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Review Article

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A REVIEW ON PLASTICS DEGREDATION BY USING MICROBES

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ABSTRACT

Plastic pollution has emerged as one of the most persistent global environmental challenges due to the widespread use, durability, and accumulation of synthetic polymers. Traditional disposal methods such as landfilling and incineration are inefficient and lead to significant ecological and health concerns. Recent advances in microbial degradation and enzymatic bioremediation have revealed promising ecofriendly strategies for mitigating plastic waste. This review explores the mechanisms, efficiency, and applications of Microbes-mediated degradation of major plastic polymers including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), and polylactic acid (PLA). Key microbial species ; such as Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, and Streptococcus spp. demonstrate selective degradation abilities enhanced by biofilm formation, extracellular enzymes, and oxidative pathways.

Factors influencing degradation, including pH, temperature, microbial density, and polymer crystallinity ,are discussed in detail. The potential of blending polymers with bioplastics, genetic engineering of microorganisms, and optimized culture conditions highlight the

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emerging potential of microbial bioremediation as a sustainable alternative to conventional waste management. This review provides a comprehensive overview of microbial strategies that could significantly contribute to long-term solutions for plastic waste reduction and environmental restoration.

KEYWORDS

Plastic pollution, Enzymatic bioremediation, Biofilm formation, Extracellular enzymes, Environmental restoration.

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INTRODUCTION

Plastic waste has become one of the most persistent and long-term global environmental challenges. Its accumulation affects ecosystems, wildlife, and human health in several harmful ways. Due to its durability and resistance to natural degradation, plastic remains in the environment for hundreds of years. Microbial degradation, however, offers a promising, eco-friendly, and sustainable alternative for reducing the negative impact of synthetic polymers. Microorganisms use enzyme-mediated pathways to convert plastics into simpler, non-toxic compounds. This approach not only highlights the remarkable potential of microbes to break down plastics but also provides valuable insight for developing new strategies for efficient waste management [1,2].

Plastics are synthetic organic polymers widely used around the world. They have replaced traditional materials such as wood, metal, and glass because of their low cost, high strength, and durability. Based on polymer demand in Europe, six major plastics dominate the market: polyethylene (PE) 29.8%, polypropylene (PP) 19.3%, polyvinyl chloride (PVC) 10.2%, polyurethane (PUR) 7.7%, polyethylene terephthalate (PET) 7.4%, and polystyrene (PS) 6.6%. Global plastic production has now reached approximately 450 million metric tons per year. Due to improper waste management, large quantities of plastic enter the environment. In 2022, around 380 million tons of plastic waste were generated, and nearly 8 million tons were released into oceans, contributing significantly to marine pollution.

A major breakthrough in plastic biodegradation occurred in 2016 when researchers isolated the bacterium Ideonella sakaiensis from a recycling plant. This organism secretes two important enzymes capable of breaking down PET: PETase and MHETase. PETase converts PET into mono-(2-hydroxyethyl) terephthalate (MHET), which is further broken down by MHETase into terephthalic acid (TPA) and ethylene glycol. These compounds can then be utilized by other microorganisms as carbon sources. This discovery generated significant interest, as it showed that certain microbes have evolved specialized pathways to degrade plastics [3].

MATERIALS AND METHODS

This review article was prepared by collecting and analyzing published scientific literature related to microbial degradation of plastics. Research papers were searched using databases such as Google Scholar, PubMed, ScienceDirect, and ResearchGate with keywords including plastic degradation, microbes, enzymes, biodegradable plastics, and PETase. Relevant studies published between 2000– 2024 were selected.

Information on types of plastics, microorganisms, enzymes, degradation mechanisms, and influencing factors was extracted and organized into major sections of the review. The collected data were compared, summarized, and presented in a systematic manner to provide a clear understanding of microbial and enzymatic plastic degradation.

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RESULTS

1. THERMAL CLASSIFICATION OF PLASTICS

predicated on the thermal tracts of plastics are divided into two classes, i.e. thermoplastics and thermosetting polymers.

