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Vermicomposting: An effective method to treat waste sludge

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Abstract

The environment is seriously threatened as a result of the world's rising volume of solid waste generation. Biodegradable pollutants will impart an unpleasant smell and create an unsanitary situation if suitable precautions are not implemented. Vermicomposting can be suitable option for handling solid waste in an eco-friendly manner. The review aims to assess the viability of using vermitechnology to extract nutrients from organic sludge and return them to the environment. This review is focused on earthworms and their mechanisms in vermicomposting process, various affecting factors and physical-microbial properties of vermicast.

Keyword: Earthworms, Environment, Microorganisms, Sludge, Vermicomposting

Introduction

A large amount of waste is generated worldwide due to various anthropogenic activities such as urbanization, industrialization and economic growth. The disposal of these wastes has become an environmental and serious problem for everyone (Ali *et al*., 2015). Sewage sludge is a by-product of wastewater treatment that is produced all over the world, as well as residue from the treatment of wastewater released from various sources such as homes, industries, medical facilities, street runoff, and businesses. This organic waste needs to be managed effectively because there is a significant production of sewage sludge all over the world. There are numerous strategies for reusing sewage sludge, as well as numerous restrictions on the application of the given management strategy (Kacprzak *et al*., 2017).

Characteristics of sludge

The properties of sludge are heavily influenced by its source and treatment. Municipal, industrial, and hospital wastewaters are the most common sources of sewage sludge. Due to raw sewage sludge's parameters, it must be processed to be reused. Large solids like grit and sand, organic and inorganic substances, pathogenic microorganisms, heavy metals, and toxic or nontoxic contaminants are the main components of sewage sludge. In general, hospital waste sludge is similar to municipal sewage sludge, but some of the hospital waste sludge contains contaminants that are toxic, non-biodegradable, or infectious (Grosser *et al*., 2013a, b; Kwarciak-Kozlowska and Krzywicka, 2014; Grosser and Neczaj, 2017).

Sludge contains phosphorus and nitrogen, two important and essential trace elements needed for wastewater treatment processes. New recovery methods are needed because of the limited sources of phosphorus. The sources of nitrogen are endless, but the demand for nitrogen in agriculture is very high (Kacprzak *et al*., 2017).All types of sludge include harmful and slightly toxic pollutants, organic substances, pathogenic microorganisms, inorganic substances and heavy metals (cadmium, chromium, copper, lead, mercury, nickel, zinc, platinum and platinum group metals (PGM), silver, etc.) (Mateo-Sagasta *et al*., 2015; Kacprzak *et al*., 2017).

Types of sludge

There are several types of sludge. It's due to the origin of the sludge, as well as which tank it comes from. Faecal sludge is distinguished from sewage sludge by its origin in domestic wastewater treatment facilities; industrial sludge by its source in industrial waste water treatment facilities; and hospital sludge by its source in hospital waste water treatment facilities. There are several forms of sludge with various qualities as a result of the type of sludge created at each stage of wastewater treatment. Raw sludge, primary sludge, secondary sludge, mixed sludge, concentrated sludge, digested sludge, dehydrated sludge, hygienized sludge, dried sludge and stabilised sludge are the common types of sewage sludge. Untreated sludges, known as "raw sludges," have a strong odour and are highly water soluble (Mateo-Sagasta *et al*., 2015).

Sludge treatment strategy

Limited water and fertilizer resources in many parts of the world are the reason for recycling sludge. In many countries, Sludge is the final waste and is used directly in the soil. In general, waste and sludge may be used directly, usually informally, in low-income countries where less attention is paid to wastewater collection and treatment. In high-income countries, the trend is reversed, with waste and sludge commonly treated and their application and use controlled and planned. Currently, there are various methods of sludge treatment. Each of them focuses on disinfecting and removing toxic compounds and limiting the amount of sludge (Grosser *et al*., 2013a and Lamastra *et al*., 2018).

For a proper treatment process, these methods incorporate mechanical, biological, physical, and chemical stages. However, all of these methods pose environmental risks and public health risks. For example, landfills may contaminate ground water, and incineration is expensive and challenging to operate, which results in ozone depletion (Raschid-Sally, 2013).

