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Importance of Plastic in Modern Society: Recycling Is the Best Way of Waste Management

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Abstract

Plastic is one of the best and useful inventions of human civilization that possesses both positive and negative expressions. It has extremely advanced the human society in various sectors. It is a polymer based on petroleum products that is used in multipurpose activities, such as household, industry, construction, electrical and electronics, automotive, medical, and packaging. The annual global production of plastics has surpassed 460 million tons in 2025, yet only about 10% of waste plastics are recycled. Over production and consumption of plastic and due to their stable and non-biodegradable nature has led to serious environmental problems, such as contamination of air, soil, sediment, groundwater, and oceans; and also it is related to climate change due to greenhouse gas (GHG) emissions. Therefore, worldwide production, consumption, and disposal of plastic are not sustainable. This paper investigates variants of plastic, and its efficient use and recycling patterns in brief.

Keywords: plastic recycling, plastic waste, non-biodegradable

1. Introduction

Plastic is a cheap durable polymer that consists of synthetic and semi-synthetic compounds mostly derived from petrochemicals (PlasticEurope, 2009). At present it becomes one of the most useful and a versatile material ever invented that is commonly used materials and becomes an integral part of our daily lives, and the modern society would not be possible without it (Soni et al., 2022). It is light with low density, high toughness, durable, ease of design and manufacturing, clean, low cost, and versatile; and use of it has been increasing in packaging, construction and infrastructure, automotive, building, electronic and electrical products, agriculture, and other sectors (Wypych, 2020). It can be molded to any shape as desired, but it is not biodegrade. It plays a significant role in the environmental, societal, and economical dimensions of sustainable development (Mohajan, 2020). It can reduce the energy and greenhouse gas (GHG) emissions, and is needed to transport goods and products (Mohajan, 2015).

During the last 60 years the global production and consumption of plastics has increased tremendously due to population growth, industrialization, consumerism, and technological development (Mohajan, 2021a). It is estimated that about 4% world annual oil production is used to produce and manufacture plastic products (Prasad et al. 2008). The oil refinery processes produce derivatives for producing plastics in ‘fluff’ and then ‘pellets’ forms. Different types of plastics materials, such as packaging materials, window frames, plastics for electrical and electronics apparatus, etc. are prepared from these pellets (Wong, 2010). About 35% of plastics produced in the developed countries are consumed for packaging. Although plastics are currently essential in human life in recent years; the management of plastic waste has become a growing problem (Achilias et al., 2007).

Plastic is reusable and recyclable. Various efficient strategies are involved in the collection, trading, transportation, sorting, storage, and reprocessing of plastic waste during the recycling. It is estimated that

globally only 10% of plastics are recycled and 14% are incinerated; the remaining 76% go to landfills or enter in the natural environment (Horton, 2021).

2. Literature Review

A literature review is a comprehensive summary and critical analysis of existing scholarly works on a specific topic that is a survey of credible sources on a topic, which is used in dissertations, projects, and research papers (Baglione, 2012). It provides an overview of current knowledge on a subject that helps to identify relevant theories and methods as well as gaps in the existing research (Bolderston, 2008).

Akash Balakrishnan and Mary Nancy Flora have discussed about plastic, its properties, various forms of it; its effect on human, nature, and ways of effective management through the recycling (Balakrishnan & Flora, 2017). Bebetto Sabu and his coauthors have shown that plastic is one of the most versatile materials of modern age. They have realized that by recycling plastic, the amount produced and wasted can be reduced but whereas the process has short-term advantages for the environment, and the long-term results are not so pretty (Sabu et al., 2017).

Roberto Nistico has stated that polyethylene terephthalate (PET) is the third most widely diffused polymer exploited in the packaging industry, monopolizing the bottles market for beverages, and covering almost 16% of the European plastic consumption in the packaging industry. He has provided a useful instrument that collects past, present, and future of the PET (Nistico, 2020). Ahmed Trimbakwala has shown that the plastic wastes can be used in road construction and the field tests withstood the stress. He has observed that the durability of the roads laid out with shredded plastic waste is much more compared with roads with asphalt with the ordinary mix. This technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income (Trimbakwala, 2017).

