and complete stabilization. The worms secrete enzymes in their gizzards, which easily transform cellulosic and protein-acoustic materials into organic waste [11]. Some of the principal enzymes involved in the vermicomposting process include cellulases for depolymerization of cellulose, β-glucosidases that are used to extract hydrolysis glucosides, amidohydrolases, N mineralizing proteases and ureases, and phosphate groups that are removed from organic matter. Enzyme activity has also been used as microbial activity markers and may also be useful for soils microbial metabolism rate interpretation [12]. Enzymes are also catalysts for significant metabolic processes, including decomposition, and ultimately contaminant detoxification [13].

Abiotic factors

The most important abiotic factors which affect vermicomposting process include moisture content, pH, temperature, aeration, feed quality, light, C: N ratio etc.

Moisture Contents

Adequate humidity content for the functioning of earthworms and microorganisms in the vermicomposting system is one of the most important factors. Earthworms must breathe through their skin and thus have adequate moisture content in the system. The ideal humidity range for vermicompost and vermicomposting is 60-80% [14, 15]. The physical and chemical variations between feed stocks can be slightly different. Even at a 5 percent difference in moisture contents, a major impact on the production of cellular disease in the *Eisenia fetida* [16]

pH

Another key parameter that affects vermicomposting process is pH. The pH ranges suitable for earthworms and microorganisms are between 5.5-8.5. However, the optimum pH is neutral or nearly neutral. There are significant changes during vermicomposting to the pH values of the feed substratum. An initial phase of low pH is often observed during vermicomposting of the feed substrate [16]. The formation of carbon dioxide and initial volatile fatties is responsible for this. As the process progresses with future CO_2 development and the use of volatile fatty acids the pH starts to increase [17].

Temperature

The optimal temperature range for earthworms is 12 to 28 °C in the vermicomposting process. The work of the worm is significantly influenced by temperature. The temperature should be above 10 °C in the winter and below 35 °C in the summer in order to maintain this system active [18]. The earthworms are unable to reproduce and metabolism is reduced also because the temperature drops within the system for vermicomposting. Earthworms do not eat at very low temperatures for food. Metabolism and earthworm reproduction starts to decrease at higher temperatures (above 35 °C), and there is mortality [19].

Aeration

For vermicomposting, oxygen is essential since earthworms are aerobic organisms; also related to the consumption of oxygen due to microbial and earthworm operations. Excessive humidity in a vermicomposting system may result in poor ventilation and may affect oxygen supply of the worms.

Feed quality

The primary necessity for vermicomposting is the right feeding material for earthworms. Many factors such as the size of food particles, diets, salt foods, etc. vary in food quantity and can be eaten by earthworm every day. Small feed waste particles ensure the process of vermicomposting is accelerated by worms. This small size of the particle allows the waste piles to be aerated and accessible to worms correctly. The food that a worm consumes ranges from 100 to 300 mg/g body weight/day. They are nourished by organic matter, live micro-organisms and degradation of macro-fauna.

C: N ratio

C: N feedstock ratio affects the growth and reproduction of earthworms. The higher C: N ratio in feedstock speeds up worm growth and reproduction. The waste degradation is slowed if the ratio of C: N is too high or too low. Unless C: N is within 25-20:1 range in plants earthworms can't assimilate mineral nitrogen.

Hydrophytes in Vermicomposting

Aquatic ferns such as *Azolla pinnata* grow on the surface of the water and quickly cover it under favourable environmental conditions. *Azolla* multiplies at 15-30 °C with an optimum temperature of 25 °C. Under nutrient deficiency and strong light conditions, *Azolla* turns red. It also turns red or brownish red in hot or cold winter. *Azolla-Anabaena* is perhaps the most promising aquatic pteriodophyte in terms of ease of cultivation, productivity and nutritional value because of its symbiotic association with a nitrogen fixing heterocystous blue-green alga - *Anabaena azollae* [20, 21]. *Azolla* is an aquatic fern, distributed in lakes, paddy fields, freshwater ponds, streams or irrigation canals which grow throughout the year [20]. *Azolla* species are capable of producing 450-600 kg N_2/ha/year. Various studies have revealed that the earthworm like *E. fetida* is fed with *Azolla* sp. exhibits successful reproduction and growth. It also points to the fact that *Azolla*-vermicomposting may be an efficient way of converting Azolla's biomass into a product that has value added, properties like vermicompost which is used locally as a rich nutrient in agriculture. Consequently, the functioning and service of the ecosystems are influenced by aquatic plants but are even damaging if excessively present [22]. The various anthropogenic activities result in a building-up of nutrients in aquatic ecosystems with massive growth of the weeds and various adverse effects associated with them. Effective weed management is difficult but of short duration in several aquatic systems. The most common methods used to control and manage aquatic weeds are biological, chemical and mechanical as well as habitat manipulation. Such processes, however, can be highly upsetting, detrimental to the environment and inefficient. On the other hand, a wide variety of harvested weeds can be converted by different species of earthworms to a nutrient-rich product called vermicompost. Among the various aquatic weeds, water orchids are the most widely used weeds for composting using various species of earthworm. *Eisenia fetida* is the most commonly used species among the different species of earthworm used for vermicomposting aquatic weeds. Vermicomposting is a highly efficient eco-biotechnological method that turns aquatic waste into a highly nutritious material suitable for the sustainable agriculture. In conjunction with recovery of organic substances and low input nutrient depletion, a wider use of water-based vermicompost weeds can solve their management and disposal problems in horticulture.