Sludge management techniques can also include energy and material recycling through incineration, pyrolysis, and gasification; reclamation; composting; and organic recycling with agricultural usage. Sludge must meet certain criteria for heavy metal or pathogen content; otherwise it may be unsuitable for agricultural use (Kacprzak *et al*., 2017; Lamastra *et al.,* 2018).

Some of the commonly used methods were chosen and applied on the basis of the form, composition, and amount of sludge material are:-

(A)Incineration- Due to the large volume decrease (by around 10%) brought on by the thermal degradation of organic materials; incineration is generally the best method for utilising sludge. Waste material is burned in the presence of excess amount of oxygen in this procedure. CO_2, H_2O, O_2, N_2 Slag and Ash are all created during this process. This method has many benefits, including reduced waste, reduced transportation costs, and decreased harmful greenhouse gas (methane). However, in addition to the fact that incineration plants require large investments and high operating costs, skilled staff is needed because improper operation of the plant can contaminate the environment(Patil *et al.,* 2014; Celary *et al*., 2016).

(B) Gasification and Pyrolysis-Both processes require high temperatures, with the only minor variation being that gasification uses little oxygen while pyrolysis does not. Hazardous gases (H2, CO, CO2, and CH4) and hydrocarbons, ash are released during pyrolysis and gasification (Antonou *et al*, 2019).The use of high temperatures in gasification and pyrolysis has a number of benefits, including the degradation of pathogens and hazardous components. The increased operating temperature also causes decrease in sludge volume. Again, Tars, heavy metals, halogens, and chemicals are emitted during gasification and pyrolysis and may have negative effects on the environment and the general public health and therefore make this technique less environment friendly. (De Lasa *et al*., 2011).

(C) Landfill-It is the most popular method of disposing of garbage. A landfill is a method for disposing of solid waste sludge on land and minimizes the amount of waste that is dumped there. These landfills exist to minimise the possibility of disposal- related environmental or public health risks. However, occasionally leachate from landfill methods gets combined with groundwater, causing water pollution (Koda, E; Miszkowska *et al*., 2017).

Biological Waste Treatment-Microorganisms are used in biological waste treatment to break down the sludge biodegradable components.

Composting-It is the most popular techniques of disposal, which uses microscopic microorganisms to break down organic waste material. Composting is a safe way of degrading sludge, and it uses an aerobic process to break down complicated degradable materials into products that are both organic and inorganic (Fernando et *al*., 2012).

Vermicomposting*:* This process is same as composting but in this process earthworm use composting degradable organic matter (Arumgam, *et al.,* 2018). Earthworms are invertebrates and classified as members of Class Oligochaeta, Family Lumbricidae, and Phylum Annelida. The earthworms are long, cylindrical, elongated organisms with soft bodies and uniform ring like structures made of segments in entire length of their body. Earthworms have a reproductive period of about 66 days, but this can vary from species to species, however the quality of organic inputs has an impact on the rate of reproduction. Earthworms are hermaphrodites because they have both male and female gonads. In spite of being hermaphrodite, cross fertilization is found in them. The mature worms have a characteristic epidermal ring called the clitellum that contains gland cells to create the sticky girdle like structure known as the cocoon at the time of egg laying. Without any larval stage, they lay their eggs in a cocoon (Hait, and Tare 2012; Atiyeh 2020).

Various earthworms are used for vermicomposting and these include *Megascolex mauritii, Eisenia fetida, Eudrilus eugeniae, Perionnyx excavates,* and *Lampito rubellus*, *Eisenia andrei* (Huang K., *et al.,* 2014).

Looking at their impact on the environment, it appears that vermicomposting is more attractive, low cost technology than landfill, open burning, incineration, pyrolysis, gasification and composting.

Earthworms play an important role in the decomposition of organic matter and soil metabolism through feeding, fragmentation, aeration, turnover and dispersion Earthworms are involved in the recycling of nutrients, soil structure, soil productivity and agriculture, and their application in environment and organic waste management is well understood. They help in the degradation of substrate indirectly by affecting microbial population structure and dynamics and also directly since their gut is capable of undertaking cellulolytic activity. Thus products of cellulose hydrolysis are available as carbon and energy sources for other microbes that inhabit the environment in which cellulose is degraded and this availability forms the basis of many biological interactions (Gomez-Brandon et *al.,* 2012).

