Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Spl Issue [3] 2022: 294-300

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

REVIEW ARTICLE **OPEN ACCESS**

A study on plastic Degradation by microbes

Archana Dowarah[1], Anjali Thakur[2], Dhwani Upadhyay[2], Prasad Andhare[3], Indrani Bhattacharya[2]
Parul University, P.O Limda, Waghodiya, Vadodra -391760 Gujarat- India
1: Student, M. Sc. Biotechnology, Parul Institute of Applied Sciences, Parul University, Post Limda, Waghodia, Gujarat, 391760
2: Assistant Professor, Parul Institute of Applied Sciences, Parul University, Post Limda, Waghodia, Gujarat, 391760
3: Assistant Professor, Biological Sciences, PDPIAS, Charotar University of Science and Technology,
*Corresponding Author: Dr. Indrani Bhattacharya;
E Mail: indrani.bhattacharya82083@paruluniversity.ac.in

ABSTRACT
The rapid use of plastic and polythene is our present day life has become a major concern for environmental pollution. Especially plastic bags which are use a extensively is becoming an ecological threats as it is very difficult to be degraded naturally because of the presence of long heavy carbon chain. Most eco-friendly and acceptable method uses microbes for degradation of plastic, polythene and thermocol. Microorganism play a very important role in the biological decomposition of various materials in the natural environment, this is called biodegradation. Synthetic material including plastic and polythene waste accumulates in the environment and passes an ever increasing ecological threat. Biodegradation of this plastic waste using patent microbial strain could provide a solution to the present problem. Intensive exploitation, inadequate recycling, low repeated use, and plastic remarkable resilience to environmental and microbiological action culminate in massive trash accumulation in terrestrial marine setting, posing a significant risk to human and animal existence. Plastic biodegradations has attracted a lot of scientific attention in recent decades. Enzymes for their biodegradations are in scare supply because to the comparably brief evolutionary time of their presence in nature. Plastics are designed for use in conditions that are typical of human hobby, and their physicochemical properties change slightly when exposed to invert conditions such as low temperature, salt, or low or high pH which are typical of extremophilic Microorganisms lives and enzyme work. This review is a primary to comply the extremely little information on mesophilic bacteria biodegradations of typical manufactured plastics in natural and laboratory settings.
KEYWORDS- *Bacteria, polythene, degradation and screening.*

Received 25.08.2022 Revised 26.09.2022 Accepted 24.10.2022

INTRODUCTION

The word ''plastic'' was derived from the Greek word '*plastikos*' which means the ability to converted into various shapes.Plastics are synthetic or semi-synthetic materials that contain polymers as a key constituent and become mobile when heated, allowing them to be moulded into moulds, depending on the materials used [1] . The plastic is basically made up of carbon, silicon, hydrogen, oxygen and nitrogen. The basic materials of plastic oil, coal and natural gas are used for extraction. They are made up of linking monomers together with the help of chemical bonds. Polythene plastic comprises of 64 of total linear hydrocarbon polymer which have long ethylene monomer chains. The general formula of polythene is $(C_2H_4)_n$, where 'n' is the number of carbon atom.

The five most common petroleum-based polymers used to create single-use plastic goods are low density polythene, high density polythene, and polythene terephthalate.LDPE, which is mostly used to create plastic carry bags and food packaging materials, is the most abundant petroleum polymer on the planet, accounting for up to 64% of single use plastics that are thrown after only a few uses, resulting in the large and rapid accumulation in the environment. Despite efforts to recycle and recover energy, the negative consequences of LDPE trash accumulation in landfills and oceans, which is effectively "non-biodegradable", are escalating. Micro-plastics have been detected everywhere on the, including in arctic snow. As a result, an environmentally friendly disposal solution must be established [2].

STATUS OF POLYTHENE POPULATION

Plastic, particularly polythene, is being used more and more. Every year, 25 million tonnes of synthetic plastic accumulate along the beaches and on land [3-5]. Polythene make up 64% of all synthetic plastics, and it's utilized to make bottles, carry bags, disposable items, garbage cans margarine tube, milk jugs, and water tube [6]. Similarly plastic accounts for 60-80 percent of total marine garbage. All of the polythene garbage, as well as other plastic debris, generated by human activities eventually finds its way into the ocean via river, canals/channels, and municipal drainage. As a result beaches have been recognized as excellent storage location for polythene (plastic) garbage.Chemical and mechanical weathering degraded polythene trash at dumping sites, however mineralization takes a longtime. Every year, more than 500 million 1 million polythene bags are used all over the world.Polythene is robust and long-lasting, taking up to 1000 years to decompose naturally. Furthermore sunlight dissolves plastic into tiny harmful components which contaminate soil and water, where they might be unintentionally consumed by animals and thus enter the food chain, particularly in the marine plant [7].

