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GLOBAL PLASTIC WASTE SCENARIO: A REVIEW ON PRODUCTION, FATE AND FUTURE POSPECTS

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ABSTRACT

Due to the progressive advancement of science and technology, rapid development, and population increment in an uncontrolled way, the usage of plastic materials also expanded around the globe. Recently, it became a global challenge to manage, minimize and mitigate this plastic waste (PW) which is broadly publicized in the media and scientific articles. Though few research articles focused on the acute generation of plastic, poor management, and health risks and issues associated with PW. These articles stab to draw attention to these issues as well as explained future prospects and possible alternatives to plastic. From 1950 to 2020, 70 years plastic generation rate has increased by about 22233% which is alarming and uncontrolled. It is predicted that by 2050, the plastic production rate will be more than 650 million tons. However, though the USA produces maximum plastic India is at the top of the list for plastic pollution. Soil, water, human and marine life, and overall, the environment is greatly affected by PW. Hence, PW is getting increased in an uncontrolled way due to the low recycling rate. Therefore, the study aims to outline the critical discussion about global plastic production, current management practices, and mitigation measures to minimize the negative impact of plastic.

Keywords: *Plastic Waste, Plastic Production, Soil and Ocean Pollution, Future Prospects, Recycle and Reuse*

INTRODUCTION

The invention of plastics was a significant milestone that resulted in an improvement in the quality of human life. Since their first synthesis in the early 1900s, plastics have replaced many types of materials in the production of consumer products, including wood, metals, and ceramics, due to their light weight, durability, resistance to corrosion by most chemicals, diversity of applications, ease of processing, and low cost. Aside from the benefits mentioned above, studies have shown that plastic-based products are responsible for lowering the cost of production in various fields of human endeavor, as well as diversifying the product offer and expanding its market globally, with a predominant growth in the packaging sector and a consequent increase in profits for chemical, oil, and manufacturing companies (Sartorius, 2010; Dauvergne, 2018).

Cities are confronted with an increasing and unavoidable application of organic and inorganic waste as a result of rapid industrial advancement and population growth. According to the researchers, the world currently generates about 1.7-1.9 billion metric tons per year (BMTPA) of waste, which will increase to 27 BMTPA by 2050, with Asia alone contributing nearly one-third of this waste (Modak et al. 2010; Nations, 2010). Approximately 50-70% of this massive waste generation is collected for disposal, with uncontrolled landfilling accounting for 15% of the collected waste (Modak et al. 2010; Ramos and Vicentini, 2012). The environmental impact of this waste is exacerbated by the presence of plastic litter, which accounts for nearly 5% of municipal solid waste (Sharmin et al., 2016). People in North America and Asia consume 100 and 20 kg of plastic-driven products per capita, respectively. Plastics' non-biodegradability complicates their easy and safe disposal. A large portion of this waste plastics ends up in landfills, energy generation through incineration, which produces hazardous emissions as well as particulate matter, and an enormous amount of 10-20 million tons of plastics dumped into the ocean each year, slowly deteriorating the marine ecosystem. Furthermore, approximately 4% of total used fossil fuels are used as a feedstock for the production of plastic products, with another 3-4% required to power these manufacturing industries (Gourmelon, 2015).

For several years, Asia has been the largest consumer of polymers, producing 30% of all plastic waste (Markus et al., 2014). Between 1992 and 2016, China imported 45% of the world's plastic waste, resulting in the "dispersion" of massive amounts of plastic waste after China's ban, which is expected to reach 111 million metric tons by 2030. (Brooks et al., 2018). This resulted in the transfer of the global plastic recycling system, causing global plastic recycling to panic (Huang et al., 2020). While many countries have recognized the importance of recycling and utilizing domestic plastic waste streams, they lack the necessary industrial infrastructure and capacity (Brooks et al., 2018). Because of the ban, a large amount of plastic waste was exported to other Asian countries such as Indonesia, Vietnam, Malaysia, and the Philippines (Wang et al., 2019) In addition, Turkey has emerged as a new plastic waste recycling market in some European countries (Liu et al., 2018). As a result, these countries implemented import control measures to reduce the import of plastic waste. Although some scholars have stated that an import ban in developing countries would force developed countries to establish new plastic treatment facilities (Wang et al., 2020), the plastic waste trade remains profitable for traders for the time being (Naayem, 2021). On the one hand, some local businesses in some countries prefer to import low-cost plastic waste rather than invest in domestic waste recycling systems (Dell, 2021).

In contrast, developed countries have realized that exporting plastics is a more cost-effective approach than domestic processing (Wang et al., 2020). According to some scholars, the rapid inflow of plastic waste after China's ban has overwhelmed Turkey's waste management, and waste pollution in Turkey and its Mediterranean coast has continued to rise (Gündodu, 2021). Malaysia (Chen., 2021) Thailand (Sasaki, 2021), and other countries are in the same situation. The pursuit of profit by capital has prompted the continuation of the plastic waste trade under the goal of public governance policy. These "displaced" plastic wastes present a challenge to global plastic waste governance because most countries cannot manage excessive plastic waste imports sustainably (Dauvergne, 2018), and the risk of plastic waste being illegally dumped into the ocean and freshwater is increasing (Huang et al., 2020)

The vast majority of plastic monomers, such as ethylene and propylene, are derived from fossil hydrocarbons. None of the commonly used plastics degrade in nature. As a result, rather than decomposing, they accumulate in landfills or the natural environment (Barnes et al., 2009) Only destructive thermal treatment, such as combustion or pyrolysis, can permanently eliminate plastic waste. As a result, the near-permanent contamination of the natural environment with plastic waste is becoming an increasing concern. Plastic debris has been discovered in all major ocean basins (Barnes et al., 2009), with 4 to 12 million metric tons (Mt) of plastic waste generated on land entering the marine environment in 2010. (Jambeck et al., 2015). Contamination of freshwater systems and terrestrial habitats is also becoming more common (Wagner et al., 2014; Rillig, 2012; Zubris, 2005). (Zubris, 2005; Dris, 2017). Plastic waste is now so pervasive in the environment that it has been proposed as a geological indicator of the Anthropocene epoch (Zalasiewicz et al., 2016).

