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# AN INNOVATION IN SOLID WASTE MANAGEMENT: A MICROBIAL PERSPECTIVE

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## ABSTRACT

Municipal solid waste (MSW) creation in developing cities is accelerated by population growth, economic expansion, and rising living standards. Waste is defined as material that is pointless, undesirable, or discarded. It comes in three different forms: solid, liquid, and gas, with solid or semi-solid waste being one of the most pressing issues right now. Different kinds of waste require different methods of treatment to maintain the environment. The review intended to give an overview of solid waste management, and handling of solid waste using the action of microorganism that aids in the generation of useful products like biofertilizer. The biofertilizer so generated helps to improve the quality of soil for agricultural purposes and reduce the use of chemical fertilizers. The microbial decomposition helps to create compost of organic waste made from kitchen waste, industrial wastes from the paper & pulp industry, and sugar industries. The plant develop quickly when this compost is used, and their height, leaf area, leaf density, germination period, and frequency all increase. Thus, this review helps to get insight into innovation in solid waste management using microorganisms and in turn, produce the product that are helpful and eco-friendly.

**KEYWORDS:** Solid waste, waste management, bio-composting, microorganisms, biogas.

## INTRODUCTION

The top three nations that create municipal solid trash are the USA, China, and India. High-income populations produce more waste paper, metals, and glass than low- to middle-income populations do. Along with income, the composition of solid wastes varies.[1] Composting, landfilling, waste-to-energy conversion, recycling, and incineration are all methods used to manage municipal solid waste.[2] More than 50% of the solid garbage produced in rural areas is made up of organic waste. Animal waste and agricultural waste make up the majority of the organic part. Composting is the most useful method for handling solid waste in rural areas due to the organic nature of trash.[3]

### ➢ COMPOSITION OF WASTE

One of the main causes of the rising rate of garbage generation is the growing population, so managing that waste is crucial. Radioactive waste, hazardous waste, municipal solid waste from agriculture and animals, industrial non-hazardous waste, construction and demolition debris, Oil and gas production waste, mining and extraction waste, fossil fuel, there are numerous distinct forms of waste created, including combustion waste and sewage sludge.[4] These wastes are a serious issue nowadays and have a direct impact on the environment, thus it is imperative to handle the generated trash properly to prevent or minimize environmental issues.[5] The socioeconomic level of the households has a significant impact on household solid waste, which is quite varied.[6] The amount and methods of solid waste removed from landfills largely depend on the content of garbage, so understanding its composition can help to enhance the sustainability of waste management. Additionally, this helps to identify recycling opportunities to support the requirement for recyclable trash collection services and to choose a mixed waste pricing structure to support waste recycling initiatives. The majority of the garbage produced, according to an analysis of its composition, was organic waste (69.1%), which was followed by plastic (10.6%), inert materials (8.7%), paper (4.6%), textile (2.5%), metal (1.2%), glass (1.1%), metal (0.6%), and hazardous materials (1.6%). Food and kitchen garbage (organic part) have consistently made up more than two-thirds of the waste composition in the study.[7] Depending on factors including geographic location, climate, eating and cooking habits, cultural traditions, level of national advancement, and socioeconomic standing, the waste composition varies from place to place.[8]


**Figure-1 Characteristics of solid waste.[9]**

- **MUNCIPLE GARBAGE MANAGEMENT**
- Composting
- Vermicomposting
- Landfilling
- Incineration
- Bio-methanation
- Pyrolysis

