Microbial Degradation of Plastic Waste: A Review

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Abstract- *Plastics are the synthetic (man- made) polymers. They are the petroleum products made by extracting oil, coal and natural gas which are the basic material for plastics. They are made by polymerizing of monomers. They are widely used in packaging, agricultural products, medical and paramedical equipments, defense, information and space science. Extensive use of plastic in past few decades has resulted several environmental problems. The removal of plastic from environmental sphere has emerged as a big scientific challenge for scientific community across the globe. Continuous research is being undertaken by the researchers to mitigate the problem of plastic pollution. Plastics are widely used both in food or commercial industry. Plastic, one of its products is known to be expanding with changing lifestyles and increasing population. However, it causes serious effects on the environment due to its non degrading nature. Burning of this plastic waste and burying of the plastics releases harmful toxic material which is a major pollutant in environment. Also, there is an undesirable effects on the environment and it is known to be major problems with waste deposition and utilization. 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.The most commonly used non-degradable solid waste is polythene which is a linear hydrocarbon polymers consisting of long chains of the ethylene monomers. Degradation is defined as reduction in the molecular weight of the polymer.*

Keywords- Plastic, Environmental Problems, Plastic Pollution, Microbial Degradation.

I. INTRODUCTION

Plastics are the synthetic(man-made) polymers. They are the petroleum products made by extracting oil, coal and natural gas which are the basic material for plastics. They are made by polymerizing of monomers. They are widely used in packaging, agricultural products, medical and paramedical equipments, defense, information and space science. The advantages of using plastics are:

1. Cost-effective
2. Light in weight
3. Better shelf life
4. Extreme durability
5. Unbreakable

Approximately 140 million tons of synthetic polymers annually are being produced globally[1].

Plastic material has several disadvantages and the most important one is that they are resistant to degradation in environment. They persist for longer time in the environment. After its use, plastic wastes are dumped at landfill sites, natural terrestrial habitat and oceans.[2]

Plastics are synthetic polymers that are made up of long chains of repeating molecular units called monomers. Monomers are the building blocks of polymers. Most common plastics known as polythene or poly ethylenes are thermoplastic materials that are produced primarily by the catalytic polymerization of ethylene gas (C2H4) at elevated temperatures (T) and pressures (P). The polyethylene molecules usually contain branches of various lengths of all the hydrocarbon polymers, polyethylene has the simplest structure and the highest ratio of hydrogen to carbon in its backbone.

Table 1. List of various types of plastic used in everyday life

Type	**Use / Applications**
Polyester (PES)	Fibers, textiles
Polyethylene terephthalate (PET)	Carbonated drinks bottles, peanut butter jars, plastic film, microwavable packaging
Polyethylene (PE)	Wide range of inexpensive uses including supermarket bags, plastic bottles
High-density polyethylene(HDPE)	Detergent bottles and milk jugs
Polyvinyl chloride (PVC)	Plumbing pipes and guttering, shower curtains, window frames, flooring

Polyvinylidene chloride (PVDC) (Saran)	Food packaging
Low-density polyethylene (LDPE)	Outdoor furniture, siding, floor tiles, shower curtains, clamshell packaging
Polypropylene (PP)	Bottle caps , drinking straws, yogurt containers, appliances, car fenders (bumpers) plastic pressure pipe systems
Polystyrene (PS)	Packaging foam, food containers, plastic tableware, disposablecups, plates, cutlery, CD and cassette boxes
High impact polystyrene(HIPS)	Refrigerator liners, food packaging, vending cups
Polyamides (PA) (nylons)	Packaging foam, food containers, plastic tableware, disposable cups, plates, cutlery, CD and cassette boxes
Acrylonitrile butadiene styrene (ABS)	Electronic equipment cases (e.g., computer monitors, printers, keyboards) drainage pipe
Polycarbonate (PC)	Compact discs, eyeglasses, riot shields security windows,traffic lights, lenses
Polycarbonate/Acrylonitrile butadiene styrene (PC/ABS)	A blend of PC and ABS that creates a stronger plastic. Used in car interior and exterior parts and mobile phone
Polyurethanes (PU)	Cushioning foams, thermal insulation foams, surface coatings, printing rollers
Melamine formaldehyde (MF)	One of the aminoplasts and used as a multicolorable alternative to phenolics
Plastarch material	Bio degradable and heat-resistant thermoplastic composed of modified cornstarch
Phenolics (PF) or (phenol)	High-modulus, relatively heat-resistant and excellent fire resistant polymer used for insulating parts inelectrical fixtures, paper laminated product (e.g., Formica) and thermally insulation foams
Polyetheretherketone(PEEK)	Strong chemical and heat-resistant thermoplastic biocompati bility allows for use in implant applications and aerospace moldings
Polyetherimide (PEI) (Ultem)	A high-temperature, chemically stable polymer that does not crystallize
Polylactic acid (PLA)	A biodegradable thermoplastic that can be converted into a variety of aliphatic polyesters derived from lactic acid

