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Plastic Degrading Bacteria

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ABSTRACT : Plastic is widely used in today's world because it is strong, light, and doesn't easily break down. Every year, about 140 million tons of plastic are made around the world. A large part of this ends up in the environment as waste, especially from industries. Around 30% of plastic is used in packaging for food, cosmetics, medicines, and chemicals, and this number is increasing each year.Because plastic takes hundreds of years to break down naturally, it causes serious problems for land, air, and water. Common ways to get rid of plastic, like burying it in landfills or burning it, also cause harm. Landfills take up valuable space, and burning plastic releases harmful gases into the air. Recycling is better, but it is expensive and doesn't always give good results.To solve this problem, many countries are trying to reduce plastic use. Some, like Bangladesh, have even banned plastic bags. Many places now follow the 3Rs—Reduce, Reuse, and Recycle—to manage plastic waste.

One new and promising way to deal with plastic waste is biodegradation, which means breaking plastic down using tiny living things like bacteria and fungi. This process turns plastic into safe materials like carbon dioxide, water, and methane. Fungi are especially useful because they make enzymes that can break down plastics like polyethylene (PE), PVC, PET, and polyurethane (PUR).Scientists have found several enzymes—like laccases, cutinases, and lipases—in fungi that work well in breaking down plastic in the lab. These fungi come from different groups and show great potential for use in real-life situations. More research is being done to improve these enzymes using genetic techniques. If successful, fungal biodegradation could become a natural, low-cost, and safe way to reduce plastic pollution and protect the environment.

I. INTRODUCTION

Today in this modern world plastic has become an essential product in human life. Approximately around 140 million tons of plastic is produced every year. Among that major amount of plastic is found in Ecosystem as Industrial waste products. Packing of food products pharmaceuticals, cosmetics, detergents, chemical etc. holds around 30% of total worlds usage and increases by 12%. Today paper and other cellulose based are being replaced by plastics due to its better tensile strength, lightness, resistance to water and microbial attack. Plastic has been categorized in following types - polythene (LDPE, MDPE, HDPE) polypropylene (PD), polystyrene (PS) and polyvinyl chloride (PVC). Due to this increasing use of plastic, plastic has become the mother industry to thousands of components and products that are produced in sectors like automobile, electrical good, furniture, agriculture, packaging and sanitary wares, plumbing, construction, etc. As plastic growth is increasing every year over the last century the disposal of this annually produced plastic i.e., 72% of world's plastic is released into the environment or either in landfills or into the sea. Now these disposals methods are increasing soil pollution air pollution and water pollution in the world. Due to this reasons, plastic degradation is becoming an important issue for the entire world. Every country's government is taking efforts for reducing the use of plastic. They are implementing various schemes and rules for the same. Some countries have directly banned the use of plastic in the country. For instance, Bangladesh has banned plastic bags from March 2002 as flooding was caused by blockage of drains in the country due to excess amount of plastic in drainage and pipeline. Many countries have adopted the 3R principle i.e., Reduce, Re-use and Recycle as effective solution for minimizing plastic.

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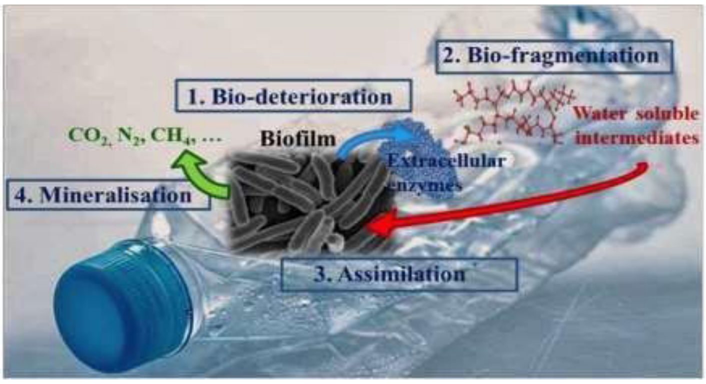
Fig 1: Plastic degrading types



Plastic pollution is a growing environmental problem, in part due to the extremely stable and durable nature of this polymer. As recycling does not provide a complete solution, research has been focusing on alternative ways of degrading plastic. Fungi provide a wide array of enzymes specialized in the degradation of recalcitrant substances and are very promising candidates in the field of plastic degradation. This review examines the present literature for different fungal enzymes involved in plastic degradation, describing their characteristics, efficacy and biotechnological applications. Fungal laccases and peroxidases, generally used by fungi to degrade lignin, show good results in degrading polyethylene (PE) and polyvinyl chloride (PVC), while esterases such as cutinases and lipases were successfully used to degrade polyethylene terephthalate (PET) and polyurethane (PUR). Good results were also obtained on PUR by fungal proteases and ureases. All these enzymes were isolated from many different fungi, from both Basidiomycetes and Ascomycetes, and have shown remarkable efficiency in plastic biodegradation under laboratory conditions. Therefore, future research should focus on the interactions between the genes, proteins, metabolites and environmental conditions involved in the processes. Further steps such as the improvement in catalytic efficiency and genetic engineering could lead these enzymes to become biotechnological applications in the field of plastic degradation.