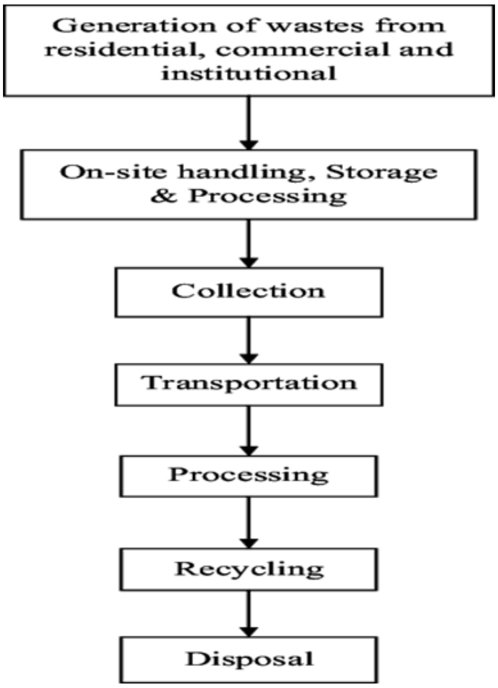


**Figure-2 Municipal garbage management and treatment.[10]**

**1.1 Composting**

Organic wastes are readily biodegradable wastes. These wastes come from a variety of sources, including municipal solid trash, urban solid food waste, and agricultural, market, and kitchen waste. These wastes could cause a number of environmental issues if improperly managed. Composting is therefore the best low-cost alternative approach to solve this issue. All kinds of organic waste, including leftover fruits, vegetables, plants, and yard debris, can be broken down using the composting method. The organic waste content could be used to regulate the environment, contribute nutrients to the soil and enrich the crops. The quality of the compost products can be affected by a variety of circumstances, though, as different organic waste types contain varying percentages of the macronutrients nitrogen, phosphorous, and potassium (N, P, K).[11]

Both nitrogenous (materials rich in nitrogen) and carbonaceous (materials rich in carbon) ingredients must be present for composting to take place. The amount of carbonaceous or nitrogenous components depends on how good the compost is that is needed. Typically, a ratio of almost 1:1 is preferred. For this study, dry garden trash was used to fulfil the carbon requirement whereas kitchen garbage was used to fulfil the nitrogen need. The personnel of the university's residence halls collected the kitchen garbage for the study regularly from the residences in nylon bags. For a week, this procedure was followed for each compost pile. Vegetable and fruit peelings, which are high in nitrogen, are made up of kitchen waste.[12] The amount of carbon (C) and nitrogen (N) lost to the atmosphere throughout the composting process varies from 30% to 63% and 19% to 42%, respectively. The loss of phosphorus (P) is less than 2%, primarily due to runoff.[13]

A better technique or process must be developed to turn garbage into a usable material to fulfill the problems of municipal solid waste management. It is possible to turn the biodegradable organic waste into environmentally acceptable organic manure. Organic manure reduces environmental pollutants while improving soil aeration and soil fertility. The use of chemical fertilizers and other chemicals is now understood to be detrimental to soil productivity and a source of air and water pollution. Due to the high percentage of biodegradable organic matter, adequate moisture level, and C/N ratio in municipal solid trash, it can be composted. The following are just a few of the many advantages of composting.[14] Bacteria, actinomycetes, and fungi are common decomposers in nature. Special organisms are not necessary because these exist naturally in dirt, dust, fruit and vegetable matter, and garbage of all kinds. These naturally occurring bacteria' activities lead to controlled breakdown.[15] Municipal solid waste (MSW) includes commercial and non-hazardous industrial waste, street sweeping leftovers, construction and demolition waste, and home garbage and junk-treated bio-medical solid waste Microbial farming, which composting is, necessitates energy, food, and habitat. These microbes need nitrogen to create proteins and carbon for energy. Bacteria create enzymes to transform complicated carbohydrates into simpler ones so they can be consumed as food.[16] The composting process continues until the final microbes devour the rest of the nutrients and the majority of the carbon is transformed into water and carbon dioxide. The carcasses of deceased microorganisms and humus in the compost still contain the nutrients that become accessible during decomposition.[17]