Md. Tanvir Hossain and his coworkers have stated that polypropylene (PP) is a versatile polymer with numerous applications that has undergone substantial changes in recent years, and have provided a comprehensive review of recent research in PP and its advanced functional applications. They have emphasized on the promising potential of PP while addressing unresolved concerns, with the goal of guiding future research and promoting innovation in polymer applications (Hossain et al., 2024). Irena Žmak and Carina Hartmann represent the results of the analysis of the current state in waste management of plastic bottles in Germany. They have observed that the plastic recycling rate has risen from 15 to 100% (Žmak & Hartmann, 2017).

3. Research Methodology of the Study

Research is a creative and systematic investigation to discover or refine knowledge about a particular subject (Kara, 2012). It involves the collection, organization, and analysis of evidence to increase understanding of a topic that is characterized by a particular attentiveness to controlling sources of bias and error (Groh, 2018). Methodology is the systematic method to resolve a research problem through data gathering using various techniques, providing an interpretation of data gathered and drawing conclusions about the research data (Murthy & Bhojanna, 2011). It is divided into quantitative and qualitative research, where quantitative research is the main methodology of the natural sciences that uses precise numerical measurements (Berg, 2009). On the other hand, qualitative research is more characteristic of the social sciences that give less prominence to exact numerical measurements. At present many social scientists use mixed method research that combines quantitative and qualitative methodologies (Creswell, 2003). Research methodology is a structured and scientific approach used to collect, analyze, and interpret data to answer research questions or test hypotheses that describes the techniques and procedures used to identify and analyze information regarding a specific research topic (Howell, 2012). It is a logical and systematic plan to resolve a research problem, and it is a way of explaining how a researcher intends to carry out the research (Andiappan & Wan, 2020).

4. Objective of the Study

Plastic is low cost, lightweight, durable, clearness, water resistance, weathering, easy to handle, and has relatively high strength and corrosion resistance (Andradi, 2015). Plastic production and consumption was 380 million tons in 2017 compared to only 1.5 million tons in 1950 annually in the world with a projection of 34 billion tons by 2050. Plastic is not biodegradable and is one of the major environmental problems if it does not dispose properly (Tiseo, 2020). Main objective of this article is to discuss the aspects of plastics with the reuses and recycling (Mohajan, 2025e). Other minor objectives of the study are as follows (Mohajan, 2018):

1) to highlight on types of plastics,
2) to focus on plastic waste, and
3) to investigate plastic recycling.

5. Types of Plastics

Plastics are long-chain high molecular weight polymers (Mohajan, 2025d). At present there are more than 30 different types of plastics in regular use (Scott, 1999). Some major plastic resin types are polyethylene terephthalate (PET), polypropylene (PP), polycarbonate (PC), polyvinyl chloride (PVC), polystyrene (PS), nylons, low-density polyethylene (LDPE), and high-density polyethylene (HDPE). These do not easily degrade, and remain in waste streams in environment for 100 to 1,000 years (McCrum et al., 2007).

5.1 Polyethylene Terephthalate (PET)

American chemist Wallace H. Carothers (1896-1937) has discovered the synthetic polyester. The first activities related to polyesters fibers are performed by the American chemist Julian W. Hill (1904-1996). In 1941, the English chemist John R. Whinfield (1901-1966) and his assistant James T. Dickson have synthesized and patented PET (Nistico, 2020). The PET is the largest thermoset plastic consists of repeating $C_{10}H_8O_4$ units that is one of the most widely used and versatile plastic polymers, and shares about 55% of global plastic market. It is excellent wear resistance, low coefficient of friction, high flexural modulus, and superior dimensional stability makes it a versatile material for designing mechanical and electro-mechanical parts (Malik et al., 2017). It is one of the most diffused thermoplastic polymers available on the market. It can be semi-rigid to rigid, depending on its thickness. It is known as the safest and easy to be recycled of all plastics (Ji, 2013). It is a very light, strong, unreinforced, impact-resistant, stiff synthetic fiber, semi-crystalline, and resin with a melting peak temperature between 225°C and 255°C (Locock et al., 2017).

The PET is a member of the polyester family of polymers that is used in fibers for synthetic fibers in clothing, containers and bottles for liquids and foods, thermoforming for manufacturing, packaging foods and some other consumer goods, and in combination with glass fiber for engineering resins (De Vos et al., 2021). Plastic bottles and containers made of PET are used for soft drinks, bottled water, alcoholic drinks, detergents, edible oils, cosmetics, pharmaceutical products, and juice packaging. Its popularity comes from its very light weight, physical clarity, and remarkable strength (Andrady, 2015). Products made of PET are generally large in volume and can take about one thousand years to decompose under natural environmental conditions (Silva et al., 2013).