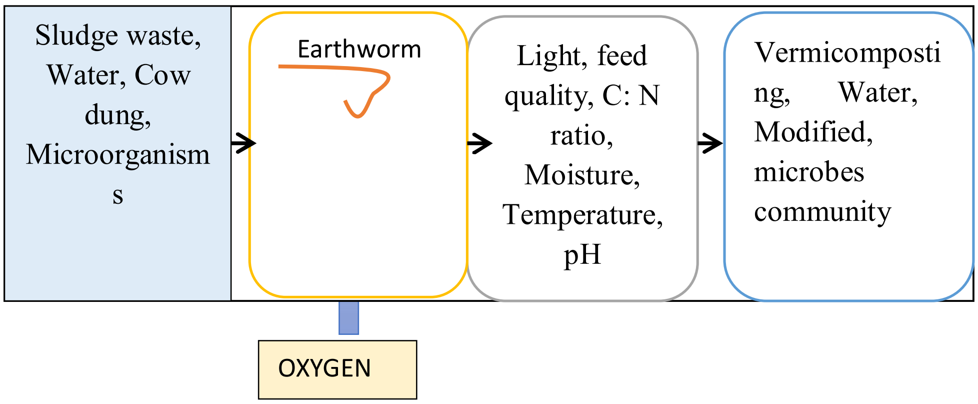

Fig: 1 Use of earthworm degrade sludge in suitable condition

Vermicomposting is a mesophilic process using microorganisms and earthworms that are active between 10 and 32 °C. Vermiculture makes it possible to use earthworms as natural bioreactors for cost-effective and environmentally friendly waste management. Earthworm fertility is based on cocoon production rate, cocoon hatching success, and the number of offspring hatched from each cocoon. Successful composting depends on the fertility of earthworms. The type of substrate used and the type of earthworms introduced play an important role in plant growth and yield. The waste to be stabilized should support inadequate biomass needed for effective processing. The time, cost and space requirements could compete economically with conventional methods of composting (Gomez-Brandon *et al.,* 2012).

Properties of Vermicompost

The properties of Vermicompost which decide whether it can be used as fertilizer in agriculture and plant nutrient are as follows:-

Physical property:

The texture of the soil profile is modified when cast forms in the soil. As rain falls, it washes out the fresh cast and after a few days, the cast dries and becomes stable. According to a study, the amount of decomposing organic that is consumed by earthworm affects the stability of the cast. The amount of bacteria in the cast will be high if the eaten material has a higher organic content and many biological secretions of bacteria mix with it making the cast more stable (Samal *et al*., 2017).

Microbial property:

Although earthworms play an important role in the vermicomposting process, microorganisms whether they come from the soil or the earthworm's gut actually carry out the biochemical degradation of organic materials. There is no arguing about the interdependence and synergistic interactions between earthworms and microbes. The availability, abundance, and growth rate of the substrate are increased by earthworm's physical activities of aeration, mixing, and grinding (Hao *et al*., 2016).

Vermicompost is a diversified collection of microbial communities that include phosphate solubilizes N_2 fixers, enzyme producers, and bacteria that encourage plant growth. For example, Chitrapriya *et al*., 2013; Dominguez *et al*., 2019; and Kolbe *et al*., 2019 reported the bacterial composition in the vermicomposting as phylum Proteobacteria, Bacteriodetes, Actinobacteria, Firmicutes, and Verrucimicrobia.

Although bacterial diversity was low in the starting material and in the initial vermicomposting phase, it increased dramatically over the course of the procedure.

Factors affecting vermicomposting: Some important factors that can affect the vermicomposting process, earthworm development, cocoon generation and microbial diversity are:-

Abiotic factors:

(a)Moisture content: The moisture content of organic wastes and the degree of earthworm growth are closely correlated. The vermicomposting process and the growth of earthworms at various moisture and temperature ranges suggested that 65-75% is the optimum moisture at all range of vermicomposting temperature. Earthworms breathe via their skins, so the bedding used for vermicomposting needs to be able to retain enough moisture to prevent the worms from dying. Further moisture content is lower than 45% it can be fatal to the worms (Ansari and Samal *et al.* 2019).

