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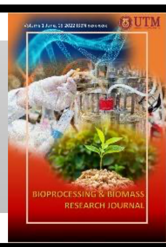

Research Article

Recent Understanding on Biodegradation and Abiotic Degradation of Plastics: A Review

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ABSTRACT

The global plastic litter has turned into an environmental problem of grave concern founded on its persistence and adverse impacts on the ecosystem. Addressing this issue requires effective degradation strategies that can complement or replace current waste management practices. This review presents an update of the current advances on biodegradation of plastics with an overview of the various plastics, their properties, and typical applications. This review also describes conventional abiotic degradation mechanisms (thermal, photodegradation, hydrolytic, and mechanical) and their advantages and limitations. The role of microbes as effective biodegradation agents with emphasis on individual strains and specific plastic types is explored. The bioprocess of plastic biodegradation is outlined to indicate how microbial action breaks down synthetic polymers into harmless products in the environment. A comparison of biodegradation with other non-biological degradation processes is also included, their impact on the environment, operational feasibility, and potential for future application. In conclusion, microbial biodegradation has been proved to be a viable, eco-friendly option that can be an integral part of the solution for the global plastics pollution issue.

INTRODUCTION

In 1855, an inventor named Alexander Parkes created one of the first plastic items named "Parkesine" (Govind *et al.,* 2023). Plastic is a polymeric substance that may be moulded or formed by applying heat and pressure (Khare & Khare, 2023). Plastic is typically paired with other specific properties such as low electrical conductivity, low density, transparency and toughness that allow plastics to be manufactured into a wide range of products (Desidery & Lanotte, 2022). Plastic is widely used to make a variety of industrial products such as drinking bottles from polyethylene terephthalate (PET), flexible garden hoses from polyvinyl chloride (PVC), insulating food containers

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from foamed polystyrene, and shatterproof windows made of polymethyl methacrylate. Then, in 1907, Leo Baekeland furthered his research on plastic production. He introduces the first wholly synthetic material or its name as Bakelite (Ebnesajjad, 2017).

Plastic manufacturing is determined by whether the plastic is synthetic or bio-based (Lors *et al.,* 2025). Synthetic polymers are produced from crude petroleum, combustible gas, or coal (Geyer, 2020). Meanwhile, biobased plastics, are produced from sustainable materials such as carbohydrates, starch, vegetable fats and oils, microscopic organisms, and natural substances (Zhao *et al.,* 2023). By far most of the plastic being used today is synthetic plastic due to the simplicity of assembling techniques associated with the handling of unrefined petroleum. Usually, plastic production involves a polymerization reaction. Before undergoing this reaction, the raw material needs to be extracted from the complex mixture of the compound. Then, when obtaining the specific compound, the reaction of polymerization will continue. In the petroleum sector, polymerization is the process by which monomers of light olefin gases, or gasoline, including ethylene, propylene, and butylene are converted into higher molecular weight hydrocarbons (Hu *et al.,* 2022). It begins with a basic component such as ethylene or propylene. Ethylene or C_2H_4 is a stable two-carbon molecule with a double bond under standard condition. As shown in **Figure 1**, Polyethylene (PE) is formed when a large number of ethylene molecules contact with one another in the presence of a catalyst, breaking the double bond and forming a chain of carbon atoms. The chain length increases in proportion to molecular weight and polymers can have a wide range of molecular weights (Urbanek *et al.,* 2018).

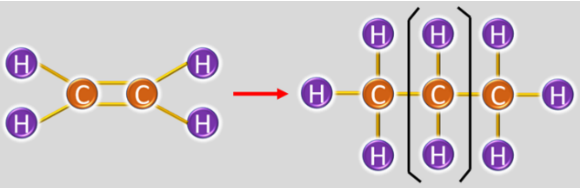

Figure 1 Reaction of ethylene molecules in the presence of a catalyst to form polyethylene

In the polymer industry, several catalysts are employed, and new catalysts are developed every year. Various catalysts are used in the same reactor to produce polymers with different properties. Each PE or PP process licensor's reactor designs incorporate unique catalyst formulations. Depending on the reactor type, the catalysts may be solid particles or suspended in a hydrocarbon or solvent (Urbanek *et al.,* 2018). The manufacturing of synthetic plastics is one of the sectors of the world economy that is expanding quickly. Due to their distinct characteristics, plastics are preferable to other materials. Because of these qualities, the size of plastic manufacturing has increased by more than a factor of 20 since 1964, and it currently surpasses 300 million tonnes per year, reaching 335 million tonnes in 2015 (Asiandu *et al.,* 2021).

