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REVIEW

The implementation of microbes in plastic biodegradation

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Abstract

Most microorganisms are necessary for the decomposition of plastics and the production of bioplastics. It takes plastic materials more than a thousand years to degrade significantly. To degrade solid waste, microorganisms for the degradation of plastics should be configured meticulously. In the manufacture of equipment, a variety of plastic polymers are utilised, focusing on how they will be used. This article reviews about a detailed summary of the microbes that degrade several forms of plastics including polyethylene, polypropylene, polystyrene, polyurethane, polyethylene terephthalate, and polyvinyl chloride also the harmful effects of plastics on humanity.

Keywords Microbes · Plastics · Solid waste · Decomposition · Biodegradation

1 Introduction

Plastics have gained a great deal of attention compared to any other solid component. The bulk of plastics, nevertheless are not biodegradable and require a very good number of years to degrade [1, 2]. According to this year's data, the world's plastics production is recovering after a difficult time. Plastics continue to be in high demand, as seen by the 4% increase in worldwide output in 2021 to more than 390 million tonnes [3]. Global production of synthetic plastics is estimated to be over 400 million metric tonnes (Mt) in 2020; but, with the pandemic disease in 2019 (COVID-19), production is expected to increase nearly by 600 Mt annually by 2050 [4]. By 2060, it's predicted that 17% of the plastic waste generated worldwide would have been recycled, up from nine per cent in 2019. Because of their toughness and durability, they are frequently used. These naturally resistant polymers don't degrade biologically in the environment for considerably many years [5]. The issue of plastic is currently viewed as being equally relevant to the problem of growing and unknown quantities of microplastics in the surrounding environments [2]. The bacterial species are connected to the degrading materials. Microorganisms degrade plastics by converting polymers into oligomers and monomers through specific enzymatic activities. The microbial cells then take these enzymatically broken down, water-soluble chemicals and digest them. Degradation is the term used to describe the partial or whole breakdown of a polymer caused by many variables related to the environment, such as heating, light, water, force, and bacteria [6]. The term "biodegradability" refers to a substance's susceptibility to microbial deterioration. The main methods for addressing the present issue of plastic waste include landfilling, incineration, recycling, and biodegradation [7].

There are many disposable plastic objects in daily life, including plastic bags, garbage bags, disposable tableware and lunch boxes, and product wrapping bags. For bioplastics used in disposable goods, faster decomposition rates and mechanical properties that can survive the rigours of frequent usage are also required. Unfortunately, whether done automatically or manually, remaining mulch film accumulation cannot be completely removed for a long time, and retrieving leftover mulch film is getting progressively more expensive. These polymers are often landfilled together along with municipal solid trash when their useful lives are through. A few of the dangerous elements present in plastics that might release and endanger the surrounding environment and may interfere with people's health are phthalates, polyfluorinated substances, antimony trioxide, brominated flame retardants and bisphenol A [8].

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Bioplastics have a tremendous influence on global efforts to protect the environment. For the environment to develop sustainably in the twenty-first century, bioplastic development is a must. Therefore, advancing bioplastics research and product development is a goal shared by all nations.

Despite substantial global advancements in the management, treatment, and recycling over the past three decades. The majority of plastic trash still be disposed of in landfills or is publicly burnt, generating carbon monoxide (CO) and carbon dioxide (CO_2). They could, reasonably, wind dumped in landfills designed specifically for that purpose [9]. The recycling process is a substitute for the landfill for resource recovery, chemical recovery or energy recovery [10, 11]. In general, plastics may be classified into three types based on the size of their particles. All plastic materials > 5 mm is classified as macroplastics [12, 13]. Products made of plastic materials and other trash may become microplastic, or chunks < 5 mm when they reach the marine environment. The particle size range of 50 m to 5 mm is typically used to characterise macroplastics [14]. It is assumed that biodegradation is a more efficient and profitable way to stop this global issue. Our comprehension of the available biodegradation processes and their effectiveness, however, is insufficient. Within this perspective, the goal of the current review is to discuss the impacts of various types of plastics on the environment and the impact on human health as well as to provide the details of synthesised plastic's biodegradation process, including the elements that affect it.