Plastic has its role in modern society. Its an essential part of our cars, computers, mobile phones, childrens toys and practically most everything we use on a day-to-day basis. Plastic food and beverage containers became popular fairly recently (in the 1970s) and have become ubiquitous in our lives since then. Our food it seems is always touching plastic. Plastics play a part in every phase of food production and preparation. Food gets processed on plastic equipment and packaged and shipped in plastic-lined boxes and cans. At home we store and reheat the leftovers in plastic containers.

During the past five years public awareness has slowly grown over concerns about compounds in some plastic bottles and food containers. The compounds on which most concerns have focused are Bisphenol A (known as BPA) which is used in tough polycarbonate products and epoxy resins that line tin can and a group of plastic softeners called phthalates. Research has shown that these compounds can leach from plastics into the food and drinks that we consume more so if they are heated to high temperatures, raising additional concerns about the kinds of plastics that are used as containers in microwave ovens.

Plastics are in most cases made from petrochemicals through an energy intensive process that itself creates lots of pollution and toxic discharge. The fact is every plastic container used is making the planet less habitable. Also most plastic in the world is not recycled and usually ends up in landfills, where it degrades very slowly. Every year 25 million tonnes of synthetic plastics are being accumulated in the sea coasts and terrestrial environments [3,4].

Due to accumulation of large number of waste plastic and there least degradation in environment ability of microorganisms used plastic as a carbon and energy source has been recently established.

The biodegradation of polyethylene has been reported in a number of research studies published over the last 30 years however there is general agreement that the process under normal conditions is extremely slow [5]. At dumping sites, polythene waste is degraded by both chemical and mechanical weathering but it takes long time for mineralization and may remain in the microscopic form for long time [6].

For the degradation of polyethylene two different strategies of potential mechanism have been followed. In the first approach degradation studies have been performed using pure strains able to degrade polyethylene [6-11]. This approach can help in study of enzymatic mechanism work for polyethylene degradation but it limits the co-operative process of microorganisms. The second approach is which uses complex environments and microbial communities [12-15].

II. DISCUSSION

Toxic effects of plastics

Plastic polymers are not particularly reactive and their large size limits transport across biological membranes[16]. They are therefore not considered as toxic in the polymeric material, however non-polymeric components such as residual monomers, oligomers, low molecular weight fragments, catalyst remnants, polymerisation solvents and a wide range of additives can be present. Several of these are hazardous to human health and the environment for instance carcinogenic, mutagenic, toxic for reproduction, sensitising and hazardous to the aquatic environment with long lasting effects.

Since the non-polymeric compounds usually are of low molecular weight and are either weakly bound or not bound at all to the polymeric macro-molecules they or their degradation products can be emitted from the plastic product to air, water or other contact media (e.g. food) [17]. Additives such as antioxidants, Ultra Violet (UV) stabilizers or plasticizers are necessary to protect packaging from UV mechanical or oxidative deterioration or to increase softness or to improve the overall appearance or quality of the plastic product Many of the chemical compounds that are common in commodity plastics have been compiled in legislative lists by the European union and some compounds with available toxicity data have been assigned Specific Migration Limit (SML) values for specified test conditions or worst case conditions which must not be exceeded during the use of the packaging in order to be permitted in the EU market [18]. A large amount of different additives or other constituents of plastic packaging are however still not compiled into the lists and/or have unevaluated toxicity.

This is specially likely if the compounds are degradation products from additives or polymers. European union has also stablished regulations concerning the overall migration, which is the sum of all contents that migrates from the polymer into the food or food stimulant without taking the identity of specific compounds into consideration. The overall migration is typically determined gravimetrically by evaporating the food stimulant and weighing the residue, after the migration tests.