The most preferable waste management strategies proposed by the European Union (EU) and the United States Environmental Protection Agency (EPA) focus on waste prevention and reduction, with reuse, recycling, energy recovery, and disposal as the least preferred options (European Commission, 2013; Plan, 2014). Biodegradable plastics management could be included in these strategies because they can open up new end-of-life waste management options not available to non-degradable plastics, such as anaerobic digestion and composting. Food contamination of current non-biodegradable plastics prevents or limits recycling options, whereas food-contaminated biodegradable plastics can be composted.

Following that, this paper provides an outlook on how the disruption caused by plastic waste can act as a catalyst for both short-term and long-term changes in plastic waste management around the world. Also, some selected sustainable technologies for plastic waste management have been proposed in light of social and economic aspects, as well as challenges to meeting sustainable goals.

MATERIALS AND METHODOLOGY

Data collection methods

For this current review, all information was collected from published online journals, Google Scholar, ResearchGate, ScienceDirect, conference papers, electronic books, Government sites, Web links, Springer Link, and Policy documents. The relevant information selected for this study was for the last two decades (2002-2022) to get current data. Moreover, more than 100 articles were reviewed and 55 published articles were chosen for citation. By giving scientifically valuable information on the current state and prospects of plastic, our findings will help policymakers, academics, government, and non-governmental organizations globally.

RESULTS AND DISCUSSIONS

Based on related literature found, this review article is subdivided into eight segments: Plastic production, Plastic types, Cumulative 1950-2017, Projections to 2050, Health risks and issues associated with the acute generation of plastic waste, Soil and Ocean pollution due to plastics, Post-Consumer Plastic Waste management practices, Future Prospects of Plastic and Possible Replacements.

Plastic production

The heightening Growth of the plastic industry is visible over than last 50 years. During these periods, Plastics production ramped up from 1.5 million metric tons (Mio. t) in 1950 to ~322 Mio. t, shown in figure 1, and is predicted to increase by more than 600 million tons by 2050. The generation rate gradually increased from 1950 to 1990 and after that, a sharp peak is noticed till 2020. In 1990, plastic production was 105 Mio. t which has increased to 180 million within just 10 years with an increment of about 71%, which is alarming and the growth trend is continuous. Global plastic production increased by about 3.4% in 2015 compared to 2014. The compound Annual Growth Rate (CAGR) of plastic from 1950 to 2015 is about 8.6% (Jambeck et al., 2015). Plastic became a part and parcel of lifestyles of people due to its multipurpose nature, outstanding durability, corrosive resistance, good thermal properties, and comparably cheap and non-toxic nature. The distribution of plastic production in the top 10 countries globally is as follows, United States (34.02 Mio. t), India (26.33 Mio. t), China (21.60 Mio. t), Brazil (10.68 Mio. t), Indonesia (9.13 Mio. t), Russia (8.47 Mio. t), Germany (6.68 Mio. t), United Kingdom (6.47 Mio. t), Mexico (5.90 Mio. t), and Japan (4.88 Mio. t) (Law et al., 2020). Most waste plastics are generated due to single-use plastics being dumped after their initial application (Ayeleru et al., 2020).

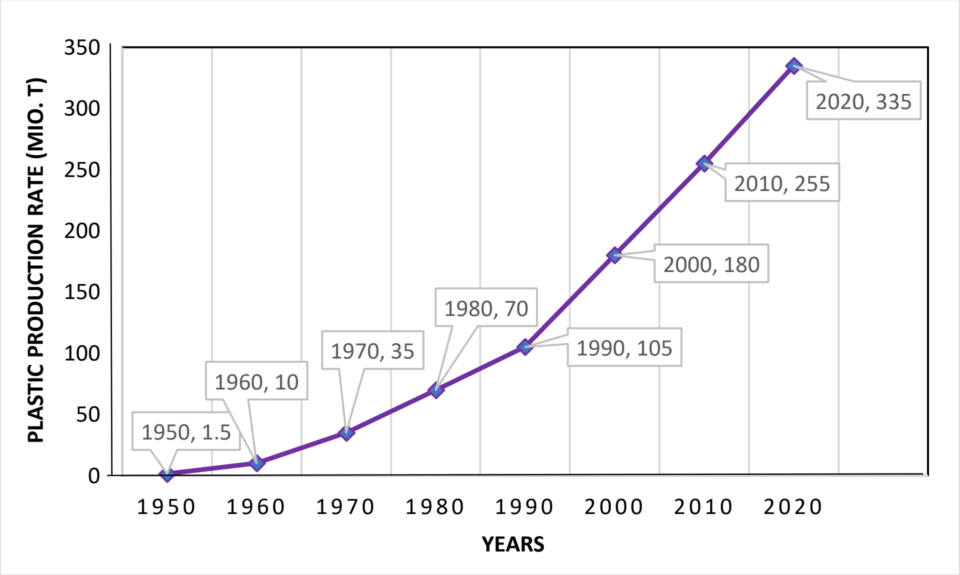

Figure 1 World Plastics Production 1950-2020. Source data from Plastics Europe Market Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH

Though the USA produces the maximum proportion of plastics throughout the globe, India is the most PW-generating country (Meijer et al., 2021), with 13 million tons (Mt) following China (12.3 Mt), Philippines (4 Mt), Brasil (3.3 Mt), Nigeria (2 Mt), Tanzania (1.7 Mt), Turkey (1.6 Mt), Egypt (1.4 Mt), Dr Congo (1.3 Mt), Thailand (1.3 Mt) as shown in figure 2. Due to rapid urbanization and globalization, people's living standards also upgraded which resulted in an increasing amount of plastic waste (PW) generation (Plastic Market Size, Share & Trends Report, 2022 - 2030, n.d.).

