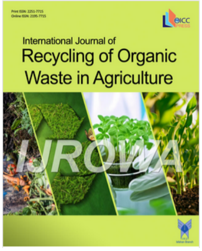

Volume 13, Issue 1, 132401 (1-15)

International Journal of Recycling Organic Waste in Agriculture (IJROWA)

https://dx.doi.org/10.57647/j.ijrowa.2024.1301.01

Improvement of soil health and crop production through utilization of organic wastes: A sustainable approach

Hiranmai Yadav , Ajay Neeraj *, Parul Vats

School of Environment and Sustainable Development, Central University of Gujarat, Gandhinagar, Gujarat, India.

***Corresponding author**: ajaycug24@gmail.com

Received 08 Dec. 2022; Accepted 26 Aug. 2023; Published Online 30 Sept. 2023 REVIEW PAPER

Abstract:
Purpose: Solid organic waste is a major environmental issue in various parts of the world. Proper management techniques for disposing of such wastes can reduce health issues as well as contamination of the environment. Modern scientific techniques in conjugation with traditional practices can manage biowaste in an efficient, economical, and sustainable manner. This present review highlights the possibilities of utilizing biowastes from various sources for the enhancement of soil fertility, residue management, crop growth and higher yields.
Methodology: The article is prepared from secondary materials i.e. research and review articles published in different journals. The review of literature from these articles in terms of soil quality, salinity, impact of salinity on crop production and possibilities to reclamate saline soil to improve productivity of soil were systematically carried out. A summary of the present work was developed using the following approach.
Result: Various management practices, in-situ and ex-situ techniques help reduce biowastes and transform them into useful nutrients that could be applied to soil for alleviating the nutritional deficiency in saline/sodic soil. Composting using microbes and earthworms has been traditionally practiced for reducing/converting waste into compost and applying them to agricultural fields to improve soil fertility and crop productivity.
Conclusion: Using waste management techniques and converting biowaste into manure for enhancing agricultural productivity provides sustainable agriculture practices in addition to pollution reduction.

Keywords: Agriculture; Bioconversion; Organic biowaste; Soil fertility; Sustainability

1. Introduction

Valorization involves the utilization of biowastes or biodegradable wastes that are a form of biomass with the capacity of decomposition under anaerobic or aerobic conditions. Biowastes include agricultural residues, animal waste, forestry, manure, sewage sludge, food wastes, and household wastes (kitchen wastes, garden waste, paper, cardboard as well as natural textiles). Various agricultural activities including cultivation, harvesting and animal husbandry produce waste. Sustainable management of solid wastes is of global concern these days and the implication of unsound solid waste management is seen in many cities of the world (India 2022; Das 2020). Urbanization and increasing population are the major problems that have increased the burden of solid wastes (Minakshi 2014). As per the definition given by Environment Protection Agency, solid wastes are defined as any unwanted substance (garbage or refused material), byproducts from treatment plants of wastewater, any other discarded products from commercial mining, agricultural practices, or any other community-based sources. Nearly everything we leave behind forms a kind of waste.

According to the World Bank (2018) every year, the world generates 2.01 billion tonnes of municipal solid waste (MSW), of which at least 33%, which is very conservative, is not carried out in an environmentally sound manner. The projected waste generation of regions across the globe is shown in Fig. 1. Globally, on average, 0.74 kg of waste is generated per person per day, but it varies widely from 0.11 to 4.54 kg. Although high-income countries represent only 16% of the world's population, they generate about 34% or 683 million tonnes of wastes worldwide (Kaza et al. 2018).

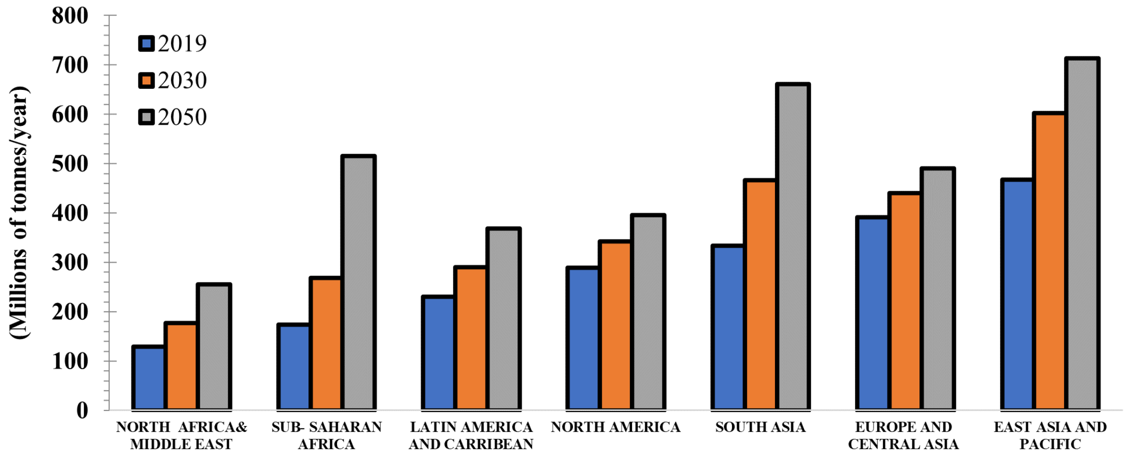

Figure 1. Projected waste generation of different continents/subcontinents up to the year 2050, (millions of tonnes/year) published in WHO Report 2.0 (2015).

About 7 – 10 billion tonnes of solid waste is accounted for from households, commercial places, industries, and construction (Wilson et al. 2015). Most of the developing countries of Africa and Asia with lower-income cities will double their MSW generation within 15 – 20 years. In these countries, the disposal of waste is a significant problem. Dandora, located on the outskirts of Nairobi is a landfill that has a vast spread of over 53 hectares and receives 730,000 tonnes of industrial, medical, and agricultural wastes annually. Awotan landfill in Ibadan, Nigeria has become a breeding ground for diseases, and the biggest dump in Bekasi, Indonesia, which is Bantar Gebang receives 230,000 tonnes of waste annually (Buragohain et al. 2020).

According to various studies and projections, the amount of waste generated worldwide is expected to increase significantly in the coming decades. Specifically, it is estimated that by the year 2050, the global population will have doubled from its current level, and waste generation also expected to rise by approximately 3.40 billion tonnes. This rapid increase in waste generation can be attributed to a number of factors, including the growth of consumerism and the trend towards disposable goods, as well as a lack of infrastructure and resources in many parts of the world to properly manage and dispose of waste in general, waste generation and income levels share a direct relationship (positive or negative). High-income countries are projected to increase their daily waste generation and per capita by 19% by the year 2050 when compared to the low and middle-income countries, which are anticipated to grow by about 40 percent or more. It has been seen that in countries with lowermost levels of income, waste generation initially decreases, henceforth, increments at a much faster rate when income increases, at low levels of income than higher this happens due to the difference in the per capita income and gross domestic product (GDP) of the county, lower per capita income makes the people reduce their purchase capacity compared to higher per capita income increases the purchase capacity thereby ultimately increases waste generation proportion.

India falls under lower middle-income country as per the World Bank report (2018) and is one of the largest countries beside China with a 1.27 billion population and contributing to 17% of the world population. According to the World Bank report, (2014), the maximum number of people lives in rural areas as compared to urban areas, but there is a swift movement towards urban centers. The rapid growth of the population and unplanned urbanization increase solid waste. As per the Central Pollution Control Board (CPCB) report, 1.2 million per day of MSW is generated by household, commercial and industrial activity in India (Board 2012). All over India, be it the residential area, industrial area, roadside and slum area, dumping is the most common practice. Above 2,000 tonnes/day of waste is generated (mpcb.govt.in 2021). The Deonar landfill on the outskirts of Mumbai was opened in 1927, with a capacity of about 17 million tonnes of waste. Now, this landfill is closed, but around 5 million people are living within a 10 km radius of it, where the landfill is still providing them a source of income through scrap material recycling (mahenvis.nic.in 2009).

However, there is a long way to go to implement effective solid waste management. Poor solid waste management practices like improper collection, transportation in some areas, and lack of knowledge of advanced technologies affected the management and increased the pollution load (Nandan et al. 2017). Proper disposal of waste improves the scenic beauty of the area and quality of life. The main motive of the solid waste management technique is to eliminate wastes from the vicinity for a healthy, beautiful environment and public health.