2.1 Thermo- plastics

It's a type of plastic that can be putrefied for several times but on warming it can not suffer any chemical change in its composition. samples of thermo- plastics are polypropylene(PP), polyethylene(PE), polyvinyl chloride(PVC), polystyrene(PS) and polytetrafluoroethylene(PTFE). These plastics are ranges from 20,000 to 500,000 (atomic mass unit) in molecular weight and are generally known as common plastics. Macromolecules are arranged in direct manner in the form of chain in which particles and molecules are attached carbon chains. By opening of double bond that is demanded to form direct macromolecules and the response is progressed by free radical medium. This type of polymerization is known as addition polymerization and samples include are polypropylene and polyethylene.

2.2 Thermosetting polymers

Another type of plastic is the thermosetting plastic in which plastic once melt and casted into a certain shape, after solidification it can not be melted and modified again. All chemical changes, unrecoverable, are not specimens of thermosetting polymers(Ghosh et al., 2013). Polyurethanes and phenol formaldehyde under favor-suitable conditions are formed by step growth polymerization. At each step, H ? O and HCI are released as a by products and allowing the condensation ofbi- functional molecules inter molecularly. In thermosetting plastic, monomers convert themselves into an infusible mass by sustain small chemical changes on heating.

Table 1.Thermal Classification of Plastics

Category	Definition	Key Property	Examples
Thermoplastics	Plastic that repeatedly melted & reshape	Linear, branch chain, flexible, recyclable	Polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate,
Thermosetting Polymers	Plastics that cannot be remelted after curing	Highly cross linked, heat resistant	Bakelite. Polyurethane,Epoxy, Melamine

2. TYPES OF BIODEGRADABLE PLASTICS BASED ON THEIR DEGRADATION MECHANISMS

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Degradable plastics can be grouped into two main types, depending on how they break down. Oxo biodegradable plastics and (b) Hydro-biodegradable plastics (Mukamto et al., 2015; VázquezMorillas et al., 2016)[22]. The hydro- biodegradable plastics are those that are degraded through hydro- lytic mechanisms (Nampoothiri et al., 2010). Examples of these plastics include cellulose, starch, and widely used polyesters such as polyhydroxyalkanoates (PHA). Oxo-degradation occurs in two sequential stages: an initial abiotic oxidation followed by biotic degradation. In the first stage, the carbon backbone of polyolefins undergoes abiotic oxidation, breaking down into smaller fragments. This oxidative process is accelerated by heat and UV radiation, although the overall rate of complete degradation is still not precisely known.In the first stage, the carbon backbone of polyolefins is oxidized abiotically into small fragments. Although thermal degradation and UV radiation accelerate this oxidative process, the overall rate of degradation is not precisely known. In the second stage, degradation of polyolefin is taken by microbes (Liu et al, 2014; Nikoli? et al., 2017; Montazer et al., 2018)[23].In polyethylene (PE), the polymer structure is altered by the introduction of carbonyl groups into its backbone, a modification brought about through abiotic photooxidation. Once the carbonyl group is incorporated, the modified polyethylene molecule is converted into an alcohol by the action of monooxygenase. This alcohol is then further oxidized to an aldehyde through the activity of alcohol dehydrogenase. Subsequently, aldehyde is converted into fatty acid by the action of aldehyde dehydrogenase. Finally, the fatty acid is metabolized through B-oxidation pathway (Gautam et al., 2007)[24]. Microbial colonization on the surface of polyethylene (PE) leads to changes in its mechanical properties by increasing surface roughness, reducing molecular weight, and making the material more fragile.(Palmisano and Pettigrew, 1992; Watanabe et al., 2009; Nowak et al., 2011; Park and Kim, 2019)[25]. The change in carbonyl index was ascertained through FTIR and ketone and aldehyde groups were formed. The CO, and H?O were produced as a result of ?-oxidation (Novotný et al., 2018)[26]. Gram negative bacteria including Klebsiella pneumoniae play an important role in wastewater treatment (Maal et al., 2014).Surfactants released extracellularly by K. pneumoniae facilitate the exchange between hydrophilic and hydrophobic phases. These phase exchanges help microbes to penetrate easily into the PE and degrade it[27].

3. TYPES OF BIODEGRADABLE PLASTICS

Plastics that are freely degradable can be divided into four types Photodegradable bioplastics,bio-based bioplastics, com-postable bioplastics and biodegradable bioplastics.

