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Degradation of plastics waste using microbes

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ABSTRACT

Plastics have become an important part of modern life and are used in different sectors of applications like *packaging*, *building materials*, *consumer products* and much more. Each year about 100 million tons of plastics are produced worldwide. Demand for plastics in India reached about 4.3 million tons in the year 2001-02 and would increase to about 8 million tons in the year 2006-07. Degradation is defined as reduction in the molecular weight of the polymer. The Degradation types are (a).Chain end degradation/de-polymerization (b).Random degradation/reverse of the poly condensation process. Biodegradation is defined as reduction in the molecular weight by naturally occurring microorganisms such as bacteria, fungi, and actinomycetes. That is involved in the degradation of both natural and synthetic plastics. Examples of Standard Testing for Polymer Biodegradability in Various Environments. ASTM D5338: Standard Test Method for Determining the Aerobic Biodegradation of Plastic Materials under Controlled Composting Conditions, ASTM D5210: Standard Test Method for Determining the Anaerobic Biodegradation of Plastic Materials in the Presence of Municipal Sewage Sludge, ASTM D5526: Standard Test Method for Determining Anaerobic Biodegradation of Plastic Materials under Accelerated Landfill Conditions, ASTM D5437: Standard Practice for Weathering of Plastics under Marine Floating Exposure. Plastics are biodegraded, (1).In wild nature by aerobic conditions CO_2, water are produced,(2).In sediments & landfills by anaerobic conditions CO_2, water, methane are produced, (3).In composts and soil by partial aerobic & anaerobic conditions.

This review looks at the technological advancement made in the development of more easily biodegradable plastics and the biodegradation of conventional plastics by microorganisms. Additives, such as pro-oxidants and starch, are applied in synthetic materials to modify and make plastics biodegradable. Reviewing published and ongoing studies on plastic biodegradation, this paper attempts to make conclusions on potentially viable methods to reduce impacts of plastic waste on the environment.

Introduction

Matter is destroyed and created all the time. But if there is anything that goes against this rule, it can create havoc to the entire universe. One such matter is PLASTIC. Plastics are characteristically inert and resistant to microbial attack and therefore they remain in the nature without any deformation for very long time[1]. The word plastic comes from the Greek word plastikos, which means, 'able to be molded into different shapes'[2]. The plastics we use are made from, inorganic and organic raw material such as carbon, silicon, nitrogen, oxygen, chloride and hydrogen. Basic material used for making plastic are extracted from coal, oil and natural gas. Plastics are defined as the polymers which become mobile on heating and thus can be cast into moulds. Plastics are nonmetallic mouldable compounds and the materials made from them, can be pushed into almost any desirable shape and then retain that shape[3]. Commodity plastics are used in packaging, disposable diaper backing, fishing nets and agricultural film. They include polymers such as polyethylene, polypropylene, polystyrene, polyvinylchloride, polyurethane, polyethyleneterepthalate, nylon.[4]

Improperly disposed plastic materials are a significant source of environmental pollution, potentially harming life. The plastic sheets or bags do not allow water and air to go into earth which causes infertility of soil, preventing degradation of other normal substances, depletion of underground water source and danger to animal life. In seas also plastic rubbish from ropes and nets to the plastic bands from beer packs chokes and entangles marine mammals [5]. According to the municipal administrators carry bags are the main cause of blocked drains and thus municipal wastes cannot be incinerated leading to accumulated gargage, sludge, junk [6]. On this living planet, a biosphere, plastic is a raging parasite that devours and pollutes everything.[7]

In the early 1980s the research on degradability of plastics began. Some types of plastic have been shown to be biodegradable, and their degradation mechanisms have progressively become clearer[8]. Different degradable plastics, such as polylactides, poly (3-hydroxybutyrate- 3- hydroxy valerate), ethylene-carbon monoxide polymers, vinyl ketone copolymers (Guillet process), and starch-filled polyethylene (Griffin process) [9], have been developed. These plastics differ in degradation rate, application, and price. In one development, plastics' inertness and resistance to microbial attack was reduced by incorporating starch and later prooxidants (transition metals and oil) [10].

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Three types of degradation of polyethylene in these degradable starch-polyethylene polymers can occur by different molecular mechanisms: chemical degradation, photodegradation and biological degradation. Chemical degradation occurs when the prooxidants catalyze the formation of free radicals in polyethylene, which react with molecular oxygen to attack the polyethylene matrix [11]. Heat and oxygen accelerate this chain scission of the polyethylene. Photodegradation also occurs within the polyethylene matrix whereby UV light catalyzes the autoxidation and generation of free radicals [12]. Biological degradation of these polyethylene films has been reported in pure-culture studies with various microorganisms such as *Streptomyces* sp. [13], *Phanerochaete sp. [14] Pseudomonas, Xanthomonas, Flavobacterium, Micrococci, Streptococcus, Staphylococcus, Bacillus [15] Penicillium [16] Alcaligenes, Fusarium, Amycolatopsis sp., Comamonas acidovorans, [1] , Alternaria, Spicaria* spp., *Aspergillus,[17] Aureobasidium, Poecilomyces [18]* after chemical degradation was initiated and with their corresponding extracellular enzymes.

Materials and methods

Muhammad et. Al., in their study carried out 3 experiments to observe the biodegradation of plastics[14].

Soil burial treatment. The replicate pieces of cellulose blended PVC films (6 × 2.5 cm) were buried in the garden soil in pots for three months, inoculated with the sewage sludge for the isolation of microbial strains having ability to adhere and degrade the polymer film.