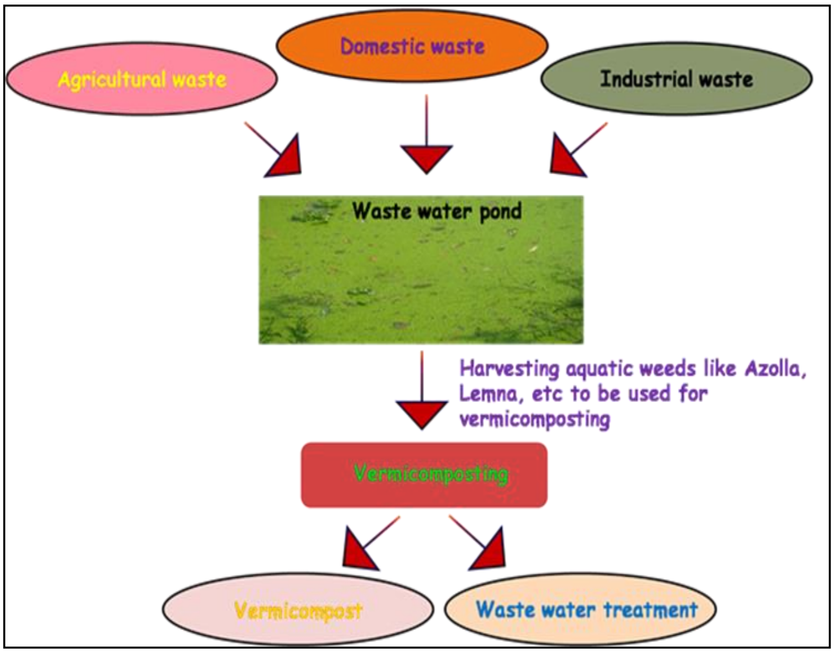

Fig 2: Aquatic weeds mediated vermicomposting.

Earthworm: Key Player of Vermicomposting

Status of earthworms

Earthworm species are around 3,320 in the world [23]. Near about 590 different ecologically preferred earthworm species in India, but there is no functional role for most species and no impact on habitats [24].

Habitat of earthworms

Species of earthworms have a variety of habitat characteristics, ecological niche, way of life and life. The physico-chemical characteristics of soils such as temperature, humidity, pH, carbohydrate, and C: N ratios etc. are the major factors influencing the distributed of earthworms in various agro-climatic zones. The majority of species prefer soil at 10 – 35 ^{0}C, and moisture at approx. pH 7; and the ratio C: N 2- 8. Earthworms are usually absent or uncommon in soil with very rough texture, high clay or pH [25].

Classification of earthworms

Based on the morpho-ecological features, earthworms have been grouped under 3 categories: (1) Endogeic (2) Epigeic and (3) Anecic [26]. Epigeic earthworms are small, organically horizontal worms that feed organic matter. There are no permanent burrows, but only for diapauses they make ephemeral burrows on the mineral soil. These are plant-based species. The life of these types with a quick reproduction rate is relatively small. These species contribute to organic matter biodegradation and release nutrients into the soil. The plant litter or animal waste in the body should be an important converter to protein for vermicomposting, so its growth levels are high. The intake, digestion and assimilation rate are expected to be high. It is reported that in areas with higher temperatures (up to 43 °C) and low temperatures (< 5 °C) one temperature tolerant earthworm species namely *Ironia fetida* can be cultivated [27].