3.1 Photodegradable bioplastics

In this type of plastic, the groups that are connected to the poly- is of the groups that are conne e mer backbone are light sensitive. When radiation force stopped also declination is n't possible. tips warrant sun so plastics in tip are n't degradable(Arikan and Ozsoy, 2014). Artificial print-declination can lead to the release of Ozsoy, Artificial can lead to the release of poisonous unpredictable organic composites(VOCs) which are potentially dangerous and associated with the environmental riding of plastic debris(Lomonaco et al., 2020)[12].

3.2 Bio-based bioplastics

Types of plastics in which 100 of carbon is attained from renewable coffers, like forestry and agrarian coffers are known asbio-based plastics. bounce, sludge, soybean and cellulose are the exemplifications of these coffers(Getachew and Woldesenbet, 2016; Marichelvam et al., 2019; Maraveas, 2020).3.3.(Compostable bioplastics)(13) In composting process, requires a specific setting in order to break down whereas biodegradable products break down naturally, the plastics are perished biologically without leaving any poisonous material(Meereboer et al., 2020)[14].

3.3 Biodegradable plastics

Biodegradable is a term that's used for the accoutrements that are disintegrated into biogases and memoir- mass by the action of microorganisms(Jain et al., 2010)

4. FACTORS INFLUENCING BIODEGRADATION OF PLASTICS

Biodegradation of plastics is a complex, multistep process governed by polymer characteristics, environmental conditions, and microbial activity. Understanding these factors is essential for optimizing microbial degradation strategies in laboratory and environmental settings

4.1 Polymer Characteristics

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Chemical Structure: Plastics with hydrolysable bonds (e.g., ester, amide, urethane) degrade more easily than those with stable C–C backbones such as PE, PP, or PS.Molecular Weight: Lower molecular weight polymers and oligomers are more accessible to microbial enzymes. Crystallinity: Highly crystalline regions resist enzymatic attack, whereas amorphous regions degrade faster.Hydrophobicity: Hydrophobic surfaces limit microbial adhesion and enzyme penetration.Additives and Fillers: Plasticizers, stabilizers, and pigments can either enhance or inhibit microbial degradation depending on their chemical nature.

4.2 Environmental Factors
Temperature: Higher temperatures increase polymer chain mobility and enzymatic activity, accelerating degradation pH: Each microbial system has an optimal pH that affects enzyme stability and activity.Oxygen Availability: Aerobic conditions generally promote faster degradation compared to anaerobic pathways.Moisture Content: Water enhances hydrolysis and supports microbial growth.UV Radiation: UV exposure causes photo-oxidation, reducing molecular weight and increasing susceptibilityto biodegradation. Nutrient Availability: Availability of nitrogen, phosphorus, and trace minerals influences microbial metabolism.

4.3 Microbial and Enzymatic Factors
Microbial Diversity: Degradation depends on the presence of bacteria, fungi, and actinomycetes capable of producing specific depolymerizing enzymes.Enzyme Production: Key enzymes such as PETase, MHETase, cutinases, laccases, lipases, and esterases determine degradation efficiency.Biofilm Formation: Microbial colonization and biofilm development enhance surface contact and enzymatic activity.Metabolic Pathways: The capability of microbes to mineralize degradation intermediates (e.g., terephthalic acid, adipic acid) influences complete biodegradation.

4.4 Physical Properties of the Plastic Surface
Surface Area: Smaller particle size and higher surface roughness increase microbial adhesion and enzyme access.Surface Modification: Oxidation, corona treatment, or mechanical abrasion can enhance degradability by introducing functional groups. 5.4 Environmental Exposure Age Weathering History: Plastics pre-exposed to sunlight, mechanical stress, or oxidation show higher degradation rates compared to fresh materials.

5. MECHANISM OF MICROBIAL PLASTIC DEGRADATION

Microbial degradation involves four major steps:

5.1 Surface Colonization and Biofilm Formation
Microbes attach to the plastic surface and form biofilms, improving enzyme concentration near the polymer.