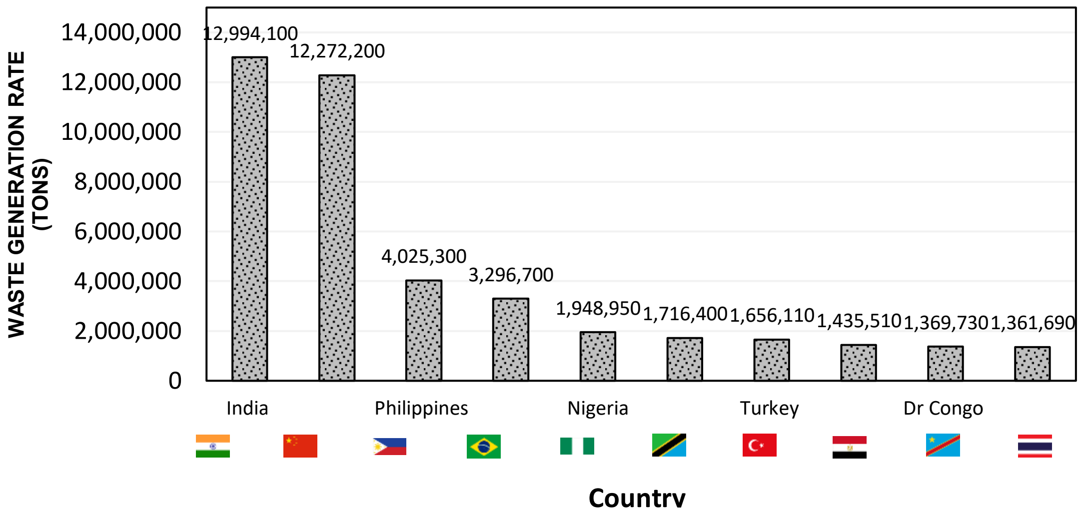

Figure 2 Ten (10) countries with the most plastic pollution. Source data from (Meijer et al., 2021)

The treemap in figure 3 represents plastic demand in various sectors which shows the major demand for plastic including the packaging, building, and construction sector. Most plastic demand of about 40.5% can be found in the packaging sector. The global packaging market is huge. In 2000, the market size was roughly $383 billion which is expected to enrich to about $980 billion in 2020 (Sydow & Bieńczak, 2019). Plastics are largely used in the construction sector in the modern world like hinges, screws, and bigger construction parts are made from plastic and are used in the construction sector (Construction Industry, 2022). The market demand for building and construction is about 20.4%. The remaining demands for plastic are in automotive, electrical and electronics, household, agriculture, and others sector.

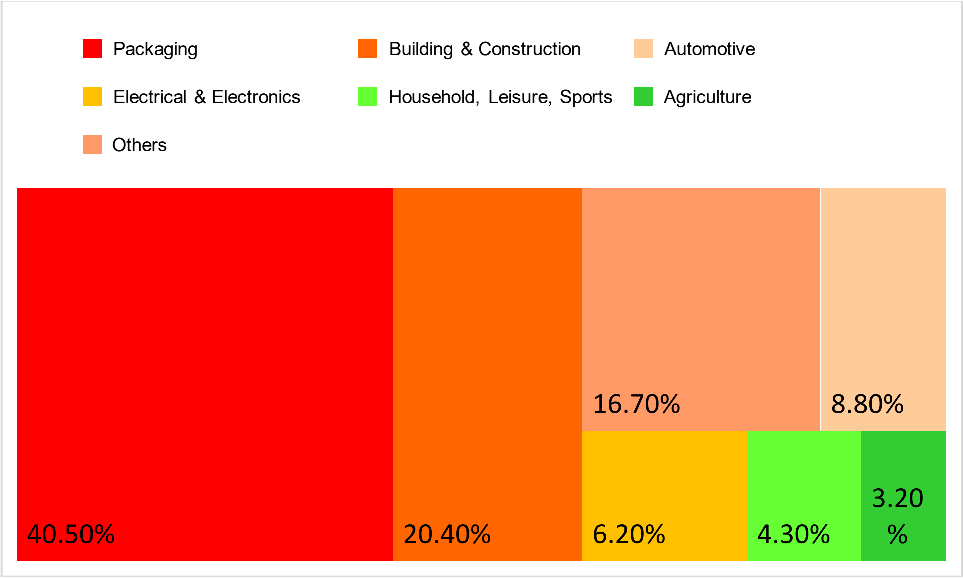

Figure 3 Converters Plastic Demand at 2020. Data from Plastics Europe Market Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH

However, Humans have produced over 8 billion tons of plastic since 1950, with more than half of it ending up in landfills and only about 9% being recycled (Meijer et al., 2021). Plastic can be subdivided into two major categories; thermoplastics and thermosetting plastics. Thermoplastics are those that remain flexible under heat. Linear polymers and a combination of linear and cross-linked polymers are examples of thermoplastics. such as PVC, nylon, polythene, etc. These two types are broadly classified into seven classes which include; Polypropylene (PP) (Type: 1), polyethylene terephthalate (PET or

PETE) (Type: 2), High-Density Polyethylene (HDPE) (Type: 3), Polyvinyl chloride (PVC) (Type: 4), Polyvinyl chloride (PVC) (Type: 5), Polystyrene (PS) (Type: 6), and other plastics (Type: 7). Details of these categories can be explained into section 4.2. However, more populous countries tend to produce more plastic waste overall. The increasing generation of PW is currently a prime concern for waste managers and policymakers as there are very limited facilities to manage this waste.