An integrated system consists of proper waste storage and processing system, followed by one or more of the following options: secondary material disposal, biological treatment of organic products, thermal treatment, and landfill. Biological treatment using composting can provide us with valuable by-products for improving the soil quality and holds potential to cycle waste into soil and further lay the foundation for sustainable food production. These solutions are combined

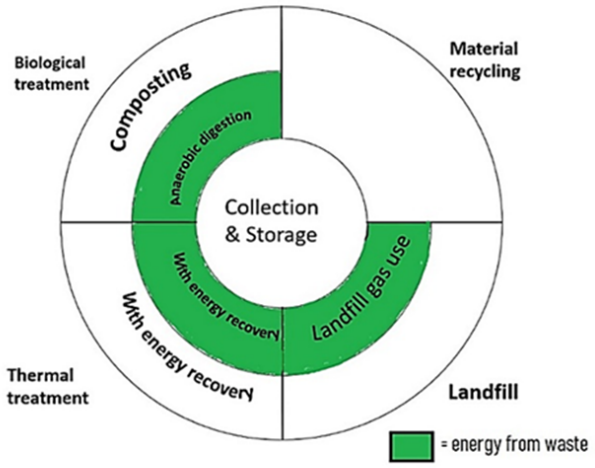

Figure 2. Elements of an integrated waste management system and recycling process.

to form an integrated waste management scheme (Fig. 2). Managing all wastes in an environmentally and economically safe manner necessitates a variety of these methods (McDougall et al. 2001).

Bioremediation is the process of utilization of microbes, their secreted enzymes, and plants for the detoxification of hazardous environmental contaminants in the soil or any other polluted environment. The indigenous microorganisms from the contaminated sites play an important role in this process (Ite and Ibok 2019). The process includes the concept of biodegradation, which is either partial or sometimes total degradation (breakdown into simpler non-toxic or less toxic compounds) or detoxification of contaminants in the environment by microorganisms and flora (Chimote 2019). Bioremediation consists of three main approaches, namely, natural attenuation (dependence on natural biotransformation activities and rates), which is occasionally called intrinsic bioremediation; bio-stimulation (stimulation of rates of natural activities by environmental optimization enhancing microbial population for higher biodegradation rates; biological amendments are one of the many ways to serve this purpose) and bioaugmentation (application of outsourced microorganisms) to the hydrocarbon-impacted ecosystem for providing potency to the existing microbial population. These principles of in-situ biotransformation have been employed several times at pilot and field-scale levels with varying degrees of success (Asemoloye et al. 2017). Majority of soil associated problems are addressed through the application of different chemicals fertilizers and neutralizing agents etc. These chemicals for the long-term use are having serious environmental effects, which through the food chains also deteriorate human health. On the other hand, a large amount of agricultural wastes is generated at the crop fields which are burnt by farmers due to their higher processing and transportation charges. Utilizing these organic wastes or residues for the enhancement of soil fertility provides the solution for two problems viz. management of agricultural wastes and soil health restoration without compromising environmental issues and human health. Therefore, this innovative approach can be a practical solution for ensuring sustainable agriculture (Neeraj et al. 2023). Further, the soil, contaminants are degraded by bioremediation using microbial metabolism and this metabolism is also, considered the most beneficial way to remediate the soil contaminants (Chimote 2019). Using various techniques for waste management and converting the waste into manure for enhancing agricultural productivity provides sustainable practice in addition to pollution reduction. This article highlights the possibilities of utilizing the biowastes from various sources for enhancement of soil fertility, residue management, crop growth and higher yields shown in Fig. 3.

Table 1. Different raw material of various organic wastes and their respective sources.

Type of waste	Sources of waste
Crop residues	Crop residues and biomass
Kitchen waste	Kitchen waste from daily use
Green waste	Fruits and vegetable waste
Biomass waste from forest	Natural forest biomass and by-product
Waste from roadside	Biomass from roadside weed and invasive plant
Biomass of aquatic plant	Dead remains of plant waste
Animal dung and urine	Domestic animals and dairies waste
Fish waste	Fish waste arises from fish industries
Poultry excreta	Poultry and layering farm
Sewage and sludge	The industrial and municipal wastewater treatment plant
Sugar and distillery waste	The effluent of the Sugar mill
Paper mill industries waste	The effluent of Paper mill
Fly Ash	Thermal power plant and brick kiln generated waste
Biogas slurry	Waste generated from a byproduct of biogas plant
Sewage and sludge	municipal wastewater treatment plant

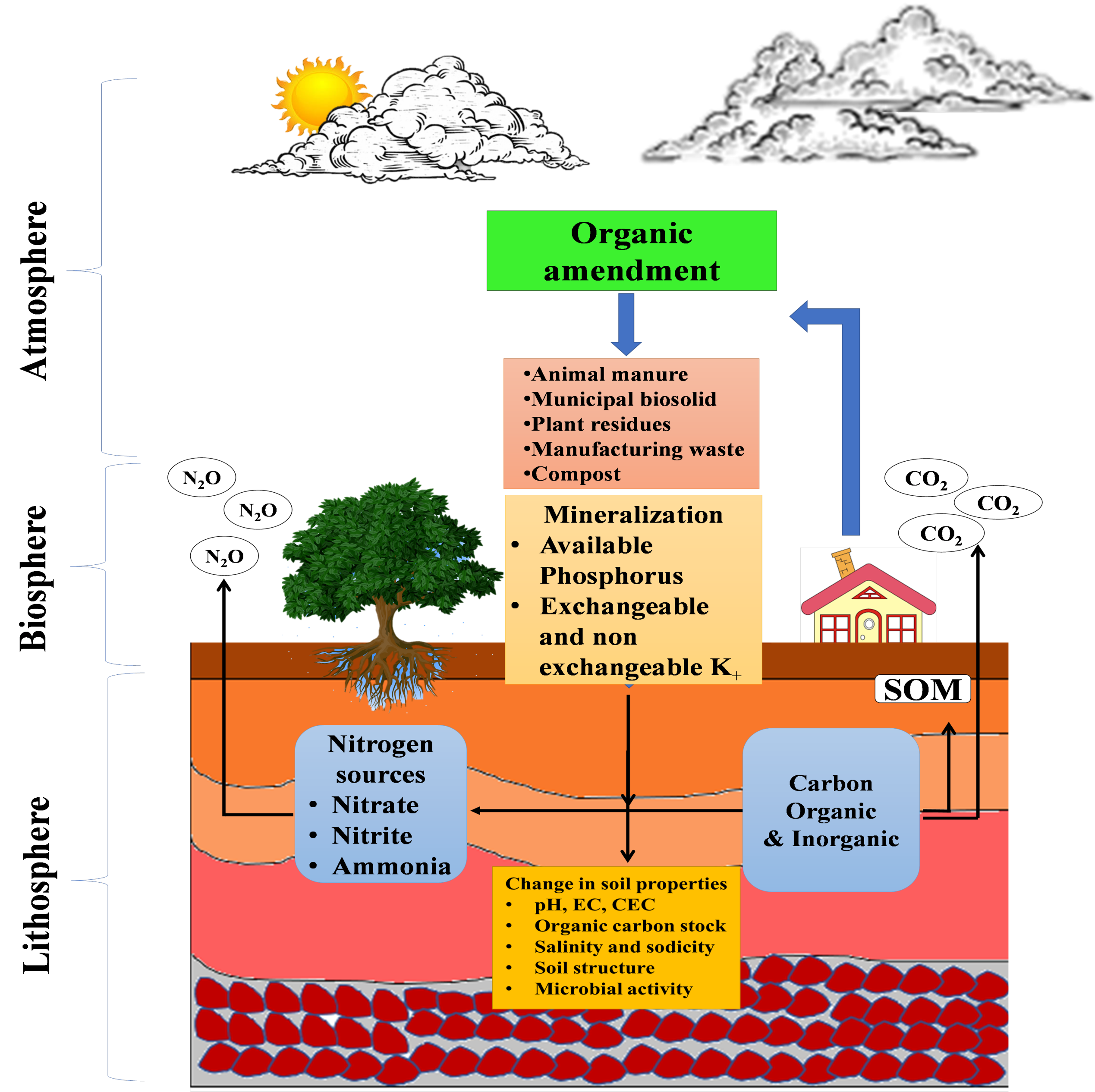

Figure 3. Systematic representation of processes in the organic waste amendment in soil.