Polythene waste is acknowledged as a major hazard to marine life. In fish, birds and marine mammals, it's has been shown to cause intestinal obstruction[8]. According to a report [9], plastic pollution in the maritime environment has harmed at least 267 species, including all mammals, sea turtles (86%) and seabird(44%). The consumption of polythene carry bags has been linked to the death of terrestrial animals such as cows.

POLYTHENE IMPACT ON VARIOUS ECOSYSTEMS

Aquatic, deserts, forests, grasslands, and tundra are the five basic groups in which the environment has been categorized. The discovery that polythene has detrimental impacts on all major biomass is exceedingly unfortunate. Total plastic trash damaging the marine and terrestrial ecosystem is estimated to be around 25 million tonnes, with synthetic plastic accounting for 64% [10].

TERRESTRIAL ECOSYSTEM

Polythene has become a severe danger to terrestrial ecosystems of all kinds.

URBAN AND RURAL AREA

Polythene is a severe danger to the environment and public hygiene in urban settings. Polythene bags gather in dumping yards, gutters, sewers, agricultural fields, and even along roadsides, eventually resulting in a massive pile of trash. This stockpile provides a breeding ground for hazardous insects such as mosquitoes and files, which spread diseases, and the situation worsens during the rainy season.

Among all the metro cities of India, Maharashtra is on top position for generating plastic waste (as shown in Table1).

AQUATIC ENVIRONMENT

Plastics not only impair land flora and animals, but they also have a negative impact on the aquatic Environment [12]. Not only are oceans affected, but discovered to be contaminated with plastic bags. Plastic marine waste poses a harm to the marine ecosystem [13]. Marine species have suffered population declines as a result of debris, either because they were entangled in their bodies or because fish and birds mistakenly mistook debris for prey and ate them. The remaining 20% comes from various bodies of water. Tourist activities on sea beaches, sewer garbage, fishing material, and waste from ships and boats are all major contributors of marine debris[14].Those plastics that are physically or chemically damaged, on the other hand, are eventually reduced to microscopic grain-sized fragments. These microscopic particles are then consumed by a variety of small animals, potentially concentrating persistent organic pollutants (POP) in the water. Marine debris has harmed 267 species worldwide, with sea turtles accounting for 86 percent, seabirds for 44 percent, and marine mammals for 43 percent [15].According to a study conducted in the United States, 55 percent of 1033 birds taken along the coast had plastic in their guts. This is owing to their productivity for selecting prey based on colour, and therefore mistaking polythene for possible prey[16].Ingestion of these polymers inhibits gastric enzyme secretion and limits feeding stimulation, resulting in decreased food intake, internal organ damage, and eventually reproductive failure[17].

CATEGORIES AND CLASSIFICATION OF PLASTIC

Plastics are divided into different categories based on their thermal qualities, design properties, and degradability. Table 2.lists many forms of plastic and their applications[14-17].

They are divided into two groups based on their thermal qualities. Thermoplastic and thermo set plastics are the two types-

THERMOPLASTIC

Thermoplastics are plastics that can be heated and cooled repeatedly to harden and soften them; non-biodegradable polymers are another term for them. Thermoplastics are plastics are made by breaking double bonds. Thermoplastics include polyethylene (PE), polypropylene, polystyrene,polyvinyl chloride, and polytetrafluoroethylenes.

THERMOSET PLASTICS

Thermoset plastics are linear solids with strongly cross-linked structures, whereas thermoplastics are not chemical changes are irreversible in this case, but they cannot be recycled. Thermoset plastics include phenol formaldehyde polyurethanes.

INVOLVEMENTS OF MICROORGANISMS FOR DEGRADATION PLASTICS

Plastics are classified as biodegradable or non-biodegradable based on their chemical properties. Non-biodegradable polymers are usually synthetic and have a common repetition of tiny monomers with extremely high molecular weight. Degradable plastics, on the other hand, are formed of starch and have a lower molecular weight. Both natural and manmade plastics are degraded by microorganism, such as bacteria fungus, and *actinomycetes*. So far the number of microbes capable of degrading polythene has been limited to 17 bacteria species and 9 fungus genera. Microbial degradation of plastic is included by oxidation or hydrolysis of the big compound polymer by microbial enzymes, which results in chain breakage of the large compound polymers by microbial enzyme which results in chain breakage of the large compound into small molecular monologue[18].

