

Unveiling the Power: Microbial Degradation by Plastic-Degrading Microorganisms

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Abstract

Plastics are more durable, flexible, cheap materials which are widely used in daily life. Different scientists have been reported harmful and adverse effects of plastics in terrestrial environments, marine ecosystem, human health, pollution in water, air etc. Nowadays degradation of plastics is becoming very friendly and economically beneficial by using various microorganisms like bacteria, fungi. This review of literature shows types of plastics based on their properties, uses of plastics in daily life and microorganisms used in degradation of plastic.

Keywords: Plastics, Bacteria, Fungi Biodegradation, Pollution

1. Introduction

Plastics are cheap petrochemical material, which are used in daily household ubiquitously (1,6). Plastic is more affordable, thermal, flexible, robust and electromagnetic insulator material (2). Plastics are widely used in construction material, food packaging packets, disposable cutlery, cassette disc because of its good properties and cheap cost (3). Plastic wastes are the good source of isolation of plastics degrading bacteria and that encode enzymatic activity to degrade plastic (4). Polyethylene is classified into mainly three categories: Low Density Polyethylene (LDPE), Linear Low-density Polyethylene (LLDPE), and High-Density Polyethylene (HDPE). Among them LDPE is widely used in daily households because of their extreme minimal weight and withstand lot before breaking down completely (5). Commonly used plastics are Polyethylene (LDPE, LLDPE, HDPE, MDPE), Polyethylene terephthalate (PET), Polybutylene terephthalate (PBT), nylon, Polypropylene (PP), Polystyrene (PS), Polyvinyl chloride (PVC), Polyurethane (PUR) (5). According to recent study, ~ 60-70% of waste plastics are accumulated in landfills and the half life span of plastic degradation is ~10s-1000s of year (6). Because of slow degrading nature of plastic, it leads to obstruct to drain pipeline, air pollution, soil pollution, drain line blockage (7).

Basic steps of plastic degradations are: photo oxidation, thermos oxidative degradation and biodegradation. Among this biodegradation method is widely acceptable; in photo oxidation degradation, UV radiations are used, while thermos oxidative method is not used because of high thermal energy requirement (8). Plastic can be degraded also by aerobic, anaerobic and enzymatic methods that cleave the polymer plastic into monomer and oligomer (9). Biodegradation of plastic has been done by over 90 genera including bacteria, fungi: among them *Bacillus* sp., *Pseudomonas* sp., *Azotobacter* sp., etc., which cleave the polymer by enzymatic reaction and convert into monomer and oligomer (10, 11). The complete and finished plastic is non-toxic but, the monomer that is used for manufacturing of plastic is toxic (10,11,12). Degradation of plastic evaluated by weight loss, tensile strength loss, changed of polyethylene texture, changes in polyethylene chain molecular disturbance (13).

Because of non-degradability or slow degradability nature of plastic, the harmful effects occur on marine environments, wildlife animals, human lives, air pollution, terrestrial pollution (14). Recent microbial studies of ruminants found plastic objects from intestinal track of invertebrates, fish, birds, shows adverse physiological activities effect; also causes aesthetic problems (15).

1.1. Classification of Plastic

Based on thermal properties, designing properties and their degradation properties plastics are classed into various types. The types and applications are listed as below in Table 1:

Table 1. Types of Plastic and their applications

Sr. No.	Types of Plastic	Application	Reference
1.	Polyethylene Terephthalate [PET]	Drinking bottles, microwavable packaging, plastics films	16

2.	Polyurethane (PUR)	Synthetic foam	17
3.	Low Density Polyethylene (LDPE)	Plastic bags, bottles, disposable container	17
4.	High Density Polyethylene (HDPE)	Food and chemical packaging such as drinking bottles, motor oil bottles, detergent bottles	18
5.	Polyvinyl Chloride (PVC)	Artificial leather, construction material, pipes, packaging blends, toys, wire, pipes, cables,	19
6.	Polypropylene fibers	Pavements, floors, overlays, industrial slabs, shotcrete, tunnel linings	20
7.	Polystyrene (PS)	Commercial products such as disposal plastic cutlery, food containers, CD jewels, License, Insulators at low temperature, plates, petri plates, Laboratory equipment	5
8.	Polyurethane (PU)	Constituent material in many industries including furniture, coating, construction materials, fibers and paints	21
9.	Polycarbonate (PC)	Building construction, automotive and transportation, optical and ophthalmic media, medicine, packaging, optical data storage device	22
10.	Polyethylene	Bottles, carry bags, disposable articles, garbage containers, margarine tubes, milk jugs, water pipes	23
11.	Polylactic acid (PLA)	Biomedical filed such as material for sutures and bone fracture fixation, packaging	24

 material and mulching films

12.	Polyester (PES)	Bottles, films, tarpaulin, sails, canoes, liquid crystal display, hologram, dielectric films	25
13.	Polyacrylamide (PAM)	Oil recovery, paper manufacturing, mining, as flocculants to improve sedimentation in sewage treatment	26
14.	Poly (butylene adipate -co-terephthalate) (PABT)	Production of blown films, and membrane products	27
15.	Poly [(2,2'-m-phenylene)-5,5'- dibenzimidazole] (PBI)	Aerospace industries	28

1.1.1 Classification based on thermal property of plastic

Based on thermal property of plastic, they are classified into two categories as: 1) Thermoplastic 2) Thermoset.

1.1.1.1 Thermoplastics

Thermoplastics are melted when heated and harden when cooled. Polyethylene terephthalate (PET), Polyethylene (PE). Low density polyethylene (LDPE), High density polyethylene (HDPE), Polystyrene (PS), Expanded polystyrene (EPS), Polyvinyl Chloride (PVC), Polycarbonate, Polylactic acid (PLA), Polypropylene (PP), Polyhydroxyalkanoates are the examples of thermoplastics.