2. Utilization of organic biowaste to improve soil properties

About 6.74 million hectares of India's total land area are affected by salinity and sodicity. Uttar Pradesh, Gujarat, and Andhra Pradesh have largely salt-affected soil (Wicke et al. 2020). In irrigated areas, salt formation is the main cause of land degradation. Salt-affected soils mostly occur in arid or semiarid climates. Also, this type of saline/sodic soil can also be found in regions where the climate and salt mobility cause saline waters and saline soils for very short periods (Shahid et al. 2018). Annual rainfall in arid and semi-arid regions is insufficient for leaching down the salts to the deeper portion of the soil (Zhang et al. 2021).
Coupled with it, high evaporation in these areas results in the accumulation of many salts in the root zone. The magnitude of accumulation of salts (soil salinization) has been found to increase with an increase in the dryness of the area (Nachshon 2018). The salt-affected soils are also encountered in humid regions, areas subjected to seawater intrusions, deltaic regions, and other low-lying areas, which occasionally get inundated by the seawater.
The modern concept of environmental management is based on the recycling of waste. Composting is a safe form of treatment of wastes and reclamation of the nutrients contained in them. The wastes generated in our day-to-day life comprises of different categories; the agricultural wastes consist of crop residues like stover, straw, husk, scraps of uncultivated plants and weeds, forest biomass, wastes produced by animals in the form of dung, urine, carcasses, wastes from pisciculture and wastes generated by human activities like garbage, sewage, and sludge, etc. (Table 1).

As soon as the harvesting season arrives, the crop residues are generated in plentiful quantity. Once the economic parts are collected, the plants are dumped as waste residues and left on the fields. This huge amount of residues when left unused creates an unpleasant smell as well as dumping issues. Nevertheless, these farm wastes are purely organic and a good organic carbon source. These farm residues can be used as a rich and inexpensive source of nutrients. The vital nutrients required for plant replenishment in crop production are decreasing due to the use of expensive synthetic fertilizers which have been in use for many years. In addition conventionally chemical fertilizer use in agriculture which have long-term harmful health effects (Humbal and Pathak 2023) and the poor efficiency of these chemical fertilizers, it has generated the need for the utilization of organic farm wastes which is important for supplying the essential nutrients to the soil for its replenishment and good health, pollution reduction and generating employment which is a great strategy for crop production in a sustainable manner (Chatterjee et al. 2017). Various essential properties of soil like pH, nitrogen content, water holding capacity, cation exchange capacity and microbial biomass in the soil are modified by food and other biowastes (Chew et al. 2019). The physicochemical and biological properties of soil are positively affected by the organic wastes, thereby stimulating the growth of the plant and ultimately enhancing crop production (Hossain et al. 2017).

Mine soil reclamation and management reduce the soluble salts and ESP (Exchangeable sodium percentage) to the level ideal for plant growth as well as for productivity as shown in Fig. 4. Reclamation is the practice to restore the sodic soil into useful and fertile land for cultivation (Neeraj et al. 2019).

3. Bioremediation practices for environmental management/soil health reclamation

Bioremediation techniques are used for the reclamation of soil and water health for many decades now (Arora 2018). These techniques use mostly indigenous bacteria, fungi, or plant species for the development of potential species for the remediation processes (Azubuike et al. 2016). Bioremediation has many advantages over other techniques used for the remediation of environmental contaminants. Especially this technique has no side effects on the soil or any other environmental factor. Plant microbes are a constructive link between the plant and microorganism; they are very effective in the reclamation of the sodic soil. Rhizospheric bacteria progressively improve the absorption of the plant nutrients which also encourages plant growth as well as restore the soil characteristics (Neeraj et al. 2019). Due to the wider utility of bioremediation, it is used as a reclamation or remediation technique by many scientists and researchers as shown in Table 2. Many research works suggest the wider acceptance of this technique for the remediation of metal, pesticides, sodicity and salinity, etc. The sites polluted with hydrocarbons is a major threat to the environment as it degrades the environment and poses serious health issues to the people residing there, so decontamination, as well as cleaning of these polluted sites is essential. The contamination of soil brought about by the crude oil adversely affects the groundwater thereby diminishing its use and causing environmental damage, economic loss and declining the agricultural efficiency of soil. The category of organic chemicals called polycyclic aromatic hydrocarbons (PAHs) has natural as well as anthropogenic origin. The natural processes are forest fires and volcanic eruptions while human activities like waste incineration, accidental leak during transportation, petroleum products usage and disposal, and incomplete combustion of fossil fuels contribute to PAHs emissions (Asemoloye et al. 2017).

In agriculture, recycling of nutrients and sustaining soil quality can be achieved by the application of organic wastes. Soil fertility improvement by solid waste application is documented by many researchers. Modifications in physical, chemical, and biological properties are brought about by the application of biowaste provides ambient conditions for plant growth. Applications of composted organic wastes are beneficial for soil and improving plant growth thereby increasing yields. Organic wastes helped to increase organic matter and balance the nutrient cycle by enhancing the microbial population. Reduction of toxic metals and improvement of soil structure is observed by application of organic wastes (Hossain et al. 2017). The conversion of organic wastes to compost helps to improve soil health and plant growth (Ahmad et al. 2007). In addition to suppressing, plant-pathogens and toxicity of waste materials (Chew et al. 2019) biotransformed waste have been documented as the beneficial effects of biowastes as organic fertilizers. Chatterjee et al. have documented the efficiency of organic wastes generated from plants, animals, and industrial activities for the replenishment of nutrients in the soil and sustaining the health of vegetation and soil as shown in Table 3 (Chatterjee et al. 2017).

In the process of decomposition of waste, the organic matter, under aerobic conditions with the activity of microorganisms or worms (such as red worms or earthworms) form compost or vermicompost, resulting in a humus-rich soil conditioner (Sharma and Garg 2018). Compost made from biodegradable MSW is an alternative to farm manure (such as cow manure), which has long been appreciated for its high microbial content and helps the plant absorb nutrients from the soil. Additionally, it helps in the restoration of organic matter in the soil, and at the same time also provides certain special nutrients thereby reducing the need for chemical fertilizers (Yadav and Garg 2019). Composting improves the water-holding capacity of the soil and protects against drought. Requiring less water per crop is a welcome feature for a water-scarce future (Orlina and Schaldach 2012).

Through altering soil porosity, compost also increases the root strength making them more resistant to pests and rot. India's agricultural soils are very low in carbon due to the cultivation of the same crop year after year and the overuse of urea. In composting, organic materials are controlled by aerobic in MSW, and many factors are considered for converting them to compost like the source of waste, the nature of waste, the time required to mature and compost processing (Meena et al. 2016). Factors affecting compost

Table 2. Efficiency of organic wastes in improving soil and crop properties.

Types of material	Source	Processing treatment into fertilizer	Parameters monitored and their effects	Reference
Organic manure	Chicken manure, compost	Inoculation with Azotobacter	Organic Production: Maximum use of manure high-growth and biomass crops of cereals with good nutritional status provided with organic fertilizers.	(Steiner et al. 2007)
	Farmyard manure; Green manure	Treatment with effective microorganisms and fertilizer solution	Shoot biomass and grain yield: Increasing the biomass of rice shoot and grain yield is considered a soil improvement using green manure	(Javaid 2011)
	Sheep excreta	Mixed with chemical fertilizer	Accumulation of heavy metals: plants with the manure of sheep controlled the uptake of Pb, Cd, and Zn.	(Elouear et al. 2016)
	Solid pig manure, solid dairy manure	Surface applied and incorporated using cultivator implement	Bacterial diversity: Organic modification achieved greater bacterial diversity with the longest effect than granular urea N treatment.	(Staley et al. 2018)
Animal Manure	Various livestock: chicken, pig and pigeon	Mixed with inorganic fertilizer in field experiment	Soil salinity: use of this organic fertilizer in soil decreased pH and secondary soil salts, increased total soluble salt. Heavy rainfall significantly reduced soil TSS concentration.	(Hamm et al. 2016)
	Pig or cattle manure in the field experiment	Mixed with inorganic fertilizer but increased biological binding.	Aggregation stability: decreased biological stability	(Guo et al. 2019)
	Pig and cattle manure	Mixed with inorganic fertilizer	Soil aggregation: The soil structure is risky due to the high salt content that can be removed by straw.	(Guo et al. 2018)
Sewage sludge	Wastewater treatment plant	Acid leaching; ion exchange; precipitation with lime water	Phosphate uptake: A higher rate than that of commercial fertilizer Recycled phosphate has low solubility and can produce its effect over a long period.	(Franz 2008)
		Thermally dried and anaerobically digested	Soil properties: Soil organic matter (SOM), total N and high-value minerals improved. Microbial properties: higher microbial activity in sewage sludge.	(Urra et al. 2019)
	Wastewater treatment plant	Hydrothermal carbonization, acidic leaching, and struvite precipitation	Phosphate Recovery: High recovery rate	(Becker et al. 2019)
Municipal activated sewage	Wastewater treatment plant	Pyrolysis process.	Element Bioavailability: long term bioavailability. Nutrient content: increased nutrient content with pyrolysis and reduced PAH concentrations and pollutant mobility	(Frišták et al. 2018)

