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Study on Degradation Rates of Plastics in the Environment

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Abstract

Polymers provide contemporary civilization outstanding performance features that are wanted by a broad variety of customers, but the destiny of polymers in the environment has become a significant management challenge that has to be addressed. Applications using polymers provide molecular architectures that are appealing to product engineers who are looking for features that have a longer lifetime. The environmental lifetimes of polymers and plastics are also heavily influenced by these qualities and features like them. Recent studies of microbial degradation of polymeric materials give new developing technical alternatives to change the large pollution danger suffered by usage of polymers and plastics. These chances are available as a result of recent research. There is a significant body of published research out there, from which one might glean insights on potential future areas of development for biological technology. In order to give the database that was used in the development of a new technology, each report of microbially mediated degradation of polymers has to be described in depth. As part of the development, the kinetics of the degradation process need to be investigated, and new techniques for accelerating the rate of deterioration need to be discovered. The process of developing new technology requires a fundamental comprehension of the dynamic relationship between biotic and abiotic processes of deterioration.

Keywords: *Polymers, kinetics, environmental*

Introduction

The formation of synthetic polymers involves the formation of strong covalent chemical bonds between hundreds or thousands of organic subunits (sometimes referred to as "monomers"). Bakelite, which was created in the early part of the 20th century by the condensation reaction of phenol and formaldehyde, is considered the first entirely synthetic polymer; nonetheless, the first mass manufacturing of polymers did not begin until the 1950s. Manufacturing throughout the world has expanded at an exponential rate since then, reaching 380 million tonnes per year in 2015. (1) At now, hundreds of different types and grades of polymer are manufactured on a commercial basis. The most significant market shares are held by low-cost, commodity thermoplastic polymers, which will be referred to collectively as "plastics" from this point forward. Polyethylene terephthalate (PET), high density polyethylene (HDPE), low density polyethylene (LDPE), linear-low density polyethylene (LLDPE), polyvinyl chloride (PVC), polypropylene (PP), and polystyrene are some of the materials that fall into this category (PS).

The first synthetic polymer was developed in 1869 in response to a business challenge to find a material that could successfully replace ivory and win a reward of $10,000. In order to fulfil the many needs of modern civilization, an unbroken chain of discoveries and innovations has resulted in the production of new polymers.

Polymers are made up of lengthy chains of atoms that are ordered in recurring components or units that frequently outnumber those that may be found in nature. The term "plastic" can be used to describe any material that is both malleable and easily formed. Recent use has shown that it is a term for a class of substances known as polymers. Plastics are now generally understood to refer to organic polymers with high molecular weights that are generated from a variety of hydrocarbon and petroleum-based sources [1].

Long chains of smaller molecules that are joined to one another by strong chemical bonds are used in the construction of synthetic polymers. These molecules are then grouped in repeating units that give desirable features. Plastics may be identified by their qualities, which include strength, flexibility, and a lightweight characteristic. These attributes are provided by the chain length of the polymers and the patterns of polymeric assembly. The qualities have shown the general utility of polymers and their manipulation for the building of a multiplicity of widely useful objects. This has led to a saturation in the market for polymers and an awareness of their less desirable features as well. A significant pattern characterised by an ongoing rise in the amount of plastics used in industrial and home applications has been seen in recent years. A significant portion of this polymer output is made up of plastic polymers that are, for the most part, incapable of biodegradation. This widespread use of plastics poses a significant threat to the environment because there is insufficient waste management and, until very recently, a cavalier behaviour on the part of the community regarding the maintenance of proper control over this waste stream. Until recently, however, there has been a shift in this cavalier behaviour. As a result of these conditions, there has been an increase in the number of efforts directed toward the development of creative techniques for the management of plastic trash, the discovery of biodegradable polymers, and education to encourage the correct disposal of garbage. Chemical, thermal, optical, and biological procedures are the many types of technologies that are now accessible for contemporary polymer degradation strategies [2, 3, 4, 5, 6]. The table that displays the physical attributes shows that there are only slight variations in density, but that there are significant variations in crystallinity and longevity. It has been demonstrated that crystallinity plays a highly directing function in specific biodegradation processes that take place on certain polymers.