The Overall Migration Limit (OML) that have been stablished for all types of plastics intended to be used in contact with food is 10 mg/dm2, during standard storage conditions such as 10 days at 40°C or other worst case high temperature usage conditions depending on the packages intended usage. A recent study ranked fifty-five polymers used in plastics production with respect to their degree of toxicity and seriousness of health impact. The highest ranking of these identified fifteen substances that were carcinogenic and/or mutagenic including polyvinyl chloride, styrene–acrylonitrile and ABS [19].

Among the more worrying materials for contaminate leaching is PVC commonly referred to as vinyl. The chemicals leached during the PVC life cycle include mercury, dioxins and phthalates. PVC is used in numerous consumer products, including adhesives, detergents, lubricating oils, solvents, automotive plastics, plastic clothing, personalcare products (such as soap, shampoo, deodorants, fragrances, hair spray, nail polish) as well as toys and building materials. Vinyl chloride is classified by the International Agency for the Research on Cancer (IARC) as carcinogenic to humans [20] . It is also shown to be a mammary carcinogen in Animals [21]. Another monomer styrene is used in the production of various plastics, resins and vulcanizers such as styrene butadiene rubber, ABS and styrene- acrylonitrile resins. Styrene is classified by IARC as possibly carcinogenic to humans (Group 2B) and is shown to cause mammary gland tumours in animal studies. It also acts as an endocrine disrupter [22]. Acrylonitrile monomer is used in the production of acrylic and modacrylic resins and rubbers. Acrylics and ABS polymers are used in production of pipes, auto parts and windows. Another and one of the hazardous monomer is BPA which is a common synthetic chemical found in plastics, food cans linings, beverage can linings, baby bottles and other consumer products which interferes with human hormones. Animal studies show a number of negative effects in off spring of BPA-exposed mice such as abnormal development of mammary end buds. BPA has been linked with premature birth, intrauterine growth retardation, preeclampsia and still birth [23]. It has also been noted that long exposure to BPA shows a significant effect on the sex hormones (progesterone) in females [24].

Formaldehyde is also used for plastic resin production such as urea-formaldehyde resins, phenolic resins, epoxy and melamine resins. IARC has classified formaldehyde as a human carcinogen (Group 1). It was linked to an increase in breast cancer risk in a 1995 study of industrial workers similar results were found in other international studies.

Many additives are used in the production of plastics and are of concern due to their potential link to cancer and endocrine disruption. Phthalates are plasticizers used to make plastics soft and pliable. Di 2-ethylhexyl phthalate (DEHP), di-n-butyl phthalate (DBP) and butyl benzyl phthalate (BBP) have been demonstrated to produce reproductive and developmental toxicity[25]. A recent study of male PVC workers in Taiwan found an adverse effect on the semen quality among the men with the highest concentrations of DEHP [26].

A study of a phthalate-exposed population in Northern Mexico found an elevated breast cancer risk among women [27]. Various metals are also used as stabilizers and colorants in polymers. Some of these include inorganic compounds cadmium, organic tin compounds barium, calcium, zinc carboxylates and antimony compounds. The lead compounds used in heat stabilizers are classified as toxic for reproduction (category 1A) very toxic with long lasting effects (both acute and chronic) and may cause damage to organs. Cadmium is classified by IARC as a human carcinogen. It also functions as an estrogen mimic (xenoestrogen)[28]. Polybrominated flame retardants used in plastic production to retard ignition and prevent fire from spreading. Polybrominated biphenyls (PBB) and Polybrominated diphenyl ethers (PBDE) have been shown to be strongly estrogenic and in some instances have been classified by IARC as possibly carcinogenic to humans (Group 2B).

In a study by Delilah Lithner on Daphnia magna, monomers like ethylene oxide, vinyl chloride, propylene oxide, bisphenol A and Benzyl Butyl Phthalate (BBP) have shown carcinogenicity, mutagenicity, specific target organ toxicity on repeated exposure, reproductive toxicity etc.

While some of the monomers like propylene oxide, phenol, maleic anhydride have shown skin sensitization, reproductive toxicity, skin corrosion and sometimes acute toxicity.

III. BIODEGRADATION OF PLASTICS

Biodegradation is an eco-friendly process in which microorganism like fungi and bacteria degrade the natural polymer (cellulose, lignin) and synthetic polymer such as polyethylene, polyurethane [29].

These micro-organisms use synthetic polymers as a substrate for their growth [30].