Continuation of Table 2

Dewater fresh sewage sludge	A municipal wastewater treatment plant	Composting using reactor	Composting process: Adding phosphate amendments promotes increased temperature, degradation of organic materials, and higher nutrient control.	(Wang et al. 2019)
Compost	Food waste and cattle manure		Increased the yield of maize.	(Wolka and Melaku 2015)
	Olive mill waste	Mechanical turning and watered to compensate for evaporation	The yield of crops is comparable with chemical fertilizers.	(Altieri and Esposito 2010)
Compost – Liquid fertilizer	Moisture from the fermentation process	Collection of moisture released	Soil regeneration: improved Zn in the topsoil and subsoil.	(Chiang et al. 2016)
Compost	Food waste: Rice, cabbage, pork	Dynamic high-temperature Bioreactors for aerobic fermentation	Matured organic fertilizer was obtained within 96 h when stable pH and EC were achieved after 96 h of fermentation. Bioreactor gives the best environment for the microorganism to reproduces because of constant collision and friction.	(Jiang et al. 2015)
	Swine manure solid fraction	Windrow composting; palletization	Possible co-fertilization to improve the sustainability of livestock for agricultural use. Comparative properties with commercial organic fertilizers.	
Vermicompost				
	Wastewater sludge; Earthworms Eisenia foetida	wastewater sludge digestion by Aerobic digestion followed by vermicomposting	Vermicompost is rich in nutrients with low pathogens rate. Vermicompost stimulates the growth highest height and weight.	(Valdez-Perezz et al. 2011)
	Cow dung, bakery industry sludge; Earthworms *Eisenia foetida*	Left for decomposition and vermicompost for three months	Vermicompost enriched nitrogen, phosphorous, and potassium content. It has the potential to biotransformation of sludge into compost for soil health improvement.	(Yadav and Garg 2019)
	Municipal solid waste; Earthworms *Eudrilus eugeniae*	Vermicompost for 8 weeks	Vermicomposting has a highly remedial and useful good management strategy that is a proper system to reduce soil ecotoxicity contaminated with heavy metals.	(Soobhany et al. 2014)

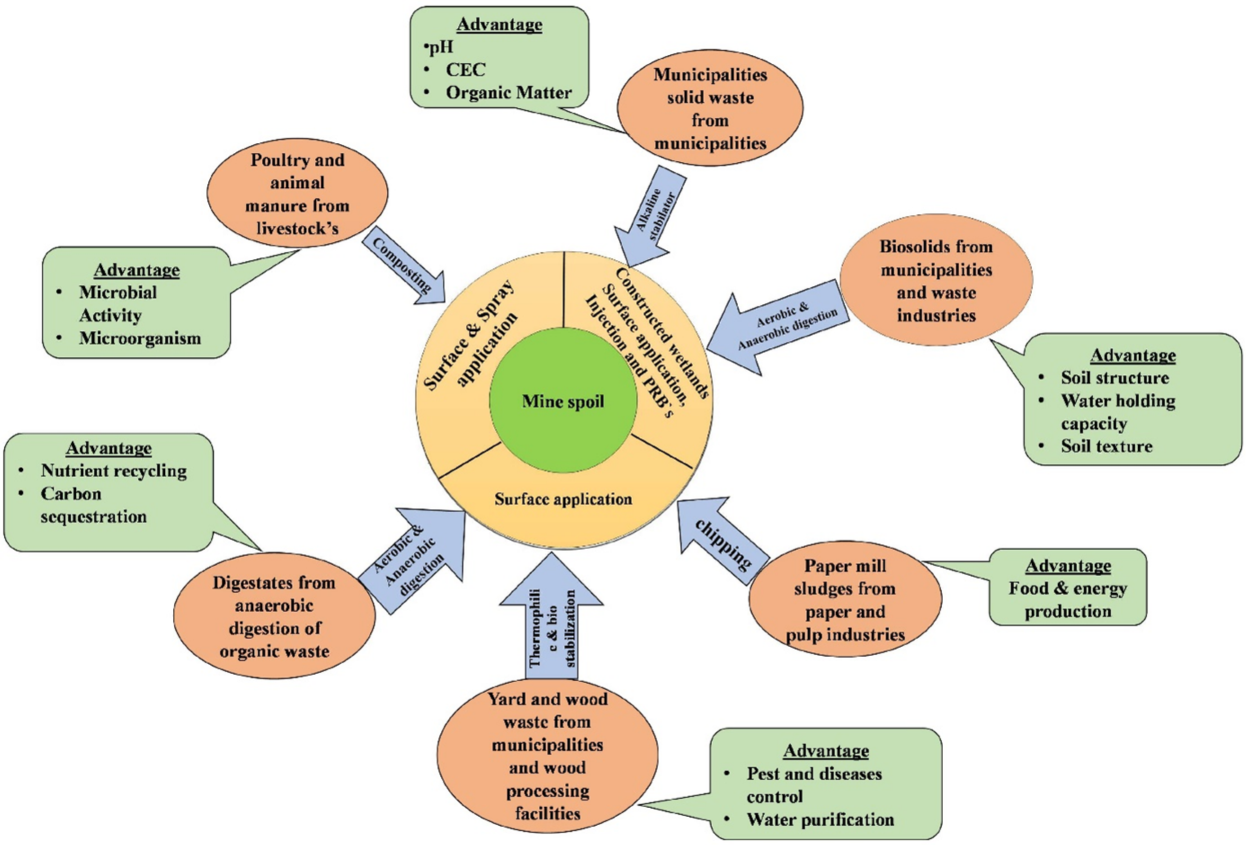

Figure 4. Various approaches of waste treatment of different type of biowaste for mine degraded soil health reclamation and their application benefits.

formation are Carbon/Nitrogen (C/N) ratio, temperature, moisture content and amount of air. Carbon is required as an energy source and nitrogen for the synthesis of protein. A high C/N fraction can be rectified by dehydrating mud and a low ratio can be corrected through the addition of cellulose. The composting process is influenced by moisture content because microbes need moisture for their metabolic activity. However, high temperature prohibits pathogenic organisms. Above 75°C, the useful microorganisms are eliminated from the composting process. The optimal temperature for the process is in the range of 50 – 60°C, and the ideal temperature is 60°C. During composting, proper control of the aeration value and the amount of air is necessary. If there is not enough oxygen, the aerobes will begin to die, and the anaerobes will replace them. Anaerobes are undesirable as they slow down the process, give off odors and release methane.

The vermicomposting process developed in the middle of the 20th century and this process has been adopted by many countries due to the importance of solid waste management and organic farming (Sharma and Garg 2019). The solid wastes are converted into valuable and useful organic fertilizer with the help of microbial activity facilitated by earthworms (Kumar et al. 2018). An earthworm can be used for the decomposition of waste and produces valuable vermicompost. Vermicompost can be utilized by farmers for soil nutrient management. Yadav et al. (2015) stated that unpleasant weeds, paper wastes can be converted into organic manure by farmers along with farm waste and available animal manure within a short period. These benefits the farmers clean the environment and reduce the utility of chemical fertilizer. Degradation of the biowaste and biosolid occurs in aerobic conditions in the environment. Here, the symbiotic interaction between earthworm and microorganism promotes the degradation of solid waste into organic fertilizer (Sharma and Garg 2018). The main product of vermicomposting is vermicompost or vermicast, which is a valuable fertilizer with high humus content, suitable for use in agriculture. Vermicompost contains high organic content suitable for organic farming and sustainable agriculture practices (Siddiqui et al. 2022). However, the selection of the potential species of an earthworm is essential for the optimization of the biodegradation process. The selection of earthworm species is based on factors such as high productivity, high organic waste consumption and high resistance to changing environmental conditions. *Epigeic* species of earthworm are most suitable in the vermicomposting process. Some examples of *Epigeic* earthworms

Table 3. The efficiency of different organic wastes for improving growth and crop yield.

