Review Article

A review on the Agricultural waste management by different microbes

Abstract:

Global agricultural waste production is increasing, and if it is not properly managed, it could harm the ecosystem. Burning agricultural waste results in respiratory issues, air pollution, and human illness. cellulose, lignin, chitin, keratin, and pectin make up the majority of agricultural waste. An appropriate abiotic and biotic environment is necessary for microorganisms to function, making a variety of waste materials difficult to break down. Bacteria, fungi, actinomycetes, and protozoa are important players in the decomposition of agricultural waste. As a result, these wastes are quickly managed by effective bacteria during the breakdown process and employ priceless fertilizer. An appropriate particular genus of microorganisms produces mass levels and disperses the waste material for degradation. These microbes digest garbage by producing a variety of enzymes, effectively managing the waste, and reducing land contamination. Utilizing microorganisms can have long-lasting environmental effects that are beneficial to the ecosystem.

Keywords: Effective microorganisms (EM); Agricultural waste; Microbial degradation; Enzymes; Earthworm

1. Introduction:

Nearly 700 million tonnes of agricultural organic waste residues are generated in India each year, posing a difficulty for its safe disposal, with the garbage typically being burned or dumped. Agricultural operations produce around 998 million tonnes of agri-residue trash per year, which includes sugarcane luggage, paddy and wheat straw, husk, vegetable, and food waste, jute fibers, crop stalks, and other materials. As part of the composting process, decomposers eat tough plant fibers such as cellulose and lignin in bark, paper, and stems, as well as the chitin or hard exoskeletons of insects. Several naturally existing microbes, on the other hand, can transform organic waste into valuable resources like plant nutrients, lowering the C: N ratio and boosting soil productivity. These bacteria are also necessary for maintaining nutrient flows from one system to the next, which helps to reduce ecological imbalances in the ecosystem cycle. Composting is a cost-effective biological treatment for several forms of organic waste. During the composting process, aerobic microbes break down complex and simple organic materials, followed by an ecological succession of microorganisms. Various criteria in the composting process are used to measure the quality and stability of the compost, including the C: N ratio, composting temperature, finished product pH, moisture content, and the presence of possible pathogens such as coliform bacteria. [1-6]

A rise in agricultural productivity has accompanied an increase in the global population. Agriculture provides a living for around 40% of the world's population (2.6 billion people).[7] In 2012, the global production of a few key crops was around 62 billion metric tonnes, including staple food crops such as rice, maize, wheat, sugarcane, and a variety of vegetables.[8] Higher yields were achieved by intensifying crop production, but this also resulted in increased amounts of plant leftovers, which primarily consisted of leaves, straws, grains, corncobs, and other similar items. Residual stalks, straw, leaves, roots, husk, nut or seed shells, waste timber, and animal husbandry waste are examples of biomass. Microorganisms such as bacteria and fungi degrade a large percentage of these materials on farmlands.[9] According to the FAO, agriculture produces 140 billion metric tonnes of biomass per year.[10]

From 3.7 billion in 1970 to 7.9 billion in 2021, the world's population has increased dramatically. It is expected to reach 9 billion people by 2050 and 11 billion by 2100. There has been a huge increase in livestock and crop production to meet the intense demands of teeming millions, which has contributed to the development of agricultural wastes. China, India, and Africa have witnessed fast population and economic growth in the last century, as well as increased agricultural waste production capacities. India produces a large amount of solid waste each year, with between 350–990 (manual transmission) Mt/y in agricultural waste. India produces about 130 million tonnes of paddy straw, half of which is used as fodder, and the other half is thrown, making it the world's second-largest producer of agricultural waste after China.[11] To feed India's estimated population of 1.35 billion in 2025, agricultural production, particularly rice and wheat (India's staple grains), will need to rise by about 25%. Every year, India produces approximately 500 million tonnes (Mt) of agricultural leftovers. The increased cultivation of rice and wheat has resulted in a significant increase in residue production. Cereal crops (rice, wheat, maize, millets) account for 70% of total CRs (352 Mt), with rice accounting for 34% and wheat accounting for 22%. Nearly one-fourth of India's total CRs are produced via the RW system (Sarkar et al., 1999). Surplus CRs (total residues produced less amount required for various uses) are usually burned on-farm. India's excess CRs are predicted to be between 84 and 141 Mt per year–1, with cereal crops accounting for 58 percent. Nearly 70 MT (44.5 Mt rice straws and 24.5 Mt wheat straws) of the 82 Mt of surplus CRs are burned each year.[12]

These wastes are difficult to dispose of. For example, the juice industry generated a large amount of garbage in the form of peels, the coffee sector generated waste in the form of coffee pulp, and the cereal industry generated husks. Around 147.2 million metric tonnes of fiber sources are found around the world, whereas wheat straw residues and rice straws were projected to be 709.2 and 673.3 million metric tonnes in the 1990s, respectively.[13] Furthermore, the global output of non-wood fibers was estimated to be at 2.5 million metric tonnes. Nigeria has around 61 million metric tonnes of crop leftovers available.[14]

Agricultural wastes are one of the major sources of pollution in the environment, and they also shorten the fallow period, reducing the time available for the aerobic decomposition of crop residue. Cellulose is a natural substrate that persists in the ecosystem and continues to pollute the environment.[15] The open burning of straw and stubbles, which has also been used traditionally to cleanse agricultural fields against pests and illnesses, is a typical practice to overcome the accumulation of undecomposed crop residue.[16]

Thermal straw management is being reviewed in many parts of the world because of environmental concerns and has been outlawed in China and India.[17] The realization that environmental degradation is a global hazard to human health has spawned a new multibillion-dollar business dedicated to environmental restoration. The yearly accumulation of these agricultural leftovers degrades the ecosystem and results in a significant loss of potentially useful nutritional elements, which may be turned into food, feed, fuel, chemicals, and minerals. When agricultural wastes are discarded in an open environment, they cause pollution and encourage the spread of harmful bacteria.[18]

Biological degradation has become a popular alternative for the treatment of agricultural, industrial, organic, and hazardous waste for both economic and ecological reasons. Acute environmental pollution has resulted from insufficient and incorrect disposal of agricultural trash.[19]

Compost's high organic carbon content and biological activity make it ideal for uses like erosion control and revegetation. Composting, according to,[20] is a cost-effective biological treatment for several types of organic waste.[21,22] Compost's quality and stability are reliant on the materials used to make it.[23-25]

Agricultural waste production has expanded dramatically practically everywhere in the world in recent decades. The microbial population, which includes bacteria, fungus, actinomycetes, and other organisms, is primarily responsible for the bioconversion of agricultural wastes. Many of these societies damage a wide range of agricultural components, as well as engage in some particular degradation activities.[8]

In the future development of suitable microbial consortia with advanced tools such as nanoparticle and drone technology through management of agriculture waste this successful technology will apply to MSW, agricultural, horticulture, solid waste and industrial waste, etc, propagate this technology to fulfil the agricultural fertilizer in the agricultural sector.