5.2 Polycarbonate (PC)

The polycarbonate (PC) is a group of thermoplastic polymers that contains carbonate groups −O−(C=O)−O−, which is a versatile and tough plastic (Parvin & Williams, 1975). It is one of the important engineering plastics with a wide variety of applications due to the excellent mechanical properties, high impact strength, heat resistance, high modulus of elasticity, excellent balance of toughness, clarity, high thermal resistance, and transparency (Cao et al., 2010).

The PC is discovered in 1898 by the German scientist Alfred Einhorn (1856-1917). It is a durable material with high impact-resistance and low scratch-resistance (Mohajan, 2021a). Therefore, a hard coating is applied to PC eyewear lenses and PC exterior automotive components (Parvin & Williams, 1975). It is used in electronic components, construction materials, 3D printing; production of compact discs, DVDs, and Blu-ray discs; production of automotive, aircraft, security components, medical devices, and smartphone manufacturing (Assadi et al., 2014).

5.3 Low-Density Polyethylene (LDPE)

The low-density polyethylene (LDPE) is a thermoplastic made from the monomer ethylene that is the first grade of polyethylene, produced in 1933 by the *English oceanographer* John C. Swallow (1923-1994) and *British scientist* Michael Willcox Perrin (1905-1988), who were working for Imperial Chemical Industries (ICI) using a high pressure process through the free radical polymerization (Malpass, 2010). It is a semi-crystalline material with milky white base color and waxy feel. It is excellent impact resistance; semi flexible soft material chemical resistance and electrical insulation are excellent (Ghatge et al., 2020). Although it is flexible and tough, breakable with density range of 917-930 kg/m^3. It can be translucent or opaque. It is one of the best and safest types of plastic, suitable for cold and hot liquids. It is highly non-reactive material and withstand up to 100^{0}C (Karl et al., 2018).

The LDPE is used to produce films or bags, containers, dispensing bottles, wash bottles, squeezable bottles, tubing, trash can liners, shrink wrap, food storage containers, bread bags, frozen food bags, wire and cable applications, electrical components, battery cases, automotive parts, housewares, and stretch wrap (Sarker et al., 2020). It is recyclable, but needs to be previously sorted from harder fractions of plastics and treated in adequate recycling processes (Achilias et al., 2007).

5.4 High-Density Polyethylene (HDPE)

The high-density polyethylene (HDPE) is high corrosion resistant plastic, hard, rigid, clear, and solvent welded thermoplastic polymer that is made from petroleum. It accounts for over 34% of the global plastic market. It is a solid material that can tolerate high temperature and strong chemicals (Araújo et al., 2008). It is safe,

long-lasting, weather-resistant, and needs low maintenance. It offers stronger intermolecular forces and tensile strength (Amjadi & Fatemi, 2020). It resists mold, mildew, and rotting; making it the ideal material for underground piping used to deliver water. It can be easily cut, machined, welded, and fabricated. The density of HDPE ranges from 930 to 970 kg/m^3 (Loultcheva et al., 1997).

It is primarily used for shampoo bottles, window frames, milk jugs, detergent bottles, margarine tubes, pipe systems, garden furniture, grocery bags, bags and damp-proof membranes, food storage containers, toys, pyrotechnic components, cutting boards, coax cable insulators, chemical containers, dustbins, corrosion-resistant piping, nursery pots, medical equipment, geo-membranes, pesticide containers, ointment tubes, plastic lumber, flower pots, cereal box liners, boating components, and oil containers (Ayadi et al., 2011; Teusdea et al., 2020).

It is used in orthopedic implants, such as knee or hip replacements for their low friction coefficient, high wear resistance, impact strength, chemical and corrosive resistance, and biocompatibility. It is also used in plastic surgery, snowboards, shoe lasts, 3D printing filament, wood plastic composites, etc. It takes 1.75 kg of petroleum to make one kg of HDPE (Yuan et al., 2002). It is easily recyclable that helps to reduce plastic production by up to 50%. Recycled HDPE is used in plastic furniture and automobile parts. Recycling of HDPE is limited due to the presence of some additives, such as chlorine, cadmium, lead, etc. (Thakare et al., 2015).