Organic waste	Crop	References
Chicken manure compost (CMC)	Tomato (*Lycopersicon esculentum*)	(Wang et al. 2017)
Sewage sludge	Triticale (, Cv Mikham-2001)	(Yagmur et al. 2017)
Municipal solid waste (food, yard and paper) composts and vermicompost's	Green bean (*Phaseolus vulgaris*)	(Soobhany 2018)
Sewage sludge	Maize crops (*Zea mays L.*)	(Tejada et al. 2016)
Municipal sewage sludge	Sweet sorghum (GK Csaba, Rona 1, Sucrosorgo 506) *Sorghum bicolor*	(Kołodziej et al. 2015)
Cow manure Vermicompost + Sewage sludge	Rice (*Oryza sativa* L.) variety Super Basmat	(Riaz et al. 2018)
Green waste vermicompost (GWV)	Calendula (*Calendula officinalis* L.)	(Gong et al. 2018)
MSW		(Lakhdar et al. 2011)
Manure	spring maize (*Zea mays*)	(Mohsin et al. 2012)
Agricultural recycling of household waste by composting	Lettuce (*Lactuca sativa*) and corn (*Zea mays*)	(Mrabet et al. 2012)
Vegetable waste and agricultural waste	fodder maize	(Naikwade et al. 2012)
Bio compost, cow dung compost	Chilly (*Capsicum annuum* L.)	(Rahman et al. 2012)
Municipal solid waste	Maize	(Simeon and Ambah 2013)
MSW compost	*Polypogonmon speliensis* (L.) Desf. and *Hordeum vulgare* L	(Ouni et al. 2014)
Municipal wastes compost and Azolla compost	English Daisy (*Bellis perennis*)	(Ramezanzadeh et al. 2014)
MSW compost	Spiny chicory	(Papafilippaki et al. 2015)
Addition of manure	*Chenopodium album* L.	(Sabir et al. 2019)
Manure with triple superphosphate (TSP)	Rice grain yields	(Andriamananjara et al. 2016)
Organic wastes	Wheat (*Triticum aestivum*)	(Debiase et al. 2016)
Farm manure	Maize	(Rehman et al. 2016)
Sewage sludge and its biochar	Maize	(Gwenzi et al. 2016)
Sewage sludge	Barley	(Matichenkov and Bocharnikova 2016)
Household organic waste	Cherry tomatoes	(Ferreira et al. 2018)

are *Eudrilus eugeniae* (Kinberg), *Perionyx excavates* (Perrier), *Eisenia fetida* (Savigny) and *Eisenia andrei* (Bouche). The process of vermicomposting or vermicast conversion of organic waste into valuable forms is carried by the biological activities of earthworms. The mechanism behind this involves the role of enzymes present in the gut of the earthworm which plays an important role in the biotransformation of organic wastes into the nutritious manure (Ravindran et al. 2016). These enzymes are secreted through calciferous glands present in foreguts of earthworms which facilitates the increase in the pH of the soil, thereby which improves the bacterial, fungal, algal, and trophozoite populations (Lemtiri et al. 2014) which ultimately increases the organic matter absorption. Antibacterial and antifungal compounds secreted in the midgut help in the prevention of plant pathogens. The presence of intestinal mucus in the earthworm's gut serves as a bioreactor, increasing microbial activity. The activity of microbes is improved because of nitrogenous compounds present in the mucus in the earthworm gut (Ravindran et al. 2016). Organic matter which primarily includes cellulose, hemicelluloses, lignin, and proteins is also degraded by microbial activity. Enzymes like lipase, cellulase, amylase, and chitinase are helped to covert complex molecules into a simpler form. Vermicompost has a lot of advantages, including nutritional restoration and long-term soil stabilization.

4. Reclamation of saline-sodic soil using biowaste and improving soil quality

The reduction in soil productivity is caused due to the deflocculating processes and the inaccessibility of basic cations such as Mg^{2+} and Ca^{2+}, which limits the general stability, degrades the structure of the soil since sodium in some species inhibits plant growth. Sodicity in agricultural soils is influenced by different irrigation practices, unorganized monitoring of water quality, as well as the content of bicarbonate, which results in its transfer to the soil (Fatemi 2021). Sodicity not only affects the physical structure but also affects the equilibium of soil nutrients as shown in Table 4. Sodicity of the soil may occur by both cultivation practices and environmental damage caused by the excess runoff and soil erosion. Sodic soil can be recovered by incorporating organic amendments (Neeraj et al. 2019). As per the reports of some other authors, it is found that gypsum doesn't restore saline-sodic soil alone as it has a neutral pH hence adding gypsum to the soil has no evident effects on alteration of pH of the soil (Tejada et al. 2006), Several studies have shown that a high application of gypsum to reclaim saline-sodic

Table 4. Effects of various organic matter inputs under soil salinity conditions.

Organic wastes	Soil salinity/salt level	Effect of organic waste on soil	References
Municipal solid waste + rice straw	EC 7.2 dS/m	The regular application of this organic amendment reduces soil salinity and increases microbial activity.	(Meena et al. 2016)
The mixture of green waste compost, sedge peat, and furfural residue	ESP 15.8 EC 3.69 mS/cm pH 7.75	There is significant potential to improve the saline soils with this amendment combination. The result of this amendment decreased bulk density, EC and ESP, and increased total porosity and organic carbon.	(Wang et al. 2014)
Green waste + biosolids	EC 23.3 dS/m ESP 24.7%	The use of compost increases the CEC of the soil which 19% more than initial and reduce the ESP (which is three time less from initial).	(Chaganti et al. 2015)
Organic fertilizer mixed + cropland manure	Salt 1–2% EC 8.5–20.4 mS/cm pH 4.58–4.79	In paddy fields, the use of organic manure can effectively overcome the problem of soil salinity, as well as improve the yield.	(Cha-um and Kirdmanee 2011)
Cassava - Industrial Waste Manure and Vermiculture	EC 4.26 mS/cm pH 7.30	Such a combination of improved soil CEC, organic carbon, total nitrogen, and extraction phosphorus, as well as decreased electrical conductivity.	(Oo et al. 2015)
Sewage sludge and fly ash	EC 4.27 dS/m ESP 6.09%	The results of amendments are determined by the original soil conditions, the rates of organic material supplied, and the quantity of water leached.	(Ors et al. 2015)
Farmyard waste+ saline water (EC 2.25 mS/cm)	EC 4.8–6.3 mS/cm	Increased porosity of the soil reduces soil bulk density and improved infiltration rate and also soil salinity decreases approximately 41.3%	(Kahlown and Azam 2003)
Manure (animal excreta+ plant residuum)	ESP 34–37 EC 4.03–5.11 mS/cm pH 8.62–8.75	This organic amendment is co-applied with chemical modifications, which reduce soil pH, salinity, and silt that help reduce EC and SAR	(Mahdy 2011)
Municipal solid waste and sewage slurry	EC 75 mS/cm pH 8.2	Compost significantly improved soil physical-chemical properties, especially C and N contents. Enzyme activities were substantially promoted in presence of both amendments	(Ouni et al. 2014)

soils increases the removal of excess Na^{+} from soil and causes a significant reduction in electrical conductivity and sodium adsorption ratio within the soil (Hamza and Anderson 2003) and it does not have much impact on the saline soil hydraulic conductivity as well as a biological activity but when is sequentially added with the MSW or using biowaste the physical, chemical, and biological characteristics are restored (Hanay et al. 2004; Abdel-Fattah 2012). Gupta et al. found that the combined application of gypsum and organic amendments in sodic soils improved soil properties, resulting in decreased soil bulk density, electrical conductivity (EC), and exchangeable sodium percentage (ESP), but also in increased soil biological activity (Gupta et al. 2016). For sodic soil management, organisms used with organic manure help to promote plant growth through the improvement of enzymatic activity in the root zone. Organic compounds like FYM (Farmyard Manure)/composted coir pith/press mud are found to improve the physical properties of soil (Yadav and Garg 2019). Researchers have also reported that bulk density and porosity alter with changes in biowaste amendments. Various organic wastes demonstrate positive effects on the germination of pea plants. The use of manure and vermicompost is very beneficial, cost-effective, sustainable, and environmentally friendly.