2 Chemical constituents of plastics

Plastics' resistance to decomposition is the main factor making them hazardous to the environment, particularly in marine environments. It can endure hundreds or thousands to millions of years for plastic waste in the ocean to degrade biologically [3]. During this period, dioxins and polychlorinated biphenyls, which are found in plastics, are emitted into the water [9]. It has been claimed that a variety of materials used in the manufacture of plastics have negative effects on both people and animals. As previously noted, the manufacture of a large amount of plastic not only poses a challenge to sustainability due to its high energy consumption and carbon emissions but also creates a significant environmental risk when the trash is disposed of.

3 Impacts of degradation of plastics on the environment

3.1 Soil

Proper management of the landfills minimises the harm to the environment and human health, but the disintegration of the plastic by-products and additives could contaminate soil and groundwater in the long run [8; 15; 16]. Artificial polymers become brittle on the leaching of plasticizers and ultraviolet (UV) light and are then broken down into tiny particles by the action of waves or grinding on beaches [17]. The plastics collected from the different sources are being buried in agricultural soils which not only contaminate the soil and also have different overall effects than biodegradable materials. The plastic in the soil disperse on the soil surface and alters the physical property which includes density of soul, water holding capacity and structure of the soil [18]. The effects of biodegradable compounds on plants and animals are still unknown. Compounds that are shed from the mulch transfer to different ecosystems through various mediums and shows have various impacts in different environments. Although the effects of their size are poorly understood, they appear to have a greater negative impact on plants than other soil organisms. Because recycling is expensive and also time-consuming, only a small amount of PE films are recycled and typically most of the farmers burn or leave the majority of PE film leftovers on the ground, resulting in the release of hazardous chemicals that weakens the structure of the soil, entangle crop roots, and cause other problems and also prevent the absorption of water and nutrients, reducing the productivity of the crops and restricts expansion of agricultural sustainability [19; 20].

3.2 Air

Microplastics also known as tiny plastic particles resulting from commercial development and breakdown is discovered in both air and food samples and the impact of these tiny particles on human health is a growing concern. These tiny particles are the product of the breakdown of the macro plastics either naturally or by artificial jeans [21]. Nowadays the focus of the researchers has been drawn to develop strategies in aiding the breakdown of plastic and finding alternatives to traditional plastics due to the negative implications of plastic use, which is unavoidable for everyday necessities. It is uncertain whether the microplastics and the compounds attached are consumed or inhaled one of the potential routes of exposure to microplastics is through breathing due to the presence of this tiny particle in the atmosphere [22; 23]). There are airborne fibres, some of them are breathed which undoubtedly retains in the fluid of the lung lining after they enter the respiratory system. The fibres that are longer persist and are harmful to the pulmonary cells while certain fibres evade the lung's mucociliary clearance processes, particularly in those whose clearance techniques have been compromised [24].

3.3 Marine ecosystem

Accumulation of plastic in the marine environment has serious impacts, a long-time increase in plastic litter in marine environments mainly harm marine life like fish and underwater organisms such as turtles and that has been recognized globally [25; 26]). Two based sources of plastic accumulation in the marine environment are either land-based or ocean-based through in-situ or ex-situ pathways, which accumulates in freshwater system like river and streams and finally end up in the ocean [27]. Underwater animals like turtles entangling in this plastic waste limit their movement, preventing their movement to the water surface and respiration and ultimately leading to drowning and death. More than 80% of the plastic trash originated from land-based sources and also beach litter enters the food chain that produces poisons and hazardous substances that are lethal to aquatic creatures and also cause harm to aquatic ecosystems such as estuaries, shallow bays, coastlines, deep sea, and Open Ocean [14]. Aquaculture may also be a substantial source of plastic pollution in the oceans, with the fishing sector accounting for around 18% of the plastic waste that has been discovered in the ocean environment. [28].Virgin resin pellets, a typical component of trash, enter the seas on occasion as a result of unintentional losses during maritime transit or the run-off from processing plants [14, 19; 29]). Since plastics and waterborne chemical substances are persistent and are endocrine disruptors that modify metabolic and reproductive endpoints in different tissues, the accumulation of these compounds in animal tissue can cause serious harm [30]. These affected marine animals taken as food by social populations indirectly cause danger to the health of humans.