Several factors that are responsible for the biodegradation are: type of polymer, characteristic of organism and the type of treatment process required [29,31]. Some of the characteristics indicating the degradation of plastics are: discoloration, phase separation, cracking and erosion. Biodegradation can take place aerobically and anaerobically.

In aerobic biodegradation of plastic, microbes utilize oxygen as an electron acceptor and then break down organic compound into smaller and simpler compound such as carbon dioxide and water as final product [32].

C plastic + O2 CO2 + H2O + C residual + Biomass

In anaerobic biodegradation, polymers are degraded in the absence of oxygen by microorganism which breakdown the organic contaminant. Mohan and Srivastava in 2010 reported that anaerobic bacteria uses nitrate, sulphate, iron , manganese and carbon dioxide as electron acceptor and break down organic compound into simpler ones.

In anaerobic or anoxic condition, the final products formed are carbon dioxide, methane and water under methanogenic condition or hydrogen sulfide, carbon dioxide and water under sulfidogenic conditions [32].

Factors affecting Biodegradation of Plastics

The biodegradation of plastics by bacteria and fungi proceeds differently under different soil conditions according to their properties. The different factors that govern biodegradation are type of organism, polymer characteristics and nature of pre-treatment. Polymer characteristics refer to its tacticity, mobility, crystallinity, molecular weight, the type of functional groups and other substituents present in its structure and additives or plasticizers added to the polymer [33]. It was observed that smaller fragments of plastics were biodegraded faster than bigger ones [34].

Biological degradability of polymers by microorganisms decreases with increase in the molecular weight of the polymer. With increase in molecular weight, there is decrease in polymer solubility which makes it unfavourable for microbial attack as the polymer needs to be assimilated into the bacterial cell membrane and broken down by cellular enzymes. Repeating units of polymers like monomers, dimers and oligomers are easily degraded and mineralised [35].

Biodegradation is enhanced by abiotic hydrolysis, photo-oxidation and physical disintegration. These processes enhance the surface area of the polymer and reduce its molecular weight; facilitating microbial degradation [33].

Amorphous regions are more susceptible to microbial degradation than crystalline regains [36]. The presence of a glucose source reduces the rate of biodegradation as glucose is a more preferred carbon source than plastic [37].

Availability of Oxygen

In the presence of Oxygen, polymers are degraded by aerobic microorganisms with microbial biomass, carbon dioxide and water as end products. But under anoxic or anaerobic conditions, consortiums of anaerobic microorganisms are responsible for the degradation of the polymer with microbial biomass, water, methane and carbon dioxide as the end products (e.g. landfills, compost).

Mechanism of Biodegradation of Plastics

The polymer which is made of many monomers is converted into monomers and then these monomers are mineralised. This is done because the large polymers cannot pass through the cell membrane, so they are first depolymerised to enter into the cell and then they are mineralised or biodegraded inside the cell. This is observed in some synthetics polymers like polycaprolactone.

Initially various physical and biological forces act on the polymer to break it down. The physical forces include heating, cooling, freezing, thawing, wetting, drying and so on; they cause mechanical damage such as cracking of the polymer. The growth of fungi on the polymer can also cause swelling and bursting of the polymer to facilitate the fungi to penetrate into it.

Environmental degradation is initiated in synthetic polymers like poly carboxylates, polyethylene, poly terephthalate, poly lactic acids and their copolymers, poly dimethylsiloxanes, etc by abiotic hydrolysis Two types of enzymes are involved in biodegradation of polymers: intracellular and extracellular depolymerases. During degradation the exo enzymes or the extracellular depolymerases from the microorganisms convert the polymers into molecules having shorter chains. These molecules are monomers, dimers or oligomers that are small enough to pass through the semi permeable bacterial cell membrane. These are then utilised by the bacteria as sources of carbon and energy. This process is termed as depolymerisation. The process in which the end products are water, carbon dioxide or methane, is called mineralisation [35].