5.2 Depolymerization
Microbial enzymes break down long polymer chains into shorter units (oligomers, monomers). Key Enzymes Include : Laccase & Peroxidase (PE, PS) Cutinase, Esterase, Lipase (PET, PU)

5.3 Assimilation
The smaller products produced by depolymerization are absorbed by microbial cells

5.4 Mineralization
Internal metabolic pathways convert the products into CO?, CH?, H?O, and biomass.

6. ENZYMATIC DEGRADATION OF SYNTHETIC POLYMERS CHALLENGES AND RECENT PROGRESS

The extensive use of synthetic polymers analogous as PET, PE, PS, PP, and PVC has played a substantial part in the global swell of plastic product, which reached a stunning 335 million tons in 2016. These equipment, which are used in numerous industry, present significant environmental obstacles because of their longlasting andnon- degradable characteristics. The adding use of these polymers in our everyday lives a careful evaluation of their environmental consequences specifically in terms of energy operation and waste product. This situation has encouraged a lower focus on the development of sustainable druthers and recovering styles. The pressing concern lies in chancing innovative results that can help the release s of plastic

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proliferation, while maintaining a balance between the avail of these polymers and their environmental traceThe discussion wreathing the use of synthetic polymers volves around their essential part in contemporary society and the responding environmental hurdles. There are ongoing sweats to probe environmentally friendly stuff and enhance recycling styles, but these trials encounter various obstacles, analogous as technological constraints and profitable viability. The operation of synthetic polymers' impact on the terrain is a multifaceted challenge that necessitates a comprehensive way .

6.1 Polyethylene(PE)
Plastic material is frequently used in packaging and holders because of its outstanding capability to repel microbial declination. instigative advancements in biotechnology have revealed the inconceivable capabilities of specific enzymes and microbial strains in effectively binding to and breaking down PE. generally, these enzymes work by oxidizing the polymer chains, initiating a process of breaking them piecemeal. Several environmental factors, similar as exposure to UV light or physical bruise, can contribute to this process.

6.2 Polypropylene(Pp)
Pp is globally used in packaging and automotive factors due to its emotional resistance to a range of chemical degeneration processes. still, recent study has uncovered the eventuality of enzymatic ways in demeaning PP. Certain microbial strains have been conceded for their remarkable capacity to cleave to and incompletely degrade PP.", The challenge is to enhance the effectiveness of these natural processes to make them more practical for wide use. A study is being conducted explore and ameliorate enzymes chapeau have the eventuality to enhance the effectiveness of breaking down the chemical bonds in Pp.

6.3 Polyethylene terephthalate(PETE/ PET)
numerous exploration has been studied on the enzymatic declination of PET, which is fluently set up in libation bottles and fabrics. Experimenters have made notable discoveries in the area of enzyme exploration and revealed the emotional capabilities of enzymes similar as PETase and MHETase in efficiently breaking down PET into its essential factors ethylene glycol and terephthalic acid. These enzymes have been set up in certain bacteria and fungi and their effectiveness and life are being enhanced for artificial use. The eventuality of enzymatic declination of PET for recovering operations is immense and offers a more environmentally friendly and effective option compared to traditional mechanical andChemical Recycling Techniques.

6.4 Polyvinyl chloride(PVC)
PVC, extensively used in the construction and packaging industriousness, poses challenges for biodegradation because of its chlorine content. There's a lack of comprehensive scientific knowledge regarding the enzymatic declination of PVC, especially when compared to other polymers. The study in this area is still in its original phases with the thing of developing reliable and effective styles for the secure breakdown of PVC.

6.5 Polystyrene(PS)
PS, a broadly y use used material in packaging and sequestration, is well known for its remarkable continuity due to its chemically stable scented structure. still, recent discoveries have unmasked the presence of certain bacteria and fungi that can reduce PS using technical enzymes. The enzymes effectively break down the styrene monomers, and the current pace and effectiveness of the process meets prospects. The present study aims to enhance the effectiveness and life of these enzymes to make the biodegradation of PS a more practical option.

6.6 Polylactic acid(PLA)
PLA, a bioplastic derived from renewable sources, is constitutionally more prone to enzymatic declination when compared to polymers made from petroleum." Research has shown that certain enzymes, analogous as proteinase K and lipase, have proven to be extremely effective in the declination of PLA. The declination of PLA happens through the hydrolysis of ester bonds, leading to the conformation of lactic acid, which can be subsequently metabolized by various microorganisms." PLA stands out for its positive environmental impact since it can be easily and

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completely broken down in composting establishments.

6.7 Polybutylene succinate(PBS)
It has been observed that PBS, BS, a type of biodegradable plastic, is more susceptible to enzymatic declination compared to conventional polymers. There have been significant findings in the field of enzyme disquisition, particularly in the area of PBS declination. especially, lipases have demonstrated comment suitable effectiveness in breaking down PBS. The declination process involves the hydrolysis of ester bonds in the polymer, causing it to break down into lower patches that can be easily broken down by natural processes." Because remarkable vulnerability to declination, PBS is an extremely fascinating material for trials that prioritize ecological sustainability .