II. LITERATURE REVIEW

Effective Disposal of Plastic has become an Important issue of today’s era. Many scientists and researchers have studied and are discovering various new methods for disposal of plastic. Among these methods, degradation of plastic using bacteria and microbes is slowly proving to be effective. The findings of some of these researchers on the topic degradation of plastic usingbacteria published in magazines, journals, books, etc. are described below.

History of plastic degrading bacteria

A group of Japanese researchers of Kyoto institute of technology spent five years researching on various types of plastic and their possible degrading methods in various dump sites, landfill, etc. In this research they came across a bacterium ideonella sakaienis 201F6 which had the potential to eat and digest plastic. It was able to break down the major two enzymes i.e., PETast and MHETase in plastic which helped to degrade the plastic within less amount of time. So, they started studying this bacterium, it’s genetic properties and physical properties, etc. After some successful researches and tests they created a bacterium by doing some genetic mutation which increased the degrading capacity and speed of the bacteria. Now this bacterium was able to degrade the plastic in some weeks, which earlier took hundreds of years to degrade. After this discovery many scientists started researching on such bacteria which are able to degrade plastic. Recently in Shiv Nadar University, Greater Noida a Professor named Richa Priyadarshini came across two strains which are able to degrade plastic same like ideonella sakaienis 2016.

The Plastic Problem: Plastic became super popular in the 20th century because it's cheap, strong, and lasts forever. But that’s also the problem—it does last forever. Most plastic doesn’t break down easily, so it piles up in landfills, oceans, and everywhere in between.

Nature Fights Back: Around the early 2000s, scientists started wondering: "Could anything in nature actually eat plastic?" Since bacteria can evolve to eat all kinds of weird stuff (like oil or metal), they became a focus.

Big Breakthrough 2016: In 2016, Japanese scientists discovered a bacterium called Ideonella sakaiensis at a plastic bottle recycling plant. This microbe could actually break down PET plastic (the kind used in most water bottles) and use it as food. It produced two enzymes that chopped plastic into smaller bits it could digest.

Enzyme Engineering: After this, researchers thought, "What if we tweak those enzymes to work faster?" So labs started modifying them to be more efficient. In 2020, a "super enzyme" made by combining two plastic-eating enzymes was created. It worked faster and under easier conditions.

More Microbe Discoveries: Other plastic-munching microbes have been found too—like fungi that can degrade polyurethane (used in foams) and bacteria from compost or landfills that break down other plastic types.

Sr. No.	Paper Title	Author Name	Key Point
1	Norwegian Soils and Waters Contain Mesophilic, Plastic-Degrading Bacteria	Colin Charnock - 2021	Norway, environmental samples, biochemical characterization
2	Aquatic Plastic Waste Biodegradation Using Plastic Degrading Microbes	Angga Puja Asiandu	Algae, bacteria, fungi, plastic biodegradation
3	Coastal Accumulation of Microplastic Particles Emitted From The Po River, Northern Italy: Comparing Remote Sensing And Hydrodynamic Modelling With in Situ Sample Collection	Elizabeth C. Atwood - 2018	Beach sediment, river plume, FT-IR ROMS, plastic degrading bacteria
4	Exploration of Plastic-Degrading Bacteria from Marina Beach, Semarang, Central Java	Awalina Choirunnisa Rachmawati – 2021	Plastic waste, polyethylene, microorganisms, degradation
5	Potential of Bacteria Isolated from Landfill Soil in Degrading Low Density Polyethylene Plastic	E. Munir – 2018	Degradation of plastic, landfills, low density polyethylene, plastic degrading bacteria

IN SUMMARY: The studies collectively highlight the presence and potential of plastic-degrading microorganisms—bacteria, fungi, and algae—in diverse environments such as soils, aquatic systems, beaches, and landfills. They demonstrate effective biodegradation of various plastic types, especially polyethylene and low-density polyethylene, using both natural isolates and environmental sampling techniques. These findings support the development of eco-friendly solutions for plastic waste management through microbial activity.

III. METHODOLOGY OF PROPOSED SURVEY

From many year's researcher have been trying to find an effective technique for Plastic Degradation better than current disposal methods. So, a group of Japanese researchers researched for five years, examining various dumping grounds in search of an effective disposal technique. Two independent searches were made, and the conformity of the selected papers were validated, considering the inclusion criteria described. Furthermore, search results from predatory/unreputable journals, unpublished literature and publications in other languages besides English were not considered for this review. Finally, data from the search results were reviewed, analysed, categorised and presented under the appropriate sections to cover the scope of the project.