Bacteria, fungi, *actinomycetessp,* and the*saccharomonosppora genus* were identified as microbial species associated with the degrading materials[19, 20]. Several factors influence microorganism growth, including water availability, redox potential, temperature carbon, and energy supply. Exoenzyme and endoenzyme linked on the surface of large molecular substrate produced microorganism that split into smaller segments. Degrading enzymes are produced by a variety of bacteria, according to a recent study[21]. Polymers are recognized by microorganisms as a source of organic chemicals.

MECHANISM OF POLYTHENE DEGRADATION

The adhesion of bacteria to the surface of polythene starts the degradation process. Extracellular enzymes produced by bacteria (*Streptomyces viridosporus T74, Streptomycesbadius* 252, and *Streptomyces scotonii* 75Vi2) and wood degrading fungi lead to polythene decomposed [22]. Peroxidases, laceases, and oxidases create extracellular hydrogen peroxide in the extracellular enzyme complex (ligninolytic system) of wood-degrading fungi[23]. The properties of this system vary depending, on the type of organism or strain as well as the culture setting. Three enzymes, lignin peroxidase(LiP), manganese peroxidase(MnP), and phenoloxidase containing copper, also known as laccase, are involved in the breakdown of lignin [24, 25]. Agriculture, chemical, cosmetic, food,fuel,paper,textiles and other sectors use these lingolyticenzymes,they have been dissolved to be implicated in the degradation of xenobiotic chemicals and pigment. Manganese peroxidase oxidises phenolic compounds in the presence of H_2O_2 and manganese during lignin breakdown (MnP). MnPoxidisesMn II to Mn III, which is then oxidised by monomeric phenols, phenolic lignin dimers, and synthetic lignin. Mn III is formed when phenoxy radicals are formed. In the case of polythene degradation, there is no such report, but a similar tendency is expected. The polythene's byproducts differed depending on the condition of decomposition. CO_2 and H_2O, methane and microbial biomass are the end product of anaerobic/ methanogenic decomposition, and H_2S, C_2O and H_2O and microbial biomass are the end product of salfidogenic decay[26].

Factors that influence plastic degradation

Humidity, temperature, pH, oxygen presence or absence, sunlight, water, stress and culture conditions all affect polymer degradation, as well as microbial population and enzyme capability. When fungi grow at the lower P^H, they produces the most CO_2 and have the most lignolyticaction. Polyester chemical and physical qualities have a significant impact on its biodegradability. The molecular weight of plastic is one factor that influences its biodegradation (Mn). Low molecular-weight compounds are preferred by biodegradation.

Rhizopusdelemar lipase enzymatic hydrolysis of poly PCL diol was quicker at lower molecular weight. Enzymatic degradability is strongly influenced by a polymers melting temperature (Tm). In general, the greater the melting point of polyester,the less biodegradable it is. With the passage of the time, the enzymatic degradability reduces. The higher the melting point of polyester the less biodegradable it is. With time, the enzymatic degradability decreases. The polymer degradability was reduced by higher order structure features including crystallinity and modulus of elasticity. Additives,antioxidants, stabiliser used in polymer manufacture can slow degradation and may be hazardous to microorganisms [27].Aside from the structural factors, the molecule composition and physical form of polymer (polyester and films, pellets, and fibers) can also affect the biodegradability of polymer. Finally, the mechanism of degradation and the pace of process acceleration determine how and when polymers degrade.

FUTURTE PROSPECTIVE

It is recommended that the best status of Polythene contamination in its location be updated. A public awareness campaign on polythene pollution should be promoted at a large scale.It is recommended that starch-based polythene or biodegradable polythene be used. Microbes responsible for polythene breakdown should be isolated from all source and screened to identify the most effective isolates. To characterize at the molecular level, effective microorganisms are required. The biodegradation of polythene is carried out by extracellular enzymes. These enzymes needed to be identified, and the gene will be exploited to improve the polythene degrading capacity of other commonly found bacteria.Following field studies, the most effective polythene degrading microorganism should be mass produced to degraded polythene on commercial scale.

