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COMPARATIVE STUDY OF SYNTHETIC PLASTICS AND BIODEGRADABLE PLASTICS

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ABSTRACT
In the present time Plastics are seen as an environmental threat because they are difficult to degrade. It is the most persistent pollutant which left unchanged in the environment for centuries. The production and the accumulation of the Plastic waste materials in the environment are unavoidable. The use of Plastic material has contributed a major amount of negative effects on the environment from the aspects of human health and habitat. They are resistant to harass by most microorganisms and hence remain non degradable. The efficient decomposition of plastic bags takes about thousand years. It is also release CO_2 and dioxins due to burning and cause global warming. Biodegradable plastics are designed for the solution of this environmental problem which is made from biodegradable polymers. There are increasing demands of this type of plastic those are easily degradable. The present review discusses about the plastic pollution, its types and the solution of the plastic pollution.

KEY WORD: Plastics, Pollutant, Environment, Microorganisms, Biodegradable.

INTRODUCTION

One of largest concern to science and other people is the Environmental Pollution and Plastic pollution plays a key role to this pollution (Sandhu *et al* 2016). Plastic pollution is one of the most important ecological troubles that we face today. We have all contributed to this problem directly or indirectly. The use of plastic has transformed our life in many ways (Muthukumarand and Veerappapillai, 2015). Plastics is a synthetic polymer, they are the petroleum products made by extracting oil, coal and natural gas which are the basic material for plastics. Now a day's synthetic polymers are used in numerous industries, of which packaging appliance covers 30% of plastic use throughout the world (Pathak and Navneet, 2017). The use of plastic especially polyethylene is growing day by day. Every year 25 million tons of synthetic plastic are being accumulated in the ocean coats and global environment (Artham *et al.,* 2009). About 64% of total synthetic plastic are being used in enormous quantity for the production of bottles, carry bags, disposable articles, garbage containers, margarine tubs, milk jugs, water pipes and also used in packaging, agricultural products, medical and paramedical equipments, defence, information and space science (Sangale *et al.,* 2012). Plastics are very useful for us because they are cost effective, light in weight, better self life Extreme durability and Unbreakable. About 140 million of synthetic plastic polymer is produced globally (Besseling *et al.,* 2017). Plastic material has several disadvantages and the most important one is that they are resistant to degradation in atmosphere. They persist for longer time in the atmosphere (Bouwmeester *et al.,* 2015). After its use, plastic wastes are discarded at land fill sites, natural terrestrial habitat and oceans. In the aquatic environment alone, but of total aquatic wastes generated by the human activity final enters into marine water through rivers, canals/channels and metropolitan drainages As a result all beaches were reported to be the excellent depository sites for the plastic wastes (Singh *et al.,* 2016).

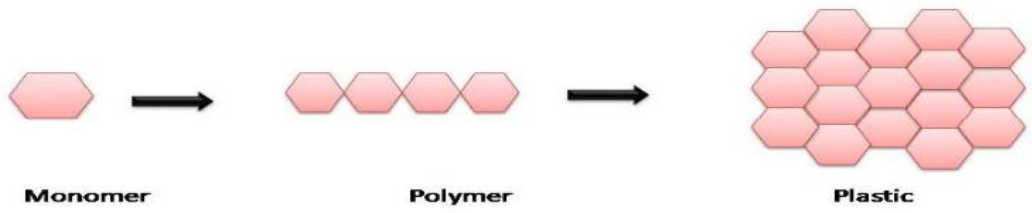

DIAGRAM 1.1: Formation of plastic (Fan *et al.*, 2011)

History of Plastics: Nitrocellulose was the first plastic material and it is obtained by Parkes in 1862 and Hyatt in 1866. In 1897 Galalith was produced in Germany by reacting casein (a milk protein) with formaldehyde. The first synthetic thermoset polymer (a phenol-formaldehyde), known as Bakelite, was obtained by

Baeleland in 1907 through the polycondensation of phenol with formaldehyde. In 1909-1910 Bakelite was commercialized. The industrialization of this plastic material is considered to be the beginning of truly synthetic plastic era and of the plastic (Feldman, 2018).