The term "waste" refers to a product or substance that has outlived its usefulness (Azelee *et al.,* 2019). Waste such as decaying organic materials are employed as food or chemical reactants in natural ecosystems. Waste generated by humans, on the other hand, takes a long time to degrade. According to the World Bank Group (2021), by 2050 global waste is predicted to reach about 3.4 billion tonnes due to the increase in world population. Humans produced an astounding quantity of garbage which is about 2 billion tons per year, or around 2.04 trillion kilograms per year. The average amount of garbage generated per person each day is 0.74 kilos, but it could change between the range of 0.11 to 4.54 kilograms depending on people's lifestyles (Abdel-Shafy *et al.,* 2018). There were various types of waste have been produced in the world such as liquid waste, solid waste, and hazardous waste. Each of these waste products harms the environment in its own way.

PLASTIC WASTE

Plastic waste refers to any plastic product that has been abandoned after usage or after its intended life has gone. Applications in the market include those for packaging, electrical and electronics, building and construction, transportation and automotive, home goods, furniture, and others. Plastics are being used more and more in packaging because they can handle wear and chemicals better, are easy to shape, difficult to tear, and have high mechanical strength (Yousaf *et al.,* 2024).

Plastic materials and compounds used by manufacturers are different depending on their own set of properties. Various types of plastic are used in plastic products such as Acrylic or Polymethyl Methacrylate (PMMA), Polycarbonate (PC), Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), and Acrylonitrile-Butadiene-Styrene (ABS) (Reusch, 2013). Out of all these types of plastic, polyethylene is the most common plastic used in industries (Verma *et al.,* 2025). Depending on the density of polyethylene utilized with the produced plastic has different physical characteristics. As a result, polyethylene may be found in a wide variety of products. **Table 1** shows the type of plastic with their properties and applications.

Table 1 Type of plastic with their properties and applications

Types	Properties	Application	Reference
Low density Polyethylene (LDPE)	soft, waxy solid	film wrap plastic bags	(Mogni, 2021)
Polyethylene high density (HDPE)	rigid, translucent solid	electrical insulation bottles toys	(Mogni, 2021)
Polyethylene Linear Low Density (LLDPE)	higher tensile strength, higher impact, puncture resistance	cushioning films elastic films ice bags garbage bags	(Mogni, 2021)
Polypropylene (PP)	atactic: soft, elastic solid isotactic: hard, strong solid	similar to LDPE carpet upholstery	(Mogni, 2021)
Poly(vinyl chloride) (PVC)	strong rigid solid	pipes siding flooring	(Mogni, 2021)
Poly(vinylidene chloride) (Saran A)	dense, high-melting solid	seat covers films	(Mogni, 2021)
Polystyrene (PS)	hard, rigid, clear solid soluble in organic solvents	toys cabinets packaging (foamed)	(Mogni, 2021)

Poly(methyl methacrylate) (PMMA, Lucite, Plexiglas)	hard, transparent solid	lighting covers signs skylights	(Mogni, 2021)
Acrylonitrile-Butadiene-Styrene (ABS)	Strength, tough, resistant to heat distortion, flammable and good electrical properties.	Refrigerator lining Lawn and garden equipment. Highways safety device.	(Hari, 2018)
Polycarbonate (PC)	Low water distortion, transparent, resistance and ductility.	Safety helmets Lenses Light globes	(Hari, 2018)
Polyamides (nylon)	Strength, abrasion resistance, tough, low coefficient of friction.	Bearing Gears Bushing Jacketing for wires and cables.	(Hari, 2018)
Polyethylene Terephthalate (PETE or PET)	Resistance to organic materials and water, recyclable, shatterproof, high strength-to-weight ratio.	Fibers for clothing Container for food and liquid.	(Reusch, 2013)

Monomers, which are lengthy sequences of repeating units, make up plastic molecules. The atoms that make up a plastic's monomers make them different from each other. As well as the arrangement of those atoms inside the molecule can define many of its characteristics.