However, certain species can live at moisture levels between 50% and 90% but they develop more quickly between 80 and 90%. In vermicomposting, microorganisms also play a crucial role. When the moisture content is below 40% its clitella develops later, while when it is below 10 percentages, it almost completely ceases (Ansari *et al*., 2012; Tamanreet K., 2020).

(b)Temperature: An earthworm is a poikilothermic, and its body temperature is greatly influenced by environmental temperature. Further, earthworm's activity, metabolism, growth, respiration, feeding consumption and reproduction are significantly influenced by temperature. The temperature of vermicomposting system needs to be kept above 10°C in the winter and below 35°C in the summer. A higher temperature in the composting bed encourages microbial activity, which indirectly lowers the oxygen content by which the life and activity of earthworms are negatively impacted. Accoriding to studies, earthworm's activity increase significantly in the temperature range of 10°C to 30°C. (Sinha *et al*., 2012; Arora, *et al*., 2015; Sudkolai *et al*., 2017).

(c) pH: The ideal pH range for biological earthworm activities is between 6.5 and 7.5. Near neutral pH levels promote higher earthworm activity. The pH of the vermicompost is also influenced by the type of substrate. If the food source is acidic, the pH of the compost can fall much below 7.If the food source is alkaline ,the pH of the compost drops to neutral or slightly alkaline .Calcium carbonate can be added to change the pH upward ,while peat moss can be used to change the pH downward. Although the pH range for compost should be between 6.5-7.5, but the active microorganisms in vermicomposting can retain their activity even at a pH of around 4 (Ananthavalli, *et al.,* 2019;Samal, *et al*. 2019).

*(d)**Bulking agent**:* It functions as the first source of microbes that promote the biodegradation process. With the right bulking agent, organic waste can be converted into vermicompost. The capacity of the feeding material to stimulate microbial activity determines the quality of the earthworm's growth and reproduction (Bhatia et *al*., 2013; Sharmaa*, et al*., 2018).

(e) Ammonia and salt content: Organic wastes with high quantities of ammonia are unfavourable to earthworms. Earthworms are so sensitive to salt that they prefer salinities of less than 0.5%. An excessive amount can reduce growth and damage their delicate skin because earthworms are unable to regulate their osmotic pressure (Kaur *et al*., 2020).

(f) Light: Earthworms are photophobic. They can only perceive light through their skin because they lack eyes. According to research, the earthworm's anterior region is more sensitive than its middle and posterior regions. To perceive light, the earthworm's anterior end accumulates light –sensitive cells. Earthworms try to keep out of sunlight because the sun's heat dries out their skin (Rajiv *et al*., 2013; Mishra *et al*., 2019).

(g)C: N ratio: The C: N ratio affects how quickly organic material degrades, and when it is too high or too low, degrading waste proceeds very slowly. Microbial activity declines if the substrates C: N ratio is too high and its nitrogen content is low. Earthworm development and reproduction rates are always favoured by substrates with high C: N ratios because microorganisms need carbon for body metabolism and nitrogen for protein synthesis, an ideal C: N ratio is essential for successful vermicomposting process (Shak, 2014; Samal, *et al.* 2019).

(h)Feed quality: During vermicomposting, feeding quality has a significant impact on earthworm development and reproduction .Earthworms always favour pre-treated and partially degraded organic materials (Gomez F.M.J.*et al*., 2015). If toxic metal is present in the organic waste, worms may die .It was reported that cow, sheep, horse, and goat dung had more favourable feed for the creation of value –added fertilizer as compared to buffalo, camel and donkey dung (Arora and Kazmi, 2015; Ali *et al*., 2015; Singh *et al.,* 2020).

(i)Aeration: Earthworms require oxygen to survive and cannot exist in anaerobic environments. The earthworm's vascular skin is where it breathes .The oxygen gas that the skin absorbs diffuses into the blood and is carried to all of the body's cells. The oxidation of food in the earthworm cells uses oxygen and the metabolism process results in the production of carbon dioxide. They work well with porous, well – aerated raw material (Chowdhury *et al*., 2014; Samal *et al.,* 2017).