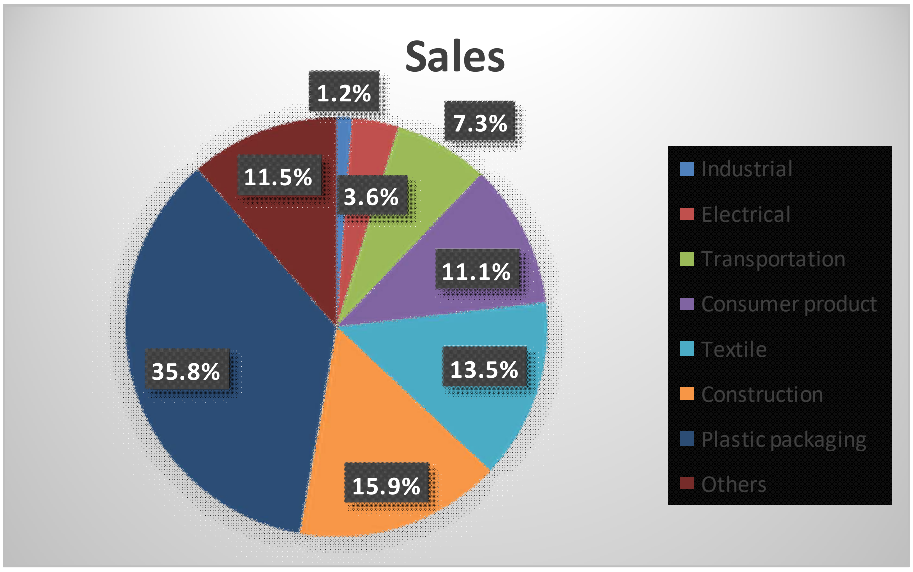

Figure 1. Per capital plastic consumption worldwide 2018. [11]

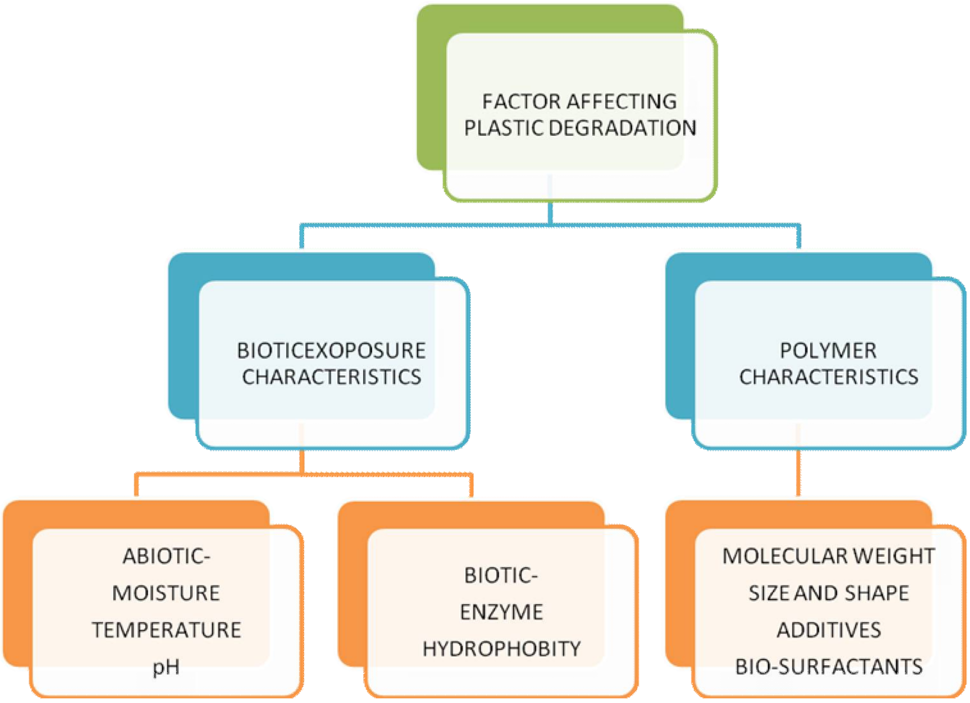

Figure2. Factors which effects on plastic degradation

Table1: Municipal solid waste(MSW) generated from different cities in India in 2018[12]

Name of the state	MSW (tonnes per day)
MAHARASHTRA	8589
WASTE BENGAL	4475
DELHI	4000
GUJARAT	3805
KARNATAKA	3118
MADHYA PRADESH	2286
PUNJUB	1001
HARYANA	623
ASSAM	196
HIMACHAL PRADESH	35
TRI PURA	33

Table2 : Types of plastics and their application[14-17].