4 Harmful effects of plastic components on humans

The report in Table 1 lists toxic harmful chemicals that are released by various types of plastics during the period of degradation and their harmful effects on exposure to humans.

4.1 Mechanism of biodegradation

In the majority of everything that exists, bacterial microorganisms make up a broad spectrum among all living things. Bacteria are found inhabiting both their biotic and abiotic components of the environment and have the ability for obliterating toxins [31, 32]. Since debris made from plastic is so pervasive, it is practically impossible to eradicate it from the ecosystem, exceeding the damage to the environment continually and making the ecosystem repository of improperly handled plastics. The most commonly used methods for treatment of the plastic is landfill, incineration, treatment with chemical, and recycling of plastic, but is found to be ineffective in minimising the pollution caused by plastics. Although plastics made from renewable energy would probably biodegrade, there is no assurance that the plastic will dissolve completely [33]. To evaluate a sustainable and optimal degradation for the application, it is critical to compare the rate of biodegradation of the polymer in various environments. Heat, humidity, light (UV), and the presence of chemicals are the main environmental elements that have an impact on MPs. Figure 1 highlights the possible microorganism and its role in biodegradation of plastics.

A process by which environmental chemicals are subjected to structural transformation or alteration by microorganisms (via metabolic or enzymatic action). Plastics that can decompose into CO_2, CH_4, and microbial biomass through microbial activity are considered biodegradable. The carbon base from plastics is used by microorganisms to absorb carbon and produce energy [34]. The first phase in the microbial biodegradation methods is the passion of the microbes for the polymer substrate, which is followed by colonisation [35, 36]. The polymer is then attacked by microorganisms, which decompose into low-molecular-weight monomers, dimmers and oligomers before mineralizing them into CO_2 and water [37]. The biodegradation of plastic has been shown to involve both aerobic and anaerobic pathways [38]. The final products of polymer degradation in aerobic biodegradation are water, CO_2 and microbial mass. Oxygen molecules act as electron acceptors in this process. The complete plastic biodegradation process was proposed to be categorised into four stages (i) Biodeterioration, (ii) Biofragmentation, (iii) Bioassimilation, and (iv) Mineralization [39].

The majority of the carbon in the metabolised substrates releases energy in aerobic conditions through chemical conversion to CO_2. The process of biological biodegradation is quite different. Certainly, a physical attack such as gnawing or boring occurs when a microbial agent is involved, as is the case with rodents, insects, and marine borers. The approach does not involve atoms and molecules. Any unintended disruption of molecular bonds, such as the shortening of polymer chains, is a mistake. The action is not at the polymer molecule level, but rather at the physical structure level. The actions of microorganisms can be mechanical, chemical, or enzymatic [40] report that the appearance of various microbial species in a certain hierarchy causes a rise in biodegradation, which makes it easier to produce simple compounds. Extracellular polymers generated by microorganisms may function as surfactants in chemical biodeterioration, facilitating the transit of hydrophobic and hydrophilic phases. These interchanges accelerate the rate at which microbial species penetrate the surface [41].

Table 1 Lists of toxic harmful chemicals

Chemicals	Presence in Type of Plastic	Harmful Effects
Polybrominated diphenyl ethers	Flame retardants in plastics, polyurethane foams	Diminishes consciousness while harming the central nervous system
Toluene	All plastics	Depression may be brought on by respiratory and ocular irritation
Xylene	All plastics	The eyes are irritated. Additionally, it can have an impact on the central nervous system, which lowers consciousness and hinders learning
Di-2-ethylhexyl phthalate	Polyvinyl Chloride	Carcinogens can form DNA adducts
Polychlorinated biphenyls	Polyethylene, polyethylene terephthalate, polypropylene, polyvinyl chloride, polystyrene (All plastics)	Interferes with thyroid hormone
Polychlorinated naphthalene	Polyvinyl chloride paints and coatings; and often small particles discharged during abrasive blasting	Carcinogenic, may induce pulmonary oedema, and serious eye damage
Perfluoro octanesulfonic acid	Fluorinated polymers	Carcinogenic, irritating to the skin, eyes, and respiratory system. Influence on the central nervous system as well as the liver, spleen, and blood-forming organs
Perfluorooctanoic acid	Fluorinated polymers	Carcinogenic, irritating to the respiratory system, skin, and eyes. impact on the liver, spleen, and blood-forming organs as well as the central nervous system
Bisphenol A	Polycarbonate, phthalate esters, polyvinyl chloride	Mimics oestrogen, Ovarian disorder
Phthalate esters	Polyvinyl chloride, polystyrene	Interference with testosterone, sperm motility
Dioxin	All plastics	It affects the skin, eyes, and respiratory system and is carcinogenic. It harms the liver, bone marrow, digestive, neurological, and circulatory systems
Polycyclic aromatic hydrocarbons	All plastics	Developmental and reproductive toxicity
Persistent organic pollutants	All plastics	Potential harm to the nervous system and reproductive damage