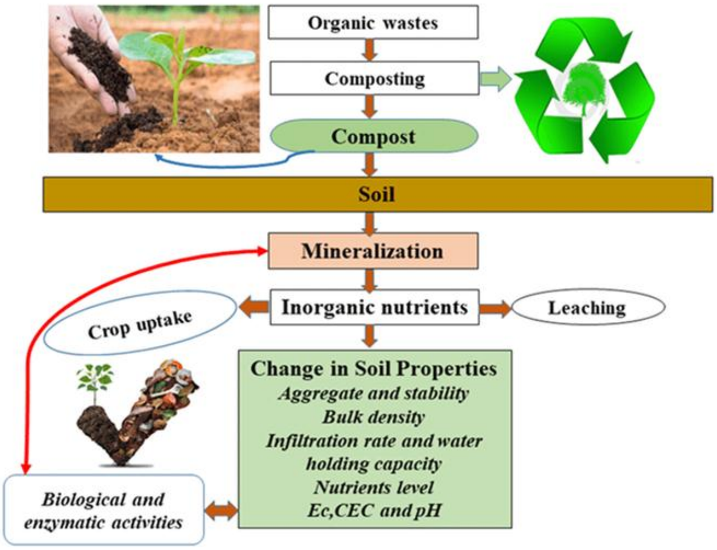


**Figure-3 Recycling of Organic Wastes through Composting.[18]**

**Composting process parameters**

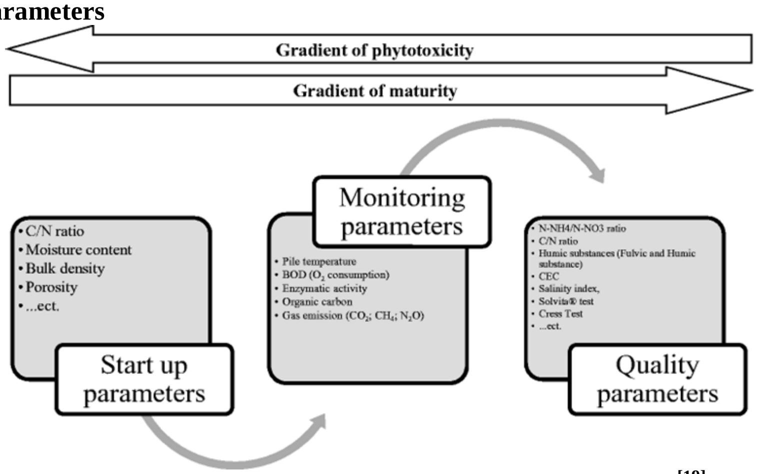


**Figure-4 Composting parameters and compost quality.[19]**

### 1.2 Vermicomposting

Organic materials, such as yard wastes, human waste, animal manure, sewage sludge, food waste, and composts, have been proven to be beneficial for plant growth and yield as well as the maintenance of soil fertility. It has been demonstrated that the new methods for using organic amendments in farming are successful in raising crop yields, boosting soil fertility, and enhancing soil structure. Vermicomposting has been cited as a practical, quick, and affordable method for the effective use of crop residues and organic waste. Vermicomposting is a non-thermophilic biodegradation process that uses microorganisms and earthworms to break down organic material.[20] According to rumors, earthworms function like mechanical blenders. The organic matter is broken down by earthworms, which also change its physical, chemical, and biological status and eventually lower its C: N ratio.[21] It expands the surface area of organic materials, making it easier for microbes to attach to them, which is much more conducive to microbial activity and further degradation. Vermicomposting takes less time than traditional composting since the material goes through the worms' digestive tracts more quickly.[22] Products made from earthworm castings (also known as worm manure) are high in microbial activity, plant growth regulators, and pest-repelling properties. Large and diverse wastes can be found in agricultural residues and residues from the food industry. Composting and vermicomposting are profitable technologies that might be applied at the industrial level to repurpose industrial wastes.[23] These recycled goods enrich the soil with nutrients, promote finer growth, and gain commercial value. Coffee husks were discovered to be compostable and suitable for vermicomposting. Aside from potash and lignin, the coffee pulp contains a higher amount of cellulose, but it also retains moisture incredibly well and decomposes slowly. Vermicasts are as fine as organic manure and potting medium due to the strong bacterial proliferation in earthworm intestines, which promotes soil fertility and plant growth.[24] Coffee pulp will compost in three weeks if it is turned into a heap of standard compost every few days.[25] The manufacturing of instant coffee produces solid wastes with high organic content. The experiments produced high-quality compost with a carbon-to-nitrogen ratio in the order of 13:1 to the organic matter and modified its physical, chemical, and biological status while gradually lowering its C: N ratio. Studies on the suitability of the forced aeration composting process to a mixture of this coffee waste and agricultural waste were sufficient. It expands organic matter's surface area, making it easier for microbes to attach to it, which is much more conducive to microbial activity and further degradation. Vermicomposting takes less time than traditional composting since the material goes through the worms' digestive tracts more quickly. Products made from earthworm castings (also known as worm manure) are high in microbial activity, plant growth regulators, and pest-repelling properties. Large and diverse wastes can be found in agricultural residues and residues from the food industry. Composting and vermicomposting are profitable technologies that might be applied at the industrial level to repurpose industrial wastes. These recycled goods enrich the soil with nutrients, promote finer growth, and gain commercial value.[26] Coffee husks were discovered to be compostable and suitable for vermicomposting. Aside from potash and lignin, the coffee pulp contains a higher amount of cellulose, but it also retains moisture incredibly well and decomposes slowly. Vermicasts are as fine as organic manure and potting medium due to the strong bacterial proliferation in earthworm intestines, which promotes soil fertility and plant growth. Coffee pulp will compost in three weeks if it is turned into a heap of standard compost every few days. The manufacturing of instant coffee produces solid wastes with high organic content. The experiments produced high-quality compost with an appropriate carbon-to-nitrogen ratio in the range of 13:1 to 15:1, thanks to studies on the suitability of the forced aeration composting method to a combination of agricultural wastes and this coffee waste.[27]