Plastic types

Plastics, also known as synthetic polymers, have only been mass-produced for about 70 years, but they have outgrown the majority of man-made materials. Plastic can be subdivided broadly into seven categories in current modern days;

Polypropylene (PP): Polypropylene is a very flexible, soft material with a relatively low melting point. Thermoplastic & thermoplastic materials become liquid at their melting point (roughly 130 degrees Celsius in the case of polypropylene). In a nitrogen environment, PP degrades in a single step, beginning at 300 °C and ending at 475 °C. PP can be easily copolymerized with polyethylene to combine into composite plastic. Polypropylene is highly impermeable to water. Chemical formula of PP is $(C_3H_6)_n$.

polyethylene terephthalate (PET or PETE): PET is an aliphatic polyester whose general chemical formula is $(C_{10}H_8O_4)_n$. It has high strength, high rigidity and hardness and very low moisture absorption rate. PET products have low permeability to oxygen, carbon dioxide and water. PET is not biodegradable. Its polymer chain breaks down at a relatively low temperature.

High Density Polyethylene (HDPE): HDPE comes with an outstanding temperature range and short periods of heating with up to 248°F (120°C) or for long periods up to 230°F (110°C) is considered safe. HDPE has a low degree of branching, is not readily biodegradable. Very low water absorption. It's general formula is $(C_2H_4)_n$. Others notable properties of HDPE is high stiffness, strength, toughness, resistance to chemicals and moisture, permeability to gas, ease of processing, and ease of forming.

Low Density Polyethylene (LDPE): LDPE breaks down more easily than other plastics. It decomposes within 290 to 350 °C. During high temperature processing of LDPE in the presence of air thermal oxidation occurs. LDPE is insoluble at normal temperature It practically does not permeate in water and steam, but it has a good permeability to carbon dioxide and oxygen. The monomer of LDPE is ethylene which is same as HDPE.

Polyvinyl chloride (PVC): PVC comes in two basic forms: rigid (sometimes abbreviated as RPVC) and flexible. It is very dense compared to most plastics (specific gravity around 1.4). Polyvinyl Chloride has outstanding tensile strength. The formula for PVC is $(H_2C–CHCl)_n$, where n is the degree of polymerization. Other properties of PVC are abrasion-resistant, lightweight and tough and resistant to all inorganic chemicals.

Polystyrene (PS): PS is a clear, amorphous, nonpolar commodity thermoplastic. It can be copolymerized with methyl methacrylate. It is insoluble in water. Polystyrene is soluble in most chlorinated and aromatic solvents, though not in alcohols. Unmodified polystyrene is clear, rigid, brittle and moderately strong. Chemical formula of PS is $(C_8H_8)_n$.

Other plastics: polycarbonate, polyctide, acrylic, acrylonitrile butadiene, styrene, fiberglass, nylon plastics are considered in this category. These plastics are use in mostly plastic CDs and DVDs, baby bottles, large water bottles with multiple-gallon capacity, medical storage containers, eyeglasses, exterior lighting fixtures etc.

However, different categories of waste generation rate presented on figure 2 which shows PP is the most waste generating type plastic and LDPE is the lowest respect to waste generation (only 4%). Degradation rate of plastic is very slow, it can take 5-10 years or even 1000 years in. Due to slow degradation rate, plastic is a hazardous pollution and dangerous to environment in various ways. Soil and groundwater can be directly affected by leaching toxic chemicals of PW.

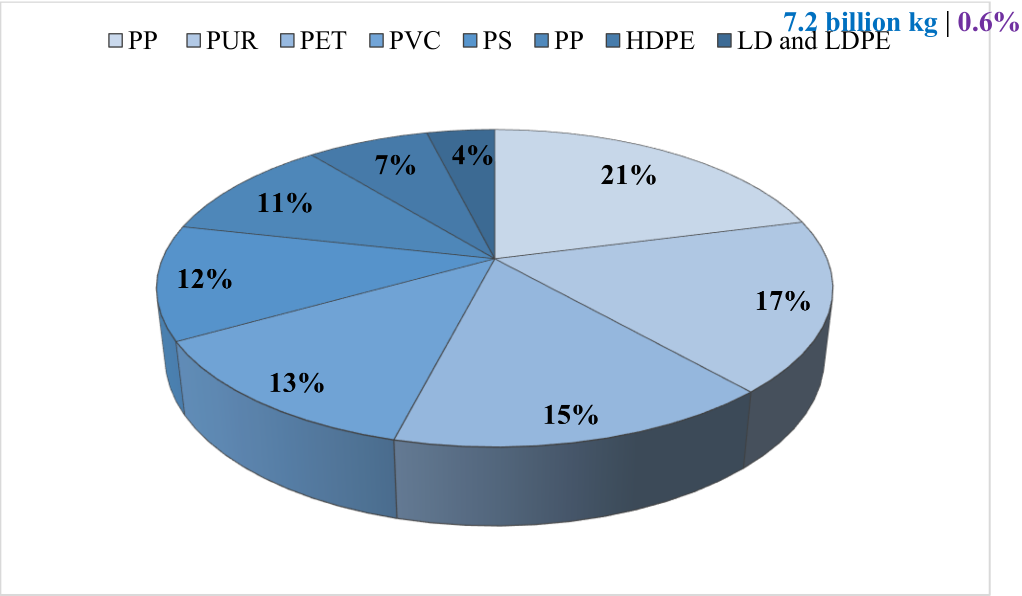

Figure 3 Different types of Plastic Waste Generation in 2015. Adapted from (Ayeleru et al., 2020)