Biotic factors

The biological component includes stocking density (Earthworm population) and microorganisms.

(a)Stocking density: Earthworms alter the nutrient dynamics and microbial populations in the vermicomposting system. The earthworms stocking density has an impact on a number of functions, including feeding, reproduction, respiration and burrowing activity etc. Earthworms reproduce frequently when there is a low population density . To achieve maximal population growth in the shortest period of time, optimal earthworm density must be maintained (Xing M.*et al*., 2012; Ali, U.*et al*., 2015).

Advantage of vermicomposting: Vermicompost made from the various organic wastes listed above can be utilized as an effective organic manure .Vermicompost reduces the need for chemical fertilizers and the amount of waste that is sent to the environment. **Fig.2** shows some of the benefits of using vermicompost (Joshi *et al*., 2015).

Conclusion

Thus vermicomposting is one of the most environmental friendly, low-cost, effective, and better ways to manage different organic-rich solid and liquid waste. Earthworms and microorganisms work together in a symbiotic and synergistic way to decompose all organic contaminants and turn them into valuable products. The distribution of various microorganisms in a composting bed is significantly influenced by earthworm excreta, or vermicast. Earthworms can effectively degrade a variety of organic waste, including biomedical waste sludge, sewage sludge, milk slurry and industrial waste sludge, by mixing it with other organic materials like cow dung, leaf litter, and agriculture waste, but a high proportion of organic sludge kills eartworms. Therefore, municipalities, hospitals, and farmers will save money by implementing this technology, and also help save the environment.

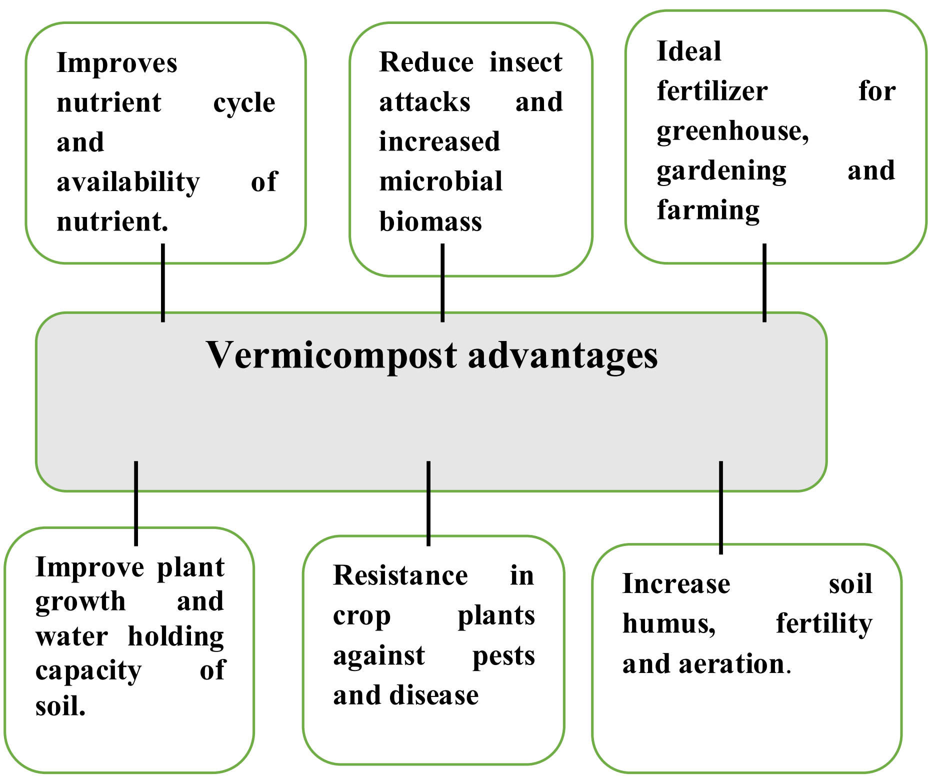

Fig: 2 Different advantages of vermicomposting

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