TYPES OF PLASTICS

Non degradable: There are various types of non degradable plastics that we use every day in our daily life. These plastics can be divided into two major categories one is Thermoset or thermosetting plastics and other is Thermoplastics (Calderón *et al.,* 2011).

1. **Thermoset or Thermosetting**– After making process of these plastics once cooled and hardened, these plastics keep their shape and cannot return to their original form. These are tough and durable and used for making auto parts, air craft parts and tires. Example polyesters (Freudenrich, 2018).
2. **Thermoplastics-** These plastics are less rigid than Thermoset, and become softer upon heating and return to their original form. Example Polyethylene (Kiyama *et al.,* 2012)

Some common synthetic plastics:

- Polystyrene (Styrofoam): It is made by styrene monomer it is very hard plastic which is used in making for Furniture, Cabinets (for Computer Monitors and TVs), glasses and utensils. When we heat the polystyrene and blow air through the mixture, it forms Styrofoam. Styrofoam is light weight, mouldable and an outstanding insulator(Casado *et al.,* 2013)
- Polyvinyl Chloride (PVC): When we polymerize vinyl chloride, Polyvinyl Chloride (PVC) is formed. When it is made its fragile, so manufacturers insert a plasticizer liquid in it to make it soft and mouldable. PVC is generally used for pipes and plumbing, because it's durable and cheaper than metal pipes.(Chung *et al.,* 2011).
- Polytetrafluoroethylene (Teflon): In 1938 it is made by Du Pont. It is formed by polymerization of tetrafluoroethylene molecules (CF2=CF2). This polymer is stable, temperature resistant, strong, and has a nearly frictionless surface. Teflon is used for cookware, waterproof coating etc (Col *et al.,* 2013).
- Polyvinylidine Chloride (Saran): Saran reins makes by Dow, which are synthesized by polymerization of vinylidine chloride molecule (CH2=CCl2). Saran is used for the packaging of food items because it is impermeable to food order(Corsi *et al.,* 2014)
- Polyethylene: the most commonly known plastic polymer is polyethylene, which is made from ethylene monomer (CH2=CH2). In 1934 first polyethylene was made. Polyethylene can be divided into two parts. First is high-density polyethylene (HDPE) and other is Low Density Polyethylene (LDPE). HDPE is a harder than LDPE with higher melting point (Della *et al.,* 2014).
- Polypropylene (PP): Polypropylene is prepared by Karl Ziegler and Giulio Natta in 1953 with propylene monomer (CH2=CHCH3) and receive the Nobel Prize in Chemistry in 1963. Polypropylene is used in car trim, battery cases, bottles, tubes, filaments and bags (Castro *et al.,* 2009)

We can also divide plastics on the basic of their size like Micro plastic and Nano plastic (EerkesMedrano *et al.,* 2015). Some small plastic particles are present everywhere in the environment and cause huge concern because micro (1µm and 5mm) and Nano (1nm to 1µm) size plastic particle are very small amount so it can be taken up by many organisms and raises questions of potential bioaccumulation and biomagnification there are rising evidence that micro plastic are ingested by marine organisms (Galloway *et al*., 2017). But Nano plastics are more harmful than micro plastic because they are permeable for biological membranes (Bhattacharya *et al.,* 2010).

Sources of Micro plastic and Nano plastic: They can enters our environment either by primary micro and Nano materials (*e.g*. Cosmetic and cleaning products, namely toothpastes and exfoliating creams and scrubs, Plastic resins used in air blasting; 3D printing, adhesives), or indirectly as secondary Microplastic and Nanoplastic produced by the breakdown of larger plastic debris, due to exposure and animal and microbial activities, including plastic bags, bottles and fishing gear (Duis and Coors, 2016). It was already proven that photo degradation of marine Microplastic wastes and disposable polystyrene coffee cup generated Nanoplastic(Carr *et al*., 2016). Direct source of them are plastic mulch films and greenhouse materials and indirect sources include general littering and the use of treated waste water and bio solids (Coppock *et al.,* 2017).