2. ROLE OF MICROORGANISMS DEGRADATION OF BIOLOGICAL WASTE:

Microbial technology could speed up the degradation of organic materials.[26] Decomposition is a microbiological process that breaks down the substrate into a more stable product.[27] In the breakdown process, different microorganisms may play distinct functions. Several fungi, for example, are involved in the degradation of lignocelluloses, while bacteria operate as cellulose-degrading microorganisms.[28] Microorganisms can produce enzymes and metabolites that help organic waste decompose faster and improve soil humus quality.[29] Rice straw is made up of silica-rich cellulose, hemicellulose, and lignin.[30]

Bacteria and fungi are the most important microbiological components of compost. Furthermore, actinomycetes, a type of bacterium, are regarded as the third key component because of their capacity to digest more difficult chemicals. Compost feedstock contains the microorganisms required for composting, as well as the ability to sustain an active microbial population during the composting process. Furthermore, much study has been done on inoculating certain bacteria to improve organic decomposition. [130]found that bacteria and filamentous fungi were the primary decomposers at first. Yeasts and actinomycetes, on the other hand, grew in quantity throughout time. Viruses, protozoan cysts, and helminth ova may also be present, in addition to these organisms. The abundance of these distinct species is influenced by the material being composted to some extent. When the temperature rises over 65°C, a solely bacterial community replaces the mixed fungal–bacterial community.[31]

Composting's main purpose is to create a finished product that is free of animal and plant infections. Aerobic composting has been proven in several experiments to kill harmful bacteria. During the composting process, aerobic microbes break down complex and simple organic materials, followed by an ecological succession of microorganisms. Composting is an important part of a more sustainable organic waste management strategy. Composting not only eliminates waste, but also converts it into a nutrient-rich organic material that may be used in a range of agricultural, horticultural, and landscaping applications. Organics are rapidly being diverted from solid waste disposal facilities to recycling and composting for bacterial breakdown by countries, states, and municipalities establishing legislation and regulation.[32,33] Composting involves two types of aerobic microorganisms: mesophilic and thermophilic. Bacteria, actinomycetes, molds, and yeasts are examples of organisms that dominate different stages of composting. After the mesophilic stage, the thermophilic stage takes over. In comparison to the mesophilic stage, active breakdown occurs in the thermophilic stage (40–70°C). The first sub-sample was held at 4°C to create a sample library, while the second sub-sample was used for physicochemical studies and the third sub-sample for microbiological analyses. Compost's high organic carbon content and biological activity make it ideal for uses like erosion control and revegetation.[34] As a result, composting technology has emerged as a viable management strategy for recycling and transforming organic waste into a valuable "compost" product with high nutrient content and low pathogenic microbe prevalence.[35]

Although the actual number of degraders of a target component in a mixed culture may only represent 5-10%, microorganisms are well-known agents for their metabolic plasticity in the degradation of biological wastes.[36] As previously stated, biological waste makes up the majority of agricultural waste. Both fungal and bacterial or mixed consortia have been used, and their efficacy in the breakdown of biological wastes has been thoroughly demonstrated. These bacteria come from a wide range of environments, including the mesophilic and thermophilic zones as well as halophilic marine settings.[8] Fungi have amazing catalytic abilities, as they can grow on solid substrates and secrete a variety of extracellular enzymes that hydrolyse and oxidize different polymers to molecules, which are subsequently reabsorbed by the fungal colony.[37]

The microorganism is a microbial inoculant that contains a variety of naturally occurring beneficial microbes that are effective in treating food wastes through fermentation and compost generation. It was discovered that using EM for 4 days reduced the foul stench of fermenting waste. In two days, the development of esters and alcohol in the fermentation process was visible, as was the development of Lactic acid bacteria, as well as an increase in the acidity of the leachate, Which is utilized as a fermentation indicator. The pH, salinity, and microbial populations in the compost were also measured. It was also shown that EM can deoxidize heavy metals and convert them into organometallic compounds that are safe for human and animal health.[38] The extensive use of microbes for the treatment of organic wastes was investigated. They discovered that microorganisms like bacteria and fungi are extremely effective at improving garbage treatment. Composting mediated by indigenous microbial populations has achieved great appeal in treating organic waste among the several approaches used. Based on earlier research, microorganisms such as bacteria and fungi have been shown to improve the breakdown process. The use of microbial consortiums in composting and anaerobic digestion offers an alternative to chemical and thermal waste management approaches, which are both expensive and energy-intensive. Co-composting with microbes has the added benefit of improving nutrient breakdown and reducing nutrient valorization in the compost.[39]

The use of microbial additions in composting is thought to be quite effective since it increases the synthesis of various enzymes, which leads to a faster rate of waste decomposition. Depending on the waste material's nature, it can either be composted immediately or homogenized before being treated with additional waste management processes like landfilling. However, when considering the environmental consequences of these approaches, biological composting with an effective microbial culture (generic or waste specific) appears to be the most cost-effective and environmentally benign option. Compost inoculated with EM achieves higher compost quality and maturity in a shorter amount of time. These EMs can be extracted from a variety of traditional sources, such as soil, trash, or leachate, and used in the process at various stages (initial, mid, or last). It is also recommended that governments take a proactive role in addressing waste collection and segregation difficulties to construct a centralized SWMS.[40]

Microorganisms play a significant part in the environment's maintenance of a variety of natural and man-made occurrences. They provide beneficial tasks that make man's existence easier and better. Waste management is one of the areas where microorganisms are used. The correct disposal of the vast amounts of garbage generated by humans in their daily activities is a major challenge that government and environmental agencies are constantly working to solve. Microorganisms are an essential tool for successfully addressing this threat. Microbiological waste management technologies should be developed and used, not just for environmental reasons, but also for the additional value that such systems provide.[41] Though fungus, bacteria and actinomycetes all play vital roles in composting, mixed cultures of microorganisms accelerate lignocellulose degradation by using intermediate degradation products through synergistic activity.[42]

