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# *Impact of Plastic Pollution on the Environment and Application of Multidimensional Degradation Technology*

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***Abstract:*** With the rapid development of the plastics industry, plastic degradation has formed a complex and diverse industry in just a few decades, occupying an important position in the development of the economy. Plastic products are widely used because of their low price, portability, and durability, but their difficult-to-biodegrade characteristics have led to serious environmental pollution problems worldwide, causing widespread international attention to effective plastic waste management and degradation technologies. Based on the current situation of production and technology development at home and abroad, this paper studies the mechanism and future development trend of degraded plastics by analyzing the degradation methods of biodegradable plastics, photothermal degradable plastics, starch-modified plastics, microbial degradable plastics, and so on. Multi-dimensional degradation technology and reuse is a necessary path for the sustainable development of the plastics industry, and also an effective way to solve the problem of plastic pollution.

## 1. Introduction

As a kind of chemical raw material, plastics are polymer compounds made of monomers, polymerized by polymerization or condensation reaction, with medium deformation resistance, between fiber and rubber, and consist of synthetic resins and additives such as fillers, plasticizers, stabilizers, lubricants, colors, and so on[1]. Nowadays, with the acceleration of global industrialization, the world's use of plastic manufactured goods has exploded, and plastic products are widely used in all walks of life because of their cheap, lightweight, durable, and other characteristics[2]. However, according to the United Nations Department of Environment statistics global plastic waste has exceeded 4.9 billion tons[3], and "white" pollution is making the ecological environment suffer serious pollution. The OECD (OECD) warned on June 3 that if nothing is done, global plastic will nearly triple from 460 million tons to 1.231 billion tons in 2060, compared to 2019 levels[4]. Most plastics are discarded after being used or disposed of waste in the form of plastic waste disposal, which is set to increase by the same proportion, from 353 million tons to 1,014 million tons[5-6] . Plastic waste poses an immediate threat to human health by contaminating the environment and the food chain and may affect long-term human health through the accumulation of microplastics.

The essence of plastic pollution is that plastic waste leaks into the natural environment such as soil and water and is difficult to degrade, bringing visual pollution, soil destruction, microplastics, and other environmental hazards. Faced with non-degradable plastics in the natural environment that need 2 to 3 hundred years to completely degrade, and very easy to cause white pollution, soil sclerosis, and other environmental problems, the widespread and persistent plastic pollution has caused widespread concern in the international community. Traditional plastics are mostly non-biodegradable materials, and their decomposition process in the natural environment may take hundreds of years. Currently, countries are paying great attention to the degradable use of plastics and are striving to find effective technologies for plastic waste management and degradation. This paper establishes, for the first time, an integrated assessment framework for evaluating the efficiency and applicability of different degradation technologies under specific environmental conditions. This framework not only considers the degradation rate, but also includes multiple dimensions such as environmental impact, economic cost and social benefit. Research on environmental adaptability and synergistic effect: This paper thoroughly explores the adaptability of various degradation technologies, such as biodegradation, photothermal degradation, starch-modified degradation and microbial degradation, under different environmental conditions, and analyzes the potential synergistic effect of these technologies, which provides a new perspective for realizing a more efficient degradation of plastics. Through the cost-benefit analysis, this paper puts forward a series of policy recommendations aimed at promoting the wide application of multidimensional degradation technologies. These recommendations take into account economic feasibility and social acceptance, and provide practical guidance for building a long-term and stable plastics circular economy system. Prospects for application of innovative technologies: This paper not only focuses on current degradation technologies, but also predicts future technological development trends and explores the potential applications of these technologies in environmental protection and sustainable development.

## 2. The Chemical Basis for the Difficulty of Plastic Degradation

The plastic chemical molecular structure has two types: one for the linear molecular structure, resulting in the structure of the macromolecular substances called linear macromolecular materials; the second for the body structure, with the structure of the macromolecular compounds known as the body type polymer compounds. Although there are cross-links between the molecular structure, but the cross-link area is small, and not easy to dissolve. Two different structures show two opposite characteristics. The linear structure, which can be dissolved by heating, is characterized by lower hardness and heat resistance. The hardness and heat resistance are influenced by the body shape. There are two types of resins, thermoplastics made from streamlined polymers and thermosetting resins made from bulk polymers. Degradation of plastics due to their chemical form and structure is now a challenge.

