Importance of Biological Processes for Pollution Control

Gungun Mishra
Ramjas College, University of Delhi,

Pollution is a major problem created mainly by overloading human population, rapid economic growth and anthropogenic activities. The multidimensional pollution caused by barely processed plastic waste are mainly Land Pollution (depletion of fertile land area), Water Pollution (dumping of wastes into water bodies), Air Pollution (accumulation of harmful gases into atmosphere), are all aggravating environmental pollution leading to severe issue worldwide. Such environmental degradation and pollution cause deterioration of the environment and natural resources including soil, water, and air; the loss of ecosystems; and the extinction of wildlife.

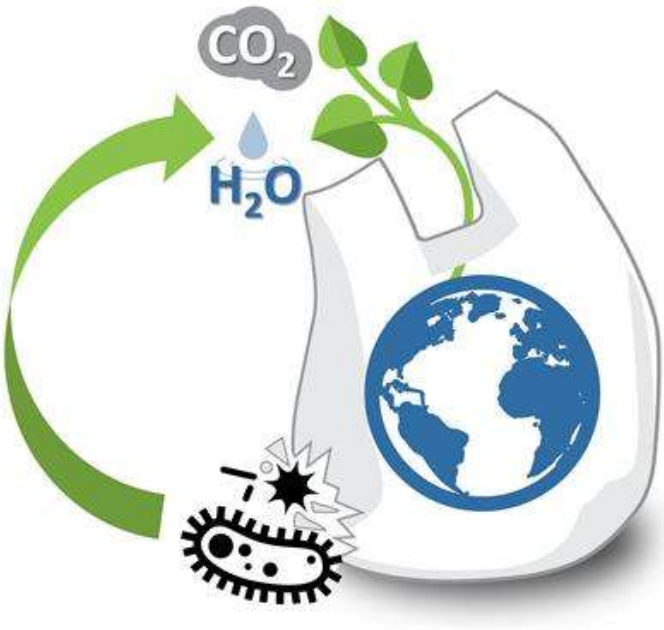

Figure: Showing Microbial Degradation of Plastics

Plastic products have become an integral part of our daily life such as packaging or wrapping materials, shopping/garbage bags, containers, toys, household items, industrial products, and building materials.

Plastic being cheap and versatile is a huge and unavoidable menace for the society. Easy availability and inexpensive nature of plastic has cost us a lot. Human activities with plastic further pollute or degrade the quality of soils and land utility. It negatively disturbs food production, livelihoods, climate changes, and marine ecosystem. As per Swachh Bharat Mission Plastic Wate Book Report (March 2019), production of plastic globally is around 150 million tonnes per year. According to the reports for year 2017-18, Central Pollution Control Board (CPCB), India has projected that India produces approximately 9.4 million tonnes per annum plastic waste, (that is 26,000 tonnes of waste per day). Around 5.6 million tonnes per annum of plastic waste is recycled (which is about 15,600 tonnes of plastic waste per day) and 3.8 million tonnes per annum of plastic waste is left uncollected or littered. Major share of these uncollected or littered plastic waste goes in open dump yards, water bodies and landfills hampering our planet's biodiversity and posing major risk to living. However, a lot of methods were taken up to solve the bulkiness and recycling of plastic waste but actions like 'Reuse, Reduce and Recycle' got beaten by the irresponsible consumption and exceeding demands of plastic use by the growing population and economic growths.

Pollution degradation by biological systems and reutilization of the by-products generated by its treatment is a highly effective measure to solve threats of plastic waste accumulation and enhance plastic waste management system.

Image Source: https://www.frontiersin.org/research-topics/8688/microbial-degradation-of-plastics

Some micro-organisms like algae or bacteria and worms have been found suitable to control such pollutions. For example, an environment-friendly solution includes use of the Wax Worm (Galleria mellonella) which helps to degrade polyethylene (PE) by oxidation and depolymerisation with its salivary enzymes.

Polyethylene (PE) is the most commonly produced and stable polyolefin derived plastics accounting for 30% of synthetic plastic production, hence contributing majorly to the plastic waste pollution. Further adding to the struggle, PE is also one of the most resistant polymers, and non-biodegradable waste with very long C-C chains making it hydrophobic in nature. Its crystalline form, and dense structure makes it tougher to undergo its biodegradation process. The high energetic cost of PE chemical treatment further creates problem for its Sustainable Plastic Waste Management Plan.

Biodegradation emerges out as a promising technique for treatment of Polyethylene Waste.

It refers to environmental degradation of long polymeric chains in presence of abiotic factors such as air, light to form smaller molecules which can be further metabolized easily by biological agents. The crucial step in degradation of PE by biological agents is the oxidation of polymeric chains within them, which can be a long process if Polyethylene (PE) polymers are not pre-treated (using heat or UV exposure methods). It takes years by abiotic factors to introduce oxygen atom into these chains which has to go further to be treated by micro-organisms. No enzyme from any micro-organisms have been identified that has the potential to degrade PE or plastics of other classes, if not pre-treated.

The insects mainly from the order: Lepidopterans and Coleopterans have been found out to be capable of biodegradation to certain extend. One such example is the larvae of Wax worms, Galleria mellonella, which has enzymes namely demetra, arylphorin and Ceres, hexamerin.

These enzymes are phylogenetically related to phenol-oxidases (enzymes targeting aromatic rings) and hemocyanin, an oxygen transporting protein that too shows phenoloxidase activity. These enzymes brings about the scission of the long polymeric hydrocarbon chains of Polyethylene into smaller molecules within few hours as observed under Gel Permeation chromatography (GPC) method. The confirmatory deterioration due to polymer oxidation was found by RAMAN spectroscopy.

The action of the salivary enzymes of wax worm larvae is equivalent to the abiotic pre-treatment of PE in shorter duration. It overcomes the problem of lingered-on mechanism of polymer oxidation which is the first and most important step of PE Degradation. These enzymes are referred to as, PEases (causing Lysis of Polyethylene) and are the first enzymes capable of producing such modifications on a PE film working at room temperature in a short duration. The identification of invertebrate enzymes capable of oxidizing PE in a few hours provides a parallel solution in the field of plastic degradation and opening up various possibilities which may help to solve the plastic waste pollution issue.

Several researches have implied the ability of enzymes Demetra and Ceres to break the Polyethylene polymer chain and their action against the C-C bonds, alkanes and plant phenolic, a constituent of Pollen and wax material present in the ecological niche. These enzymes in natural host provide storage, immunity and defence against plant phenolic extracts. Hence, such innate ability may help to deal with the toxic phenolic groups found out around them. Larvae of Galleria mellonella are armoured by similar enzymes. Utilizing the wax worms defence mechanism may turn out to be degradation mechanism for plastics or related non-biodegradable products around our ecological surroundings. How benevolent of Nature!