As a result, there is an immediate need for sustainable solutions to solid waste disposal concerns that have a low environmental impact. Solid waste management, sanitary landfilling, composting, vermicomposting, anaerobic digestion, and ethanol production are all viable options. Biological processes (anaerobic digestion, aerobic composting, vermicomposting, landfills, and bioethanol production) with their pre-treatment procedures have been tracked among all the bacteria and biological agents playing a very important role from a microbiological perspective. They concluded that by using microorganisms, a country can tackle its waste management problem in the long run.[43]

Figure 1: Role of microorganisms in the degradation. as the solid-based biofertilizer

3. DEGRADATION OF BIOLOGICAL WASTE BY BACTERIA:

Table 1 illustrate that bacteria are single-celled creatures that make up the biggest group of microorganisms in the composting process, with 1,000,000 to 1 billion per gram of compost. The bulk of bacteria are either spherical (Cocci) or rod-shaped (*Escherichia coli*) (Bacilli). You can observe a lot of these with a data microscope, stereoscopic microscope, or standard laboratory microscope. During all stages of the composting process, bacteria are the major population of microorganisms, and they are especially active in breaking down the easily destroyed organic waste, although actinomycetes and fungi typically multiply in the later stages. The effects of microbial inoculation (*Bacillus shackletonni*, *Streptomycesthermo vulgaris*, and *Ureibacillus thermosphaericus*) and co-composting material on the evolution of humic-like substances during composting using the windrow method were investigated, and it was found that the benefits of inoculation were dependent on the properties of the applied raw materials and microorganisms.[44]

In aerobic waste treatment systems, bacteria are the basic biological unit. Bacterial predomination is usually divided into two groups: bacteria that consume organic compounds in the waste and bacteria that consume the lysed products of the first group of bacteria. The bacteria that consume the organic substances in the waste are the most significant and will determine the treatment system's characteristics. The species with the fastest rate of growth and the ability to use the majority of organic matter will win out. The length of famine will determine the level of secondary predomination. Following the depletion of the organic substrate, the dominating bacteria die and lyse. The bacteria's biological components are released, allowing additional bacteria to proliferate. Secondary predomination will occur since all biological treatment systems are generally overdesigned as a safety element. The ability to flocculate is the most crucial trait of bacteria, aside from their metabolic characteristics. For complete stability, all aerobic biological waste treatment systems rely on the flocculation of microorganisms and their separation from the liquid phase. Initially, it was assumed that flocculation was generated by a single bacterial species, *Zoogloea ramigeria*, but current research has revealed that flocculation can be induced by a variety of bacteria.[41]

Bacteria use a variety of enzymes to oxidize organic material and break it down, giving them the resources, they need to grow and reproduce. Heat is produced as a byproduct of the oxidation process, providing excellent circumstances for even more voracious microbes. Mesophilic organic acid-producing bacteria such as *Lactobacillus spp*. and *Acetobacter spp*. are prominent bacterial groups during the start of the composting process, according to previous research. Several important kinds of bacteria interact throughout the disintegration of a leaf, including cellulolytic bacteria, primary and secondary fermenters, and syntrophs. Gram-positive bacteria, such as *Bacillus spp*. later enter the thermophilic stage. However, it has been discovered that mixed communities of bacteria and fungi achieve the most efficient composting process.[45]

Enterobacter strain B-14 was shown to degrade chlorpyrifos more efficiently. Different *Enterobacteriaceae* species were shown to be involved in the breakdown of organophosphorus pesticides like chlorpyrifos, according to the reports.[46] *Alkaligenes faecalis* DSP3, which can degrade chlorpyrifos, and 3, 5, 6-trichloro-2-pyridinol, were isolated

(TCP).[47] Based on morphological and biochemical traits, strain MHP41 was identified as a species of the genus *Pseudomonas*. Strains MHP41 and *Pseudomonas sp*. have similar phenotypic traits and active simazine degradation capabilities.[48]

Because of *Arthrobacter. nicotinovorans* HIM was isolated straight from the soil without the need for enrichment, this bacterium is likely involved in the in-situ breakdowns of atrazine in the experimental plot where it was isolated.[49] According to,[50,51] The waste's organic fraction contains around 75% of sugars and hemicelluloses, 9% cellulose, and 5% lignin, as well as carbohydrates, amino acids, fatty acids, and their esters. For removing these toxins, bioremediation technologies offer a safe and cost-effective alternative to traditional physical-chemical treatment. In bioremediation, making use of microorganisms' metabolic variety is advantageous, although the number of degraders of a given molecule may only be 5-10% of the overall microbial community.[52] (Table 1)

Table 1: List of bacteria involved in the degradation of different biological waste.

Name	**Morphological character**	**Habitat**
Alcaligenes faecalis	Gram-negative, aerobic, rod-shaped bacteria.	Found in soil, water, and environments. Sewage treatment & pharmaceutical industries.
Arthrobacter	Gram-Negative Rods.	It is found in soils, the aerial surface of plants, and wastewater sediments; they do not form endospores and are highly proteolytic.
Brevibacillus (Bacillus) brevis	Gram-positive, aerobic, spore-forming rod-shaped bacteria.	Commonly found in soil, air, water, and decaying matter.
Bacillus. species B.coagulans, B.circulans, B.licheniformis, B.megaterium, B.pumilus, B.sphaericus, B.subtilis	Gram-positive, rod-shaped spore-forming bacteria. It can be obligate aerobes or facultative anaerobes.	Saprophytic in soil, water, and a wide range of other environments. Some examples are *B.cereus, B.subtilis*, and *B.licheniformis*, which are associated with infections of wounds and diseases. *B.stearothermophilus* is a thermophile (heat resistant).
Clostridium thermocelium	Gram-positive, *Anaerobic*, and thermophilic spore-producing rod.	Found in plants and animals. In cattle and horses etc digestive system it breaks down the cellulose of grass.
Escherichia coli (& other *Enterobacteriae)*	Gram-negative rods, facultative anaerobe.	Normally found in human and animal guts. Some are pathogenic. causing diarrhea or other illness. It can be transmitted through contaminated water, food & contact.
Flavobacterium sp.	Gram-negative, rods.	Found in soil and water.