TABLE NO. 1.1: Role of Plastic Industry in Indian Economy (*www.indianmirror.com*)

S No.	Plastic related issue	In 2005	In 2015
1	Consumption of Plastic Polymers	4.7 Million Tonnes	18.9Million Tonnes
2	Employment In Plastic Industry (Direct+ Indirect)	2.5 Million	9.5 Millions
3	Plastic Industry's Turnover	Rs. 35,000 Crores	Rs.1,33,245 Crores
4	Export of Plastic Products	US$ 1900 Millions	US$10215 Millions
5	Contribution of Polymers and Plastic Products to the Exchequer.	Rs. 6200 Crores	Rs. 15990 Crores

Plastic is a major cause of the environmental pollution. Plastics bags are also responsible for this problem. These bags are barrier against moisture and steam (Cózar *et al.,* 2014). While the process of recycling plastic is a good technology to reduce plastic waste in the environment, lots of problems encountered during this process (Faure *et al.,* 2015). Sometimes recycling costs are higher than the cost of production of new plastics. Plastics are petroleum based products and it is not a degradable material and can last for hundreds of years (Faris, 2014). Nowadays synthetic polymer plastics those are resistant to chemical and physical degradation are disposed together with other

wastes (Foruzanmehr *et al.*, 2015). For the solution of this problem there are some polymer called biodegradable polymer, and a plastic those are made from this polymer called biodegradable plastics (Yrikou and Briassoulis, 2007].

Solution for the plastic pollution

There are three types of biodegradable plastic are currently used namely photodegradable, semi-biodegradable and perfectly biodegradable plastics (Hayden *et al.*, 2013). Photodegradable plastics have light-sensitive groups which are directly inserted in their polymeric composition as additives. Polymeric structure of plastic can degrade by high rate of UV radiation (Kaliya *et al.*, 2000). Semi degradable plastics are starchy plastic in this plastic starch is inserted into their composition for holding their small polyethylene parts (Hirai *et al.*, 2011). This plastic is easily degraded by some bacteria. The third types include biodegradable plastic which are comparatively new and promising and these are used by bacteria (Abolfazl *et al.*, 2017). In recent years Biodegradable plastics have been studied intensively, and many types of products such as garbage bags, compost bags, poly bags and agricultural mulch films are developed by this plastic (Huerta *et al.*, 2017). Biodegradable plastics can be decayed after dumping to the environment by the activity of microorganisms to generate the final products CO_2 and H_2O (Lambert *et al*., 2013). These plastics can be produced from oils, or plant based products. When we decomposed them in soil it will be susceptible to bacteria, fungi or other microorganisms that use them as food (Tharanathan, 2003).

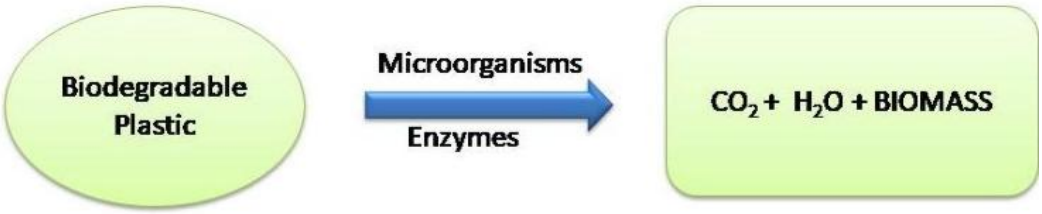

DIAGRAM 1.2: Degradation procedure of Biodegradable plastic

There are an increasing number of commercial biodegradable plastics some of them are as follows:

- **Starch based plastics:** Starch based plastics are mainly made from potatoes, wheat, rice and corn (Gao and Wen, 2016). Out of these four starches, corn starch is very commonly used because it is the cheapest and most commonly used, while starch is the most expensive (Raquez *et al.*, 2011). This plastic is used for eating utensils, dishes cups and other products. Starch biodegradable plastics can be processed using predictable technologies such as injection molding, blow molding, blown film, extrusion and thermo forming (Keshavarz and Roy, 2010). In this process starch converts into lactic acid polymer chain called Polylacticide (PLA) or polygloycolic (PGA). Both are crystalline polymers, but PLA is more hydrophobic than PGA. High shiny finish and transparency are other features of PLA plastic. [Mohanty *et al.*, 2000].
- **Bacteria based plastics:** This plastic is made by using polymer chain polyhydroxyalkonates (PHA), it is produced in bacterial cells. About 30% of soil bacteria synthesize PHA (Wu *et al*., 2000). PHA is industrialized rapidly to locate application in many fields. Over 150 different PHA monomers reported with the thermal and mechanical flexibility (Gautam 2009). PHA monomer is also used for making bio fuel.
- **Soy based Plastic:** Biodegradable plastic are also made from Soybeans. Soybean is rich in protein with limited fats and oils (Geyer *et al* 201). About 55% protein is present in soyabean, this high amount of protein helps it to be molded into plastic material and films. Soy based plastic are commonly used in food packaging, compression and plastic injection molding (Ghosal *et al.*, 2016).
- **Cellulose Based Plastics**: this plastic is comes from plant cellulose material. Wood pulp, hemp and cotton, hemp and cotton are commonly used cellulose sources. On this earth Cellulose is the most abundant biopolymer, which exist in a variety of species such as animals, plants and bacteria (Huerta *et al.*, 2018). For researcher it is important to study the mechanical properties and thermal stability for packaging materials. In the market some cellulose based packaging material has appeared but their use is limited because of high manufacture costs. (John *et al.*, 2007).
- **Lignin Based Plastic:** In paper manufacturing industries lignin based plastic is a by- product. Lignin is a low cost, renewable, biodegradable, and non toxic particle (Chen, 2009). It is a potential substitute for oil phenolic, epoxy resins and adhesives. It has potential as filler and features used in the preparation of biodegradable plastics. (Cazacu *et al.*, 2002).
- **Natural Fibre Reinforced Plastics**: Bamboo, jute, sisal, kenaf and bagasse are some natural fibers used as reinforcement in composites due to its low cost, specific strength and biodegradability (Cao *et al*., 2006; Shibata *et al.*, 2005). At the present time studies of natural fibers become more popular because of its low density and available in large quantity (Bombelli *et al.*, 2017). Natural fibers material used in various fields such as the automotive and packaging industries. Because they have huge advantages like that is eco friendly, low cost, low density, carbon dioxide absorption and biodegradability (Inoue *et al.*, 2007). We can classify them into two categories: non wood fibres and wood fibres. Another type of natural fibre is grass fibre which has attracted the attention of researchers as reinforcing fibres for automotive applications (Thoma, 2001).

TABLE NO. 1.2: Difference between synthetic and Biodegradable plastics (Gnanavel *et al*., 2012)

S No.	Synthetic Plastic	Biodegradable Plastic
1.	In composting process it takes more than 400 years.	In composting process it takes about 180 days at most.
2	It is a threat for other organisms.	It is a food source for other organisms
3	Toxic compounds are added into it.	Non toxic compounds are added into it.
4	About 265 million tons synthetic Plastic were produced every year.	Only 0.7 million tons Biodegradable plastic were made every year.

CONCLUSION

This review covered the major information about the synthetic and biodegradable polymers, their types and uses. It is obvious that without plastic we can't meet our day to day life needs, but because of its detrimental affect it is required to develop proficient process for its safe disposal and also developed some alternative of synthetic plastic like starch based plastic. This article studied the use of natural polymer as the basis for a biodegradable plastic. Biodegradable plastics should be regarded as a solution to promote sustainable development. It is also a very good alternative to petrochemical plastics in the near future.

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REFERENCES

Abolfazl, J.S., Ahmmad, R.S., Yashar B., Sajad, A., Mehdi, J.H., Mahboubeh, A.S., Zahra, B., Farnaz, R. B. (2017) Bioplastic and the Environment. Electronic journal of biology. 13(3), 274-279.

Artham, T., Sudhakar, M., Venkatesan, R., Madhavan Nair, C.S, Murty, K.V.G.K., Doble, M. (2009) Biofouling and stability of synthetic polymers in sea water. Int. Biodeterior. Biodegrad. 63,884–890.