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Enzymes involved in plastic biodegradation.

Plastic-degrading enzymes, like other enzymes involved in the biological degradation of polymers, have since been classified into two broad categories, viz., extracellular and intracellular enzymes. However, the most studied group among the two are the extracellular enzymes which possess a wide range of reactivity, from oxidative to hydrolytic functionality. These diverse groups of enzymes have been found to act similarly to microbial laccases, peroxidases, lipases, esterases and cutinases as have since been classified as such. Furthermore, these extracellular enzymes are posited to be involved in heterogenous reactions occurring at the solid/liquid interface, as they act on the macromolecules available at the surface of the solid plastic while present in the liquid phase. Other groups of enzymes are involved in the surface functionalisation of the hydrophobic plastic surfaces, degradation of the plastic metabolic intermediates into monomeric units, and the final mineralisation of the final monomeric intermediates.

Polyethylene-degrading enzyme.

Polyethylene degrading biocatalysts have been identified from actinomycetal, bacterial and fungal sources, which include hydroxylases, laccases, peroxidases and reductases. A manganese peroxidase was identified as the major enzyme involved in the degradation of PE by two lignin- degrading fungi, Phanerochaete chrysosporium and Trarnetes versicolor. Another enzyme, alkane hydroxylase was found to be important in the breaking down of PE by Pseudomonas sp. E4, which was further confirmed by cloning the gene in E. coli and evaluation of the recombinant protein. Subsequently, an enzymatic system in P. aeruginosa was found to contain alkane hydroxylase together with rubredoxin and rubredoxin reductase which was revealed to be responsible for the degradation of low molecular weight PE.

Polyurethane-degrading enzymes.

Different enzymes including cutinases, esterases, lipases, laccases, peroxidases, proteases and ureases from bacterial and fungal sources have been shown to possess PU-degrading abilities. The activity of serine and cysteine hydrolase has been highlighted in the Pestalotiopsis microspore PU degradation Recently, the synergistic effects of esterase and an amidase on the degradation of various PU- derivatives, via a proposed stepwise mechanism, was also demonstrated. Using proximity ligation-based metagenomic analysis, a variety of enzymes involved in PU were identified. The enzymes were shown to be responsible for the metabolism of various PU intermediates and included different dioxygenases, decarboxylases, dehydrogenases, transferases, ligases, hydrolases, isomerases and peroxidases. However, it has been noted that most of the PU- ester-linked PUR and less likely on polyurethane ethers

Nylon-degrading enzymes.

Some nylon-degrading enzymes have been identified from fungal and bacterial sources. Such enzymes include a manganese peroxidase from a white-rot fungus identified as strain IZU-154, which was shown to strip off the surface of Nylon 6 and cause deep horizontal grooves formation in the polymer. Peroxidases are a group of heme-containing enzymes, which catalyse the oxidation of a wide variety of organic and inorganic substrates using hydrogen peroxide as the electron acceptor. In addition, the metabolism of 6-aminohexanoate, an intermediate product of nylon has been shown to be catalysed by three different hydrolases in Flavobacterium and Pseudomonas strains. These enzymes which were identified as 6-aminohexanoate-cyclic-dimer hydrolase, 6-aminohexanoate - dimer hydrolase and endo-type 6-aminohexanoate-oligomer hydrolase, acting in tandem converted the nylon intermediate to its monomer, 6-aminohexanoate, under mesophilic and neutral to alkaline pH conditions.

Polyethylene-degrading terephthalate enzymes.

Since the first description of the enzymatic hydrolysis of PET polymers using Thermobifida fusca hydrolases, many other enzymes including cutinases, esterases, lipases and carboxylesterases have been shown with PET-degrading ability. The enzymatic hydrolysis of PET has been noted to be generally based on a surface erosion mechanism. Perhaps one of the most studied plastic degrading enzymes is PETase, an aromatic polyesterase, from I. sakaiensis 201-F6 with a basic hydrolase fold. This enzyme metabolises PET to bis(2-hydroxyethyl) - TPA (BHET), MHET, and TPA while its accessory enzyme MHETase acts on the MHET intermediate converting it to terephthalic acid and ethylene glycol. The enzyme was, however, thermolabile and subsequent engineering of the PETase enzyme aimed at increasing its thermostability resulted in a new variant which was found to be 14 times more active than the original biocatalyst.

Polystyrene-degrading enzymes.

Even though the microbial degradation of polystyrene by various bacteria and fungi has been demonstrated, the major enzymes involved in the initial depolymerisation of the polymers have not been clearly identified.