Polymer	Abbreviation	Density (23/4°C)	Crystallinity (%)	Lifespan (year)
Polyethylene	PE	0.91–0.925	50	10–600
Polypropylene	PP	0.94–0.97	50	10–600
Polystyrene	PS	0.902–0.909	0	50–80
Polyethylene glycol terephthalate	PET	1.03–1.09	0–50	450
Polyvinyl chloride	PVC	1.35–1.45	0	50–100+

Selected features of major commercial thermoplastic polymers

Polymers are primarily marketed polymeric materials that are based on carbon and have been proven to have desired physical and chemical characteristics in a wide range of applications. These features may be used to a variety of different fields. A new study provides evidence for the vast variety of commercial materials that have been introduced into the global market since 1950 under the category of plastics. The total amount of virgin polymers that were manufactured on a large scale between the years 1950 and 2015 was estimated to be 8300 million metric tonnes [8]. Plastic materials have emerged as a significant contributor to the accumulation of solid waste on a global scale. Their annual consumption is estimated to be over 311 million tonnes, and 90 percent of them are derived from petroleum. The increase in the percentage of solid waste that is composed of plastic from less than 1% in 1960 to more than 10% in 2005 may be partly attributable to the rise in the use of plastic packaging. Plastics used in packaging are recycled in an extremely insignificant amount. If the present manufacturing and waste management trends continue, it is possible that the amount of plastic garbage in landfills and that which is found in the natural environment would reach 12,000 Mt by the year 2050 [9].

Structures and characteristics of polymers

Polymers are readily identifiable as useful chemicals because they are composed of a large number of repeating units [10]. The term "-mer" refers to the fundamental repeating unit of a polymer, whereas the term "poly-mer" refers to a chemical that is made up of a large number of repeating units. As a result of the chemical properties of the monomers, polymers may be chemically produced in a number of different ways, and the resulting product might be whatever one might want it to be. There are various instances of polymers that may be found in nature. These polymers can either be utilised directly or turned into materials that are required by society to fulfil certain demands. Concerning polymers are typically made up of carbon and hydrogen, with extensions including oxygen, nitrogen, and chlorine functions (see Figure 1 for examples). Chemical resistance, thermal and electrical insulation, strength and light weight, and a wide variety of applications in which there is now no suitable alternative are all qualities of polymers that continue to make polymers desirable. The automobile industry, the building and construction industry, and the packaging industry all have significant applications for polymers [12].

Biological degradation

The activities of many microbial species are utilised in the process of biodegradation, which breaks down organic substrates (polymers) into smaller molecular weight pieces that may then be further broken down into carbon dioxide and water. When it comes to biodegradation, the chemical and physical characteristics of a polymer are both very essential. The biodegradation efficiency that may be accomplished by microorganisms is directly proportional to the primary features of the polymers, such as their molecular weight and crystallinity. Exo-enzymes have a wide range of reactivity, ranging from oxidative functionality to hydrolytic functionality, and they are the enzymes that are initially involved in the breakdown of polymers. These enzymes are called exo-enzymes. Depolymerization is an overarching term that may be used to describe their effect on the polymer. In most cases, the complicated polymer structure is broken down by the exo-enzymes into smaller, more straightforward parts that the microbial cell is able to take up and use to finish the breakdown process.

Prerequisites for testing the biodegradation of polymers

During the process of polymer breakdown, which ultimately leads to mineralization and the production of process end-products such as carbon dioxide, water, and methane, the generation of new products is an ongoing and continuous process. For the aerobic degradation process to take place, oxygen is necessary since it acts as the terminal electron acceptor. During the process of breaking down plastic into its component parts, aerobic circumstances result in the production of carbon dioxide and water in addition to the cellular biomass of microorganisms. In environments with sulfidogenic conditions, the biodegradation of polymers results in the production of carbon dioxide and water. Under anaerobic circumstances, the decomposition of polymer results in the production of organic acids, water, carbon dioxide, and methane. When aerobic degradation is compared to degradation under anaerobic conditions, it is discovered that the aerobic process is more effective. When it comes to the creation of energy, the anaerobic process generates less owing to the lack of oxygen, which serves as the electron acceptor and is more effective in contrast to CO2 and SO42.