Besseling, E., Quik, J.T., Sun, M., Koelmans, A.A, (2017) Fate of Nano- and Microplastic in freshwater systems: a modeling study. Environment Pollution, 220, 540–548

Bhattacharya, P., Lin, S., Turner, J.P., Ke, P.C., (2010) Physical adsorption of charged plastic nanoparticles affects algal photosynthesis. J. Phys. Chem. 114, 16556–16561.

Bombelli, P., Howe, C.J., Bertocchini, F. (2017) Polyethylene bio-degradation by caterpillars of the wax moth Galleria mellonella. Curr. Biol. 27, R292–R293.

Bouwmeester, H., Hollman, P.C.H., Peters, R.J.B. (2015) Potential health impact of environmentally released micro- and Nanoplastic in the human food production chain: experiences from nano toxicology. Environmental Science Technology. 49, 8932–8947.

Bouwmeester, H., Hollman, P.C.H., Peters, R.J.B. (2015) Potential health impact of environmentally released micro- and Nanoplastic in the human food production chain: experiences from nanotoxicology. Environ. Sci. Technology.

Calderón, P.D., Matamoros, V., Bayona, J.M. (2011) Occurrence and potential crop uptake of emerging contaminants and related compounds in an agricultural irrigation network. Sci. Total Environ. 412, 14–19.

Cao, Y., Shibata, S. and Fukumoto, I. (2006) Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments. Composites part A‖: Applied science and Manufacturing, 37(3), 423-429

Carr, S.A., Liu, J. and Tesoro, A.G. (2016) Transport and fate of microplastic particles in wastewater treatment plants. Water Res. 91, 174–182.

Casado, M.P., Macken, A., Byrne, H.J., (2013) Ecotoxicological assessment of silica and polystyrene nanoparticles assessed by a multitrophic test battery. Environ. Int. 51, 97–105.

Castro, S.S., Burdman, S., Matan, O. (2009) Natural functions of bacterial polyhydroxyalkanoates. Microbiol Monogr. 3, 31-61.

Cazacu, G., Pascu, M.C., Profire, L., Vasile, C, (2002) Environmental friendly polymer materials. Polyolefin's-lignin based materials. Environ. Prot. Ecol. 3(1), 242–248.

Chen, G.Q., (2009) A poly hydroxyl alkanets based bio- and materials industry. Chem. Soc Rev. 38, 2434–2446.

Chung, S.Y., Yettella, R.R., Kim, J.S., Kwon, K., Kim, M.C., Min, D.B. (2011) Effects of grilling and roasting on the levels of polycyclic aromatic hydrocarbons in beef and pork. Food Chem.129, 1420–1426.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J. (2013) Microplastic ingestion by zooplankton. Environ. Sci. Technol. 47, 6646–6655.

Coppock, R.L., Cole, M., Lindeque, P.K., Queirós, A.M. and Galloway, T.S. (2017) A small-scale, portable method for extracting microplastics from marine sediments. Environ. Pollut. 230, 829–837.

Corsi, I., Cherr, G.N., Lenihan, H.S., Labille, J., Hassellov, M., Canesi, L., Dondero, F., Frenzilli, G., Hristozov, D., Puntes, V., Della Torre, C., Pinsino, A., Libralato G., Marcomini, A., Sabbioni, E., Matranga, V., (2014) Common strategies and technologies for the ecosafety assessment and design of nanomaterials entering the marine environment. ACS Nano. 8 (10), 9694-709.

Cózar, A., Echevarría, F., González-Gordillo, I.J., Irigoien, X., Úbeda, B., Hernández-Leónd, S., Palmae, A. T., Navarrof, S., García-de-Lomas, J., Ruizg, A.,

Fernández-de-Puellesh, M.L. and Duartei C.M. (2014) Plastic debris in the open ocean. Proc. Natl. Acad. Sci. USA . 111 (28), 10239–10244.

Della, T.C., Bergami, E., Salvati, A., Faleric, C., Cirino, F., Dawson, K.A. and Corsi, I. (2014) Accumulation and embryo toxicity of polystyrene Nanoplastic at bearly stage of development of sea urchin embryos Paracentrotus lividus. Environ. Sci. Technology. 48. 12302-12311.