Shake flask experiment. Cellulose blended PVC films were incubated with the isolated microbes from soil burial experiments in shaking condition. Mineral salt media (MSM) used per 1000 mL contained in distilled water were; K_2HPO_4, 1 g; KH_2PO_4, 0.2 g; NaCl, 1 g; $CaCl_2.2H_2O$ 0.002 g; boric acid, 0.005 gm; $(NH_4)_2SO$, 1 g; $MgSO_4.7H_2O$, 0.5 g; $CuSO_4.5H_2O$, 0.001 g; $ZnSO_4.7H_2O$, 0.001 g; $MnSO_4.H_2O$, 0.001 g and $FeSO_4.7H_2O$, 0.01 g. Cellulose blended PVC film (3 pieces) in MSM (90 mL) were inoculated with 10 mL of spore suspension (10 ± 2.1 × 106 spores mL -1) and incubated at 30°C for 3 months. After every 4 weeks polymer samples were retrieved and evaluated visualy and with infrared spectroscopy measured on Bio- Rad Merlin FTIR (Excaliber Series FTS 3000 MX, USA).

Sturm test. CO_2 evolution as a result of cellulose blended PVC biodegradation was determined by sturm test [19]. The pieces of polymer were added to culture bottles containing MSM (285 mL) without any carbon source. Spore suspension of *Phanerochaete chyrosporium* PV1 (2.9 × 106 spores mL-1) was used as inoculum 5% (v/v) in test and control bottles (without plastic). Sterlized air was supplied to keep conditions aerobic and reaction bottles were stirred continuously by placing them on magnetic stirrer. After 30 days, gravimetric analysis of CO2 production was done by trapping the gas in adsorption bottle containing KOH (1 M). The precipitates formed after titration with barium chloride solution (1 M) of test and control were filtered, weighed and calculated for CO_2 produced per liter.

In another study by Emmanuel et.al. the ability of a complex enzyme (LIQ 1) to degrade polymers such as Sesbania gum and Guar gum was investigated. The study was based on an assumption that the polymer compounds dissolved in water wold increase viscosity and be able to plug an artificial rock sampls (made of pulverized coal) placed in a pressured chamber. The study was also based on an assumption that complex (LIQ1) would slowly degrade the polymer compounds thereby reducing their viscosity and hence forth unplugs the artificial rock. The polymer compounds were not auto degradable at room temperature though showed a decreasing viscosity after one hour[20]

UV light treatment was done by Kenneth et.al. evaluate the photosensitivity of each film of a plastic bag. A UV lamp with long (365-nm)-wave was used. Plastic strips (2.54 by 15.24 cm) were cut in machine direction and placed into a UV box (17.78 by 40.64 cm) at a distance of 17.78 cm from the lamp for 8 weeks [13]. The plastic strips were turned twice a week to ensure even exposure to the light. Samples were removed after 1, 2, 3, 4, and 8 weeks. Film mechanical properties and polyethylene molecular weight distributions were determined. Sasek et.al. used two methods of degradation. This included:

Composting technique: The composting was run under controlled conditions in a thermal insulated composting chamber using a standard mixture of raw materials used for cultivation of white button mushroom(*Agaricus bisporus*)obtained from a local mushroom compost-producing company[23]. Specimen of polymeric foils in small stainless steel containers were buried in the compost pile for 42,100 or 180 days; during the first weeks the temperature in the pile was close to 60^0C.

Fungal treatment: Few fungal strains were obtained from the culture collection of *Basidiomycetes.* These fungal cultures were prescreened using nutrient rich, glucose rich, extract agar [24] in pertidishes. Surface-sterilized (3% H_2O_2, 2 min) copolyester filaments were put on agar medium surface with simultaneous inoculation with the fungus. Other degradation tests were performed in liquid media, selected fungal strains were cultivated statically in 250 ml Erlenmeyer flaskcontaining 15ml of culture mediain which piece of poly(ester-amide) or copolyesters film were immersed. Before inserting into nutrient medium, the polymer pieces were suface sterilized (3% H_2O_2, 2 min). two culture media were used viz. nitrogen limited medium [25] and the above mentioned nutrient rich glucose malt extract medium.

Summary and conclusion

Plastics are one of the major threats to the environment. Studies are made all over the world are to degrade the polymer or bring out a biodegradable plastic. There are some plastics which resist degradation and some degrade to certain extent. Some of them remain as persistent organic pollutant (POP). The studies are about the degradation of different kinds of plastic in biological means and other means. The plastics which were studied are polyethylenes, polyvinyl chloride, polyesters, polyhydroxyalkanoates, polylcaprolactone, polylactic acid, polyurethane, polyvinyl alcohol, nylon and polyethylene, Sesbania and guar gum, polyester-polyurethane etc. Bacterial and fungal species are used widely for degradation. Many strains of *Pseudomonas* spp were used. The organisms which degrade the hydrocarbon in the plastics and use them as carbon source can be employed. Some of the microorganisms involved were *Pseudomonas spp., Xanthomonas spp., Flavobacterium spp., Micrococci, Streptococcus, Staphylococcus,Bacillus, Phanerochaete chyrosporium, Penicillium frequentans, Bacillus mycoides, Pseudomonas putidaVM15A, Streptomyces spp., Aspergillus spp*. The results are confirmed by the weight, tensile strength and decrease in viscosity in some cases, molecular weight distribution, and fragility. The HDPE plastics are showing resistance to soil conditions than LDPE. This study is useful for the molecular design of biodegradable polymers and for the molecular evolution and breeding of degradation enzymes and microbes. The enzymatic degradation of gum was also effective. The pure culture biodegradation assay shows the ability to identify which portion of the degradation is due to chemical degradation and what can be attributed directly to biological degradation. Through these studies degradation of plastic can be made effective.

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