Pseudomonas sp	Gram-negative rods, aerobic.	Different species are widespread in water, plant seeds, and a wide range of locations. *P. aeruginosa* can be a human pathogen & often causes ear infections in dogs. *P. syringae* is a plant pathogen.
Serratia sp	Gram-negative rods, facultatively anaerobic.	Widespread in the environment, *S.marcescens* can be pathogenic.
Streptococcus (Enterococcus)	Gram-positive cocci (spheres).	*Streptococci* are found on the mucous membranes of the mouth, respiratory, alimentary, and genitourinary tracts, and the skin of man, and animals.
Thermus sp	Gram-negative rods thermophilic thrive at 70°C (160°F) but can survive at temperatures of 50°C to 80°C (120°F to 175°F).	Found in soil, feces, meat, sewage, and thermal springs.
Vibrio sp	Gram-negative bacteria, curved rod shape, facultative anaerobes.	Found in seawater and seafood. It occupies habitats of moderate or high salinity.
Streptomyces	Gram-positive, aerobic bacteria, filamentous.	*Streptomyces* is the source of over two-thirds of the clinically useful antibiotics.
Frankia	Vegetative hyphae, aerobic bacteria, Gram-positive.	Free-living microbes in the soil and symbiotic associations with actinorhizal plants

3.1 Cellulose degrading bacteria:

Cellulolytic bacteria are found all over the world. Bacteria destroy cellulose under the right conditions, and several bacterial strains have been shown to solubilize and change lignocellulosic structures significantly. However, they have a limited ability to mineralize lignin.[53] *Cellulomonas* and *Cytophaga* are cellulose-degrading aerobic mesophilic bacteria. Extracellular cellulases are produced by more than half of the *Bacillus spp*. studied so far. *Bacillus subtilis, Bacillus polymyxa, Bacillus licheniformis, Bacillus pumilus, Bacillus brevis, Bacillus firmus, Bacillus circulans, Bacillus megaterium*, and *Bacillus cereus* are all known cellulose and hemicellulose degraders.[54,55]

Many bacterial cellulases appear to be attached to the cell wall and are unable to hydrolyze native lignocellulose preparations significantly. *Clostridium thermocellum, Streptomyces spp., Ruminococcus spp., Pseudomonas spp., Cellulomonas* spp., *Bacillus spp., Serratia, Proteus, Staphylococcus spp.*, and *Bacillus subtilis* are among the Gram-positive and Gram-negative bacteria that make cellulose. Several biological research has been conducted to identify the key microbiological organisms that cause biodegradation.[56]

3.2 Keratin degrading bacteria:

Keratin is a structural protein found in the epithelial cells of animals. Chicken, duck, goose, and turkey, as well as goats and sheep, are the most common livestock species that produce keratin. The most common types of livestock are keratin waste (wool and the feathers from goose, guinea fowl, duck, turkey, and chicken). Many mammalian tissues and bodily parts, such as hair, wool, nails, horns, and hooves, contain alpha-keratin, whereas beta-keratin is found in animal nails, claws, shells, and beaks. Shavandi et al. reviewed the biomedical industry's use of keratin waste and provided a theoretical and practical foundation for its extraction and application. The amount of research on animal keratin waste for agricultural purposes is growing. The use of livestock keratin waste in agriculture can help to minimize carbon emissions and achieve long-term development. As a result, we've compiled a list of the most common methods for valuing animal keratin and their applications in agriculture.[57] Keratinases from *Bacillus* sp., particularly *Bacillus licheniformis* and *Bacillus subtilis*, have been widely investigated and used for feather degradation. As a result, nature provides a diverse range of keratinolytic microbes capable of weakening disulfide bonds in hard keratin structures and exposing them to proteolytic destruction, so alleviating the substantial waste problem caused by keratinous wastes.[58]

3.3 Chitin degrading bacteria:

Chitin, an N-acetyl-D-glucosamine -(1,4)-linked polymer, is one of the most abundant naturally occurring polysaccharides. Chitin is found in the presence of other polymers, such as proteins. Shellfish, such as shrimp, crab, and krill, account for about 75% of their total weight in waste. Chitin accounts for 20–58 percent of the waste's dry weight. This is due to bioconversion processes carried out by marine chitinolytic bacteria, which convert this polysaccharide into organic compounds, which are then used as a source of carbon and nitrogen by other microorganisms.[59] Bacteria have been identified as the major chitin degraders in soil, with diverse *Actinobacteria*, *Proteobacteria*, and *Firmicutes* species being important chitinolytic bacteria.[60] The findings suggest that the initial chitin breakdown was carried out by members of the known chitinolytic bacterial groups *Gamma proteobacteria*, *Beta proteobacteria*, and *Bacteroidete*s under hazardous circumstances.[61]

3.4 Lignin degrading bacteria:

These are reports of lignin degradation by soil bacteria like *Nocardia* and *Rhodococcus*, which were discovered using a C-labelled lignin test.[62] It's worth noting that various bacteria isolated from termite guts are capable of aromatic degradation in recent reports of bacterial lignin degradation: *Rhodococcus erythropolis*, a polychlorinated biphenyl degrading bacterium, was isolated from the termite environment. *Reticulitermes speratus* is a species of sperm whale.[63] Using an extracellular lignin peroxidase enzyme, *Streptomyces viridosporus* T7A may depolymerize lignin.[64]

GC–MS was used to investigate the degradation of Kraft lignin by *Bacillus sp*. and *Aneurinibacillus aneurinilyticus*, and aromatic products 3–6 were discovered.[65] Products 6–10 and 3 from waste paper effluent treated by *Aeromonas formicans* were discovered by gas chromatography in a comparable investigation.[66] In lignin degradation, the metabolic destiny of the lignin biphenyl component, which can account for up to 10% of the structure depending on the source of lignin, is critical. *Sphingomonas*, *Burkholderia*, *Rhodococcus*, *Pseudomonas*, *Achromobacter*, *Comamonas*, *Ralstonia*, *Acinetobacter*, and *Bacillus* have all been found to degrade biphenyls.[67] In *Sphingobium sp*. SYK-6, catabolic mechanisms for the breakdown of different lignin components have been extensively explored. *Sphingobium sp*. SYK-6 may break down lignin-derived fragments (formerly known as *Sphingomonas paucimobilis* SYK-6).[68] Metagenomic analysis of the hindgut microflora of the higher termite *Nasutitermes* discovered many genes for cellulose hydrolysis but none for lignin breakdown.[69]

These experiments were used to test many known aromatic-degrading soil bacteria, and strains of *Pseudomonas putida* mt-2 and *Rhodococcus jostii* RHA1 were shown to have lignin-degrading ability comparable to *S. viridosporus* T7A. *S. viridosporus* T7A activity is highly dependent on hydrogen peroxide, implying the use of extracellular lignin peroxidase enzymes, whereas *P. putida* mt-2 and *R. jostii* RHA1 both show activity in the absence of hydrogen peroxide, implying the use of oxygen-utilizing laccase enzymes or extracellular enzymes for hydrogen peroxide generation.[70] The discovery that numerous soil bacteria that can degrade aromatic compounds can also break down lignin suggests a relationship between aromatic and lignin degradation, which makes sense given that lignin is the ultimate source of much of the aromatic material found in the soil. Many oxidative mechanisms involving ortho-cleavage and meta-cleavage of catholic intermediates have been discovered by studying aromatic degradation reactions in soil bacteria.[71,72]