DEGRADATION OF PLASTIC

Plastics are polymers that have been chemically synthesized and are difficult to degrade. Plastic degradation is typically a slow process influenced by a variety of environmental factors, including air humidity, moisture in the polymer, temperature, pH, ultraviolet (UV) radiation, polymer properties, and biochemical factors (Weinstein *et al.,* 2020; Haider *et al.,* 2018; Rostampour *et al.,* 2024; Fu *et al.,* 2022; Cai *et al.,* 2023; and Wang et al.; 2023). There are many non-biological mechanisms of plastic degradation widely studied such as thermal degradation, photodegradation, hydrolytic degradation and mechanical degradation.

Non-biological Mechanisms of Plastic Degradation

Thermal Degradation

Thermal degradation is one of the primary plastic degradation processes, and it significantly alters the polymer properties. Heating will trigger molecular structure changes. For example, a decrease in average molecular mass, which is detrimental to plasticity and can lead to the development of hard, brittle structures (Shakirova *et al.,* 2020; Ray & Cooney, 2018). The thermal degradation processes vary by polymer type. For instance, polyethylene has wide property modifications under elevated temperatures, especially through chain scission and free radical formation (Yang *et al.,* 2023a). Furthermore, thermal stability of some plastics, such as polycarbonate and polystyrene, is typically evaluated using methods such as thermogravimetric analysis (TGA) to increase understanding of their thermal degradation behavior (Wang *et al.,* 2024; Doblies *et al.,* 2019).

Photodegradation

Photodegradation is an important process in the environmental breakdown of plastics. This photodegradation is mainly driven by ultraviolet (UV) radiation. When plastics are exposed to sunlight, UV light is absorbed, generating reactive oxygen species (ROS) like hydroxyl radicals and singlet oxygen (He *et al.,* 2024; Mundhenke *et al.,* 2022). During oxidative degradation, reactive oxygen species (ROS) cause polymer chains to break, resulting in microplastics and benzoic acid (Schiferle *et al.,* 2023; Alimi *et al.,* 2018). The degradation rate of plastics like LDPE and polystyrene varies based on the type of plastic and the exposure to UV light. For example, carbonyl groups are formed in polyolefins like LDPE, which increases their brittleness and susceptibility to fragmentation (Gewert *et al.,* 2018; Alimi *et al.,* 2018; Song *et al.,* 2020). In response to these changes, plastics become more susceptible to mechanical degradation, which leads to the formation of microplastics (Bhattacharjee *et al.,* 2023; Waldman & Rillig, 2020; Danso *et al.,* 2019).

Additionally, additives in plastics might influence photodegradation. Thus, additives like photostabilizers absorb UV radiation and help slow degradation (Walsh *et al.,* 2021; El-Hiti *et al.,* 2021; Andrady *et al.,* 2023). Those without these additives degrade faster and contribute more to microplastic pollution (Walsh *et al.,* 2022). A photocatalytic degradation strategy is also being investigated as a way to accelerate plastic breakdown under sunlight in recent studies.

Hydrolytic Degradation

Hydrolytic degradation is a process of plastic degradation by reaction with water that capable to change their chemical structure which leading to degradation of plastics. It Is particularly important for biodegradable plastics such as PLA and polyesters such as PET. In PLA, various parameters such as temperature, pH, crystallinity and plasticizers control the level of water molecules that can penetrate and hydrolyze the ester bonds, which will produce smaller molecules such as lactic acid (Xuan *et al.,* 2019; Merino & Athanassiou, 2022). Furthermore, PET is tougher and requiring heat and a catalyst to decompose into terephthalic acid and ethylene glycol, with environmental factors such as temperature and microbes also playing a role (Stanica-Ezeanu & Matei, 2021; Kilanko & Olamigoke, 2024).