Plastics, which are solid materials, are subject to the impacts of biodegradation at the surface where they are exposed. The outside layer of an unweathered polymeric structure is the section that is often subject to the impacts of biodegradation, whereas the innermost part of the structure is typically immune to these effects. The plastic's structural integrity might be mechanically compromised by the effects of weathering, opening the door for bacterial or fungal hyphae to invade and begin the process of biodegradation at interior loci of the plastic. The amount of surface area a piece of plastic has is directly proportional to the rate at which it will biodegrade. Assuming that the circumstances of the surrounding environment do not change, the rate of biodegradation will pick up speed as the amount of surface area that has been colonised by microbes grows.

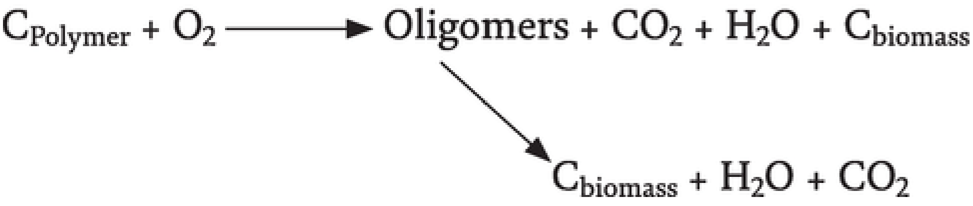
Through a process called biochemical transformation, microorganisms are able to convert complex organic molecules into more straightforward chemical forms. Polymer biodegradation is a process in which any change in the polymer structure occurs as a result of polymer properties alteration that occurs as a result of the transformative action of microbial enzymes, molecular weight reduction, and changes to mechanical strength and surface properties that are attributable to microbial action. These changes can be attributed to polymer biodegradation. The following is an example of how to create the biodegradation reaction for a carbon-based polymer in aerobic conditions:

$$C_{\mathrm{Polymer}} + O_2 + \mathrm{Biomass} \longrightarrow CO_2 + H_2O + C_{\mathrm{biomass}}$$

E1

In the process of microorganisms assimilating the carbon that makes up the polymer (Cpolymer), a conversion to carbon dioxide and water takes place, along with the formation of new microbial biomass (Cbiomass). In response, Cbiomass is mineralized over time by the microbial community or stored away as polymers for future use.

The process of aerobic plastic biodegradation is represented by the following set of equations, which provides a more comprehensive account of the phenomenon:



where carbon polymer and freshly created oligomers are transformed into carbon biomass, but carbon biomass then converts to carbon dioxide using a separate kinetics scheme. The process of converting organic matter into carbon dioxide is known as microbial mineralization. It is anticipated that each oligomeric fragment will go through a series of successive phases in which the chemical and physical characteristics will be changed, ultimately resulting to the benign conclusion that is sought. When the pollutant degrades at a rate that is sufficiently rapid for respirometry to provide expected rates of biodegradation, a technology has been developed and optimised for monitoring aerobic biodegradation using oxygen respirometry. This technology was developed for the purpose of monitoring aerobic biodegradation of small organic pollutants. Differential scanning calorimetry, scanning electron microscopy, thermal gravimetric analysis, Fourier transform infrared spectrometry, gas chromatograph-mass spectrometry, and atomic force microscopy are some of the analytical methods that are used when polymers are under consideration. Other methods include: Fourier transform infrared spectrometry, Fourier transform infrared spectrometry, and Fourier transform infrared spectrometry.