Before a bio-fragmentation, the hydrolysis procedure, which is brought out by a variety of specialised hydrolytic enzymes including oxidases, peroxidases and depolymerases may take place. The pace of biodegradation is increased by the polymeric material's increased hygroscopic characteristics, which also boosts microbial augmentation. Two more methods that free radical oxidation could raise the molecule's polarity are the hydroxyl function of carboxyl or carbonyl group addition or formation [42, 43]. Bio-fragmentation involves the plurality of enzymes that are hydrolases and oxidoreductases to hydrolyze naturally abundant polymers, soil microbes readily create the hydrolases cellulases, amylases, and cutinases (e.g., starch, cellulose and cutin). Some enzymes that depolymerize (co)polyesters have been shown to have this active assimilation allowing the ability of the microorganisms [44–47] to grow and reproduce while ingesting nutritious substrate (e.g., polymeric compounds) from the environment. Through assimilation (e.g., polymeric materials), microorganisms can grow and reproduce while consuming substrate that is rich in nutrients. Things around the microbial cells must pass through their membranes to be absorbed. Depending on the microbial ability to live in aerobic or anaerobic conditions, three essential catabolic processes are available to give the energy: aerobic respiration, anaerobic respiration, and fermentation. Depending on the microbial ability to live in aerobic or anaerobic conditions, three essential catabolic processes are available to give the energy: aerobic respiration, anaerobic respiration, and fermentation.

4.1.1 Aerobic respiration

These microbes require cell-oxygenated substrates, which are the fundamental routes for catabolism (e.g. glycolysis, catabolism of amino acids, purine as well as pyrimidine and β-oxidation etc.,) to create a finite amount of energy. Then, to create increased energy, electron transport systems that decrease oxygen to water realise oxidative phosphorylation [48]. Anaerobic respiration: They utilise final electron acceptors besides oxygen (e.g., S, CO_2, Fe^{3+}, NO_3^- and SO_4^{2-}) [49]. Additionally, more ATP molecules are produced as a result than in insufficient oxidation.