Another recent alternative is the Enzymatic hydrolysis process. In this process, it will use enzymes such as cutinase and polyester hydrolase to break down the polyester under mild conditions that will produce less hazardous residues and by-products (Zimmermann, 2020; Kawai *et al.,* 2019). Enzyme catalysis techniques coupled with microwave-assisted treatment further enhance PET degradation (Guo *et al.,* 2023). Processes of chemical recycling are also being developed that utilize hydrolysis for degrading plastic waste into valuable chemical feedstocks (Li *et al.,* 2024; Myren *et al.,* 2020). It is through understanding such hydrolytic processes that biodegradable plastic design and recycling processes become better, such that plastic waste management is improved further.

Mechanical Degradation

Plastics can be mechanically degraded by physical forces such as shear stress, impact, abrasion, and compression. It is due to these forces that the chain breaks due to scission, resulting in a reduction in tensile strength and elasticity (Gabriel and Tiana, 2020; Phanthong and Yao, 2023). Mechanical degradation of plastics is a process of weakening polymer chains by physical forces like shear stress, impact, abrasion, and compression. Then, the chain breakage occurs due to these forces and results in loss of tensile strength and elasticity and ultimately failure of the material (Gabriel and Tiana, 2020; Phanthong and Yao, 2023). Polypropylene (PP) and polyethylene terephthalate (PET) are degraded by repeated mechanical stress (Phanthong and Yao, 2023). Further erosion of plastic surfaces is caused by abrasion due to surface or particle abrasion (Al-Darraji *et al.,* 2024). Increasing the surface area also enhances the potential for biochemical degradation (Phanthong *et al.,* 2021; Julienne *et al.,* 2019), as well as photo-oxidative degradation (Iñiguez *et al.,* 2018; Schyns and Shaver, 2020). Environmental factors like humidity, temperature, and soil burial also accelerate this process by creating combined physical and biological stress (Han *et al.,* 2020).

Mechanical recycling relies on controlled mechanical breakdown to yield useful recycled commodities. Over-mechanical stressing during processing such as extrusion, however, degrades the polymer, resulting in recycled plastics of less quality compared to virgin plastics (Schyns and Shaver, 2020; Gabriel and Tiana, 2020; Phanthong and Yao, 2023). Therefore, maximum recycling methods must be used to minimize degradation and ensure product quality. Understanding how environmental conditions and mechanical stress affect degradation can maximize recycling effectiveness and reduce plastic waste.

Comparisons of Different Non-Biological Mechanisms of Plastic Degradation

As mentioned earlier, there are a variety of non-biological plastic degradation mechanisms like thermal degradation, photodegradation, hydrolytic degradation, and mechanical degradation. Moreover, each of these mechanisms contains its own characteristics, advantages, and disadvantages. Therefore, **Table 2** depicts a comparison of different kinds of plastic degradation mechanisms.

From the table, each degradation process has its advantages and limitations. An ideal plastic waste management system could therefore include the simultaneous use of these degradation processes, scientifically engineered based on environmental conditions and polymer type. More research is needed to increase the efficiency of these processes and reduce their limitations.

Table 2 Advantages and disadvantages of non-biological mechanisms of plastic degradation

Degradation Mechanism	Advantages	Disadvantages	Citations
Thermal Degradation	Effective for certain plastics; can recover energy	High energy consumption; toxic byproducts	Baburaj *et al.,* 2023
Photo-degradation	Reduces energy requirements; transforms plastics effectively	Slow rate; environmental hazards due to byproducts	Wang *et al.,* 2019; Tahmasebi *et al.,* 2019; Aruljothi *et al.,* 2023; Szczepanik *et al.,* 2021
Hydrolytic Degradation	Tailored conditions; biodegradable effectiveness	Slower rates; requires moisture; limited for non-biodegradables	Deymeh *et al.,* 2023; Garg *et al.,* 2022
Mechanical Degradation	Reduces polymer size; enhances further degradation	Increases microplastics; requires additional mechanisms	Chiu *et al.,* 2019; Buerge *et al.,* 2019; Aiello *et al.,* 2022