**Vermicomposting process parameters**

- Organic waste
- Water
- Earthworm
- Oxygen
- Worm biomass

### 1.3 Landfilling

The physical structures known as landfills are utilized to dispose of remaining solid wastes on the earth's surface. The remaining solid waste is disposed of by the process of landfilling. Monitoring the incoming trash stream, placing and compacting the garbage, and installing environmental monitoring and control infrastructure are all included in landfilling. The biodegradation of deposited organic material inside the landfill produces raw landfill gas (LFG), also known as the source gas, which typically contains 50–60% methane and 40–50% carbon dioxide.[28] Hundreds of distinct compounds are also present in LFG in trace concentrations (together, 1% of the total volume; referred to as "trace gases"), either as a result of hazardous waste and/or disposed-of waste products or as a result of waste degradation processes taking place in the landfill body.[29]

There are two different kinds of landfills:

- sanitary landfills
- secured landfills

On the surface of the planet, solid waste is disposed of using landfills, which are actual physical constructions. Landfilling is used to get rid of the residual solid waste. Landfilling includes observing the incoming trash stream, placing and compacting the waste, and putting in place the infrastructure for environmental control and surveillance. A typical raw landfill gases (LFG) composition is between 50 and 60 percent methane and 40 to 50 percent carbon dioxide. LFG is additionally referred to as the source gas and is produced when organic waste decomposes inside a landfill. The presence of thousands of different compounds in LFG at trace concentrations (totaling 1% of the total volume; referred to as "trace gases") is also caused by hazardous waste, discarded waste products, or waste degradation processes. Sanitary landfills account for 37% of all disposal of regulated waste worldwide. Landfilling is the most cost-effective, particularly in underdeveloped nations where it often entails dumping garbage into a depression or abandoned mining site. Leachate and landfill gases are produced by landfills and can be harmful to both natural and human systems. When complex molecules are broken down by methanogens, landfill gases (LFGs) are created. Up to 90% of these gases are methane and carbon dioxide, but they can also contain CO, N2, alcohols, hydrocarbons, organosulfur compounds, and heavy metals.[30] Leachate and biogas management in landfill bioreactors (LBRs) has many benefits, including faster stabilization of solid waste, less leachate, and in situ leachate treatment. These benefits have reduced environmental dangers, enabled an extension of the waste site's useful life, and encouraged cost-cutting. Landfill microorganisms produce a variety of reactions involving organic components and heavy metals.[31] Microbial processes in these systems, however, limit our ability to design the next generation of landfills that: (1) increase the rate and extent of waste decomposition, (2) produce by products with some economic value (for example, methane that can be used for energy generation), and (3) minimise their overall impact on causing climate change by emitting greenhouse gases.[32]