6.8 Polyurethane(PUR)
Enzymatic declination of PUR can be fairly complex due various chemical compositions. still, certain enzymes analogous as esterase and ureases show great eventuality in breaking down PUR. The enzymes have the capability to specifically target certain bonds in the PUR polymer, performing in its declination. researchers in this field are concentrated on uncovering and enhancing the effectiveness of these enzymes with the thing of developing effective ways for breaking down PURs. The significance of this issue stems from the wide use and patient presence of PURs in the atmosphere[15].

7. MICROBIAL DEGRADATION OF PLASTICS

7.1 Bacteria
Bacteria are among the most abundant and influential organisms in nature, and many species have the ability to break down plastics. In recent years, researchers have discovered plastic-degrading bacteria in a variety of environments, including marine ecosystems, landfills, soils, and composting sites.

7.1.1 Pseudomonas Species
Presently, among the different bacterial rubrics associated with plastic declination, Pseudomonas spp. account for 21. The foremost microbial studies on plastic biodegradation also started with Pseudomonas spp. Different species of Pseudomonas spp. have been used for the declination of plastics. Among them, Pseudomonas aeruginosa has entered important attention and has been verified to degrade colorful plastics. aeruginosa insulated from the bowel of superworms showed diurnal weight loss of 0.64, 0.098, and for PE, PS, and PP, independently. P. aeruginosa insulated from waste dumps showed polyethylene (PE) declination rates of 6.5 and 8.7 after 60 days of incubation in minimum swab medium(MSM) and BushnellHaas broth(BHM), independently. P. aeruginosa insulated from sewage water- defiled face soil incubated in nutrient broth(NB) medium for one month PP showed a weight loss of 5.37. also, other species of the Pseudomonas, similar as Pseudomonas citronellolis, Pseudomonas putida, Pseudomonas alcaligenes, and Pseudomonas fluorescens, have also been shown to degrade different types of plastics. In the marine terrain, Pseudomonas spp. have been extensively detected on plastic biofilms, but there have been many reports of their strains being separated together to degrade plastic compared with terrestrial sources. Feedback Pseudomonas aestusnigri insulated from marine beach samples could effectively degrade PET with a new carboxvlic a ester hydrolase. Pseudomonas rhodesiae insulated from Brazilian deep- ocean sediments could form biofilms on largely viscosity polyethylene(HDPE) and result structural changes in the plastic. Microbial colleges formulated by P. putida and P. stutzeri separated from Bangalore Lake could degrade low- viscosity polyethylene(LDPE), which showed advanced degradability and 90 weight loss after 40 days of incubation.

7.1.2. Bacillus Species
Bacillus spp. can effectively degrade different types of plastics, represented by Bacillus cereus, Bacillus safensis, and Bacillus subtilis. For prototype, B. cereus insulated from mangroves in Peninsular Malaysia performed in weight losses of 1.6, 6.6, and 7.4 for PE, PET, and PS, independently, in 40 days. B. subtilis H1584 insulated from pelagic waters degraded LDPE, which led to a weight loss of 1.75 in 30 days. B. subtilis insulated from seawater 0- 30 cm depth showed a weight loss of 1.54 for LDPE after 90 days of incubation. Bacillus paralicheniformis G1 insulated from deep- ocean deposition was set up to degrade PS by roughly 18 in the first 30 days and reached 34 in 60 days.

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7.1.3. Alcanivorax Species

Species within the rubric Alcanivorax are extensively distributed in the ocean and are well-known hydrocarbon beguilers. Their rush in biofilms of marine plastics also prognosticated their capacity to degrade plastics. Alcanivora sp. 24 insulated from marine plastic waste could reduce mass by 0.9 after 34 days of incubation with LDPE. Alcanivorax borkumensis insulated from the Mediterranean Sea could form biofilms on LDPE, with a significant weight loss of 3.5 after 80 days. Alcanivorax wenustensis insulated from the deep ocean could degrade polycaprolactone(PCL) and make its face rough. Alcanivorax xenomutans insulated from mangroves could effectively degrade PS by observing the quantity of strain growth.