BIODEGRADATION

Microbes as Biodegradation Agent

Microorganism-based biodegradation is a unique approach that can be utilized to address this issue (Dailin *et al.,* 2022). This procedure involves the catalytic simplification of chemical compound complexity (Dailin *et al.,* 2024). Bioremediation can be achieved by using microbial approaches which depend on the metabolic potential of the microorganisms (Sayyed *et al.,* 2020). Microbes can be used for different industrial biotechnological applications such as agriculture, food and biopharmaceutical (Sukmawati *et al.,* 2020; Islam *et al.,* 2022; Dailin *et al.,* 2020). Numerous types of plastics are broken down by microbes especially bacteria and fungi strains during biodegradation. They can generate a variety of enzymes that can break down plastic polymers. This might aid in environmental preservation by preventing plastics from damaging the land, air, and water (Paço *et al.,* 2016). Hence, this review focuses on the microbial degradation of plastics with an emphasize on the current use of different types of microbes with the ability to degrade plastic material.

Some bacteria, like *Pseudomonas* and *Bacillus*, collaborate to break down plastics like PET (used in most bottles). These bacteria produce enzymes called polyester hydrolases that make it possible to transform PET into a less hazardous and more easily recyclable material (Roberts *et al.,* 2020; Cifuentes *et al.,* 2020; Salvador *et al.,* 2019).

Besides that, there are also fungi such as *Aspergillus* and *Cladosporium* that are involved in the breakdown of different plastics. They release enzymes such as laccases and peroxidases, which break down the rigid framework of plastics into easy, non-toxic chemicals (Brunner *et al.,* 2018; Luz *et al.,* 2020; Bertocchini and Arias, 2023).

In addition to bacteria and fungi, microbes within the guts of insects like *Galleria mellonella* (caterpillars of the wax moth) are also able to degrade plastics like polyethylene and polystyrene. Gut microbes utilize enzymes that might be used in the future for industrial recycling or environmental cleanup (Chen *et al.,* 2023; Lou *et al.,* 2020).

Therefore, the understanding how these microbes work enables scientist to identify new mechanisms to transform plastic waste into useful products, reduce pollution and can enhance the eco-friendly methods of plastic waste management as a a solution to the global plastic pollution problem (He & Liu, 2024; Nisha *et al.,* 2020; CF *et al.,* 2021). The **Table 3** shows some microbes use as a plastic biodegradation agent including their target plastic types.

Table 3 List of microbes use as a plastic biodegradation agent including their target plastic types