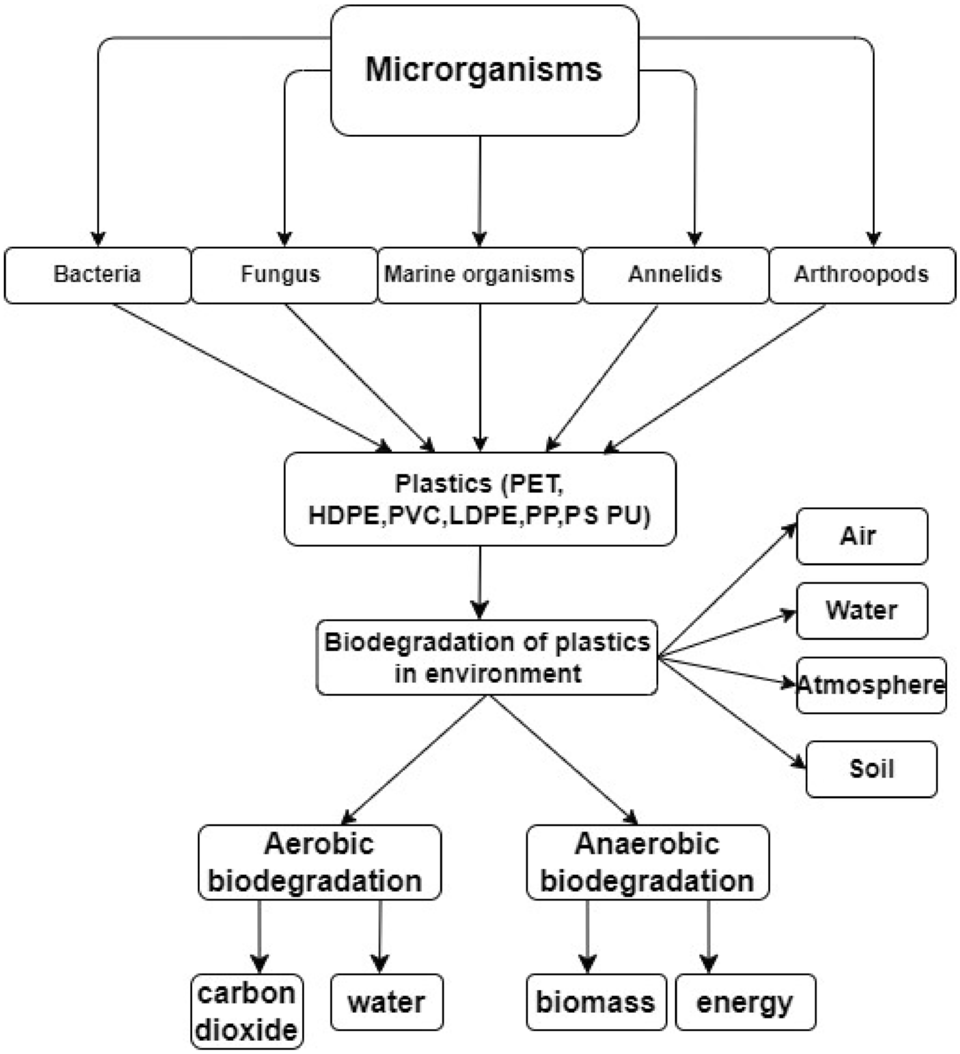

Fig. 1 Biodegradation of plastics

4.1.2 Fermentation

As final electron acceptors, they are not likely to require oxygen or other foreign mineral compounds. Their only means of generating energy is by fermentation, a partially completed oxidation cycle. Final electron acceptors are created by the cell itself from endogenous organic compounds [50].

4.1.3 Mineralization

The final stage of the biodegradation process. Hydrolytic conversion affects the excretion of CO_2 and water molecules inside the cell, and the energy produced by this plays a role in cell growth and development. There are several publications explaining how plastic biodegrades and fragments, however, there is very little information accessible regarding how plastic goods assimilate and get mineralized [50].

4.2 Plastic biodegradation by bacteria

There are various reports available on different types of plastic degradation by microbes are listed in Table 2. [51] reported the polyvinyl chloride biodegradative ability of five bacterial strains was checked under aerobic conditions, towards films made of polyethylene, polypropylene, polystyrene, and polyvinyl chloride. Polyvinyl chloride film degradation by *Pseudomonas citronellolis* and *Bacillus flexus* were demonstrated and tested for the characterisation of Fourier-transform infrared spectroscopy (FT-IR) spectra, Gel permeation chromatography (GPC) analysis, and weight loss are the parameters analysed. It is reported that the rate of biodegradation was found to be 19% in gravimetric in 30 days and 10% average molecular weight loss. The biodegradation of used polyvinyl chloride plastics was validated by a sample exposed to experimental settings for 45 days and chemical analyses performed on the incubated films.

Table 2 Plastic degradation microbes

Microorganism	Type of plastic tested	Evaluated parameters	References
Pseudomonas citronellolis; Bacillus flexus	Polyvinyl chloride	FT-IR spectra, GPC permeation chromatography analysis, weight loss	[51]
Paenibacillus sp.	Polyethylene, LDPE	FT-IR, SEM, weight loss	[52]
Pseudomonas sp.	Polyphenylene sulfide	FT-IR, XPS, weight loss	[53]
Pseudomonas aeruginosa RD1-3; *Pseudomonas knackmussii* N1-2	Polyethylene	AFM, SEM, viability test, whole genome characterisation, weight loss	[54]
Clostridium thermocellum	Polyethylene terephthalate	SEM, UV, weight loss	[55]