Duis, K., Coors, A. (2016) Microplastics in the aquatic and terrestrial environment sources (with a specific focus on personal care products), fate and effects. Environ. Sci. Eur. 28,1–25.

Eerkes, M.D., Thompson, R.C., Aldridge, D.C. (2015) Microplastics in fresh water systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Res. 75, 63–82.

Fan, D., Chang, P.R., Lin, N., Yu, J. and Huang, J. (2011) Structure and properties of alkaline lignin-filled poly (butylene succinate) plastics. Iranian Polymer Journal, 20 (1), 3-14.

Faris, N.A., Noriman, N.Z. and Sam, S.T. (2014) Current research in bio degradable plastic , applied mechanics and materials,1-10.

Faure, F., Saini, C., Potter, G., Galgani, F., Alencastro, L.F., Hagmann, P. (2015) An evaluation of surface micro- and mesoplastic pollution in pelagic ecosystems of the Western Mediterranean Sea. Environ. Sci. Pollut. Res. Int. 19, 19.

Feldman, D. (2008) Polymer History. Designed monomer and polymer.11 (1), 1-15.

Foruzanmehr, M., Elkoun, S., Fam, A., Robert, M. (2015) Degradation characteristics of new bio-resin based-fiber-reinforced polymers for external rehabilitation of structures. J. Compos. Mater. 50, 1227–1239.

Freudenrich, C. (2018) Types of plastic. How stuff works.

Galloway, T.S., Cole, M. and Lewis, C. (2017) Interactions of Microplastic debris throughout the marine ecosystem. Nat. Ecol. Evol. 1,116.

Gao, D.W., Wen, Z. D. (2016) Phthalate esters in the environment: a critical review of their occurrence, biodegradation, and removal during waste water treatment processes. Sci. Total Environ.541, 986–1001

Gautam, S.P. (2009) Biodegradable plastic impact on environment. Central pollution control board, 1-44.

Geyer, R., Jambeck, J.R., Law K.L (2017) Production, use, and fate of all plastics ever made. Sci. Adv. 3, e1700782.

Ghosal, D., Ghosh, S., Dutta, T.K., Ahn, Y. (2016) Current state of knowledge in microbial degradation of polycyclic aromatic hydrocarbons (PAHs): a review. Front. Microbiol.

Gilloway, T.S. (2015) Micro and Nano plastic and Human Health, Marine Anthropogenic Litter, 343-366

Gnanavel, G., Mohana, J., Valli, V.P. and Thirumari murugan, M. (2012) A Review of Biodegradation of Plastics Waste. International journal of pharmaceutical and chemical sciences.1(3), 1019-1022.

Hayden, K., Webb, J.A., Russell, J.C. and Elena, P.I. (2013) Plastic Degradation and Its Environmental Implications with Special Reference to Poly (ethylene terephthalate). Polymers 5, 1-18.

Hirai, H., Takada, H., Ogata, Y., Yamashita, R., Mizukawa, K., Saha, M., Kwan, C., Moore, C., Gray, H., Laursen, D., Zettler, E.R., Farrington, J.W., Reddy, C.M., Peacock, E.E., Ward, M.W. (2011) Organic micro pollutants in marine plastic debris from the open ocean and remote and urban beaches. Mar. Pollut. Bull. 62, 1683–1692.

Horton, A.A., Walton, A., Spurgeon, D.J., Lahive, E. and Svendsen (2017) Microplastics in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities. Sci. Total Environ. 586, 127–141.

Huerta, L.E., Mendoza, V.J., KuQuej, V., de los, A., Chi, J., Sanchez, D., Cid, L., Chi, C., Escalona, S.G., Gertsen, H., Salánki, T., van der Ploeg, M., Koelmans, A.A. and Geissen, V. (2017) Field evidence for transfer of plastic debris along a terrestrial food chain. Sci. Rep. 7, 14071.

Huerta, L.E., Thapa, B., Yang, X., Gertsen, H., Salánki, T., Geissen, V. And Garbeva, P. (2018) Decay of low-density polyethylene by bacteria extracted from earthworm's guts: a potential for soil restoration. Sci. Total Environ. 624, 753–757.