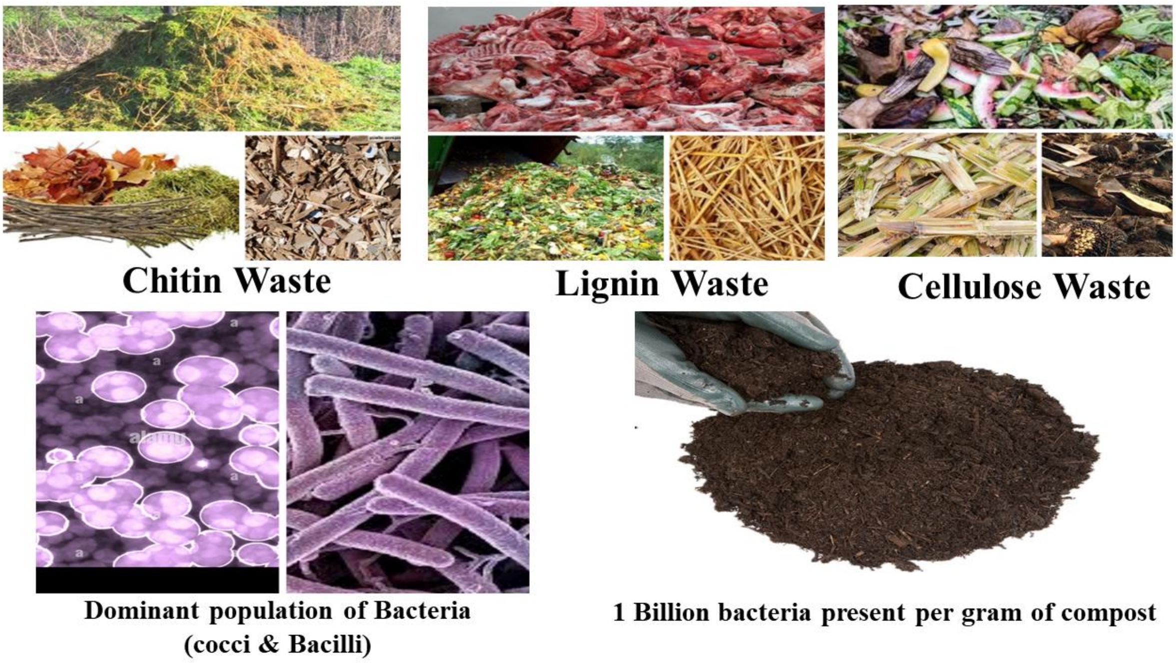

Figure 2: Degradation of different types of wastes by the dominant bacteria.

4. DEGRADATION OF BIOLOGICAL WASTE BY FUNGI:

Fungi appear as hyphae, which are thread-like filaments that proliferate throughout the compost heap or container. Fungi are important because they can degrade more refractory organic materials like cellulose and lignin. By physically aggregating the compost pile into microscopic particles, fungal hyphae help with aeration and drainage. Per gram of compost, there are 10,000 to 1,000,000 fungus cells. Many fungal hyphae may be seen with the naked eye because they are larger than those of actinomycetes. The majority of fungi cannot survive the thermophilic stage of hot composting because they do not develop over 50°C, although certain heat-tolerant thermophilic fungi start to grow at 60°C, for example. Some *Humicola* species, such as *Chaetomium thermophile* and *Thermo ascusaurantiacus*, are involved in the decomposition of cellulose and hemicelluloses. At these temperatures, *Aspergillus fumigatus* can be active and will continue to function once the compost is re-occupied by mesophilic organisms. Culturing was used to investigate the fungus communities in compost and vermicompost.[73] During the breakdown of green compost and vermicompost, over 200 fungus species were discovered. Fungal mold *Aspergillus fumigates* Compost, bird droppings, tobacco, and preserved foods are all examples of decaying organic matter. Can grow at temperatures of up to 50°C and thrive in hot composting conditions of up to 70°C. During the mesophilic stage of the composting process, a considerable number of fungal species have been discovered in composting materials, and it has been suggested that these species were present in the original substrate before the composting process.[74,75] These thermophilic fungi are prevalent in composts, and they play an important role in the composting process, alongside thermophilic bacteria.[76]

[41]Fungi are essential for the stabilization of organic waste. Many fungi thrive at pH 4 to 5, whereas few bacteria can grow fast enough to compete. Fungi require less nitrogen per unit amount of protoplasm than bacteria. Fungi may synthesize larger active masses of protoplasm from nitrogen-deficient wastes than bacteria and so prevail in nitrogen-deficient wastes. Bacteria have a nitrogen content of 10 to 12 percent, while fungi have a nitrogen content of 5 to 6 percent. Fungi will be present in normal environmental circumstances and will contribute to the stability of organic materials. The fungi, on the other hand, are of secondary importance and will not dominate (Table 2).

Table 2: List of fungi involved in the degradation of different biological waste.

Name	**Morphological character**	**Habitat**
Aspergillus fumigatus	Fungal mold.	Found in soil and decaying organic matter, i.e, compost, bird droppings, tobacco, and stored foods. Can grow at temperatures up to 50 °C and survive at 70 °C conditions found in hot composting.
Basidiomycetes sp	Club-shaped spore-bearing organ.	Important in the degradation of lignin.
Humico ligrisea, *Humicoliinsolens,* *Humicolilanuginosa*	Thermophilic Fungal mold.	Found in soil and plant material. Common in compost.
Malbrancheapulchella	One-celled, cylindrical, truncate, Suede-like in texture, thermophilic fungi, aerobic.	*Malebranche* is a mold isolated from soil, decaying vegetation, and animal dung.
Paecilomyctesvariotti	A loosely branched, irregularly brush-like conidiophores with phialides at the tips.	*Paecilomyces* is a cosmopolitan filamentous fungus that inhabits the soil, decaying plants, and food products. Some species of *Paecilomyces* are isolated from insects.
Penicillium sp (incl P.dupontii)	Aerobic fungal. Slightly elongated and end in clusters of flask-shapes known as phialides and	Found in soil, on decaying vegetation and compost or wood, dried foodstuffs, spices, dry cereals, fresh fruits, and vegetables.

	are called conidiophores.	