Low-density polyethylene (LDPE) biodegradation has been reported [52] and tested for weight loss measurements, FT-IR, and scanning electron microscope (SEM). Bacterial colonisation of *Paenibacillus* sp., isolate on the plastic surface and physical changes and formation of cracks and pits have been visualised by scanning electron microscopy and chemical characteristics, such as bond scissions and formation of new functional groups in the respective ranges of [carboxylic acids (3300–2500 cm^{-1}), esters (1210–1163 cm^{-1}), and ethers (1075–1020 cm^{-1})] have been tested by FT-IR. An experiment was conducted [53], in which polyphenylene sulfide showed excellent structural stability and was also been degraded by *Pseudomonas* sp., separated from the gut of super worms, showed active bioremediation potency of bead form of plastic incubated for 10 days and analysed for a weight loss of 9.71% and the beads was further analysed by FT-IR, X-ray photoelectron spectroscopy (XPS). Microbe such as *Pseudomonas knackmussii* N1-2 and *Pseudomonas aeruginosa* RD1-3 showed biodegradation of polyethylene mulching film after incubating it for 56 days and characterised for atomic force microscopy (AFM), SEM, viability test, and whole genome. The biodegradation capability of *Pseudomonas knackmussii* N1-2 and *Pseudomonas aeruginosa* RD1-3 were seen to be 5.95 ± 0.03% and 3.62 ± 0.32% of weight loss respectively [54]. *Clostridium thermocellum a* being a genetically engineered thermophilic bacterium showed enzymatic degradation of polyethylene terephthalate by a thermophilic cutinase. The parameters analysed after degradation experiments were SEM, ultraviolet spectra, and weight loss.

4.3 Marine microorganisms degrading plastics

Plastic materials are a considerable form of waste in coastal and marine environments. According to studies, plastic pollution causes the deaths of millions of marine species every year. Table 3 summarises the marine microorganisms degrading plastics. As per the report of [56], 32% of landfill waste ends up in the seas and marine areas causing marine pollution. Hence, to investigate the potential plastic-degrading bacteria among different prominent locations, different types of plastics such as LDPE, polyethylene terephthalate and polystyrene were used as the carbon source. A thick biofilm was specifically formed on LDPE by *Alcanivorax borkumensis* to degrade the petroleum-based plastic. Some of the studies show that the polypropylene microplastics were to be deteriorated by bacterial isolates from the mangrove sediments *Bacillus* sp. and *Rhodococcus* sp. The maximum weight loss of 6.4% by *Rhodococcus* sp. strains 36 and 4.0% by *Bacillus* sp. strains *27* after 40 days of incubation. Further, the SEM and FT-IR revealed structural and morphological changes [57]. An [58] experimented on mixed naturally weathered plastic pieces and incubated marine consortium. FT-IR, size exclusion chromatography (SEC) and GPC, sinking velocity, and weight loss were the methods used for evaluating the rate of biodegradation. The number-average

Table 3 Marine microorganisms degrading plastics

Microorganism	Type of plastic tested	Evaluated parameters	References
Alcanivorax borkumensis	LDPE	Denaturing gradient gel electrophoresis (DGGE)	[56]
Bacillus sp. and *Rhodococcus* sp.	Polypropylene	FT-IR spectra, SEM, weight loss	[57]
Bacillus and Pseudonocardia	Polystyrene	FT-IR, SEC and GPC, sinking velocity, weight loss	[58]
Bacillus paralicheniformis G1	Polystyrene	Weight reduction, FT-IR, TGA–DSC, NMR analysis, SEM, siderophore biosynthesis, whole genome characterization, chemotactic proteins, involved putative genes	[60]
Paracentrotus lividus	Polyethylene, polyvinyl chloride	Weight loss, toxicity test	[61]

molecular weight of polystyrene pieces declined by 33% and 27% in INDG and BIOG treatment and sinking velocity were increased by 30% respectively incubated with *Bacillus* sp. and *Rhodococcus* sp. for 5 months.