**Landfilling process parameters**

- waste separation at the source
- Identification of the number of unsanitary landfill sites
- Construction of the number of sanitary landfill sites

### 1.4 Incineration

The ability of waste incineration technology to satisfy the objectives of safety, waste minimization, and resource utilisation has led to its widespread use around the world. Ashes, flue gas, and heat are produced as a result of the combustion of garbage at extremely high temperatures with oxygen during the waste treatment process known as incineration.[33] For the combustion of unprocessed or minimally processed trash as well as the segregated portion of high calorific value waste, incineration is a practical method. Depending on the waste's composition, density, moisture content, and inert content, it may be possible to generate energy (between 65% and 80% of the energy contained in the organic matter can be recovered as heat energy, which may be used for direct thermal applications or to generate electricity using steam turbine generators).[34] MSW incineration aids in lowering landfill volume. When there are no viable alternatives to incineration.[35]

The pressure on landfill space is reduced by the incineration of MSW and the reuse of burned wastes. However, because they could expose the environment to harmful heavy metal elements, the reuse of MSW incinerator residues must be governed.[36] The analysis of environmental regulations from various nations that apply to MSW, much less those for recycling MSW leftover following incineration, is not extensively reported.[37] The process of incinerating garbage produces bottom ash, carbon dioxide, water, and non-combustible elements while being carried out in the presence of air and at a temperature of 850°C.[38] There are several different kinds of incinerators, including.[39]

- fluidized bed
- rotary kiln
- fixed grate, and
- moving grate models

### 1.5 BIO-Methanation

Bio-methanation, also known as anaerobic digestion, is the process of turning organic waste into methane and manure through microbial action without the presence of air. Due to the high organic content of the solid wastes from agro-based companies, bio-methanation is the most practical method for treating them because it yields useful products like enriched manure and biogas. Acidification and methanation are the two stages of the bio-methanation process.[40] Organic material is microbiologically transformed into biogas under anaerobic conditions through the process of biomethanation. Fermenting bacteria, organic acid oxidizing bacteria, and methanogenic archaea are the three primary physiological types of microorganisms that are engaged. Organic material is broken down by microorganisms into methane and carbon dioxide through a cascade of metabolic reactions. The procedure is dependent on the syntrophic interactions of hydrogen scavengers (homoacetogens, hydrogenotrophic methanogens, etc.) and hydrogen producers (acetogens).[41]

### 1.6 Pyrolysis

In an inert atmosphere, solid fuel is heated during pyrolysis, a thermochemical conversion process, without the need of an oxidizing agent.[42] As a conversion process, pyrolysis produces three by-products: a gas combination, a liquid (bio-oil/tar), and a solid residue (char).[43] Fast pyrolysis for the production of bio-oil and slow pyrolysis for the manufacture of charcoal are two technologies that both use and differ in the mechanism of heat transfer.[44] The two primary downsides of the pyrolysis procedure are that the product stream is more challenging than for many alternative treatments and that the high CO concentrations prevent direct venting of the product gas into the cabin.[45] Excellent research has been done on the pyrolysis of solid waste to produce energy.[46]