7.1.4. Actinomycetes

Presently, actinomycetes that degrade plastics are basically insulated from soil. still, some actinomycetes have also been insulated from marine surroundings that can effectively degrade plastics. Kocuria palustris insulated from Arabian Sea seawater could reduce PE weight by 1 after 75 days of incubation. Rhodococcus ruber insulated from mangrove deposition degraded PP with 6.4 weight loss after 40 days of incubation.with 6.4 weight loss after 40 days of incubation. Rhodococcus pyridinivorans P23 insulated from deep ocean deposition could reduce the weight of PET by 4.28 after five weeks of civilization. Nocardioides marinus insulated from Pacific Ocean deep- ocean sediments could reduce the weight of PET by 1.2- 1.3 in 30 days. Gordonia sihwensis, Gordonia mangrovi, and Gordonia bronchialis insulated from mangroves showed PS degradability with 4.69- 7.73 declination rates in one month. Srreptomyces gougerotti, Micromonospora matsumotoense, and Nocardiopsis prasina insulated from the ocean could degrade LDPE, PS, and polylactic acid(PLA) to varying degrees.

7.1.5. Other Bacterial Species

Numerous other bacterial species of Proteobacteria, Firmicutes, and Actinobacteria can degrade plastics. Lysinibacillus sp. JJY0216 insulated from soil grooves degraded 9 and 4 of PE and PP, independently, in 26 days. Achromobacter denitrificans Eb113 laiyuandi showed weight losses of 6.5 and 22.3 for LDPE and PVC, independently, in one month. Alcaligenes faecalis(MK517568) degrades LLDPE by 3.5, HDPE by 5.8, and Polyester by 17.3 after 40 days of incubation. Meyerozyma guilliermondii and Serratia marcescens insulated from the gut of wax worms showed PE weight losses of 13.9 and 3.57 within 60 days, independently. Brevibacillus brevis from soil could degrade nylon 6, 6 microplastics with a weight loss of roughly 22 w/ w after 35 days of incubation. Acinetobacter bacterium insulated from naiads of Tribolium castaneum could degrade PS, causing 12.14 weight loss after 60 days of incubation. Marinobacter gudaonensis, Thalassospira xiamenensis, and Marinobacter sedimimum insulated from Pacific Ocean deep-ocean sediments could reduce the weight of PET by 1.2- 1.3 in 30 days.

7.2. Fungi

Fungi are important in environmental plastic declination, as they move through substrates with their filamentous network structure, exploring and growing in places that are more delicate for other microorganisms to reach. Feedback preliminarily, biodegradation by fungi with polyesterase conditioning has been reported, which are solely terrestrial fungi, Several marine plastic-demeaning fungi have been insulated. For illustration, the marine red incentive Rhodotorula mucilaginosa insulated from plastic debris in the North Sea can efficiently degrade PE using an isotopically labelled system. Penicillum spp. insulated from the Red Sea Coast could attach to LDPE flicks and grow in wealth. The marine fungus Alternaria alternata FB1, which was insulated from plastic debris, can degrade PE by forming holes across the film. Aspergillus sp. insulated from the Bay of Bengal could beget 22 weight loss of PE in six weeks. Zalerion maritimum insulated from Portuguese littoral waters was particularly active in demeaning PE microplastics, with a mass change of 56.7 in 14 days. Some terrestrial Aspergillus, similar as Aspergillus nomius RH06 and Aspergillus clavantus JASK1, can degrade LDPE plastics, as estimated by weight loss and variation in morphology, similar as cracks and crevices. Other fungal species of terrestrial origin also have significant plastic degradability, including Trichoder sp., Monascus sp., Clitocybe sp., Penicillum spp., and Phanerochaete sp., Among them, only Penicillum spp. and Aspergillus sp. of marine origin have been insulated, while Trichoderma sp., Monascus sp., Clitocybe sp., and white- spoilage fungi of marine origins have yet to be insulated.