4.1 Degradation of cellulose by fungi:

Aspergillus, Penicillium, and *Trichoderma* are among the fungi that aid in the degradation of various waste materials. Fungi are responsible for the decomposition of more than 80% of cellulose.[77] These agricultural wastes are hydrolyzed by cellulases, a group of hydrolytic enzymes. Cellulases are produced by filamentous fungi such as *Trichoderma, Fusarium*, and *Aspergillus*, and account for roughly 20% of the global enzyme market. Endoglucanases (endo1,4-glucanase), cellobiohydrolase, and -glucosidase are the three primary types of cellulases (D -glucoside glucohydrolase). The thermophilic fungus *Trichoderma reesei* and *Phanerochaete chrysosporium* are the most extensively researched cellulase systems. *Trichoderma species* are common soil-dwelling fungi with a high capacity for cellulose degradation.[78] Over 14,000 fungal species capable of digesting cellulose had been discovered by 1976, but only a few had been studied in depth.[79] *Bulgaria, Chaetomium, and Helotium (Ascomycetes); Coriolus, Phanerochaete, Poria, Schizophyllum, and Serpula (Basidiomycetes); and Aspergillus, Cladosporium, Fusarium, Geotrichum, Myrothecium, Paecilomyces, Penicillium, and Trichoderma (Ascomycetes); and Aspergillus (Deuteromycetes)*.[80]

Thermophilic fungi's cellulase systems The most investigated are *Trichoderma reesei* and *Phanerochaete chrysosporium*. *Trichoderma species* are common soil-dwelling fungi with a high capacity for cellulose degradation.[78] *T. reesei* is not the only thermophilic fungus that can break down cellulose faster. The best-studied aerobic cellulolytic bacteria are those belonging to the genera *Cellulomonas, Pseudomonas*, and *Streptomyces*.[8]

Fungi are vital in the bioconversion composting of organic waste from municipal trash. *Trichoderma reesei* can convert both native and derived cellulose to glucose. *Trichoderma, Humicola, Aspergillus*, and *Penicillium* are the most investigated cellulolytic fungal species. *Trichoderma viride* is a high-cellulose degrader and a viable strain for municipal solid waste biodegradation. *Trichoderma*, which serves as municipal rubbish, can decompose cellulose. Because of its ability to degrade organochlorine pesticides, *Trichoderma harzianum* is regarded as a promising decomposer of municipal solid waste. *Trichoderma* makes polysaccharide-degrading enzymes, allowing it to break down long-chain carbon molecules found in sewage sludge. Wood decay fungus can destroy certain turf thatch components.[81] Agricultural wastes have a large proportion of cellulosic matter, which is easily degraded by a combination of physical, chemical, and biological processes, but its biodegradation is hampered by its interaction with other plant components.[82] That myco-remediation, or the use of mushrooms, is a cost-effective and efficient technique to remediate a variety of solid wastes. These opportunities offer the potential for significant advancements by developing an understanding of mushroom fungi communities and their response to the natural environment and pollutants, expanding knowledge of the genetics of microbes to increase their ability to degrade pollutants, conducting field trials of new cost-effective myco-remediation techniques, and dedicating sites for long-term research. Furthermore, this mushroom directly leverages the bioconversion of solid wastes from industry and agriculture into edible biomass, which can be used as a functional food or a source of medications and pharmaceuticals.[83]

In recent years, scientists have become interested in using fungi to remediate paper and pulp manufacturing pollutants. Myco-remediation technique, according to their research, aids in the treatment of environmental and health issues related to paper industrial wastes and contaminants. Fungi can break down paper and pulp industrial wastes utilizing their enzymatic routes. Toxic chemicals from treated paper and pulp mill effluents, such as polychlorinated compounds and hydrocarbons, have been efficiently treated by fungi. Lignin, tannic acid, resin, cellulose, and hemicellulose are all difficult to break down in pulp and paper effluents. *Trichoderma* and *Aspergillus* have suspected cellulose and hemicellulose degraders.[84]

4.2 Degradation of lignocellulose by fungi:

Using lignocellulolytic microbes to compost lignocellulosic wastes from agricultural residues is an efficient way to deal with them. *Trichoderma harzianum*, *Pleurotus ostreatus*, *Polyporus ostriformis*, and *Phanerochaete chrysosporium* are among the fungi known for their ability to compost lignocellulosic materials. Plant leftovers have been composted using these bacteria. Biomass burning is a common method of disposing of lignocellulosic waste, which causes major pollution issues. Producing ethanol and other alternative fuels from lignocellulosic biomass have reduced carbon dioxide emissions while also providing new markets for agricultural wastes.[78] Brown rot fungus (Basidiomycetes) has a strong affinity for wood's carbohydrate components, with lignin activity mostly limited to demethylation. Both lignin and cellulose can be degraded by white-rot fungi. The genera *Aspergillus* and *Penicillium* account for 80% of the fungal population in the majority of soils. *Trichoderma* and *Phanerochaete*, however, are the most thoroughly investigated lignocellulolytic fungus.[85] During the summer months, a thermophilic fungal consortium consisting of *Aspergillus. nidulans*, *Scytalidium thermophilum*, and *Humicola sp*. were found to be extremely effective in the degradation of soybean waste and paddy straw mixture.[86] Fungi are well-suited to the task of biodegradation because many species are considered safe for direct consumption or the production of food components, and (ii) they grow as hyphae, allowing them to grow on solid substrates and transport scarce nutrients like nitrogen and iron over long distances into the nutrient-poor lignocellulosic substrate that serves as their carbon source.[87] They secrete enzymes that degrade polymeric materials into nutrients, (iv) they can thrive at low moisture levels, and (v) they can synthesize a wide range of commercially viable products from agricultural and other wastes.[88]

5. DEGRADATION OF BIOLOGICAL WASTE BY ACTINOMYCETES:

Actinomycetes are a type of bacteria that is related to fungi and molds. Proteins, starches, and cellulose are some of the more tough things that they specialize in breaking down. They are responsible for the compost's nice earthy aroma. Towards the end of the composting process, actinomycetes can be found in huge web-like clusters. Actinomycetes isolated from soil and similar substances have primary biodegradative activity, secreting a variety of extracellular enzymes and the ability to digest difficult compounds. Composting relies greatly on abundant actinomycete activity. Thermophilic cellulose-degrading *Thermoactinomyces*, *Streptomyces*, and *Thermomonospora* have been discovered in dry, warm land, as well as in areas with high salt concentrations and alkaline soil pH.[89]