### 1.7 Bio-composting

Composting is the decomposition of organic waste utilizing readily available soil microbes to create compost. When earthworms and soil insects like springtails, ants, mites, and beetles break down organic material into smaller particles, the first stage of degradation begins. Second, microbes take over after physical disintegration, and manure breaks down organic matter. Different composting methods, including vermicomposting, windrow composting, co-composting, in-vessel composting, aerobic and anaerobic composting, and anaerobic (biological) biodigesters, can be used in rural areas of developing nations.[47] Compost and compost tea are given microbial additions to boost their potency and certainty in thwarting disease. They are up to three times more suppressive than composts without supplements. Conventional compost only supports a limited number of microorganisms.[48] By secreting enzymes and hormones that stimulate plant growth and so indirectly reduce plant pests and diseases, the presence of beneficial microbes in vermin-composts such as fungi, bacteria, and actinomycetes may support plant growth. Additionally, the creation of bio-compost can be an alternative to today's standard waste disposal techniques and reduce the quantity of chemical fertilizer required in agricultural sectors.[49,50] Agroecosystems and soil ecology benefit from the addition of MSW compost.[51] By improving the physicochemical and biological characteristics of the soil, its integration into the land helps to preserve long-term productivity. It also aids in shielding the soil from overcropping, weather fluctuations, and improper management.[52]

#### 1.7.1 Microorganisms' role in composting

Microorganisms play a critical role in the transformation and movement of nutrients in both compost and soil. Therefore, to carry out the compost nutrient replenishment, it is crucial to examine the bacteria and fungus present during the various composting processes. Numerous bacteria are present during the composting process that contribute to the transformation of nitrogen as well as fungi and bacteria that favour the solubilization of phosphorus and potassium. The primary mechanism for the hydrolysis of organic contaminants is mediated by bacterial extracellular enzyme activity. Bacterial communities have a wide variety of genetic material that can be used to create particular enzymes for biodegradation. This results in the production of extracellular hydrolytic enzymes that can break key chemical bonds in the hazardous compounds, reducing their toxicity.[53] The main element in nutrition transformation is microorganisms. Lignocellulose, proteases, lipases, and other extra-cellular enzymes are excreted by microorganisms that are involved in the composting process and help to break down the macromolecules in organic waste. As a result, the nutrient quality of composts was enriched as a result of the initial organic wastes being inoculated with suitable microbial strains.[54] To develop high-quality biomass that is used as a source for bio-fertilizers, which will be more useful and efficient while reducing landfill waste, $CH_4$, and $CO_2$ emissions, and controlling the global warming effect. Because of this, these bio-fertilizers contain healthy bacterial communities that are actively involved in regulating soil qualities based on their biological activity.[55]

**An overview of experiments conducted by various authors using various types of solid waste as compost feedstocks**

| compost as a feedstock | Description of Effective Microorganism | Having an effect on the overall composting process | Referances |
|---|---|---|---|
| MSW, or municipal solid waste | (*Phanerochaete chrysosporium* and *Trichoderma reesei*), two bacteria that break down plant matter | A drop in the C/N ratio (below 20) indicates rapid composting | [56] |
| Fruit and vegetable wastes, leaves, hay, newspaper, wheat straw, and rice husks are examples of common organic material waste. | *Pseudomonas* and *Bacillus* species | Improved compost maturity, $NH_4$ and $NO_3$ ion amounts, and a decrease in the C/N ratio | [57] |
| Agriculture waste decomposing | Cellulolytic bacteria (*Phanerochaete chrysosporium)* | Boosting the substrate's usability, raising the pile temperature, and altering other physicochemical variables | [58] |
| Food waste | fungus, (*Paecilomyces sp*)<br>Yeast (*Pichia kudriavzevi*)<br>Lactic acid bacteria<br>Thermo-tolerant lipolytic *actinomycete, Thermoactinomyces vulgaris* A31 | With the maximum volatile solid mass reduction indicating mature compostenhanced the decomposition of organic waste in the composting process, Temperature rise, pH | [59,60] |

| | | | |
|---|---|---|---|
| | | elevation, and quickening of the composting process | |
| Organic waste | *Streptomyces sp.* and *Micromonospora sp.* are examples of actinobacterial agents. | increased the richness of the actinobacteria population, especially during the cooling stage of composting, and sped up the breakdown of | [61] |
| Kitchen waste (vegetable scraps) | Mixed *Bacillus* species, including *Bacillus thermoamylovorans, B. Brevis, B. Coagulans, and B. Licheniformis* | The efficiency of the composting process enhanced | [62] |
| Wheat bran | *Bacillus subtilis* and *Chaetomium thermophilum* | High composting efficiency, degree of humification, accelerated decomposition of protein-rich substances, and the creation of complex humic-like molecules. | [63] |