7.3. Algae

To date, only a many algae cases have been reported on plastic declination. Algae adsorbed on

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the face produces ligninolytic and exopolysaccharide enzymes to degrade plastic. The microalga Uronema africanum insulated from waste plastic bags in a brackish lake was set up to degrade LDPE wastes within30 days through compliances of erosion, bruise, groove, and crest configurations. During the disquisition, cyanobacteria appeared on plastic biofilms, showing its eventuality to degrade plastic. Smaller cyanobacteria have been insulated to degrade plastics. For illustration, Phormidium lucidum and Oscillatoria subbrevis insulated from plastic debris in domestic wastewater were set up to be able of demeaning LDPE, as they colonised PE and utilised carbon without anypro-oxidant complements orpre treatment. PET and PP can be degraded after 112 days of commerce with brackish Spirulina isolates, as verified by FTIR- ATR, SEM- EDX, and tensile strength. Plastic declination by cyanobacteria insulated from marine sources has not been reported. PETaseR280A- FLAG, produced by a marine diatom, showed the capability to degrade PET. This is the only known declination of plastics by marine- sourced algae and provides a foundation for after use of microalgae to break the plastic problem.

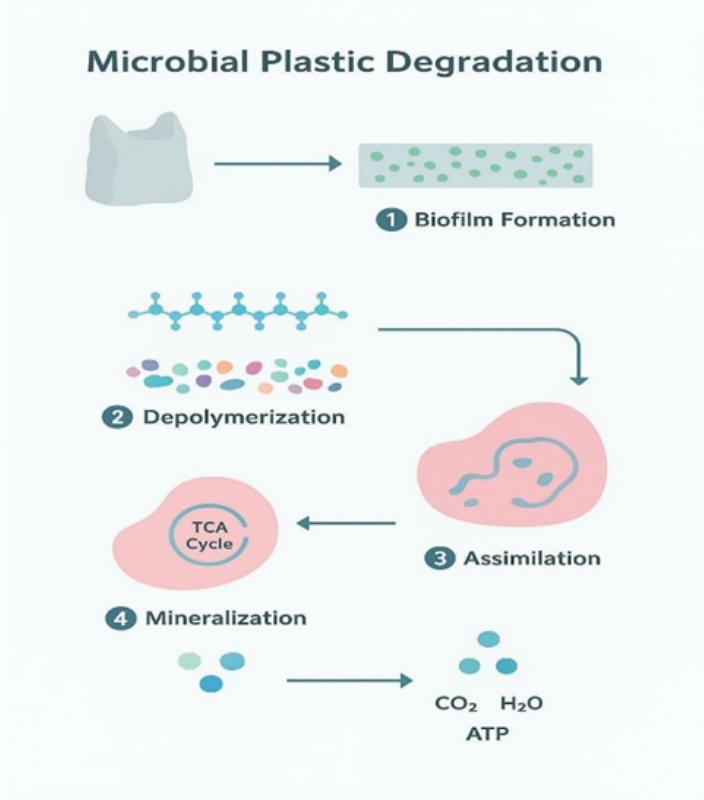


Figure 1.Microbial Plastic Degradation

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DISCUSSION

This review highlights how serious plastic pollution has become and explains why microbes are now seen as one of the most practical solutions. Since plastics like PE, PP, PET, PS, and PVC stay in the environment for decades, traditional methods like landfilling or burning are no longer enough. The document shows that many bacteria, fungi, and even algae have the natural ability to slowly break down these plastics by attaching to their surface, releasing enzymes, and converting them into simpler, harmless substances. One major point discussed is that different plastics break down at different speeds depending on their structure. For example, PET can be degraded more efficiently because specific enzymes such as PETase and MHETase can act on it. In contrast, plastics like PE and PP are tougher, but some microbes—especially Pseudomonas, Bacillus, Rhodococcus, and certain fungi—still show promising results.

The review also explains that environmental factors like temperature, pH, sunlight, and polymer crystallinity affect how fast plastics degrade. Although the microbial breakdown process is slow, ongoing research and enzyme engineering are improving these results.

Overall, the paper supports the idea that microbial degradation is not a complete solution yet, but it is a strong and eco-friendly approach that can help reduce long- term plastic waste and support environmental restoration.

CONCLUSION

Microbial degradation offers an eco-friendly and effective approach to reducing plastic pollution. Many bacteria, fungi, and algae can break down synthetic polymers through enzymatic actions that convert plastics into simpler, harmless compounds. Although some plastics remain difficult to degrade, ongoing advances in enzyme engineering and microbial biotechnology continue to improve degradation efficiency. Overall, microbes provide a promising and sustainable strategy for long-term plastic waste management and environmental restoration.

ABBREVIATIONS

None

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CONFLICT OF INTERESTS

The author has declared no conflict of interest.

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