## 3. Comprehensive Analysis of Plastic Degradation Technologies

In this paper, starting from the importance of degradable plastics in environmental protection and sustainable development, the current mainstream research methods of degradable plastics include biodegradable plastics, photo-thermal degradable plastics, and animal-eaten plastics to the research and application of the current biodegradable plastics emphasize the complete decomposition of the final plastics, and microbial decomposition of plastics is a subset of biodegradable plastics, which exclusively refers to the plastics which can be decomposed by microorganisms in a specific environment Microbial decomposition of plastics is a subset of biodegradable plastics, specifically referring to plastics that can be decomposed by microorganisms under specific circumstances. Enzymatic reactions, on the other hand, are biochemical reactions that express enzymes accelerating the decomposition process of biodegradable plastics. It is usually used in application scenarios where decomposition is required in a shorter period. Research on biodegradable plastics effectively reduces environmental pollution and promotes sustainable development.

### 3.1 Biodegradable plastics

Microorganisms prefer biodegradable plastics to traditional plastics because of the difference in their molecular structure. Conventional plastics, such as polyethylene, are composed of ethylene monomer, which has a high molecular weight and tightly linked molecular chains that are difficult for microorganisms to break down. In contrast, biodegradable plastics contain heteroatoms such as nitrogen and oxygen, structures that are preferred sources of nutrients for microorganisms. In addition, the ester-bonded structures in biodegradable plastics are easily hydrolyzed, facilitating the degradation process. The degradation of biodegradable plastics is usually divided into two main steps: microbial uptake and hydrolysis.

#### 3.1.1 Hydrolysis of polymer chains into small molecular fragments

Degradation of plastic in the natural environment of microorganisms and other roles, the physical form of large pieces of plastic film into small pieces of plastic fragments, more conducive to the attachment of microorganisms, and at the same time degradation of plastic long-chain structure into a short-chain, easier for microbial digestion, the physical form of the degradation of plastics can significantly accelerate the rate of degradation. The process of turning large films into small fragments and breaking down polymer chains into small molecule fragments is the decisive step (the most time-consuming part) in the overall degradation rate of degraded plastics. How to accelerate hydrolysis is the key to increasing the degradation rate.

#### 3.1.2 Degradation of small molecules in the presence of microorganisms

After hydrolysis, the microorganisms can eat these small molecules of degraded plastics better, and the microorganisms secrete specific degradation enzymes, after digestion, the small molecule fragments are absorbed by the microorganisms, and transformed into carbon dioxide, water, and biomass used to synthesize the microorganisms themselves, and then the degraded plastics have finished its whole cycle in the nature. The monomers from petroleum or plants are polymerized into degradable plastics and processed into various kinds of plastic products and finally transformed into water, carbon dioxide, and biomass under the action of microbial environment to return to the natural environment in another kind of harmless form. Most of the raw materials for biodegradable plastics come from natural plants and animals rather than fossil energy, and the carbon dioxide produced in the production process is greatly reduced[7].

#### 3.1.3 Analyze

Despite the challenges of high production costs and raw material supply, biodegradable plastics such as "PLA" and "PHA" are gradually being accepted by the market due to their close to traditional plastics in terms of performance and environmental advantages, especially in areas with strong policy support and environmental awareness.

### 3.2 Photothermal degradable plastics

#### 3.2.1 Principle

Photo-thermal degradable plastics achieve natural decomposition in the presence of sunlight through the addition of photodegradable agents (e.g., benzophenone, p-benzoquinone, etc.). Solar radiation triggers the photodegradable agents to accelerate the breaking of chemical bonds in the plastic, causing the material to break and disintegrate into small fragments. Eventually, these fragments are small enough to be metabolized by microorganisms, converted to carbon dioxide and water, or absorbed as part of biomolecules, thus reducing the environmental impact of plastic waste.

#### 3.2.2 Analyze

As a cutting-edge technology, photo-thermal degradation of plastics shows great potential in realizing efficient polyester recycling, but at present, due to the high cost of research and development and technical difficulties, its wide application still requires further technical maturity and cost reduction.