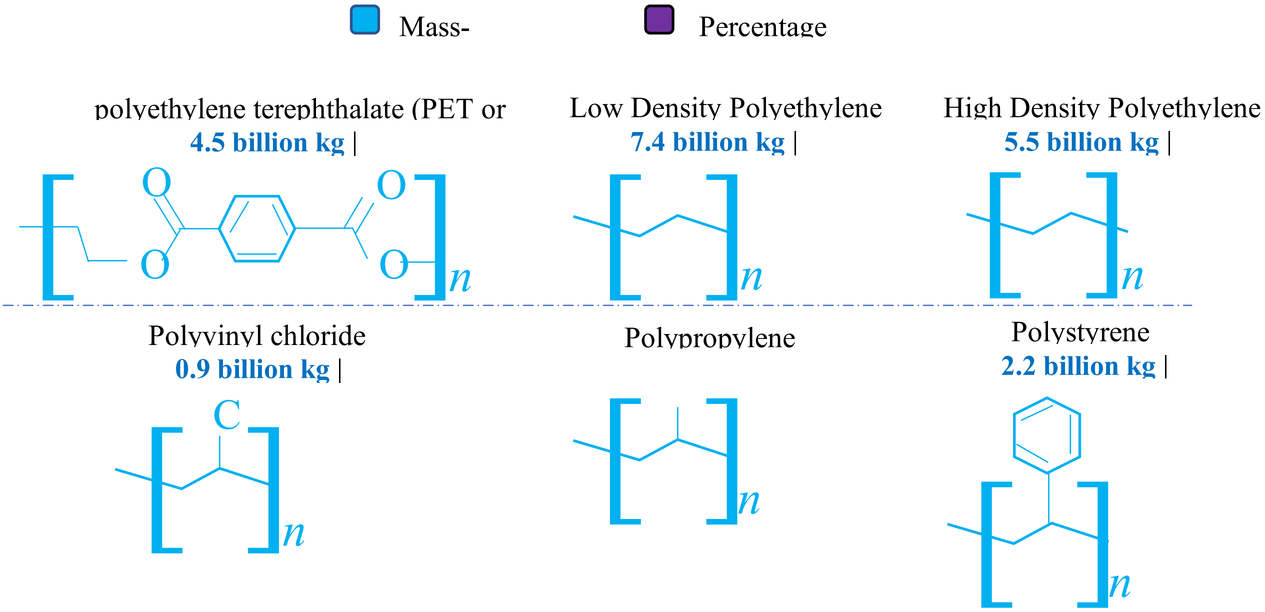

Figure 3 Chemical formula, mass production and recycle rate of various types of waste. Recreated from (Green Chemistry, 2021)

LDPE (7.4 billion kg) is the most generated waste throughout these seven categories and PVC produces the lowest (0.9 billion kg). PP is the most abundant after LDPE-type plastic with mass production of about 7.2 billion kg. The general formula of PP is $(C_2H_4)_n$ and its recycle rate is 5.3%. A Maximum Recycle rate of 19.5% can be found in the case of PET or PETE because of their comparatively low decomposition rate. Moreover, PVC-type plastic never degrades and due to this reason, the recycling rate of PVC is zero.

Cumulative 1950-2017

Production, use, and destiny of all plastics ever made from 1950 to 2017 can be explained with the help of graphical representation as shown in figure 4. From 1950-2017, during these 67 years, human beings produced approximately 9200 Mt of primary plastics and 700 Mt of secondary plastics have been produced which were reported at the end of 2017 ((Sydow & Bieńczak, 2019)). Among this total of 9900 Mt of plastics, an estimated amount of 2700 Mt and 200 Mt of primary and secondary plastics were in use, while roughly 7000 Mt had become plastic waste. Approximately 700 Mt of plastic has been recycled, 5300 Mt was cast-off and 1000 Mt was incinerated among these 7000 Mt of plastics. Only 14% of plastics were recycled more than once. The recycling rate of plastic is very low due to low commodity prices, which discourages recycling industries (Zainu & Songip, 2017).