5. Future prospects

Urbanization, rapid industrialization, advancement in technologies, race of producing agricultural products for feeding an enormously expanding population all resulted in the generation of a huge amount of wastes that have led to a situation of its disposal problem. Sustainable management of solid biowaste will address both the problem viz. proper disposal and recovery of valuable product out of it. Vermicompost is a cleaner and sustainable approach to tackle the problem of organic waste, still, it faces several hurdles in its wider acceptance and application. Proper field application of the vermicompost is the need of the hour instead of experimenting with its usage at the lab scale. Lack of awareness and knowledge is a constraint in the field application of vermicompost by the farmers. The farmers should be properly trained and guided about the process of vermicomposting and the appropriate quantity use of vermicompost to be applied in their fields. Farmers should be assured that vermicompost will only do good and is going to benefit their soil and crops in the long run. Further, in-depth research is needed to develop such techniques or processes to gain higher vermicompost in a shorter period and also without further addition of any material. Also, a great deal of study is required to ascertain the concentration of vermicompost under different soil-water-plant-micrometeorology environments. This will help to popularize the use of vermicompost for healthy soil as well as crop health and thus, achieving overall environ-mental sustainability.

6. Conclusion

Human activities produce a huge amount of waste throughout the globe, but there is a lack of proper management strategies and hence this unmanaged waste is of utmost concern at the global level. On the other hand, agriculture is going through scarcity of proper nutrients and soil health reduction. Therefore, this unmanaged waste can be a promising material for addressing these constraints. The soil health can be improved through managed utilization of organic wastes coupled with an advanced biotechnological approach which in turn will increase crop productivity thereby helping in securing food insecurity at a global level and resulting in an im-proved economy. The organic manure produced from the degradable waste release plant nutrients, and en-hances native microflora and fauna in applied soil thereby improving soil quality. Biowaste is an eco-friendly and cost-effective method, therefore, the best-known remediation method among all. Biowaste plays a major role in the remediation of the toxic heavy metals from the soil so that it becomes non-toxic and also to reduces the bulky waste volume. The valuable properties of the biowaste make it a remarkable material that could be used in agriculture for improving soil health for a better and enhanced crop production.

Compliance with ethical standards:
Conflict of interest: The authors declare that there are no conflicts of interest associated with this study.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/),which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

Abdel-Fattah MK (2012) Role of gypsum and compost in reclaiming saline-sodic soils. *J Agric Vet Sci Sep* 1 (3): 30–8.

Ahmad R, Jilani G, Arshad M, Zahir ZA, Khalid A (2007) Bioconversion of organic wastes for their recycling in agriculture: An overview of perspectives and prospects. *Annu Micro* 57 (4): 471–9. https://doi.org/10.1007/BF03175343

Altieri R, Esposito A (2010) Evaluation of the fertilizing effect of olive mill waste compost in short-term crops. *Int Biodeterior Biodegrad* 64 (2): 124–128. https://doi.org/10.1016/j.ibiod.2009.12.002

Andriamananjara A, Rakotoson T, Razanakoto OR, Razafimanantsoa MP, Rabeharisoa L, Smolders E (2016) Farmyard manure application has little effect on yield or phosphorus supply to irrigated rice growing on highly weathered soils. *Fie Cro Res* 198:61–9. https://doi.org/10.1016/j.fcr.2016.08.029

Arora NK (2018) Bioremediation: a green approach for restoration of polluted ecosystems. *Envi Susta,* no. 1, 305–307. https://doi.org/10.1007/s42398-018-00036-y

Asemoloye M, Olowe OM, Zaffar H, Oshibanjo O, Jonathan SG (2017) Organic compost as catalyst or mediator for speedy and cost-effective bioremediation. *SSRN,* https://doi.org/10.2139/ssrn.3071988

Azubuike CC, Chikere CB, Okpokwasili GC (2016) Bioremediation techniques–classification based on site of application: Principles, advantages, limitations and prospects. *World J Micro Biotechnol* 32 (11): 1–8. https://doi.org/10.1007/s11274-016-2137-x

Becker GC, Wüst D, Köhler H, Lautenbach A, Kruse A (2019) Novel approach of phosphate-reclamation as struvite from sewage sludge by utilising hydrothermal carbonization. . *J Envi Manag* 238:119–25. https://doi.org/10.1016/j.jenvman.2019.02.121

Board CPCB:Central Pollution Control (2012) National Ambient Air Quality Status and Trends in India-2010. New Delhi:CPCB.

Buragohain P, Nath V, Sharma HK (2020) Microbial degradation of waste: A review. *Curr Trends in Pharma Res* 7 (1): 107–125.

Cha-um S, Kirdmanee C (2011) Remediation of salt-affected soil by the addition of organic matter: An investigation into improving glutinous rice productivity. *Sci Agri* 68:406–410. https://doi.org/10.1590/S0103-90162011000400003

Chaganti VN, Crohn DM, Šimůnek J (2015) Leaching and reclamation of biochar and compost amended saline-sodic soil with moderate SAR reclaimed water. *Agri Wat Manag* 158:255–65. https://doi.org/10.1016/j.agwat.2015.05.016

Chatterjee R, Gajjela S, Thirumdasu RK (2017) Recycling of organic wastes for sustainable soil health and crop growth. *Inte J Waste Reso* 7 (03): 296. https://doi.org/10.4172/2252-5211.1000296

Chew KW, Chia SR, Yen HW, Nomanbhay S, Ho YC, Show PL (2019) Transformation of biomass waste into sustainable organic fertilizers. *Sustain,* no. 8, 2266. https://doi.org/10.3390/su11082266

Chiang PN, Tong OY, Chiou CS, Lin YA, Wang MK, Liu CC (2016) Reclamation of zinc-contaminated soil using a dissolved organic carbon solution prepared using liquid fertilizer from food-waste composting. *J Hazard Mat* 301:100–5. https://doi.org/10.1016/j.jhazmat.2015.08.015

Chimote PA (2019) Review article use of bioremediation to clean the environment. *Int J Res Analyt Rev* 6 (1): 192–196.

Das A (2020) Indian landfill: The Ultimate Trash Kingdom. *The times of India,* https://www.timesofindia.indiatimes.com/readersblog/environmental/indian-landfill-the-ultimate-trash-kingdom-25565/

Debiase G, Montemurro F, Fiore A, Rotolo C, Farrag K, Miccolis A, Brunetti G (2016) Organic amendment and minimum tillage in winter wheat grown in Mediterranean conditions: Effects on yield performance, soil fertility and environmental impact. *Euro J Agro* 75:149–57. https://doi.org/10.1016/j.eja.2015.12.009

Elouear Z, Bouhamed F, Boujelben N, Bouzid J (2016) Application of sheep manure and potassium fertilizer to contaminated soil and its effect on zinc, cadmium and lead accumulation by alfalfa plants. *Susta Env Res* 26 (3): 131–5. https://doi.org/10.1016/j.serj.2016.04.004

Fatemi A (2021) A survey of water quality of Gharasou River, Kermanshah, Iran. *Env Ear Sci* 80 (18): 629. https://doi.org/10.1007/s12665-021-09923-w

Ferreira AK, Dias ND, Junior FS Sousa, Ferreira DA, Fernandes CD, Leite TD (2018) Composting of household organic waste and its effects on growth and mineral composition of cherry tomato. *Revista Ambienteand Água* 13 (3) https://doi.org/10.4136/ambi-agua.2141

Franz M (2008) Phosphate fertilizer from sewage sludge ash (SSA). *Waste Manag* 28 (10): 1809–1818. https://doi.org/10.1016/j.wasman.2007.08.0118.5

Frišták V, Pipíška M, Soja G (2018) Pyrolysis treatment of sewage sludge: A promising way to produce phosphorus fertilizer. *J Cle Pro* 172:1772–8. https://doi.org/10.1016/j.jclepro.2017.12.015

Gong X, Li S, Sun X, Wang L, Cai L, Zhang J, Wei L (2018) Green waste compost and vermicompost as peat substitutes in growing media for geranium (Pelargonium zonale L.) and calendula (Calendula officinalis L.). *Sci Hortic* 236:186–191. https://doi.org/10.1016/j.scienta.2018.03.051

Guo Z, Zhang J, Fan J, Yang X, Yi Y, Han X, Wang D, Zhu P, Peng X (2019) Does animal manure application improve soil aggregation? Insights from nine long-term fertilization experiments. *Sci Tot Env* 660:1029–37. https://doi.org/10.1016/j.scitotenv.2019.01.051