The researchers in this field [59] investigated the biodegradation potency of microbial isolates from the sediments of the Arabian Sea and tested them with polystyrene film. *Bacillus paralicheniformis* G1-incubated was at an experimental condition of pH 7.5, 30 °C and 4% salinity for 60 days. After incubation, samples were analysed in weight reduction, FT-IR, thermal gravimetric analysis (TGA)-differential scanning calorimetry (DSC), nuclear magnetic resonance (NMR) analysis, SEM, s siderophore biosynthesis, whole genome characterization, chemotactic proteins, and involved Putative genes. Around 34% of biodegradation has been reported for polystyrene film with genome analysis providing the molecular basis for biodegradation. An experiment with commercial bags (polyethylene) has been conducted to check the performance and impact of degradability from different locations incubated for 120 days with *Paracentrotus lividus*. The degradative ability of home compostable plastic delivered higher marine degradation among the industrial compostable substances. Weight loss was analysed to determine the biodegradation efficiency.

4.4 Invertebrates degrading plastic materials

Recent studies have shown that invertebrates can be a part of the degradation of plastic materials (Table 4). Some investigators have examined the significance of insects and discussed whether some insects can eventually break down plastics. A recent study reported [41] rapid biodegradation of high-density polyethylene (HDPE) by lower wax worms, larvae of *Achroia grisella* fed on a wax comb. The physiochemical properties analysed are FT-IR, H^1 NMR techniques, and weight loss percentage, [62] investigated the polyethylene and polystyrene degrading capacity of *Galleria mellonella* by feeding on the larvae of beeswax. A characteristic consumption of about 0.88 g and 1.95 g for 21 days.

Further, the depolarisation and biodegradation were confirmed by the formation of the metabolic intermediates. Subsequent studies characterized *Pseudomonas aeruginosa* strain DSM 50071 separated from the gut of *Zophobas atratus* a super worm exhibited degradation of styrofoam polystyrene for 21 days and the average rate of polystyrene reduction by the super worms was 68 mg per day [63]. In such study, dark mealworms (larvae of *Tenebrio obscurus*) and yellow mealworms (larvae of *Tenebrio molitor*) were studied in comparison after feeding the gentamicin (antibiotic), the depolymerization of polystyrene was hampered along with the inhibition of intestinal microbes M_w and M_n of the polystyrene also changed, indicating that the degradation of polystyrene by *Tenebrio* species can degrade the plastic waste [64]. Another investigation reported [65] that the rapid degradation of polystyrene by larvae of the darkling beetle *Plesiophthalmus davidis* ingested the polystyrene foam in 14 days of period *Serratia* sp. strain also showed polystyrene prominent degradation potential was analysed by microbial community species in the gut within 20 days [65].

4.5 Natural consequences of this biodegradation

The extent to which microplastics effect by spreading chemicals on the surface of the food particles is yet unknown, however, these components are found in the form of fibre, film, foam, spheres, and pellets [66, 67]. A large amount of trash end up in the coastal ecosystem as the manufacturing of plastic increases along with

Table 4 Degradation of plastic materials

Larvae insects	Type of plastic tested	Evaluated parameters	Intermediate	References
Achroiagrisella	HDPE	FT-IR, 1 H NMR techniques, weight loss percentage	–	[61]
Galleria mellonella	Polyethylene, polystyrene	Weight loss, TGA, FT-IR, Gas chromatography-mass spectrometer (GC – MS), GPC, gut microbial community structure analysis, hierarchical cluster analysis	Formation of C=O and C−O containing functional groups and long-chain fatty acids	[62]
Zophobas atratus	Polystyrene	NMR, FT-IR, and X-ray photoelectron spectroscopy	Formation of carbonyl groups oxidation pathway	[63]
Tenebrio obscures and *Tenebrio molitor*	Polystyrene	FT-IR, TGA, weight loss, SEM–EDX, GPC	Formation of functional groups of intermediates and chemical modification	[64]
Plesiophthalmus davidis larvae	Polystyrene foam	GPC, FT-IR, XPS, SEM	C–O and C=O bonds were introduced into the biodegraded polystyrene film	[65]