Types	Application
Polyethylene terephthalate (PET)	Drink bottle, peanut butter jars, plastic films, microwavable packaging
Phenolics (PE)	High modulus, relatively heat-resistant and excellent fire resistant polymer used for insulating parts in electrical fixtures, paper laminated product and thermally insulation foams
Polyethylene (PE)	Wide range of inexpensive uses including supermarket bags, plastic bottle
Polylactic acid (PLA)	A biodegradable thermoplastic that can be convert into a variety of aliphatic polyesters derived from lactic acid
Polyvinyl chloride (PVC)	Plumbing pipes and guttering, shower curtains, window frames, flooring
Low-density polythene (LDPE)	Outdoor furniture, sliding floor tiles, shower curtains, clamshell packaging
Polytetrafluoro ethylene (PTFE)	Electronics bearing, nonstick kitchen utensils
Polyamides (PA)	Fibers, tooth brush, fishing line, under-the-hood car engine molding.
Polyvinylidene chloride (PVDC)	Food packaging
High impact polystyrene (HIPS)	Refrigerator liners, food packaging, vending cups

Table 3: Different bacteria and their ability to degrade plastics are shown in table[19, 20].

Bacteria	Types of Plastic	Source	Degradation Efficiency
Aspergillusglaucus	Polythene and plastic	Mangrove soil	20.80% and 7.26%
Pseudomonas sp.	Natural and synthetic	Sewage sludge dumpsite	46.2% and 29.1%
Masoniella sp.	Plastic cup polythene bags	Dumping area	27.4%
Aspergillusniger and *Streptococcus lactis*	Polythene bags and plastic cups	Medicinal garden soil, energy park	12.25% and 12.5% respectively
Aspergillusoryzae leads	HDPE films	HDPE Film buried in soil	72%
Bacillus cereus	Polythene	Dumpsite soil	7.2-2.4%
Streptomyces sp.	LDPE	Dunghill	49.6%
Pseudomonas sp.	Raw and bogus	Household garbage dumpsite	31.4% and 16.3%
Micrococcus luteus	Plastic cup	Forest soil	38%
Pseudomonas sp.	Natural and synthetic polythene	Textile effluent drainage site	39.7% and 19.6%

CONCLUSION

We cannot meet our day to day demands without plastic, but given its negative effects, it is required to create competent disposal techniques and research alternative materials such as starch-based and mixed elastic. Although there have been numerous reports demonstrating the potential of polythene- degrading microbes, none of them have been found to have practical application. As a result, there is a strong need to screen efficient organisms and develop technologies capable of degrading stretchy efficiently while minimizing environmental effects.

ACKNOWLEDGEMENTS
This work was supported by the Department of Biotechnology, Parul Institute of Applied Sciences, Vadodara-391760, Gujarat.

CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

REFERENCES
1. Lee, B., Pometto III, A. L., Fratzke, A., & Bailey Jr, T. B. (1991). Biodegradation of degradable plastic polyethylene by Phanerochaete and Streptomyces species. *Applied and Environmental Microbiology*, *57*(3): 678-685.
2. Derraik JGB (2002) The pollution of the marine environment by plastic debris: a review. Mar Pollut Bull 44: 842-852.
3. Kaseem M, Hamad K, Deri F (2012) Thermoplastic starch blends: A review of recent works. PolymSciSer A Chem Mat Sci 54: 165-176.
4. Gu JD (2003) Microbial deterioration and degradation of synthetic polymeric materials: recent reserach advances. IntBiodeterior Biodegradation 52: 69-91.
5. Cooper DA, Corcoran PL (2010) Effects of mechanical and chemical processes on the degradation of plastic beach debris on the island of Kauai, Hawaii. Mar Pollut Bull 60: 650-654.
6. Lee B, Pometto AL, Fratzke A, Bailey TB (1991) Biodegradation of degradable plastic polyethylene by phanerochaete and streptomyces species. Appl Environ Microbiol 57: 678-685.
7. Denuncio P, Bastida R, Dassis M, Giardino G, Gerpe M, et al. (2011) Plastic ingestion in *Franciscana dolphins*, *Pontoporiablainvillei*(Gervais and d'Orbigny, from Argentina. Mar Pollut Bull.
8. Secchi ER, Zarzur S (l999) Plastic debris ingested by a Blainville's beaked hale, *Mesoplodondensirostris*, washed ashore in Brazil. Aquatic Mammals 25: 21-24
9. Yang C.Z., Yaniger S.I., Jordan V.C., Klein D.J., and Bittner G.D., (2011), Most Plastic Products Release Estrogenic Chemicals: A Potential Health Problem That Can Be Solved, Environmental Health Perspectives, 119(7): 989–996.
10. Browne M.A., Crump P., Niven S.J., Teuten E., Tonkin A., Galloway T., and Thompson R., (2011), Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks**,** Environmental Science and Technology, 45:9175–9179.
11. Webb HK., Arnott J., Crawford RJ., and Ivanova EP., (2013), Plastic Degradation and Its Environmental Implications with Special Reference to Poly (ethylene terephthalate). Polymers, 5: 1-18
12. Seneviratne G., Tennakoon NS., Weerasekara MLMAW., and Nandasena KA., (2006), Polyethylene biodegradation by a developed Penicillium-Bacillus biofilm, Current Science, 90:20-22.
13. Corcoran PL., Biesinger MC., and Grifi M., (2009), Plastics and beaches: A degrading relationship, Marine Pollution Bulletin, 58: 80-84.
14. Denuncio P., Bastida R., Dassis M., Giardino G., Gerpe M., and Rodriguez D., (2011), Plastic ingestion in Franciscana dolphins, Pontoporiablainvillei (Gervais and d'Orbigny, 1844, from Argentina, Marine Pollution Bulletin.
15. Browne M.A., Crump P., Niven S.J., Teuten E., Tonkin A., Galloway T., and Thompson R., (2011), Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks**,** Environmental Science and Technology, 45: 9175–9179.
16. Browne M.A., Crump P., Niven S.J., Teuten E., Tonkin A., Galloway T., and Thompson R., (2011), Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks**,** Environmental Science and Technology, 45: 9175–9179.
17. MuthurNoopur, Sharma Sakshi, Nupur Singh Snnuradha [2015]. Toxicity and biodegradation of plastics: A review. J Environ Dev; 9(3): 906-913.
18. Suman Mukherjee, Shamba Chatterjee[2014]. A comparative study of commercially available pasticcarry bag biodegradation by microorganisms isolated from hydrocarbon effluent enriched soil. Int J CurrMicrobiol App Sci; 3(5): 318-325.
19. Kumar S, Das, PM, Rebecca L J, Sharmila S.[2013]. Isolation and identification of LDPE degrading fungi from municipal solid waste. J Chem Pharm Res, 5(3):78-81.
20. Konduri MKR, Anupam KS, Vivek JS, Kumar RDB, Narasu ML[2010]. Synergistic Effect of Chemical and Photo Treatment on the Rate of Biodegradation of High Density Polyethylene by Indigenous Fungal Isolates. Int J Biotech Biochem; 6: 157-174
21. Deepika S, Jaya Madhuri R.[2015]. Biodegradation of low density polyethylene by microrganisms from garbage soil. J Exp Bio AgriSci; 3(1): 15-21.
22. Gnanavel G, Mohana VP, JeyaValli, Thirumarimurugan M, Kannadasan TA[2012]. Review of biodegradation of plastics waste. Int J Pharm Chem Sci. 1(3): 670-673.
23. Kim Y, Yeo S, Kum J, Song HG, Choi HT [2005]. Cloning of a manganese peroxidase cDNA gene repressed by manganese in *Trametesversicolor*. J Microbiol 43: 569-571
24. Ruiz-Dueñas FJ, Martínez AT [2009]. Microbial degradation of lignin: how a bulky recalcitrant polymer is efficiently recycled in nature and how we can take advantage of this. MicrobBiotechnol 2: 164-177.

25. Ruiz-Dueñas FJ, Martínez AT [2009]. Microbial degradation of lignin: how a bulky recalcitrant polymer is efficiently recycled in nature and how we can take advantage of this. MicrobBiotechnol 2: 164-177.
26. Maciel MJM, Silva AC, Ribeiro HCT [2010]. Industrial and biotechnological applications of ligninolytic enzymes of the basidiomycota: A review. Electron J Biotechnol, 13.
27. Arutchlevi J, Sudhakar M, AmbikaArkatkar, Dhoble M, Bhaduri S, Uppara P V [2008]. Biodegradation of polythene and polypropylene. Indian J Bioethanol 7:9-22.

CITATION OF THIS ARTICLE
A Dowarah, A Thakur, D Upadhyay, P Andhare, I Bhattacharya. A study on plastic Degradation by microbes. Bull. Env. Pharmacol. Life Sci., Vol Spl Issue [3] 2022: 294-300