Guo ZC, Zhang ZB, Zhou H, Rahman MT, Wang DZ, Guo XS, Li LJ, Peng XH (2018) Long-term animal manure application promoted biological binding agents but not soil aggregation in a Vertisol. *Soil and Till Res* 180:232–7. https://doi.org/10.1016/j.still.2018.03.007

Gupta M, Srivastava PK, Niranjan A, Tewari SK (2016) Use of a bioaugmented organic soil amendment in combination with gypsum for Withania somnifera growth on sodic soil. *Pedosphere* 26:299–309. https://doi.org/10.1016/S1002-0160(15)60044-3

Gwenzi W, Muzava M, Mapanda F, Tauro TP (2016) Comparative short-term effects of sewage sludge and its biochar on soil properties, maize growth and uptake of nutrients on a tropical clay soil in Zimbabwe. *J Integr Agri* 15 (6): 1395–406. https://doi.org/10.1016/S2095-3119(15)61154-6

Hamm AC, Tenuta M, Krause DO, Ominski KH, Tkachuk VL, Flaten DN (2016) Bacterial communities of an agricultural soil amended with solid pig and dairy manures, and urea fertilizer. *App Soil Eco* 103:61–71. https://doi.org/10.1016/j.apsoil.2016.02.015

Hamza MA, Anderson WK (2003) Responses of soil properties and grain yields to deep ripping and gypsum application in a compacted loamy sand soil contrasted with a sandy clay loam soil in Western Australia. *Aust J Agric Res* 54:273–282. https://www.publish.csiro.au/cp/ar02102

Hanay A, Büyüksönmez F, Kiziloglu FM, Canbolat MY (2004) Reclamation of saline-sodic soils with gypsum and MSW compost. *Comp Sci Utili* 12 (2): 175–9. https://doi.org/10.1080/1065657X.2004.10702177

Hossain MZ, Fragstein P Von, Niemsdorff P Von, He BJ (2017) Effect of different organic wastes on soil properties and plant growth and yield: A review. *Sci Agri Bohe* 48 (4): 224–37. https://doi.org/10.1515/sab-2017-0030

Humbal A, Pathak B (2023) Application of nanotechnology in plant growth and diseases management: Tool for sustainable agriculture. *Agricultural and Environmental Nanotechnology* 11:2475–2489. https://doi.org/10.1007/978-981-19-5454-2_6

India Times of (2022) Delhi: Ghazipur landfill fire continues till evening, no casualty; FIR filed. https://www.timesofindia.indiatimes.com/city/delhi/ghazipur-landfill-fire-continues-till-evening-no-casualty-fir-filed/articleshow/90527690.cms

Ite AE, Ibok UJ (2019) Role of plants and microbes in bioremediation of petroleum hydrocarbons contaminated soils. *Int J Agri Bio* 7 (1): 1–9. https://doi.org/10.12691/ijebb-7-1-1.

Javaid A (2011) Effects of biofertilizers combined with different soil amendments on potted rice plants. *Chil J Agri Res* 71 (1): 157.

Jiang Y, Ju M, Li W, Ren Q, Liu L, Chen Y, Yang Q, Hou Q, Liu Y (2015) Rapid production of organic fertilizer by dynamic high-temperature aerobic fermentation (DHAF) of food waste. *Bioresour Technol* 197:7–14. https://doi.org/10.1016/j.biortech.2015.08.053

Kahlown MA, Azam M (2003) Effect of saline drainage effluent on soil health and crop yield. *Agri Wat Mana* 62 (2): 127–38. https://doi.org/10.1016/S0378-3774(03)00096-9

Kaza S, Yao L, Bhada-Tata P, Woerden F Van (2018) What a waste 2.0: A global snapshot of solid waste management to 2050. *The World Bank,* https://www.openknowledge.worldbank.org/entities/publication/d3f9d45e-115f-559b-b14f-28552410e90a

Kołodziej B, Antonkiewicz J, Stachyra M, Bielińska EJ, Wiśniewski J, Luchowska K, Kwiatkowski C (2015) Use of sewage sludge in bioenergy production- a case study on the effects on sorghum biomass production. *Eur J Agron* 69:63–74. https://doi.org/10.1016/j.eja.2015.06.004

Kumar A, Prakash CH, Brar NS, Kumar B (2018) Potential of vermicompost for sustainable crop production and soil health improvement in different cropping systems. *Int J Cur Micro App Sci* 7 (10): 1042–55. https://doi.org/10.20546/ijcmas.2018.710.116

Lakhdar A, Falleh H, Ouni Y, Oueslati S, Debez A, Ksouri R, Abdelly C (2011) Municipal solid waste compost application improves productivity, polyphenol content, and antioxidant capacity of Mesembryanthemum edule. *J Haz Mat* 191 (1-3): 373–379. https://doi.org/10.1016/j.jhazmat.2011.04.092

Lemtiri A, Colinet G, Alabi T, Cluzeau D, Zirbes L, Haubruge E (2014) Impacts of earthworms on soil components and dynamics: A review. *Biotechnology, Agronomy and Society and Environment* 18 (1): 121–133.

Mahdy AM (2011) Comparative effects of different soil amendments on amelioration of saline-sodic soils. *Soil Wat Res* 6 (4): 205–16. https://doi.org/10.17221/11/2011-SWR

Matichenkov V, Bocharnikova E (2016) Utilization of sludge as manure. *Environmental Materials and Waste Resource Recovery and Pollution Prevention,* 213–220. https://doi.org/10.1016/B978-0-12-803837-6.00009-3

McDougall FR, White PR, Hindle M Frankeand P (2001) Integrated solid waste management: A life cycle inventory. *International Journal of Life Cycle Assessment* 6 (5) https://doi.org/10.1007/BF02978794

Meena MD, Joshi PK, Narjary B, Sheoran P, Jat HS, Chinchmalatpure AR, Yadav RK, Sharma DK (2016) Effects of municipal solid waste compost, rice-straw compost and mineral fertilisers on biological and chemical properties of a saline soil and yields in a mustard–pearl millet cropping system. *Soil Res* 54 (8): 958–69. https://doi.org/10.1071/SR15342

Minakshi M (2014) Solid waste as a major environment problem in major cities: A case study of Chandigarh. *Int. J Rec Res Asp,* no. 2, 278–282.

Mohsin AU, Ahmad J, Ahmad AU, Ikram RM, Mubeen K (2012) Effect of nitrogen application through different combinations of urea and farm yard manure on the performance of spring maize (Zea mays L.). *J Ani Pla Sci* 22 (1): 195–8. https://www.researchgate.net/publication/291859126

Mrabet L, Belghyti D, Loukili A, Attarassi B (2012) Effect of household waste compost on the productivity of maize and lettuce. *Agri Sci Res J* 2 (8): 462–9.

Nachshon U (2018) Cropland soil salinization and associated hydrology: Trends, processes and examples. *Water* 10 (8): 1030. https://doi.org/10.3390/w10081030

Naikwade PV, Sankpal ST, Jadhav BB (2012) Management of waste by composting, vermicomposting and it's use for improvement of growth, yield and quality of fodder maize. *ARPN J Sci Technol,* no. 5, 184–94. https://api.semanticscholar.org/CorpusID:53334901/

Nandan A, Yadav BP, Baksi S, Bose D (2017) Recent scenario of solid waste management in India. *Wor Sci News,* no. 66, 56–74.

Neeraj A, Humbal A, Hiranmai RY, Pathak B (2023) Agricultural waste as source of organic fertilizer and energy. *Agric Waste Managd Bioresour: The Circular Economy Perspective,* 173–191. https://doi.org/10.1002/9781119808428.ch8

Neeraj A, Yadav R Hiranmai, Siddiqqui MA (2019) Mapping of Sodic Soils of Uttar Pradesh. *Innov Appro Agri Envi Dev* 26

Oo AN, Iwai CB, Saenjan P (2015) Soil properties and maize growth in saline and nonsaline soils using cassava industrial waste compost and vermicompost with or without earthworms. *Land Degradation and Development* 26 (3): 300–10. https://doi.org/10.1002/ldr.2208

Orlina MM, Schaldach R (2012) Water efficiency in agricultural irrigation. *BIO Intelligence Service,* 1–17. https://www.ruvival.de/wp-content/uploads/2017/11/Water-Efficiency-in-Agricultual-Irrigation-Working-Paper.pdf

Ors S, Sahin U, Khadra R (2015) Reclamation of saline-sodic soils with the use of mixed fly ash and sewage sludge. *Arid Land Res Manag* 29 (1): 41–54. https://doi.org/10.1080/15324982.2014.903314

Ouni Y, Albacete A, Cantero E, Lakhdar A, Abdelly C, Pérez-Alfocea F, Barhoumi Z (2014) Influence of municipal solid waste (MSW) compost on hormonal status and biomass partitioning in two forage species growing under saline soil conditions. *Eco Engi* 64:142–50. https://doi.org/10.1016/j.ecoleng.2013.12.053

Papafilippaki A, Paranychianakis N, Nikolaidis NP (2015) Effects of soil type and municipal solid waste compost as soil amendment on Cichorium spinosum (spiny chicory) growth. *Sci Hort* 195:195–205. https://doi.org/10.1016/j.scienta.2015.09.030

Rahman MA, Rahman MM, Begum MF, Alam MF (2012) Effect of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of chili. *Int J Bio Sci* 2 (1): 51–5.