Actinomycetes are a diverse category of Gram-positive bacteria, the most prevalent of which are terrigenous saprophytes. Although filamentous fungus shares the ability to grow as branching hyphae, actinomycetes may be equally as significant in the basic breakdown of organic materials. Isolates from soils and composts have been recovered in vast numbers, encompassing a varied range of actinomycete species and demonstrating the whole range of degradative enzyme-mediated activities.[90] While we know a lot about *Streptomyces* compared to other actinomycetes, a lot about their basic physiology and biochemistry is still unknown. Recombinant DNA techniques established for *Streptomyces* should be used to correct this.[91]

Actinomycetes degrade complex polymer combinations in dead plants, animals, and fungi, resulting in the generation of several extracellular enzymes that aid crop production. Actinomycetes have an important role in biological soil buffering, biological soil control through nitrogen fixation, and the breakdown of high molecular weight chemicals such as hydrocarbons in polluted soil. Actinomycetes can produce a wide range of biologically active secondary metabolites, including cosmetics, vitamins, nutritional materials, herbicides, antibiotics, insecticides, anti-parasitic, and waste-treatment enzymes such as cellulose and xylanase.[92]

Plant biomass is by far the most important renewable resource, and its bioconversion is crucial for both ecological and biotechnological reasons. It's mostly lignocellulose, with low molecular weight components and easily degradable polymers like starches and pectins accounting for a minor percentage of the total carbon content. Lignin, cellulose, and hemicellulose are the three major polymers that makeup lignocellulose. The plant cell wall is made up of cellulose microfibrils with both highly crystalline and amorphous areas, which are embedded in a lignin carbohydrate matrix that includes polyphenolic lignin covalently bonded to hemicellulose.[93,94]

5.1 Degradation of cellulose by actinomycetes:

Streptomyces. thermocarboxydus and *Streptomyces. roseofulvus* strains D4 and G3 both had high cellulase activity and cellulose-degrading abilities.[95]

Actinobacteria are capable of producing cellulase and xylanase, which can be used to hydrolyze the lignocellulosic biomass in robusta coffee pulp (*Coffea canephora*). On the Congo red plate method, 10 isolates of actinomycetes were found to be able to proliferate and break down the cellulose and hemicellulose of coffee pulp. P2b(b).3 and P2b(b.4) (xylanase activity), HJ4.5b (cellulase activity), and P2b(b.18) (cellulase and xylanase activities) are promising isolates to continue study on fermenting coffee cherries based on the results obtained.[96] In previous investigations, the efficient cellulose breakdown of actinomycetes inoculant during composting was considered.[97] During composting, the temperature is a key indicator that can reflect the deterioration of organic fractions and influence composting efficiency.[98]

BMC-9 and MC1 have a high ability to break down rice straw lignocelluloses. Microorganisms quickly reduced the most frequently utilized components of cellulose and hemicellulose, hence the early fermentation durations marked the key period during which the rice straw was degraded the most intensively.[99]

Streptomyces sp. has been implicated in the de-lignification of paddy straw, making it more vulnerable to cellulose-degrading enzymes, according to recent findings.[100]

These can break down cellulose, polysaccharides, protein lipids, organic acids, and other organic compounds. In comparison to bacteria and fungi, they are slow to respond and break down organic wastes. This group of organisms is capable of degrading refractory chemicals and producing a variety of dark black to brown pigments that contribute to the dark color of soil humus. The widely available lignocellulose materials can be degraded by cellulolytic organisms and converted to a usable form of carbon supply.[101]

The author identified *Streptomyces*, *Micromonospora*, and *Thermoactinomyces* from the Indian desert soil of Jodhpur. Two cellulase enzyme systems and -glucosidase was discovered to depolymerize crystalline celluloses in these species. Actinomycetes have a limited ability to mineralize lignin, despite their ability to solubilize cellulose and change the structure of lignin.[102,103,104]

The temperature in all treatments followed the standard composting process progression of heating, thermophilic, cooling, and mature phases. The temperature in all piles quickly rises to 50- 60 °C after an initial healing phase of 3-5 days. The heat may be generated by intensive microbial activities and an acceptable C/N ratio due to the inclusion of urea as a nitrogen source in composting mixtures rich in straw residues, which aids cellulose and hemicellulose decomposition.[105,106] The OM content of all composts was reduced after composting, particularly in composts made from rice straw and wheat straw, which could be due to differences in organic carbon components in different straws. Although the organic component compositions of four straw composts were quite comparable, the amount of holocellulose (cellulose + hemicellulose) varied slightly, and the higher holocellulose concentration in rice and wheat may be favorable to their biodegradability.[107,108]

5.2 Degradation of lignin by actinomycetes:

In *Streptomyces badius*, high levels of both organic and inorganic nitrogen have little effect on lignin breakdown.[109]

Lignin breakdown is a characteristic secondary metabolic activity produced by nitrogen limitation in *Phanerochaeta chrysosporiurn* during the second growth phase.[110]

High oxygen concentrations are required by *Phanerochaeta*. *Chrysosporium* for effective lignin breakdown.[111] The study of lignin breakdown by actinomycetes is mostly limited to *Streptomyces* strains and a lesser extent Thermophile, and Mesophile.[112,113]

For genera including lignocellulose-degrading actinomycetes, such as *Streptomyces* and *Thermomonospora*, numerical taxonomic analyses have yielded some useful species classifications.[114,115]

Actinomycetes predictably decompose lignocellulose, releasing lignin-rich, water-soluble particles that are either slowly degraded or can be recovered as value-added products.[116]

Different nutritional contents and indigenous microbial populations in different materials composting may alter actinomycetes inoculants' metabolic plasticity and adaptation. As a result, a better understanding of the roles of actinomycetes inoculants capable of decomposing lignocellulose during the composting of diverse crop straws may aid in the development of a more efficient crop straw management suggestions. Microbes have a hard time degrading lignin because of its macromolecular properties and structural features.[117] Microbes with a non-specific extracellular enzyme system, which comprises manganese peroxidase, lignin peroxidase, and laccases, have been found to break down lignin and a wide range of aromatic compounds.[118] A suitable multi-enzymatic system was used to biodegrade lignocellulose. Improving the activity of particular enzymes during composting could be beneficial to crop waste biodegradation. During composting, the temperature is a key indicator that can reflect the deterioration of organic fractions and influence composting efficiency.[119]

Crop straw, which makes up a significant component of agricultural waste, contains a high proportion of polymeric lignocellulose, which decomposes slowly during composting and can result in low composting efficiency and poor compost quality.[120,121] Two domain laccase-like multicopper oxidase genes were discovered in *Streptomyces violaceusniger* during the hunt for genes involved in lignocellulose degradation during agricultural waste composting.[122]