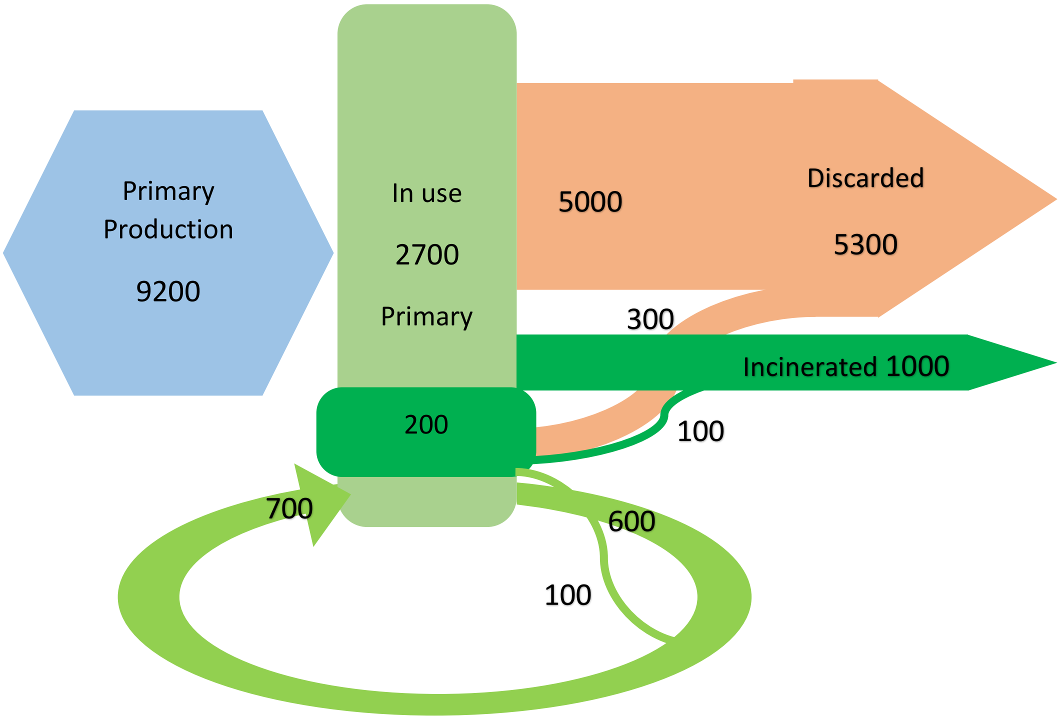

Figure 4 Cumulative production, use, and fate of all plastic ever made, from 1950 to 2017, in Mt. Recreated from (Geyer, 2020)

Projections to 2050

The plastic production rate is getting higher with time due to its various advantages. If the rising trend continues, by 2050, the global plastic production rate could increase 1100 Mt (Dris, 2017). According to the literature, if global recycling, incineration, and discard rates follow a current linear trend, then global recycling, incineration, and discard rates would reach 43%, 50%, and 7% respectively by 2050. This is a possible global scenario conferring to the current state. But the future trend can be something else as the plastic generation rate depends upon several factors which may not be considered here.

Health risks and issues associated with the acute generation of plastic waste

During the manufacturing process of plastic, it includes additives including plasticizers, stabilizers, etc. which are detrimental to human health issues (Sharmin et al., 2016). For example, bisphenol A (BPA) is a plasticizer and monomeric building block that can be used for polycarbonates and epoxy resins which can retard natural hormonal signals in the body and disrupt the endocrine system. Also, it is linked with several disorders and diseases. Various plastic polymers, their usage, and their physical properties can be shown in table 1. Most plastic takes a huge time to degrade such as LDPE takes 500-1000 years to degrade and PVC is never degradable. PETE, PVC, PS, and PP are not safe environmentally. The leached toxins (LT) from these plastics are also hazardous. Some plastic types can be highly toxic and can cause cancer and damage to the nervous system, fast changes to human genes, and metabolic disorders.

Table 1 Various plastic types and their usage, properties and associated health challenges

Plastic Polymers	Usage	Time to Decompose (years)	Physical Properties	Leached Toxins	Status	Tensile Strength (Mpa)	Ref.
PETE	Bottles, rope, combs, tote bags	10	high heat resistant, tough, solvent-resistant, environmentally sustainable due to highest recycle rate	Antimony (Carcinogenic)	Not safe	1700	(Achilias et al., 2008)
HDPE	milk jugs, soap, detergent, bleach bottles, toys, buckets	100	excellent chemical resistance, hard to semi-flexible and strong, permeable to gas	estrogen-mimicking chemicals (disrupting hormones)	Usually, safe and low risk	1000	(J. Akhtar, & Amin, 2011)
LDPE	plastic wrap, irrigation pipes, hot and cold beverage cups, garbage bags	500-1000	tough and flexible, soft, scratches easily, low melting point, stable electrical properties	estrogen-mimicking chemicals same as HDPE	safe	300	(Bhattacharyya et al., 2019)
PVC	plumbing pipes, credit cards, floor covering, pipes and fittings	never	good chemical resistance, hard and rigid, long-term stability, low gas permeability	BPAs, phthalates, lead, mercury	Not safe	2900-3300	(Bhattacharyya et al., 2019)
PP	yogurt containers, potato chip bags, packing tape, thermal vests, car parts, disposable diapers	20-30	excellent chemical resistance, hard but flexible, strong	leaching some chemicals leading to asthma or hormone disruption	Microwave safe	1325	(VERMA et al., 2016)
PS	plastic cutlery, egg cartons, take-out food containers, disposable foam cups, coat hangers	50	clear to opaque, rigid or foamed, hard, brittle, high clarity, affected by fats and solvents	highly toxic, leaching styrene can cause cancer and damage to the nervous system, affect genes	Not safe	3250	(Zhou et al., 2016)