Inoue, K., Serizawa, S., Yamashiro, M. and Iji, M. (2007) Highly Functional Bioplastics (PLA compounds) Used for Electronic Products‖. In Polymers and Adhesives in Microelectronics and Photonics. 6th International Conference on (pp. 73-76). IEEE.

John, M,J., Anandjiwala, R.D., Pothan, L.A., Thomas, S., (2007). Compos Interface 14, 733.

Kalia, V.C., Raizada, N. and Sonakya, V. (2000). Bioplastics. J Sci Ind Res. 59: 433-445.

Keshavarz, T. and Roy, I. (2010) Polyhydroxyalkanoates: bioplastics with a green agenda‖. Current Opinion in Microbiology 13, 321-326.

Kiyama, Y., Miyahara, K. and Ohshima, Y. (2012) Active uptake of artificial particles in the nematode *Caenorhabditis elegans*. J. Exp. Biol. 215,1178–1183

Lambert, S. Sinchir, C.J, Bradely E.L. and Boxall, A.B.A. (2013) Effects on Environmental condition an latex

degradation in aquatic systems. Scie, Total Environment. 447, 225-234

Masa, S., Petra, Horvat., and Andrej K. (2012) Bioplolymers and Bioplastics plastics align with nature. European regional fund, 1-30.

Mohanty, A.K., Misra, M. and Hinrichsen, G. (2000) Biofibres, biodegradable polymers and biocomposites‖. Technical University of Berlin, Institute of Nonmetallic Materials, Polymer Physics, Englische Str. 20, D10587 Berlin, Germany

Muthukumar, A. and Veerappapillai, S. (2015) Biodegradation of plastic- a brief review, International Journal of Pharmaceutical Sciences Review and Research 31(2), 204-209.

Nga, E.L., Lwangab, Esperanza, H., Eldridgea, S.M., Johnstond, P., Hua, H.W., Geissen, V. and Chena, D. (2018) An over view of micro plastic and nano plastic pollution in agro ecosystems, Science of the Total Environment. 627, 1377–1388

Pathak, V.M. and Navneet (2017) Review on the current status of polymer degradation: a microbial approach,

Pye, E.K. (2006) Industrial lignin production and applications. In: Kamm, B., Gruber, P.R., Kamm M., (eds.) Biorefineries—Industrial Processes and Products. Status Quo and Future Directions.2, 165–200.

Raquez, J.M., Bourgeois, A., Jacobs, H., Degée, P., Alexandre, M., Dubois, P (2011) Oxidative degradations of oxodegradable LDPE enhanced with thermoplastic pea starch: thermo-mechanical properties, morphology, and UV-ageing studies. J. Appl. Polym. Sci. 122, 489–496.

Sandhu, S.S., Shakya, M., Deshmukh, L., Aharwal, R.P. and Kumar, S. (2016). Determination of hydrocarbon degrading potentiality of indigenous fungal isolates. International Journal of Environmental Sciences. 6(6), 1163-1172.

Sangale, M.K., Shahnawaz, M. and Ade, A.B. (2012) A Review on Biodegradation of Polythene: The Microbial Approach, Journal of bioremediation.3, 10.

Singh, S., Shankar, S. and Shikha (2016) Microbial Degradation of plastic: A review, International Journal of Scientific and Innovative Research. 4(1),112-119.

Tharanathan, R.N. (2003) Biodegradable films and composite coatings: past, present and future‖. Trends in Food Science and Technology, 14, 71–78.

Wu, Q., Sun, S.Q., Yu, P.H.F., Chen, A.X.Z., Chen, G.Q. (2000) Environmental dependence of microbial synthesis of poly hydroxyl alkanoates. Acta Polym Sin 6, 751–756.

www.indianmirror.com/indian-industries/plastic.html.

www.science.howstuffworks.com/plastic4.htm.

Yrikou, J. and Briassoulis, D. (2007) Biodegradation of Agricultural Plastic Films‖: A Critical Review. J Polym Environ. 15, 125.