It is important to recognise that aerobic biodegradation will be the focus of our efforts because the majority of polymer disposal occurs in our oxygen-rich atmosphere. Despite this, it is important to acknowledge that environmental anaerobic conditions do exist and may be useful to polymer degradation. Because it has been discovered that anaerobic circumstances enable slower biodegradation kinetics, the contrast between aerobic and anaerobic degradation is very essential. There are several different circumstances in which anaerobic biodegradation might take place in the environment. Burial of polymeric materials triggers a complicated set of chemical and biological processes. At first, aerobic bacteria use all of the oxygen that is contained in the materials that are buried. The absence of oxygen in the following environments creates the right circumstances for the beginning of anaerobic biodegradation. The buried strata are often covered by layers that are 3 metres deep, and these layers prevent oxygen from being replenished. The beginning of anaerobic biodegradation is made possible by the presence of alternative electron acceptors such as nitrate, sulphate, or methanogenic conditions. Any preface or introduction

Development of more contemporary biodegradation models

Because of the complicated nature of the mechanisms that are involved in polymer biodegradation [27], this formulation for the aerobic biodegradation of polymers can be made more effective. The process of biodegradation, which may be summed up as the disintegration of substances brought about by the activity of microbes, followed by mineralization and the production of new biomass, cannot be simply encapsulated. For the purpose of providing assistance in the creation of comparison procedures to assess biodegradability, a novel analysis is required. Within the parameters of this discussion, polymer biodegradation is understood to be an involved process that is made up of the phases of biodeterioration, biofragmentation, and assimilation [28].

The word "biodegradation" refers to a biological process that is primarily made up of biological effects; nevertheless, in nature, both biotic and abiotic aspects play complementary roles in the organic matter degradation process. In common use, deterioration refers to the process through which the mechanical, physical, and chemical qualities of a substance are modified via degradation. Alterations to these traits are caused by a combination of biotic and abiotic influences. This biological activity takes place as a result of the development of microorganisms on the surface of the polymer or within the polymer substance itself. Microorganisms exert their influence by mechanical, chemical, and enzymatic mechanisms, which ultimately results in a modification of the gross polymer material characteristics. Environmental factors, such as air pollution, humidity, and weather, all play a significant role in the process as a whole. The contaminants that are adsorbed might help the material become colonised by other microbial species. In the process of biodeterioration, one may anticipate the participation of a wide variety of organisms, including bacteria, protozoa, algae, and fungi. The growth of a greater variety of biota can hasten biodeterioration by acting as a catalyst for the creation of simple compounds.

A material breaking phenomena known as fragmentation is necessary in order to fulfil the requirements for an occurrence known as assimilation, which comes later. Polymeric material has a high molecular weight, which means that its passage through the cell wall or cytoplasmic membrane is hampered by its size. In order for this technique to be successful, it is necessary to shrink the size of the polymeric molecules. The participation of biotic and abiotic processes, both of which are predicted to result in a diminution in molecular weight and size, can result in alterations to the size of molecules. It's possible that the use of enzymes produced from microbial biomass might achieve the necessary reductions in molecular weight. Oligomer and/or monomer mixtures are the products that may be anticipated to result from the biological fragmentation process.

Objective

1. To Conduct Research on the Conceptualization of More Recent Biodegradation Schemas

2. To Conduct Research on Biological Degradation and Analyze the Necessary Conditions for Testing Polymer Degradation

Conclusion

The environmental impact of the accumulation of plastic, particularly in the oceans of the world, is becoming an increasingly pressing worry. Poly(ethylene terephthalate), sometimes known as PET, is a polymer that is used regularly in a variety of applications, including textiles and the packaging of food. PET is one of the primary components of plastic garbage. PET is extremely resistant to biodegradation in the environment, and as a result, its accumulation is associated with a wide range of environmental concerns. These concerns include, but are not limited to, the absorption and concentration of organic pollutants, hazardous effects on marine wildlife, and dissemination of potentially invasive species to new environments. To this day, landfilling, incinerating, and recycling are the only three processes that are consistently utilised on a significant scale for the disposal of plastic. Every approach has a number of shortcomings and limitations. Incineration and landfilling both result in the discharge of hazardous secondary pollutants into the environment; however, landfilling has an additional downside in that it requires a significant amount of land area. Recycling eliminates the environmental problems caused by landfilling and burning waste; nevertheless, the recycling process itself is very inefficient, and the quality of the polymer that can be produced is declining, which is a limiting issue. The procedure also has a lower cost-effectiveness, which means that there is less of an incentive to invest in recycling facilities. The use of biodegradation as a method for the effective and ecologically responsible disposal of waste plastic is an appealing choice. However, substantial research is still being conducted in the field of biodegradation of polymers, and given the enormous metabolic potential of microorganisms, it is anticipated that it will only be a matter of time before viable biodegradation processes are developed. To date, no protocol has yet been developed to dispose of PET by biodegradation on a commercial scale.