Soil and Ocean pollution due to plastics

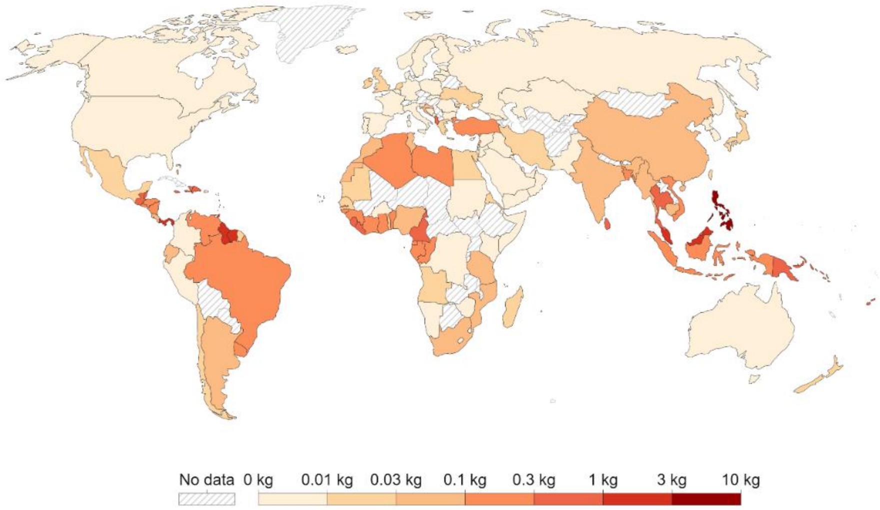

Figure 5 Plastic waste emitted to the ocean per capita, 2019 (Meijer et al., 2021) (available online: https://ourworldindata.org/plastic-pollution (accessed on 17 December 2022))

The presence of plastics in landfills and the ocean presents threats to the environment due to the nearly indestructible nature of this material. Plastic can wreak slow-but-certain havoc on an environment in multiple ways, from leaching toxic chemicals into the soil and groundwater to directly choking or poisoning animals who unwittingly ingest it. Soil pollution due to plastic can change the physical structure of the earth underfoot and limit its capacity to hold water. On the other hand, after initial application, a large quantity of plastic isn't recycled and is directly dumped into landfills ((F.c & D.h.s, 1984)). These unmanaged plastics then become plastic wastes and the ultimate place of these wastes is the ocean where they create large havoc.

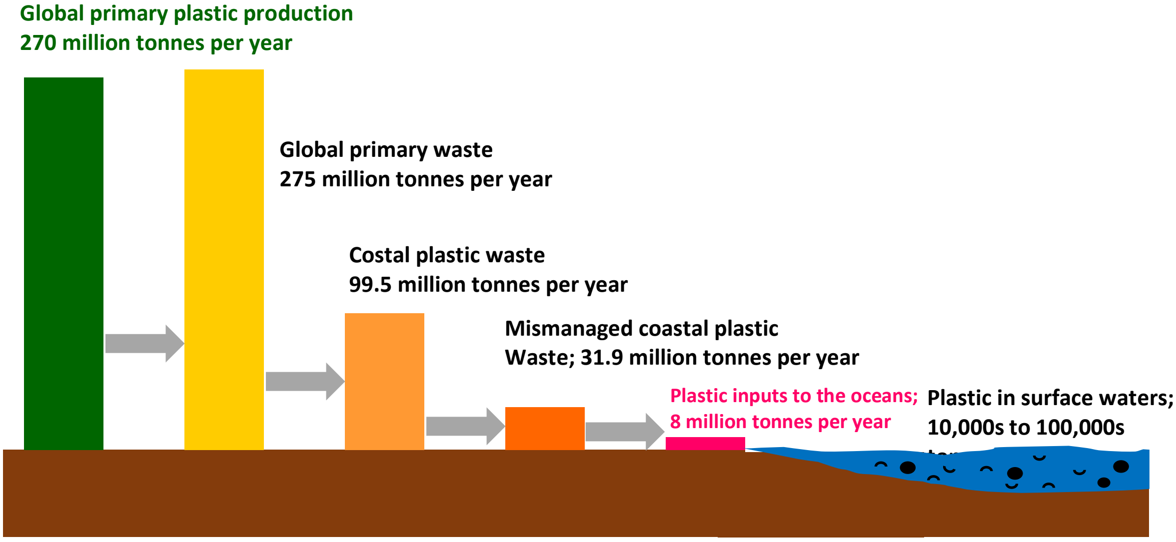

Figure 6. The pathway by which plastic enters the world's ocean. Based on (Jambeck et al., 2015) and (Eriksen et al., 2014)

Figure 6 illustrates the pathway by which plastic enters into world's oceans. Not only physically, plastic also affects waterbody chemically, especially with smaller particles (Faure et al., 2015). The above figure illustrates two researchers' findings, but the graph contains data from the year 2015. According to that, the global plastic production rate is 270 million tonnes from which coastal plastic waste is approximately 100 million tonnes. Among these, due to mismanaged coastal plastic, plastic enters the ocean at 8 million tonnes yearly. From production, approximately 3% of plastic enters the ocean every year whereas plastic in the surface water is almost 10000s to 100000s tonnes yearly. In 2021, the Philippines releases the most amount of plastic into the ocean and the proportion is about 356,371 tons (Macleod et al., 2021). These plastics degrade slowly and pollute the water bodies and are harmful to marine life. Also, microplastics have been detected in water throughout the globe, including our streams, rivers, lakes, and oceans (Gündodu, 2021).