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However, an extracellular esterase from Lentinus tigrinus has been shown to breakdown PS. In addition, some polymerases, which were sourced from Bacillus and Pseudomonas species, have also been noted to be responsible for PS degradation. Other enzymes that are involved in the metabolism of styrene, the monomer of PS before its entry into the TCA cycle have been identified as styrene monooxygenase, styrene oxide isomerase, phenylacetaldehyde dehydrogenase, and phenylacetyl coenzyme A ligase.

Mechanism of microbial plastic degradation.

Microbes break down different compounds into simpler forms through biochemical transformation. The biodegradation of plastic polymers can be observed through an alteration in the physical properties of the polymers especially by molecular weight reduction, loss of mechanical strength and change in plastic surface properties. As stated earlier, the objective of plastic biodegradation is the conversion of recalcitrant wastes to non-toxic lower molecular masscompounds that can return into the biogeochemical cycle

Biodegradation.

Biodeterioration is caused by the chemical and physical actions of microbes, or/and other biological agents, that result in the superficial degradation of the plastic polymer as well as modification in the chemical, mechanical and physical properties of the polymers. The changes which are observed in the polymers during biodegradation are also enhanced by prolonged exposure to external conditions which include light, temperature and chemicals in the environment. The biodeterioration process is the first and it is initiated by the adherence and colonisation of microbes on the polymer surface with the sole aim of reducing the resistance and durability of the plastic materials. Thus, the introduction of hydrophilic functional groups to plastic surfaces is often required to promote the attachment of the microorganisms as plastics arenaturally hydrophobic.

IV. CONCLUSIONS

Plastic pollution is a significant global environmental challenge, and traditional waste management approaches are proving insufficient. Biodegradation using microbes has emerged as a promising, sustainable alternative. Among these, plastic-degrading bacteria offer an eco-friendly solution, as they are capable of naturally breaking down synthetic polymers and reducing long-term environmental damage. Research in this area is rapidly growing, although further efforts are needed to translate laboratory findings into real-world applications.Several bacterial genera such as *Streptomyces*, *Rhodococcus*, and *Pseudomonas* have been identified as effective plastic degraders. These microorganisms produce enzymes—particularly esterases and lipases—that are central to breaking down plastic polymers by cleaving chemical bonds. Optimizing the activity and stability of these enzymes can significantly enhance the efficiency of plastic biodegradation. Understanding their biochemical mechanisms is essential for targeted improvements and the development of engineered strains with superior capabilities.Enzymatic degradation represents a key mechanism in microbial plastic breakdown, and it has gained attention as a potential strategy for sustainable plastic waste management. Advances in genetic engineering allow researchers to modify bacteria to express more efficient plastic-degrading enzymes or to survive and function in harsh environmental conditions. Cold-adapted and extremophilic bacteria, for example, show potential for degrading plastics in polar or deep-sea environments, expanding the range of applicable bioremediation conditions.

REFRENCES

1. Charnock, C. (2021). Norwegian Soils and Waters Contain Mesophilic, Plastic-Degrading Bacteria.
2. Chao, A. (2022). Analysis of Endometrial Lavage Microbiota Reveals An Increased Relative Abundance of The Plastic-Degrading Bacteria Bacillus Pseudofirmus And Stenotrophomonas Rhizophila in Women With Endometrial Cancer / Endometrial Hyperplasia.
3. Naveed, M., & Mehmood, U. (2022). Evidence of Plastic Degrading Bacteria in Aquatic Environment.
4. Viel, T., Manfra, L., Zupo, V., Libralato, G., Cocca, M., & Costantini, M. (2023). Biodegradation of plastic induced by Marin Organisms: Further Perspectives For Bioremediation Approaches.
5. Asiandu, A. P., Wahyudi, A., & Sayi, S. W. (2021). Aquatic Plastic Waste Biodegradation Using Plastic Degrading Microbes.
6. Atwood, E. C., & Falcieri, F. M. (2018). Coastal Accumulation of Microplastic Particles Emitted From The Po River, Northern Italy: Comparing Remote Sensing And Hydrodynamic Modelling With in Situ Sample Collection.

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7. Raziyafathima, M., & Praseetha, P. K. (2016). Microbial Degradation of Plastic Waste: A Review.
8. Rachmawati, A. C., & Mahardika, A. (2021). Exploration of Plastic-Degrading Bacteria from Marina Beach, Semarang, Central Java.
9. Munir, E. (2018). Potential of Bacteria Isolated from Landfill Soil in Degrading Low Density Polyethylene Plastic.
10. Urbanek, A. K., & Rymowicz, W. (2018). Degradation of Plastics and Plastic-Degrading Bacteria in Cold Marine Habitats.

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