Table 2. Different microbes and their plastic degrading efficiencies

Microorganisms	**Types of plastics**	**Source of the microbes**	**Degradation Efficiency**	**Reference**
Bacillus cereus	polyethylene	Dumpsite soil.	7.2-2.4%	38
Pseudomonas putida	Milk cover	Garden soil	75.3%	39
Streptomyces sp	LDPE	Garbage soil	46.7%	40
Pseudomonas sp	Natural and synthetic polythylene	Sewage sludge dumpsite	46.2% and 29.1%	41
Pseudomonas sp	Natural and synthetic polythylene	Household garbage dumpsite	31.4% and 16.3%	41

Pseudomonas sp	Natural and synthetic polythylene	Textile effluent drainage site	39.7% and 19.6%	41
Pseudomonas sp	Polythene and plastic	mangrove soil	20.54% and 8.16	42
Aspergillus glaucus	Polythene and plastic	mangrove soil	20.80% and 7.26%	42
Micrococcus luteus	Plastic cup	Forest soil	38%	43
Masoniella sp	Plastic cup	Forest soil	27.4%	43
Pseudomonas sp and *bacillus*	Bags	Dumping sites	12.5%	44
Aspergillus niger and *Streptococcus lactis*	Polythene bags and plastic cups	Medicinal Garden soil, Sewage Water Soil, Energy Park soil,	12.25% and 12.5% respectively	45
Rhodococcus ruber	Branched low-density (0.92 g cm−3) polyethylene	Not specified	7.5%	46
Phanerochaete chrysosporium and *Pseudomonas aeruginosa*	Polythene carry bag	Plastic dumping sites	50% and 35% respectively	47

IV. INVOLVEMENT OF MICROORGANISMS FOR DEGRADATION OF PLASTICS

The microorganism's role is very important for plastic degradation. The different types of microbes degrade different groups of plastics. The microbial biodegradation has been at accepted and process still underway for its enhanced efficiency. Table 2 shows the list of microorganisms and their plastic degrading efficiencies. Micro organisms such as bacteria, fungi and actinomycetes degrades both natural and synthetic plastics [48]. The richness of microbes able to degrade polythene is so far limited to 17 genera of bacteria and 9 genera of fungi [49]. Microbial degradation of plastics is caused by oxidation or hydrolysis using microbial enzymes that leads to chain cleavage of the large compound polymer into small molecular monomer by the metabolic process [50]. The microbial species associated with the degrading materials were identified as bacteria, fungi, actinomycetes sp. and saccharomonospora genus [51,52] . The microorganism's growth is influenced by several factors including the availability of water, redox potential, temperature carbon and energy source [53]. Microorganisms secreted by both exoenzymes and endoenzymes that are attached to the surface of large molecular substrate and cleave in to smaller segments [54,55]. Recently reported, degrading enzymes are produced by several microorganisms [56]. Microorganisms recognize polymers as a source of the organic compounds [57].

Bacteria

Microorganisms such as Bacillus megatserium, Pseudomonas sp., Azotobacter sp., Ralstonia eutropha, Halomonas sp., etc are used to degrade plastics [52].

Fungi

The growth of many fungi can also cause small-scale swelling and bursting, as the fungi penetrate the polymer solids. In recent years fungal strains have been reported for plastic degradation such as Aspergillus versicolar [59], Aspergillus flavus [60], Chaetomium spp [61], Mucor circinellodies species etc. The polythene bags were degraded by some fungal species identified such as, Aspergillus niger, A. ornatus,nidulans, A. cremeus, A. flavus, A. candidus and A. glaucus were the predominant species[59,52].

Biodegradation of polyolefins

Synthetic polyolefins are inert and their backbone consists of long carbon chains. Their high hydrophobicnature and high molecular weight prevent their degradation by microorganisms.

However, some microorganisms were capable of breaking down polyolefins of low molecular weight after photo degradation and chemical degradation.

To make polyolefins susceptible to microbial degradation, their chain length and molecular weight must be reduced and their hydrophilic level must be improved by oxidation.

Polyethylene

Polyethylene can be made susceptible to microbial degradation by adding starch and pro oxidant. These are used in making biodegradable polyethylene. The starch improves the hydrophilic nature of polyethylene so that it can be catalysed by amylase enzymes. Microorganisms can easily degrade this part. When pro-oxidant is added to polyethylene, degradation is preceded by photo degradation and chemical degradation[35].