Growth Parameters and Vermicompost

Vermicompost are reported to be the main source of vitamin, enzymes and plant growth hormone, which positively increases the root biomass, root initiation, growth of plants, and alters the morphology of plants [28]. It has been reported that a remarkable increase in the total biomass of a tomato seedling was sufficed by incorporating small amounts of pig manure vermicompost into the commercial bedding plant potting medium [29]. Vermicompost has beneficial effects on growth of plants that is in the growth of chickpea seedlings are remarkably at the lowest level of vermicompost substitution [30]. There was satisfactory evidence that vermicompost promotes plant growth [31, 32, 33]. An improvement in the growth of potatoes was recorded for 6 t/ha of vermicompost along with spinach and the turnip [34]. Twenty percentage of pig manure with vermicompost was replaced for marigold seedlings which has grown at a medium growth rate. So, vermicompost was found to stimulate root growth by increasing the distribution of root hair [35]. Vermicompost applications in field soils have improved crop growth and yields [36]. Vermicompost has a favourable effect on all yield parameters for crops such as paddy, wheat, and sugar cane [37]. It is reported that utilization of bio-fertilizer enhances the height of plant along with total dry weight and leaf area. The height of the wheat plant increased after inoculation with *Azospirillum* sp. Several studies recorded that manure compost has a positive impact on plant growth and its development by using the parameters such as flowering, blooming time, leaf area, interns develop and extend. The dry weights of the marigold plants were improved significantly, along with maximum growth of marigolds (30% rise) by the use of mixture containing compost. Some researchers have recently reported that increased growth for species that have been grown from vermicompost in humic acid-modified media [38]. The observation of increased biomass was consistent with several findings that the application of farmland manure and phosphobacteria increased the plant height in maize by up to 40% [39]. A number of studies showed that the use of biofertilizers increased in plant height in rice and senna [40]. As well as the numbers of leaves in soybeans and 41% of the total of root nodules in *Vicia sativa* with organic manure and green gram [41]. The use of green manure or biofertilizers has stimulated the growth of plants with more tillers and rice leaves. As a result maximum rise in rice biomass in soil treated with *Sesbania aculeata*. The total biomass yield increased by 33, 36 and 67 per cent in rice over control by the application of biofertilizers [42]. The development of dry weight of strawberry leaves (*Fragaria anunassa* Duch.) at a concentration of 7.5 t / ha of vermicompost. The total number of root nodules per plant in soya bean has increased after use biofertilizers [43]. Vermicompost has been reported to increase plant growth and yields in greenhouse crops as stabilized organic materials resulting from interactions between earthworms and microorganisms in a non-thermophile process [44]. Vermicompost applications have also been reported to increase the growth and yield of pepper [45]. It has been reported that when Metro Mix 360 substituted with pig manure, more floral marigold buds were found. It has been shown that humic substances help in growing of maize, oats, soya, peanuts, clover, chicory and other tropical plants [46]. The application of vermicompost to field-grown tomatoes result increment in the yield [47]. Greenhouse experiments have shown that vermicompost can significantly and consistently increase the germination, growth and yield of various vegetables and ornamentals [48, 49]. A few number of field experiments reported in the literature have shown that soil-modifying vermicompost may increase the growth and yield of some crops, such as cowpea, banana and strawberry. As announced that in response to the application of vermicompost, the yield of Thompson seedlings has also increased significantly [50]. Some investigators reported that vermicompost enhances the germination, growth and output of the seedlings the plant’s growth, number of leaves, leaf area, root nodule, fresh weight and dry weight in *Arachis hypogea*. The species are sustained increase in the yield of dry matter was recorded in animal manure application [51]. A high quantity of vermicompost (30 percent) has negatively affected fresh weight and dry weight of cucumber seedlings, which show salt stress that caused delay in growth in growth performance. Increasing data on yield and growth in various amendments, vermicompost treated plants and trees, and also the role and the productivity of leguminous plants have been identified.

Conclusion and Future Prospectives

Effluent contamination including heavy metals to the environment is of serious concern owing to its impending impact on human health. Cost effective and eco-friendly technologies are required to protect the natural resources and for easy sustenance of life forms. Considerable efforts have been made to identify plant species contributing for phytoremediation. The ability of plants, primarily hydrophytes like *Azolla* facilitate immensely in the removal of heavy metals from water sources, essentially the sewage water points. Besides being used in the process of phytoremediation, these hydrophytes are equally beneficial for the vermicomposting process and thus can be a strategic factor to be employed in the agricultural sector. The dry biomass of the hydrophytes can be a rich resource to be added with soil and other abiotic components that would favour the growth of earthworms which ultimately enhances the soil productivity for better crop yield. However, much research work is still required to reveal the molecular and cellular mechanisms underlying these eco-friendly processes. In depth soil microbial analyses would be equally significant to reveal any micro-organisms involved in the process of heavy metal uptake by plants. At the end, developing technologies specifically aiming towards effective removal or recovery of metals from plant biomass will also be noteworthy.

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