Ramezanzadeh F, Torkashvand A Mohammadi, Khakipour N (2014) The use of municipal wastes, azolla and tea wastes composts as the growth medium of English daisy. *Euro J Exp Bio,* no. 1, 510–3.

Ravindran B, Wong JW, Selvam A, Sekaran G (2016) Influence of microbial diversity and plant growth hormones in compost and vermicompost from fermented tannery waste. *Bioresour Technol* 217:200–204. https://doi.org/10.1016/j.biortech.2016.03.032

Rehman MZ, Rizwan M, Ali S, Fatima N, Yousaf B, Naeem A, Sabir M, Ahmad HR, Ok YS (2016) Contrasting effects of biochar, compost and farm manure on alleviation of nickel toxicity in maize (Zea mays L.) in relation to plant growth, photosynthesis and metal uptake. *Ecotox Envi Safe* 133:218–25. https://doi.org/10.1016/j.ecoenv.2016.07.023

Riaz U, Murtaza G, Farooq M (2018) Influence of different sewage sludges and composts on growth, yield, and trace elements accumulation in rice and wheat. *Land Degrad Dev* 29 (5): 1343–1352. https://doi.org/10.1002/ldr.2925

Sabir M, Rehman M Zia ur, Hakeem KR (2019) Phytoremediation of metal-contaminated soils using organic amendments: Prospects and challenges. *Soil Remediation and Plants* 503:192–196. https://doi.org/10.1016/B978-0-12-799937-1.00017-6

Shahid SA, Zaman M, Heng L (2018) Introduction to soil salinity, sodicity and diagnostics techniques. *Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques,* https://doi.org/10.1007/978-3-319-96190-3-1

Sharma K, Garg VK (2018) Solid-state fermentation for vermicomposting: A step toward sustainable and healthy soil. *Cur Dev Biotech Bioen Elsevier,* 373–413. https://doi.org/10.1016/B978-0-444-63990-5.00017-7

——— (2019) Vermicomposting of waste a zero-waste approach for waste management. *Sustainable Resource Recovery and Zero Waste Approaches,* 133–164. https://doi.org/10.1016/B978-0-444-64200-4.00010-4

Siddiqui MA, Neeraj A, Hiranmai RY (2022) Vermitechnology: An eco-friendly approach for organic solid waste management and soil fertility improvement—A review. *Strategies and Tools for Pollutant Mitigation,* 91–112. https://doi.org/10.1007/978-3-030-98241-6

Simeon PO, Ambah B (2013) Effect of municipal solid waste on the growth of maize (Zea mays L.). *International Letters of Natural Sciences 2,* https://doi.org/10.5901/ajis.2013.v2n10p67

Soobhany N (2018) Remediation potential of metalliferous soil by using extracts of composts and vermicomposts from municipal solid waste. *Proc Safe Env Prot* 118:285–95. https://doi.org/10.1016/j.psep.2018.07.005

Soobhany N, Mohee R, Somaroo GD (2014) Process parameters analysis for the vermicom-posting of shredded paper using Pheretimoid spp. *Int J Envir Waste Manag* 14 (1): 99–116. https://doi.org/10.1504/IJEWM.2014.062983

Staley C, Breuillin-Sessoms F, Wang P, Kaiser T, Venterea RT, Sadowsky MJ (2018) Urea amendment decreases microbial diversity and selects for specific nitrifying strains in eight contrasting agricultural soils. *Front Micro* 9:634. https://doi.org/10.3389/fmicb.2018.00634

Steiner C, Teixeira WG, Lehmann J, Nehls T, Macêdo JL de, Blum WE, Zech W (2007) Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant Soil* 291 (1-2): 275–90. https://doi.org/10.1007/s11104-007-9193-9

Tejada M, Garcia C, Gonzalez JL, Hernandez MT (2006) Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. *Soil Bio Biochem* 38 (6): 1413–21. https://doi.org/10.1016/j.soilbio.2005.10.017

Tejada M, Rodríguez-Morgado B, Gómez I, Franco-Andreu L, Benítez C, Parrado J (2016) Use of biofertilizers obtained from sewage sludges on maize yield. *Eur J Agron* 78:13–19. https://doi.org/10.1016/j.eja.2016.04.014

Urra J, Alkorta I, Mijangos I, Epelde L, Garbisu C (2019) Application of sewage sludge to agricultural soil increases the abundance of antibiotic resistance genes without altering the composition of prokaryotic communities. *Sci Tota Env* 647:1410–20. https://doi.org/10.1016/j.scitotenv.2018.08.092

Valdez-Perezz MA, Fernández-Luqueño F, Franco-Hernandez O, Cotera LF, Dendooven L (2011) Cultivation of beans (Phaseolus vulgaris L.) in limed or unlimed wastewater sludge, vermicompost or inorganic amended soil. *Sci Hort* 128 (4): 380–7. https://doi.org/10.1016/j.scienta.2011.01.016

Wang L, Sun X, Li S, Zhang T, Zhang W, Zhai P (2014) Application of organic amendments to a coastal saline soil in north China: effects on soil physical and chemical properties and tree growth. *PloS one* 9 (2): e89185. https://doi.org/10.1371/journal.pone.0089185

Wang X, Zheng G, Chen T, Shi X, Wang Y, Nie E, Liu J (2019) Effect of phosphate amendments on improving the fertilizer efficiency and reducing the mobility of heavy metals during sewage sludge composting. *J Env Manag* 235:124–32. https://doi.org/10.1016/j.jenvman.2019.01.048

Wang XX, Zhao F, Zhang G, Zhang Y, Yang L (2017) Vermicompost improves tomato yield and quality and the biochemical properties of soils with different tomato planting history in a greenhouse study. *Front Plant Sci* 8:1978. https://doi.org/10.3389/fpls.2017.01978

Wicke B, Smeets E, Dornburg V, Vashev B, Gaiser T, Turkenburg W, Faaij A (2020) The global technical and economic potential of bioenergy from salt-affected soils. *Ener Env Sci* 13 (8): 2585. https://doi.org/10.1039/C1EE01029H

Wilson DC, Rodic L, Modak P, Soos R, Carpintero A, Velis C, Iyer M, Simonett O (2015) Global waste management outlook *ISWA and UNEP: Vienna, Austria*

Wolka K, Melaku B (2015) Exploring selected plant nutrient in compost prepared from food waste and cattle manure and its effect on soil properties and maize yield at Wondo Genet, Ethio. *Env Sys Res* 4 (1): 9. https://doi.org/10.1186/s40068-015-0035-0

Yadav A, Garg VK (2019) Biotransformation of bakery industry sludge into valuable product using vermicomposting. *Bioresour Technol* 274:512–7. https://doi.org/10.1016/j.biortech.2018.12.023

Yadav RH, Kibret K, Argaw A, Taddesse T (2015) Biodegradation of locally available organic wastes by composting and vermicomposting for improvement of soil fertility and crop production. *In Office of the Vice President for Research Affairs 32nd Annual Research and Extension Workshop 143*

Yagmur M, Arpali D, Gulser F (2017) The effects of sewage sludge treatment on triticale straw yield and its chemical contents in rainfed condition. *JAPS J Ani Plant Sci* 27 (3): 971–977. https://www.thejaps.org.pk/docs/v-27-03/34.pdf

Zhang H, Ahmad Z, Shao Y, Yang Z, Jia Y, Zhong H (2021) Bioretention for removal of nitrogen: Processes, operational conditions, and strategies for improvement. *Env Sci Pol Res,* 1–17. https://doi.org/10.3390/foods10071635