### 1.7.2 Bio-Compost's Impact on the Composition of the Soil's microbial community

- an increase in nutritional content
- Expanding the Cation Exchange Capacity (CEC)
- An increase in pH, the liming effect, and an enhanced capacity for buffering

The dynamics of the N cycle and organic matter depend heavily on soil microorganisms. Changes in the microbial community's structure and makeup will affect the soil's quality.[64] The structure and content of the soil's microbial population can be considerably altered by fertilization, as is well documented.[65,66] The application of bio-compost changed the because the specific functional microorganisms in the bio-compost penetrated the soil and because of this, the community structure of soil bacteria and fungi interacted with the local microorganisms, further altering the community structure of the soil microbial community.[67]

The findings of the RDA and Mantel tests demonstrated that the major soil physicochemical parameters (such as EC, SOM, TP, NO3-N, and AK) simultaneously impacted the bacterial and fungal community composition in the soil.[68,69] Due to their larger level of stable carbon, mature composts generate SOM far more effectively than fresh and immature composts. Compost also helps to stabilize and boost crop yield and crop quality due to its numerous advantageous effects on the physical, chemical, and biological soil qualities. Therefore, the majority of researchers established that compost has an equalizing influence on annual/seasonal changes regarding the soil's water, air, and heat balance, the availability of plant nutrients, and therefore the crop yields. Compost-combined fertilization strategies frequently produce positive results, mostly due to the delayed release of nutrients and their availability in compost.[70]

The bacterial and fungal richness was dramatically boosted by high bio-compost dosages. The addition of bio-compost considerably changed the bacterial and fungal community compositions. The addition of bio-compost increased the relative abundance of good bacteria (like *Sphingomonas, Acidibacter, Nocardioides*, etc.) and decreased the relative abundance of bad bacteria (such as *Stachybotrys and Aspergillus*). The main elements affecting the composition of the soil microbial community were electrical conductivity, soil organic matter, and total phosphorus. In addition to being more sensitive to changes in environmental conditions than fungi, bacteria have a more intricate network than fungi did. Both the bacterial and fungal networks were dominated by positive interactions, with the bacterial network exhibiting stronger positive interactions. According to a functional prediction, bio-composts changed how the soil's bacterial community metabolized carbon and nitrogen. A type of compost called bio-compost is produced by combining organic waste with specialized microbes (such as animal manure, household waste, straw, and sewage sludge). Bio-compost is regarded to be more effective than conventional compost since it contains a lot of physiologically active chemicals and beneficial microbial flora (such as indoleacetic acid, gibberellin, vitamins, and amino acids).[71]

## 1.8 Biogas production from Anaerobic Digestion (AD)

Anaerobic digestion is now favoured as a sustainable alternative technology that simultaneously manages garbage in a sustainable way while producing bio-based fuel from waste.[72] Biogas management has the dual benefits of reducing greenhouse gas emissions and generating renewable electricity. In the AD process, organic material is broken down by a group of microorganisms into methane-rich biogas as a natural gas substitute. Producing fertilizers is possible using the resultant effluent. The lignocellulosic component of agricultural waste (crop residues), in particular, can limit the energy conversion efficiency of AD since it is resistant to biodegradation. One of the four phases of the AD process (hydrolysis of lignocellulosic biomass, acidogenesis, acetogenesis, and methanogenesis) has frequently been identified as the main rate-limiting stage.[73] Theoretically, the yield based on the cellulose content of agricultural waste was expected to be around 90%, but the efficiency of methane production in full-scale biogas reactors is only 50%.[74] Lignocellulose, carbohydrate, and protein make up the majority of the biomass during the composting of agricultural waste. Before composting or AD, the abundant lignocellulose composition frequently needs pretreatment processes such adding chemical and industrial enzymes, heating, or using microorganisms for biological treatment. Because they are more effective at breaking down organic matter than other microorganisms, microbes and fungus (MF) are preferred.[75, 76] For the treatment of sewage sludge, wastewater treatment plant sludge, animal manure, and agricultural residue, anaerobic digestion was used. Currently, biogas is mostly utilised to generate electricity using a traditional combustion system and as a fuel for kitchen heating. The bioconversion of biomass into methane-rich biogas has received increasing attention as a result of global warming, rising energy and waste disposal costs, and the need for environmentally friendly waste management.[77]