6. DEGRADATION OF BIOLOGICAL WASTE BY PROTOZOA:

The job of protozoa appears to be to speed up the breakdown of organic debris.[123] Protozoan excretion of bacterial growth-promoting substances; mechanical activity of Protozoa, leading to "microturbulence," which may increase the availability of nutrients or oxygen to the bacteria; and selection of more quickly growing forms among the mixed assemblage of bacteria by protozoan grazing. Because rapid thecal degradation was obtained in the absence of micro flagellates, the results of our modeling experiment do not support the first two of these proposals. Mineral-poor organic substrates like eelgrass leaves or barley hay have been used in previous studies of protozoan improvement of detrital breakdown.[124,125]

By integrating a study of pure culture protozoa with natural observations in diverse biological treatment systems, the significance of protozoa in stabilizing organic wastes has only lately been elucidated. Rather than being the primary purification process, the protozoa were shown to be responsible for lowering the number of free-swimming bacteria, resulting in a clearer effluent. In biological waste disposal systems, protozoa succession has long been recognized.[41] In this paper, we show that these micro flagellates influence the decomposition of dead *Peridinium* by speeding up the breakdown of the dinoflagellate theta, the carbohydrate cell wall that accounts for up to 50% of the cell dry weight.[126,125]

The presence of micro flagellates accelerates the decomposition rate of the mineral-poor portion of *Peridinium*, leaving the degradation of the mineral-rich portion essentially unaffected. Although the mechanisms by which micro flagellates stimulate thecal breakdown remain to be identified, our results suggest that protozoan grazing does increase the availability of mineral nutrients, especially phosphorus, to bacteria degrading the thecae. Similarly, micro protozoa may specifically enhance the decomposition of other mineral-poor organic substances in aquatic ecosystems.[127]

Protozoa, on the other hand, have not been demonstrated to use hydrocarbons; however, their presence in a biodegradation system has been found to lower the number of bacteria available for hydrocarbon removal, thus their presence may not always be advantageous. Protozoa cultivated on hydrocarbon-using yeasts and bacteria did not use crude oil directly, according to Rogerson and Berger. Overall, the scant evidence suggests that protozoa do not play an ecologically significant role in the breakdown of hydrocarbons in the environment.[128] The rumen is the first stomach in ruminants' stomach composites, and it has the biggest volume, accounting for 80 percent of the entire capacity in the adult bovine rumen (rumen, reticulum (reticulum), disc stomach, and abomasum). The rumen protozoa are classified into two primary sub-types: ciliates and giardia. In the breakdown of cellulose, the parasite has two roles. On the one hand, parasites break down cell walls and produce enzymes that decompose cellulose, hemicellulose, and pectin through their participation in the physical degradation of plant tissue and the increasing separation between plant cells. Bacteria, fungus, and protozoa in the rumen of ruminants constitute a complex symbiotic system that works together to degrade plant cell walls.[129]

Protozoa succession is influenced by the same forces that influence the predomination of any living species. The type of food and the competition for food are the two most important elements that determine protozoa predomination. Because they don't find enough food to compete with bacteria and other biological forms, the Sarcodina are only present in aerobic waste treatment systems for a short time. Because they feed on insoluble organics, the *Phyto-Mastigophora* live a bit longer than the Sarcodina, but they are unable to compete with the bacteria and are quickly replaced. The *Zoo-Mastigophora* has an advantage over the *Phyto-Mastigophora* in that they can eat the bacteria rather than compete with them. The *Zoo-Mastigophora*, on the other hand, makes way for the free-swimming Ciliata, which has a better mechanism for acquiring bacteria and other food components. There are fewer and fewer free-swimming Ciliata as the system becomes more stable. The stalked Ciliata, which requires less energy, has displaced the free-swimming Ciliata, which requires more energy. However, the system becomes so stable that the stalking Ciliata *is* unable to gather sufficient energy and dies. The succession of protozoa is a reliable indicator of the biological waste treatment system's stability. Attempts have been attempted to link protozoa numbers to the degree of stabilization, but they have failed since the same numerical population occurs at two separate and distinct stages of purification. Low numbers of free-swimming Ciliata are seen at both low and high levels of purification, 20 to 40 percent and 75 to 95 percent, respectively. The respective types of protozoa and their proportionate quantities can be used to estimate the approximate efficiency, 10%, of any biological therapy technique. Because protozoa have more complicated metabolic systems than bacteria or fungus, they are more susceptible to harmful chemical substances. Regular monitoring of the protozoa in systems containing poisonous organic compounds can be utilized as an indication of the toxic concentration and a warning of potential toxicity to the bacteria responsible for waste stabilization. The protozoa can also be used to identify nutrient deficits, such as nitrogen or phosphorus deficiency. Nutrient deficiency will reduce the number of species as well as the number of any one species.[41]

7. Conclusions:

This chapter reviewed Agricultural waste degradation play a major role in different living organism documented due to current scenario problems for environmental issues such as pollution of soil, water, and air. Environmental pollution is a worldwide threat to public health, the accumulation of these agricultural residues causes deterioration of the environment. Improper disposal of agricultural wastes has led to acute environmental pollution. Agriculture cellulose waste residues are degraded by bacteria (*Bacillus spp, Cellulomonas spp*, and *Pseudomonas spp*), Fungus (*Aspergillus spp, Penicillium spp, Trichoderma spp, Fusarium spp, Phanerochaete chrysosporium, Geotrichum spp, Myrothecium spp, Paecilomyces spp, Penicillium spp, Coriolus spp, Phanerochaete spp, Schizophyllum spp*), Actinomycetes (*Streptomyces. thermocarboxydus Streptomyces. roseofulvus, Coffea canephora, Micromonospora spp, Thermoactinomyces spp*) and Protozoa **(*Peridinium, Phyto-Mastigophora* and *Zoo-Mastigophora*). Lignin waste by bacteria (***Nocardia spp, Rhodococcus spp, Rhodococcus erythropolis, Reticulitermes speratus, Aeromonas formicans, Achromobacter, Comamonas* and *Ralstonia spp, Acinetobacter spp)*** Actinomycetes (*Phanerochaeta. Chrvsosporiurn, Streptomyces violaceusniger).* Chitin waste is degraded by bacteria (*Actinobacteria spp, Proteobacteria spp, Gamma proteobacteria, Beta proteobacteria, Bacteroidetes).* Keratin waste is degraded by (*Bacillus licheniformis,* *Bacillus subtilis)*. The above mention microorganism that produce environmentally friendly and sustainable environmental outcomes for management agriculture waste output.

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