improper disposing of the plastics. This is due to changes in global sea levels [68], rainfall, wind speed [69], and wave height [70], as well as an increased danger of floods, storms, hurricanes, and tsunamis. The various problems faced by the globe today are waste and the various ways in which it reaches the marine ecosystem that finally causes pollution. The aquatic systems polluted by microplastics are mainly due to the discharge of waste from treatment plants, overflow of sewers during heavy rains, and biosolid runoff from agricultural areas. The farmer's impressions of uncertainty over agronomic performance and concerns regarding in degradation of soil [71] make biodegradable plastic a potential option for polyethylene mulch films [72]). But often use of agricultural mulch films directly to the ground, contamination of soil is an extremely probable event. Therefore, a potential and sustainable substitute for agricultural polyethylene mulch films might be prepared from biodegradable polymers that can break down in the soil. Designing sustainable bioplastics with superior durability and toughness compared to conventional plastics requires careful consideration of the right polymers derived from algal communities as the degradation of such products may lead to an increase in the organic carbon content in the soil which impacts the physicochemical property of the soil and also in the crop in which the harmful impact is found to be more than that caused by the non-degradable plastics and found to inhibit its growth, regulate the photosynthesis, decrease the root biomass and affect nitrogen metabolite and also enter the food chain and mainly affects the human health [73]. The marine ecosystem is the most affected as most of the biohazard components end up in the ocean and the release of these by-products in the marine environment mainly impacts marine life like mussels, jellyfish and others that mainly impact the development and also affect the marine bacterial species [74]. Physical, chemical, and biological weathering processes are significant in the context of the global risk posed by the accumulation of reversible plastic pollution and have an impact on the final elimination and place of origin time zones of very poorly reversible exposure, as well as the potential impact mechanisms. Long-term effects from increased plastic burdens include a variety of effects brought on by ingesting microplastic-related toxicity that include physical harm, physiologic alterations, and decreased rates of eating, reproduction, and oxygen consumption. Long-term effects of microplastics in soil damage soil structure, nutrient availability, microbial activity, and water holding capacity [75]. Analysis of the potential for delayed toxicological consequences caused by weathering-related deterioration or other non-toxicological impacts on the carbon and nitrogen cycles, soil fertility, and biodiversity is needed for discussion. But a "wide-ranging toxicity debt" can be used to describe the possibility of delayed impacts in the instance of plastic's potential ecotoxicity [76].

5 Conclusion and recommendations

Understanding how polymers degrade in the open environment, and their biodegradability under ecologically relevant circumstances is crucial so the subsequent generations need to adopt more biodegradable polymers in certain applications for environmental safety. The capability of biodegradable materials to break down leaving no hazardous materials helps to preserve our environment from the threat posed by conventional plastic waste, as well as the species that inhabit the environment and make it a safer place. The potential impacts of accumulating and poorly reversible plastic pollution on the global environment are wide that encompass both geophysical and biological impacts on the environment. A deeper scientific knowledge regarding the degradation procedure, timeframe for full biodegradation, fate and movement of microplastics and nano plastics, and their discharge into the ecosystems needed to address properly is a challenge. Plastic waste significantly influences marine litter, which has been shown to have detrimental effects on marine lives along with public health. Numerous studies have documented the participation of several microorganisms and invertebrate species in plastic biodegradation, demonstrating their critical significance in the process. But for concluding further more research study is needed to be carried out in the future.

1. To better understand how other microorganisms might degrade polymeric materials, research should concentrate on the biodegradation process and its key characteristics.
2. Because algal biodegradation doesn't require a specialised pre-treatment or a strong carbon source, it may be a superior developing up-recycling technology than bacterial or fungal biodegradation.
3. The use of soil-biodegradable plastic mulches increased the soil aggregate stability and water infiltration rate, which was a beneficial impact on the soil, as for plants, there is a need for comprehensive and long-term studies addressing the influence of these mulches on the dynamics of soil microbial communities and their functions.
4. More studies needed to be put into creating biodegradable mulch based on renewable resources that perform better.
5. Adopting biodegradable plastics gradually, replacing them with those used in marine settings for making fishing gear, tubular nets for marine aquaculture, socks or additions from the mussel culture for painting and maintaining ships and recreational vessels.

6. It is still not known how these compounds affect our bodies negatively. The introduction of microplastics into water bodies can be prevented by sewage outflows prevention from companies equipped with filters made from ceramic.
7. Several leverage areas for boosting sustainability in the biodegradable plastics business were found through an analysis of the manufacturing of biodegradable plastics and can set a goal for the future by replacing conventional plastic for the safety of society.

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