The HDPE has some disadvantages, such as it is highly flammable, not biodegradable, sensitive to stress cracking, non-compostable, poor weathering resistance, and difficult to bonding, not resistant to oxidizing acids, not resistant to chlorinated hydrocarbons, high thermal expansion, and poor temperature capability (Huang et al., 2013).

5.5 Polypropylene (PP)

The polypropylene (PP) is an important commercial polymer that is extensively applied in many areas, such as home appliances, construction, automobile, and other industrial appliances, owing to its attractive properties, easy processing, and low cost (Liu et al., 2018). It is a high-quality general purpose engineering plastic material. It is strong, flexible, abrasion, impact resistance, dangerous, and unsafe (Jansri & O-Charoen, 2018). It is available in a range of grades and forms to suit many applications. It is economical and lightweight that is widely used in ropes because of its lightweight and hard wearing (Akinci et al., 2008). It is also used in products, such as yarn, fabrics, food packaging, meat trays, nursery pots, row covers, surgery tools, yogurt and margarine containers, bottle caps, ketchup bottles, and food pack aging (Maier & Calafut, 1998). It is highly recyclable, but recycling is limited due to contamination, difficulties in collection, and mixture with other materials (Hossain et al., 2024).

5.6 Polyvinyl Chloride (PVC)

Polyvinyl chloride (PVC) is one of the first plastics discovered that is derived from salt (57%) and oil or gas (43%). It is the third most widely produced synthetic plastic polymer (about 40 million tons), after polyethylene (PE) and polypropylene (PP); and about half of the world PVC production capacity is in China (Karlen, 2006). The largest single producer of PVC as of 2018 is Shin-Etsu Chemical of Japan, with a global share of around 30%. It is biologically and chemically resistant (Allsopp & Vianello, 2012).

It is a white and brittle solid plastic. It is soluble in ketones, chlorinated solvents, dimethylformamide. It becomes harmful and toxic if used for long-time (Holloway, 1998). It is considered as bad plastic, as it is cost effective to produce and is highly resilient to chemical and biological damages (Rahman, 2007). It is used in making clothing, upholstery, plumbing, flexible hoses or tubes, signage, phonograph records, rubber substitutes, doors and windows, flooring, inflatable products, and electrical cable insulation (Illston & Domone, 2002). It is also used to produce essential products, such as pressure pipes, outdoor furniture, food packaging, plastic bottles, shrink wrap, liquid detergent containers, bank or membership cards, etc. With cotton or linen, it is used in the production of canvas (Grause et al., 2017).

5.7 Polystyrene (PS)

Polystyrene (PS) is a *synthetic* aromatic polymer made from the monomer styrene. It is discovered in 1839 by *German apothecary* Eduard Simon (1789-1856). It is clear, glassy, rigid, brittle, opaque, and melts at 95°C (Wypych, 2020). Expanded PS is foamed, lightweight, energy absorbing, and heat insulating. It is flexible and can be easily made into different forms. It is used to make plastic models, CD and DVD cases, yoghurt pots, egg cartoons, food trays, egg boxes, and disposable utensils, video cassettes, televisions, packaging pellets, and Styrofoam peanuts (Kausar, 2021). It is also widely used in manufacturing plates, poultry trays, plastic foam cups/plates, plastic cutlery, and eyeglasses frames. It affects liver, red blood, kidneys, and stomach. It is not easy to recycle due to low density (Haynes, 2011). It presents some limitations, such as a barrier against O_2 and smog, and presenting a quite low melting point (Singh et al., 2025).

6. Plastic Roads

Plastic roads are paved roadways that are made partially or totally from plastic or plastic composites that are used to replace standard asphalt materials (Peters, 2019). These are first developed by Indian scientist Rajagopalan Vasudevan in 2001 through the use of an asphalt mix incorporating plastic waste (Thiagarajan, 2018). About 3 to 4% plastic is mixed with the bitumen that increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life (Patel et al., 2018).