Microbe Name	Type	Origin	Test Condition	Plastic Type	Degradability Result	Citations
Alcaligenes faecalis	Bacteria	Contaminated Wetlands	22°C	PE	15% weight loss after 21 days; utilized polyethylene as carbon source	Munir et al. (2022)
Alternaria japonicas	Fungus	Polluted site	Laboratory conditions	LDPE	5.8% weight loss after 1 month	Gajendiran et al. (2016)
Aspergillus sydowii	Fungus	Rhizosphere soil	Room temperature	PE Microplastic	94% reduction in tensile strength after 60 days	Yanto et al. (2019)
Aspergillus clavatus	Fungus	Landfill soil	25–30°C	LDPE	35% weight loss after 90 days	Sangale et al. (2019)
Aspergillus niger	Fungus	Soil Samples; Polluted site	28°C, 21 days; Laboratory conditions	LDPE	Significant morphological changes; demonstrated biodegradation potential	Siregar et al. (2022)
Aspergillus terreus	Fungus	Rhizosphere soil	Room temperature	PE Microplastic	50% weight loss after 60 days	Yanto et al. (2019)
Aureobasidium pullulans	Fungus	Contaminated Environments	30°C	Whole plastics	<15% weight loss under laboratory conditions	DSouza et al. (2021)
Bacillus cereus	Bacteria	Sewage Treatment Facility	30°C, aerobic	LDPE	18.4% weight loss after 30 days	Shovitri et al. (2023)
Brevibacillus borstelensis	Bacteria	Landfill site	28°C	LDPE	Up to 23% weight loss after 1 month	Shovitri et al. (2023)
Ceriporia sp.	Fungus	Ligninolytic fungi	25°C	PS	19.44% weight loss after 1 month	Sargen (2021)
Cladosporium cladosporioides	Fungus	Shoreline Plastic Debris	22°C, 8 weeks	PU	13.4% weight loss after 4 weeks	Brunner et al. (2018)
Coriolopsis byrsina	Fungus	Mangrove soil	28°C	Polyethylene	20% weight loss after 60 days	Kuswytasari et al. (2019)
Curvularia senegalensis	Fungus	Soil Samples	30°C	Bioplastics	25% weight loss after 30 days	Siregar et al. (2022)
Cymatoderma dendriticum	Fungus	Ligninolytic fungi	25°C	PS	15.5% weight loss after 1 month	Sargen (2021)
Enterobacter cloacae	Bacteria	Contaminated Soil	30°C, aerobic	Polyhydroxybutyrate (PHB)	Significant enzymatic activity leading to effective plastic degradation	Munir et al. (2022)
Fusarium oxysporum	Fungus	Contaminated Soil	27°C	PET	Reduction in molecular weight; effective degradation	Cognigni et al. (2023)
Micrococcus luteus	Bacteria	Soil Samples	30°C	Various Plastics	10–15% mass loss after incubation	Montazer et al. (2019)
Mucor species	Fungus	Landfills	25°C	PE	10% mass loss after 30 days	DSouza et al. (2021)
Penicillium simplicissimum	Fungus	Soil	25°C	PVC	15% total mass loss	Temporiti et al. (2022)
Pestalotiopsis sp.	Fungus	Ligninolytic fungi	25°C	PS	74.43% weight loss after 1 month	Sargen (2021)
Pseudomonas sp.	Bacteria	Soil	Laboratory conditions	LDPE	15% weight loss after 1 month	Mandan et al. (2017)
Pseudomonas aeruginosa	Bacteria	Environmental Isolation	Aerobic conditions	LDPE	35.2% weight loss; significant hydrocarbon degradation	Sunil et al. (2023)
Rhodococcus rhodochrous	Bacteria	Oil-contaminated sites	30°C	PU	~40% weight loss after 7 days	Nisha et al. (2020)
Zalerion maritimum	Fungus	Isolated Dark; stirred at 120 rpm	Laboratory conditions	PE Microplastic	44.1% weight loss after 14 days	Soud (2019)
Zophobas morio gut microbiota	Bacteria	Gut of Wax Moth	In vivo	PS	Rapid degradation of polystyrene fragments observed	Lou et al. (2020)

Process of Plastic Biodegradation

Plastic biodegradation is a complex process under the influence of environmental factors and microbial action. It occurs in a series of important stages known as film development, degradation, fragmentation into pieces, assimilation, and mineralization. Some component of the plastic polymer is broken down in each stage into low molecular weight, non-toxic substances via biological and non-biological pathways. The biodegradation process of plastic polymers is shown in **Figure 2**.

Film formation is the beginning of the process, where microorganisms adhere to plastic surfaces and develop a microenvironment conducive to later degradation. The polymer chemical structure and environmental factors such as temperature and humidity at this phase affect the rate of degradation (Dissanayake *et al.,* 2024). The communities of microbial that exist in sediments plays an important role as well (Yang *et al.,* 2023b).

Then there is degradation, where plastic physically degrades, typically accelerated by UV light and other environmental conditions. It results in fragmentation, where plastics are fragmented into small pieces. The levels of decomposition are differs depending on the plastic composition and weather conditions (Peng *et al.,* 2022; Sharma & Neelam, 2022).

When the fragments fragment, the microbes degrade the tiny pieces at the assimilation stage. There are organisms like *Aspergillus niger* that have been known to degrade such food pieces (Ahmed *et al.,* 2025). Different microbial communities can lead to varying rates of breakdown of plastic (Philippe *et al.,* 2024).

Finally, mineralization converts the remaining plastic materials into inorganic compounds like CO_2, signifying the end of the biodegradation process (Beiras & López-Ibáñez, 2023). The process is efficient based on microbial strains and environmental conditions (Oliveira *et al.,* 2020).