Biotic and Abiotic hydrolysis

Biodegradation of plastics is preceded by biotic or abiotic degradation to give monomeric or oligomeric products. Hydrobiodegradable polymers (E.g. polyesters and thermoplastic Starch) are degraded by biotic or abiotic hydrolysis whereas hydrophobic hydrocarbon polymers (E.g. Polyolefins) are resistant to hydrolysis and cannot be biodegraded. They are also resistant to oxidation. But by adding pro-oxidant additives, they can be made oxobiodegradable. Pro-oxidants that are based on metal combinations capable of yielding two metal ions having similar stability and having oxidation number differing by only one unit are the most active or effective. E.g.Mn^{2+}/Mn^{3+}. The material uses Oxygen from the atmosphere to degrade by a free radical chain reaction. Hydroperoxidases are formed as the primary product; they either thermolyse or photolyse under the catalytic action of a pro-oxidant. This leads to chain scission that produces low molecular mass oxidation products such as carboxylic acids, alcohols, ketones and hydrocarbon waxes. Peroxidation causes hydrophilic surface modification which favours microorganisms. They can bio-assimilate the low molecular mass oxidation products. Thus prooxidants enable thermo-oxidative degradation of Polyethylene. Temperature, the type and amount of additives, partial pressure of Oxygen and the type of polymer affects the rate of degradation. Temperature is the most important factor that affects degradation of Polyethylene. Low partial pressure of Oxygen can drastically slow down the rate of degradation [62].

Polyvinylchloride (PVC)

PVC is strong and has low moisture absorption. It resists abrasion. PVC can be degraded by chemical and photo degradation but there are very few reports on biodegradation of PVC. It has many commercial and industrial applications like rigid pipes, shoe soles, garden hoses, textiles, electrical wire insulation, pipes and fittings, synthetic leather products and floor coverings.

Polystyrene

Polystyrene is a synthetic plastic that gives products like styrene, benzene, toluene and acrolein on thermal or chemical degradation. There are very few instances of biodegradation of polystyrene reported so far but biodegradation of its monomer styrene has been reported a few times.

It has many commercial and industrial applications like manufacturing of disposable cups, packaging material, electronics and laboratory ware due to its properties like lightweight, stiffness and thermal insulation [35].

Products of microbially degraded/treated plastics The literature shows that CO_2 gas is a major product emitted during biodegradtion of polythene [66,67,64]. Generation of aldehydes, ketones and carboxylic acids was recorded in smoke of film extrusion of LDPE in an extrusion coating process [63].Rhodococcus rubber (C208) produced polysaccharides and proteins by using polythene as carbon source [69]. In another report, Rhodococcus rhodochrous ATCC29672 (Bacterium) and Cladosporium cladosporoide ATCC 20251 (Fungus) used polythene with production of polysaccharides and proteins, while Nocardia asteroids GK911 (Bacterium) produced proteins [68], ketones and carboxylic acids was recorded in smoke of film extrusion of LDPE

Toxicity of biodegraded plastic

Insolubility in water and relative chemical inertness of pure plastics make them low toxic. Several plastic products can be toxic due to the presence of some additives in them, e. g. plasticizers like adipates and phthalates are frequently added to brittle plastics like polyvinyl chloride to make them bendable enough. Traces of these compounds can percolate out of the product. The compounds leaching from polystyrene food containers have been predicted to interfere with hormone functions and are supposed to have carcinogenic effect. The finished plastic is non-toxic but the monomers that are used in the production of the parent polymers can be toxic. Toxicity study of biodegraded polythene on plants was monitored by observing their effect on seed germination in seeds like ground nut, sunflower, safflower, sesame and soybean [66]. It was recorded that seed germination (%) decreases in treated seeds, while in case of larvae (Chironomous spp.) no toxicity was detected in terms of decreases in mortality rate. S. aureus, P. aeruginosa, A. niger, Rhizopus spp. and Streptomyces spp. were used for degradation of polythene bags and plastic cups and toxicity level of biodegraded polythene was studied using Vigna radiata. It was observed that addition of biotreated polythene granules reduced soil pores size, which may have negative effect on the nutrient uptake by the root of plant.

V. CONCLUSION

Studies showed the effect of plastic waste on the aquatic and marine ecosystem, and thus, it has become one of the major problems for the modern environmentalist. To the get rid of such a problem, people usually put them in landfills or burn it, but both these practices cause very serious threats to the environment and the ecosystem. Some plastics are designed to be biodegradable and can be broken down in a controlled environment such as landfill. Biodegradation of waste plastic by microbes is an innovative research solving many environmental problems. This review discusses on the literature of microbes used for biodegradation of plastic waste. Most of the plastic wastes are degrade by the microorganisms.

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