When plastic is mixed with hot bitumen, plastics melt to form an oily coat over the aggregate and the mixture is laid on the road surface like a normal tar (Mohajan, 2021b). Recently plastic wastes, such plastic-carry bags, disposable cups, and PET bottles are used in plastic road construction (Poweth et al., 2013). Plastic mix in asphalt can reduce the viscosity of the mix that allows a lower working temperature, and reduces volatile organic compound and carbon monoxide (CO) emissions (Subramanian, 2016).

7. Plastic Waste

The plastic waste is one of the main problems of the society. Also, it is one of the major causes of environmental pollution and destruction, becomes carcinogenic to human, causes birth defects in human, impairs immunity, damages livelihoods, and increases endocrine disruption (Wamba et al., 2023). The plastic pollution crisis is causing the environmental destruction, sickness, mortality, and damage to livelihoods. At present plastic cannot be collected effectively, so the dumping causes huge health and environment problems (Babaremu et al., 2022). Plastic contains dioxins that causes damage to the nervous system, causing tumors, genetic mutations, and some genetic diseases, which cause birth defects, and disruption in fertility, reproduction, and sexual maturation. Negative impacts of plastic are carcinogenic, mutagenic, toxic for reproduction, harmful to aquatic life, etc. (Lang. et al, 2009).

Plastic waste is filling our oceans at an exponential rate that has become a global catastrophe (Mohajan, 2025c). Plastic debris is a threat to marine wildlife. About 5 trillion pieces of plastic weighing about 322 million tons are currently littering in oceans and the pollution is increasing rapidly (Eriksen, 2014).

8. Plastic Recycling

Plastic recycling is the system for recovering waste plastic and reprocessing them into useful and valuable products. It has grown significantly during the last few years. Plastic can be recycled into new plastic bottles, plastic boxes, t-shirts, fleeces, and stuffing for pillows (Loultcheva et al., 1997). The recycling chain of plastic consists of several traders, waste sorters, grinders, and pellet makers. The waste plastics are heated up to 2,700-3,000°C to convert into liquid-vapor state, and it is collected in condensation chamber in the form of liquid fuel (Wong, 2010). At present global plastic recycling processes are logistically inefficient, expansive, fragile, and even environmentally harmful. The PET and HDPE are safe and recyclable. Only 10% of the world's plastic is currently recycled (Tulashie et al., 2022).

9. Importance of Plastic Recycling

Plastic recycling is one of the easiest ways to be environmentally friendly that reduces rubbish going to landfill, pollution, and raw material extraction that saves energy and combats climate change (Collings, 2007). It is saving a lot of energy and natural resources, such as petroleum, water, and other natural resources and conserves the balances in nature (Mohajan, 2025a). It opens up job opportunities, and involves a reduced cost in materials for new goods (Velis et al., 2022). For recycling plastic requires less energy and fossil fuels that results in reducing GHG emissions, and brings benefits to the environment. Waste plastics have economic value. Plastic recycling conserves energy, reduces CO_2 emissions, saves landfill space, and saves marine life (Moniruzzaman et al., 2012).

More than 400 species of oceans, such as seabirds, sea turtles, fishes, and marine mammals have been injured or killed after ingesting plastic materials. Recycling is the most economic method of managing plastic wastes (Barnes et al., 2009). Because it reduces the exploitation of non-renewable petroleum-plastic raw materials, limits the quantity of plastics sent to landfills, and provides cheaper route to plastic production (Mohajan, 2025b). China is the largest importer of recycling plastics from Japan, USA, UK, Germany, Netherlands, Belgium, and many other countries (Hopewell et al., 2009).

10. Conclusions

We are living in the plastic age. At present plastic is a very important issue in the modern society, and global consumption of it is increasing at an average rate of 10% per year. The plastic is widely used in making electrical instruments, medical instruments, telephones, automobile parts, lamps, goggles, optical instruments, household appliances, etc. It is estimated that in every minute, more than one million plastic bags are thrown away after an average use of just 15 minutes, and consequently plastic pollution is increasing at an alarming rate. It is considered one of the major crises that is threatening the sustainable development. Plastic recycling is the best strategy for the end-of-life management of plastic products that increases economic sense, and reduces negative

environmental impacts. It guarantees that existing resources will be used sensibly and sustainably. On the other hand, global demand for recycled plastics is also increasing. Recycled plastics can be used for high end application, with low cost and reasonable price that provides an approach for the sustainable management of plastic wastes.

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