Overall, plastics biodegradation is founded on the interaction of environmental factors, microbial processes, and the plastic material. Ongoing studies contribute to reinforcing plastic waste management and producing progressively better biodegradable products.

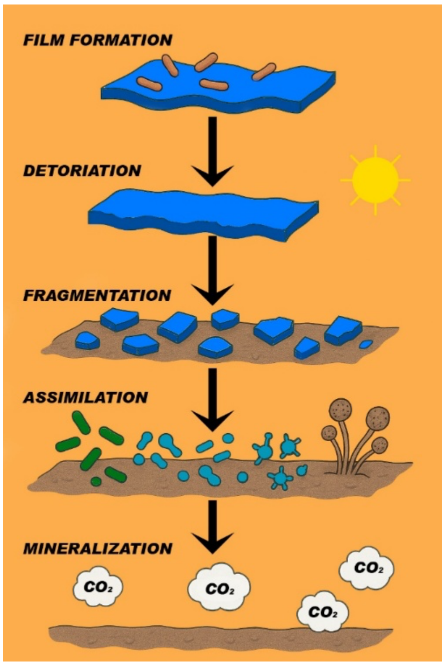

Figure 2 The biodegradation process of plastic polymers

COMPARISON OF BIODEGRADATION AND NON-BIOLOGICAL DEGRADATION OF PLASTICS

Plastic waste management is a one of the environmental sustainability concerns around the world. The two different approaches are biodegradation and non-biological degradation have mechanisms for addressing the problem differently. Both processes possess their own pros and cons and have opportunities to curb plastic pollution in the future. The **Table 4** below shows a comparison between the two approaches, which summarizes their implications for waste management policy and environmental impact.

Table 4 Advantages and disadvantages of non-biological mechanisms of plastic degradation

Aspect	Biodegradation of Plastics	Non-Biological Degradation of Plastics
Advantages	Breaks down into non-toxic products (water, CO_2, biomass) - (Ahmed *et al.,* 2018) Reduces plastic waste accumulation Derived from renewable resources - (Abdullah *et al.,* 2023; Samuel *et al.,* 2024) Potential to mitigate greenhouse gas emissions Can be optimized through microbial activity - (Gan & Zhang, 2019)	Enables material recovery through recycling Existing infrastructure in some regions
Disadvantages	Dependent on environmental conditions - (Najmi *et al.,* 2025) Inconsistent degradation rates Limited efficiency in some environments - (Royer *et al.,* 2023) Requires appropriate disposal systems	Often energy- and chemically-intensive (Usman *et al.,* 2023) Environmental concerns due to emissions Low global recycling rates (~9%) - (Maraveas, 2020) Reliance on landfilling increases pollution and ecological harm - (Das *et al.,* 2018)
Future Potential	Innovations improving material properties and biodegradability (Sousa *et al.,* 2022; Narančić *et al.,* 2020) Supports circular economy	Needs advancements in recycling technologies Until improved, shift towards biodegradable options is favoured - (Kakadellis & Rosetto, 2021)

	Helps reduce persistent pollution	
Environmental Impact	Can lower ecological footprint Returns nutrients to the biosphere	Currently contributes to long-term pollution if not properly recycled or disposed

In conclusion, both biodegradation and non-biological degradation processes contribute to plastic waste management, but with different advantages and disadvantages. As the need for green solutions rises, biodegradable plastics as well as recycling technologies will contribute increasingly to minimizing the effect on the environment and driving a circular economy

CONCLUSION

Research on the biodegradation of polymers made from petroleum has been a ground-breaking effort to reduce environmental plastic pollution. The microorganisms that have been claimed to biodegrade various synthetic polymers have been covered in this review. Depolymerases that contribute to the decomposition of plastics are still poorly understood. Therefore, future work should focus on discovering additional depolymerases from the microbes that break down plastic. A deeper knowledge of the underlying molecular mechanisms of biodegradation may result from more studies of the genes and/or gene products (enzymes) that hydrolyze the high molecular weight polymers used to make petro-plastics. Based on this information, genetic engineering techniques to produce recombinant microbial strains and/or enzymes might be used as the preferable option to accelerate the biodegradation of synthetic petroleum-based plastic waste.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper

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