References

1. Derraik, J.G.B. The pollution of the marine environment by plastic debris: A review. Mar. Pollut. Bull. 2002, 44, 842–852.
2. Pemberton, D.; Brothers, N.P.; Kirkwood, R. Entanglement of Australian fur seals in man-made debris in Tasmanian waters. Wildl. Res. 1992, 19, 151–159.
3. Azzarello, M.Y.; van Vleet, E.S. Marine birds and plastic pollution. Mar. Ecol. Prog. Ser. 1987, 37, 295–303.
4. Barreiros, J.P.; Barcelos, J. Plastic ingestion by a leatherback turtle Dermochelys coriacea from the Azores (NE Atlantic). Mar. Pollut. Bull. 2001, 42, 1196–1197.] [
5. Moore, C.J.; Moore, S.L.; Leecaster, M.K.; Weisberg, S.B. A comparison of plastic and plankton in the north Pacific central gyre. Mar. Pollut. Bull. 2001, 42, 1297–1300.
6. Mato, Y.; Isobe, T.; Takada, H.; Kanehiro, H.; Ohtake, C.; Kaminuma, T. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ. Sci. Technol. 2001, 35, 318–324.
7. Rios, L.M.; Moore, C.; Jones, P.R. Persistent organic pollutants carried by synthetic polymers in the ocean environment. Mar. Pollut. Bull. 2007, 54, 1230–1237.

8. Hirai, H.; Takada, H.; Ogata, Y.; Yamashita, R.; Mizukawa, K.; Saha, M.; Kwan, C.; Moore, C.; Gray, H.; Laursen, D.; Zettler, E.R.; Farrington, J.W.; Reddy, C.M.; Peacock, E.E.; Ward, M.W. Organic micropollutants in marine plastic debris from the open ocean and remote and urban beaches. Mar. Pollut. Bull. 2011, 62, 1683–1692.
9. Schecter, A.; Colacino, J.; Haffner, D.; Patel, K.; Opel, M.; Päpke, O.; Birnbaum, L. Perfluorinated compounds, polychlorinated biphenyls, and organochlorine pesticide contamination in composite food samples from Dallas, Texas, USA. Environ. Health Perspect. 2010, 118, 796–802.
10. Chung, S.Y.; Yettella, R.R.; Kim, J.S.; Kwon, K.; Kim, M.C.; Min, D.B. Effects of grilling and roasting on the levels of polycyclic aromatic hydrocarbons in beef and pork. Food Chem. 2011, 129, 1420–1426.
11. Zhou, Q.; Gao, Y.; Xie, G. Determination of bisphenol A, 4-n-nonylphenol, and 4-tert-octylphenol by temperature-controlled ionic liquid dispersive liquid-phase microextraction combined with high performance liquid chromatography-fluorescence detector. Talanta 2011, 85, 1598–1602.
12. Masó, M.; Garcés, E.; Pagès, F.; Camp, J. Drifting plastic debris as a potential vector for harmful algal bloom (HAB) species. Sci. Mar. 2003, 67, 107–111.
13. Censky, E.J.; Hodge, K.; Dudley, J. Over-water dispersal of lizards due to hurricanes. Nature 1998, 395, 556.
14. Barnes, D.K.A.; Milner, P. Drifting plastic and its consequences for sessile organism dispersal in the Atlantic Ocean. Mar. Biol. 2005, 146, 815–825.
15. Walker, T.R.; Reid, K.; Arnould, J.P.Y.; Croxall, J.P. Marine debris surveys at Bird Island, South Georgia 1990–1995. Mar. Pollut. Bull. 1997, 34, 61–65. [