1.1.1.2 Thermoset

Chemical structures can be changed when heated so cannot be remelted are known as thermoset. Polyurethane (PUR), Phenolic resins, Epoxy resins, silicone, vinyl ester, acrylic ester are examples of thermoset plastics.

1.1.2 Classification based on designing property of plastic

According their designing property of plastic, they are classified as electrical conductivity tensile strength,

thermal stability, durability and degradability.

1.1.3 Classification based on degradability of plastics

Based on degradability nature, they are classified as degradable plastic and non-degradable plastic. Non-degradable polymer are synthetic and repeated units of its monomer. Degradable polymers are made up of starch.

2. Microorganisms involved in Plastic degradation

The role of Microorganisms in plastic degradation is very important. The different types of microorganisms have ability to degrade different groups of plastics. Table 2 shows different types of microbes have ability to degrade different types of plastic.

Table 2. Types of Plastic, microorganisms and their efficiency to degrade polyethylene

Type of Microbe	Type of Plastic	Source of Plastic	Degradation Efficiency	Reference
<i>B. siamensis</i>	LDPE	Soil of waste disposal site	8.46 ± 0.3%	29
<i>B. cereus</i>	LDPE	Soil of waste disposal site	6.33±0.2%	29
<i>B. wiedmannii</i>	LDPE	Soil of waste disposal site	5.39 ± 0.3%	29
<i>B. subtilis</i>	LDPE	Soil of waste disposal site	3.75± 0.1%	29
<i>p. aeruginosa</i>	LDPE	Soil of waste disposal site	1.15± 0.1%	29
<i>Bacillus sp.</i>	LDPE	Petroleum soil	23%	30
<i>Fusarium sp. II</i>	LDPE	Petroleum soil	44%	30
<i>B. siamensis</i> BS 10L	LDPE	Soil	13.40± 0.013%	31
<i>B. siamensis</i> Plasma treated BS 10L	LDPE	Soil	27.78±0.014%	31

<i>Fussarium sp.</i>	HDPE	Soil	2.65 %	32
<i>Staphylococcus aureus</i>	PE	Dumpsite Lagos	25%	33
<i>Streptococcus sp.</i>	PE	Dumpsite Lagos	31.2 %	33
<i>Bacillus sp.</i>	PE	Dumpsite Lagos	25 %	33
<i>Micrococcus sp.</i>	PE	Dumpsite Lagos	31.2 %	33
<i>Bacillus safensis</i>	LDPE	Pure culture media	18.6 %	34
<i>Bacillus amyloliquefaciens</i>	LDPE	Pure culture media	18 %	34
<i>E. coli</i>	PVC	Dump sol with plastic	5.32%	35
<i>Pseudomonas sp.</i>	PVC	Dump sol with plastic	40.53 %	35
<i>Klebsiella</i>	PVC	Dump sol with plastic	23.06 %	35
<i>Staphylococcus</i>	PVC	Dump sol with plastic	10.92 %	35
<i>Aspergillus Niger</i>	LDPE	Garbage soil	26.17 %	36
<i>Aspergillus flavus</i>	LDPE	Garbage soil	16.45 %	36
<i>Streptomyces sp</i>	LDPE	Garbage soil	46.7 %	36

2.1 Bacteria

Rodococcus ruber strain C208 has been isolated and have high degradation ability (37). *Pseudomonas putida* isolated from garden soil samples (38). *Bacillus licheniformis*, *Pseudomonas cereus*, *Pseudomonas putida*, *Bacillus subtilis*, *Bacillus cereus* was isolated from citrus mealybug by degradation of chlorpyrifos and

polyethylene by endosymbiotic bacteria (39). *Acinetobacter guillouiae* was isolated from novel screening method using redox indicator (40). Polyethylene degrading bacteria, *Klebsiella pneumoniae* Mk-1 was isolated from soil sample (41). In addition, *Pseudomonas aeruginosa* strain SKN1 and SKN2 were isolated from waste landfill which have ability to degrade low density polyethylene bacteria (42). *Bacillus weihenstephanensis* were isolated from garbage soil which have ability to degrade LDPE and HDPE (43). *Kocuria kristinae*, *Dermaococcus nishinomiyaensis*, *Pseudomonas stutzeri*, *Acinetobacter haemolyticus* were isolated from payatus dumpsite, which have ability to degrade polyethylene Glycol and Low-density polyethylene (44).

2.2 Fungi

Mortierella sp., *Doratomyces microspores*, *Fusarium solani*, *Fennellomyces* sp., *Aspergillus fumigatus*, *Verticillium* sp., *Lecanicillium sakseanae*, *Cladosporium* sp., *Trichoderma* sp., were isolated from soil and compost which have ability to degrade Poly (lactic acid) (PLA) (45). *Fussarium oxysporum*, *Fussarium falciforme*, *Purpureocillum lilacinum* fungi were isolated from dumpsite and have ability to degrade low density polyethylene (46). *Penicillium simplicissium* fungi was isolated from local dumpsite and have ability to degrade polyethylene (47). *Aspergillus clavatus* strain JASK1 was isolated from landfill soil which degrade low density polyethylene (48). *Aspergillus niger*, *Aspergillus flavus*, *Penicillium* sp., *white rot* and *brown rot* fungi were isolated from waste disposal site which have ability to degrade low density polyethylene bags (49). *Fusarium oxysporum*, *Aspergillus fumigatus*, *Lasiodiplodia crassispota*, *Aspergillus niger*, *Penicillium* sp., *Tricoderma harzianum* were isolated and screened of polyurethane (PU) and low-density polyethylene (LDPE) degrading soil fungi from municipal solid waste (50).

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