### 1.8.1 The microbial activities in the anaerobic digestion process

Methane (CH4) and carbon dioxide are gases that are created throughout the process. In the presence of oxygen, some bacteria cannot survive. Anaerobic respiration is among them the most practical and straightforward method of energy production. Ethyl alcohol, used in many industries, is created via this procedure. The process is used in the fermentation of lactic acid. Microorganisms use a series of processes called anaerobic digestion to break down biodegradable material in the absence of oxygen. Anaerobic digestion is influenced by a wide variety of microorganisms, including bacteria that produce acetic acid (acetogens) and archaea that produce methane (methanogens). These organisms promote the use of various chemical processes to convert biomass into biogas. Physical confinement prevents the process from involving gaseous oxygen. The anaerobic digestion system produces biogas from a variety of feedstocks thanks to the microbiome that lives inside anaerobic digesters, which is a renewable energy source. Hydrolysis, acidogenesis, acetogenesis, and methanogenesis are the four steps of anaerobic digestion that typically occur in succession; the first three processes are handled by bacteria, and the last stage is carried out by archaea.[78]

### Hydrolysis

Large organic polymer chains make up biomass; in order for bacteria to easily utilise these chains, these chains must first be broken down into smaller constituent parts. Hydrolysis is the process of severing the chains and dissolving the smaller molecules into a solution. Fermentative bacteria convert complex organic materials, such as proteins, lipids, and carbohydrates, into soluble and biodegradable subcomponents such as monosaccharides, amino acids, higher fatty acids, and alcohols during hydrolysis, the first stage of anaerobic digestion. Typically, the rate-limiting stage in digestion is hydrolysis. Bacteroides, Clostridium, and Acetivibrio are among the microorganisms used in this procedure.[79]

### Acidogenesis

During this stage, acidifying (fermentative) bacteria transform water-soluble chemicals, such as hydrolysis products, into short-chain organic acids (formic, acetic, propionic, butyric, and pentanoic), alcohols (methanol, ethanol), aldehydes, carbon dioxide, and hydrogen. The third stage, acetogenesis, will involve the transfer of hydrogen, carbon dioxide, acetic acid, and water, which will then quickly be used by the methanogenic bacterium in the final stage.[80]

### Acetogenesis

In acetogenesis, acetogenic bacteria transform soluble organic acids from hydrolysis and acid production into acetate, hydrogen, and carbon dioxide.[81] These bacteria convert the CO2 and H2 into acetate. The syntrophic acetate-oxidizing bacterium (SAOB) oxidizes both substances. The acetogenic and SAOB are often found in the phylum Firmicutes and the genera Clostridium and Acetobacterium, respectively. Here, two different types of microorganisms play an important role: the homoacetogene microorganism, which produces acetate starting from carbonic anhydride and hydrogen, and the acetogenic microorganism, Which uses the by-products of acid-producing microbes as a sublayer to produce hydrogen binding.[82]

### Methanogenesis

Methane is created at this point using substrates including acetic acid, H2, CO2, and formate as well as byproducts from earlier stages such as methanol, methylamine, or dimethyl sulfide. Methanosaeta, Methanobacterium, and Methanosarcinaceae are frequently found in methanogenesis processes, where hydrogenotrophic methanogens use reduced CO2 as a source of carbon and energy to generate methane.[83,84]

## CONCLUSION

Based on the literature survey it can be concluded that many types of solid waste are harmful to the environment. Household waste is used after composting but it is less effective so when microbes are added to this decompose and after being used as bio-fertilizer in the soil it enhances the growth and reproduction of the plant. Biogas is used to create energy and heat kitchens using a typical combustion mechanism.

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