### 3.3 Microbial decomposition of plastics

#### 3.3.1 Principle

Microorganisms degrade plastics by secreting hydrolytic enzymes such as PE Tase and proteases. The enzymatic reaction of PE Tase breaks the carbon bonds of PET plastics in the presence of water molecules and breaks them down into mono (2-hydroxyethyl) terephthalic acid (MHET) and glycol that can be utilized by bacteria. Similarly, a wide range of microorganisms such as Pseudomonas aeruginosa and Aspergillus are also effective in degrading polyethylene (PE). The enzymes produced by these microorganisms are highly diverse and are important biocatalysts for industrial production and biotechnological applications. Genetic engineering approaches can enhance the efficiency of these enzymes to facilitate the degradation of PET and other polyester plastics.

#### 3.3.2 Analyze

The team of Chao-Min Sun discovered a marine bacterial colony that can significantly degrade polyethylene (PE) and terephthalate (PET) plastics[8-9]. The colony was able to break down PE into fragments within two weeks and degrade a wide range of resins such as PP, PS, and PVC. For biodegradable PUR plastics, the colony can cause penetration within a day, complete degradation within a month, and further breakdown into small fragments within two weeks. Microbial decomposition of plastics technology can effectively transform plastics under specific conditions, but the efficiency is greatly affected by environmental factors, and the current economic cost is relatively high, which limits its popularization in large-scale industrial applications.

### 3.4 Animal decomposition of plastics

Spanish biologist Federica Bertocchini accidentally discovered a kind of bug that can eat plastic, i.e. waxworm, because of beekeeping[10-11]. The saliva and intestines of wax worms contain an enzyme that can degrade plastic bags into glycol, and through many studies, finally, one hundred wax worms were able to digest a whole plastic bag in twelve hours, with a digestive rate 1,400 times faster than that of other organisms. Therefore, it is assumed that the proteins in wax worms can be extracted and reused and that if the proteins themselves are used, then large-scale replication using biotechnological means can be accomplished. This step could be accomplished by biotechnological means. In the information available, we also found that British and Spanish scientists carried out a time trial, which showed that one hundred wax worms could be degraded into 92 kg of plastic bags in twelve hours. In the case of fungi and microorganisms, the rate of biodegradation of plastics is about 0.13 kg/day, but the experimental technicians carried out a spectroscopic analysis of the larvae or the feces of animals that have eaten plastics, and the results showed that the chemical bonds in the resin are broken, and the polyethylene is decomposed into glycol, thus forming incompletely bound single substances. The decomposition of plastics by animal waxworms has the dual advantages of environmental protection and cost-effectiveness, but its decomposition efficiency and the technical difficulties of its large-scale application currently limit its dissemination to a wider range of fields.

### 3.5 Enzymatic degradation

Modified PCL can be degraded in two days under industrial composting conditions at 40 ℃. Enzymes discovered and optimized through biotechnology provide an efficient and environmentally friendly pathway for the decomposition of PLA and PCL plastics, and despite the high production cost of enzymes, they have great potential for specific industrial applications and are expected to reduce costs through technological innovations and promote their use in a wider range of markets.

## 4. Conclusion

In this paper, multiple degradation mechanisms, including biodegradation, photothermal degradation, starch-modified degradation and microbial degradation, are comprehensively applied to improve the efficiency and effectiveness of plastic degradation. Meanwhile, the proposed assessment framework can comprehensively evaluate the performance of different degradation technologies in specific environments, including degradation rate, environmental adaptability, economic cost and policy support, etc., which provides a scientific basis for selecting the most appropriate degradation technologies. This paper explores the synergistic effect between different degradation technologies and finds that the degradation rate of plastics can be significantly improved through reasonable combinations, while reducing the negative impact on the environment. At the same time, it takes into account various factors such as social, economic and technological aspects, providing comprehensive support for building a plastic circular economy system.

As an environmentally friendly material, degradable plastics are of great significance in alleviating global pollution problems. Through an in-depth understanding of the nature, types, applications, and future development trends of degradable plastics, this paper explores their great potential in environmental protection and sustainable development. Although degradable plastics have effectively curbed the problem of plastic waste pollution, there are still some difficulties in the management of plastic pollution, and it is still necessary for multiple social actors to respond in a concerted manner and build a long-term and stable plastics recycling economy system.

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