Post-Consumer Plastic Waste management practices

After use, most of the plastics become PWs, and to manage these wastes, several strategies have been adopted globally. There are two strategies to manage PW which include landfilling, and recycling (Hopewell et al., 2009). Landfilling is the least preferred technique in plastic waste management (PWM) due to its detrimental environmental impact on soil and groundwater (Shen & Worrell, 2014). Landfilling is the oldest technique for PWM which was previously adopted by most countries (Swift & Wiles, 2004). But the process is unsuitable as PW can remain unchanged without biodegradation for more than 1500 years (Nkwachukwu et al., 2013). Thus, currently developed countries putting strategies and discouraging the landfilling action of plastic. Graphical representation in figure 4 also shows the PWM rate of the landfill, recycling, and energy recovery of PW in million tons which also depicts the landfilling rate currently decreasing due to its hazardous impact on the environment and mankind.

However, recycling is a good option for PWM to use the limited resources and minimize the impacts on the environment. The recycling process includes primary recycling, secondary recycling (mechanical recycling), tertiary recycling (chemical recycling), and quaternary recycling (energy recovery) (Tansel & Yildiz, 2011). Primary recycling is the direct application of uncontaminated PW materials to produce new plastics without losing their properties (selke, 2006). Furthermore, Mechanical recycling transforms PW into valuable materials and the process is currently gaining attention in PWM (ref). The process includes plastic collection, sorting, washing, grinding, and remelting and the converted plastic properties are like the original one. Additionally, chemical recycling (CR) is a popular technique to fabricate the PW as a feedstock for the manufacture of new products. CR process breaks down the intermolecular bond of the polymers via chemical reactions and the outputs are purified products like the original one. The process occurs at high temperatures and uses solvents. Results from the graph shows, recycling is getting popular with time and in the period 2006-2020, the recycling rate almost doubled and heightened continuously.

Finally, quaternary recycling also termed the energy recovery process is gaining attention recently. Various conversion techniques are available to convert plastics into energy whereas hydrothermal liquefaction (HTL), gasification, and pyrolysis are the most popular. With these techniques, PW can be converted into valuable products.

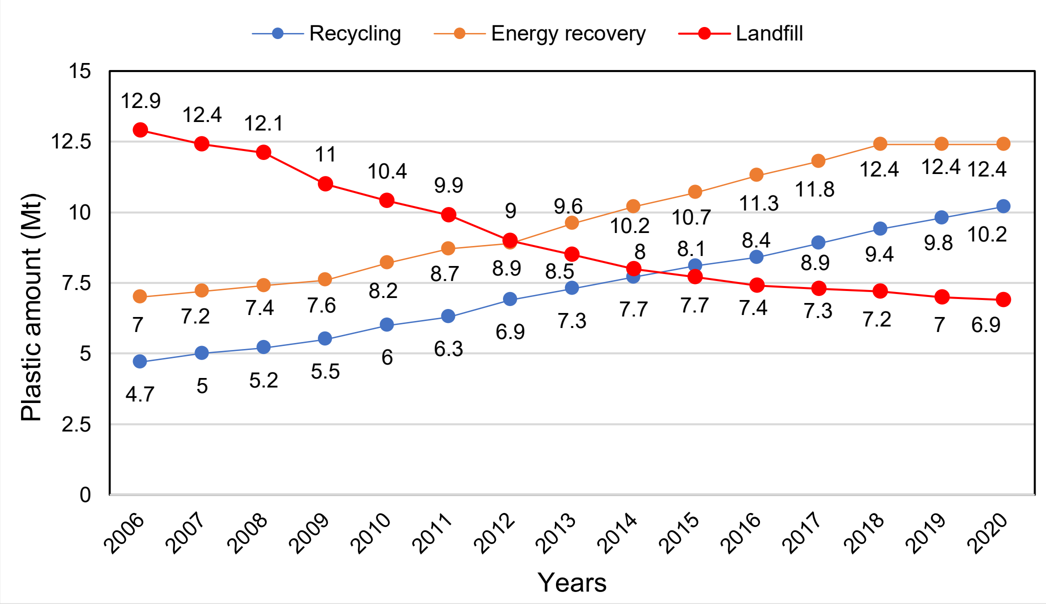

Figure 4 Recycling, Energy recovery and Landfill rate from 2006-2020. Data from Plastics Europe Market Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH

Future Prospects of Plastic and Possible Replacements

To minimize, handle and manage this large quantity of plastic waste; plastic managers, policymakers, and concerned authorities taking various steps. One of the prospects can be minimizing the use of single-use plastic as most of the single-use plastics can be dumped into the environment after their initial use. But this phenomenon can be complex if the general public and policymakers aren't working hand to hand together. The market for single-use plastics is very large due to the high usage of plastics in food packaging and other industries. The government needs to take the strong initiative to decrease or ban the single use of plastics.

However, the recycling rate needs to be increased. The ratio of plastic manufacturing to recycling rate is comparatively very low. There are several reasons behind it and the cost of recycling plastic is higher than newly manufactured plastic. The government needs to take proper initiatives to solve these issues by encouraging the manufacturers to recycle the plastics and bounce them with proper opportunities.

Additionally, the most effective solution regarding plastic waste can be the thermochemical conversion of plastic which is a "Waste to Energy (WtE)" concept. Currently, several conversion processes are available among them hydrothermal liquefaction (HTL) and pyrolysis are the most suitable for plastic. The end product through these processes is bio-crude. HTL process occurs at 280-375° Celsius in an enclosed system where pressure generates almost 4-25 MPa and pyrolysis occurs at 800° Celsius with atmospheric pressure. These techniques provide a double-edged solution by reducing PW and making valuable products from it.

Also, we need to minimize the usage of plastics, and to do that we must identify goods that can be used as an alternative to it. Plastic alternatives include bio-plastics, stainless steel, glass, platinum silicon, wood, bamboo, cardboard, paper, cotton, pottery, ceramics, etc. For instance, use jute polymer or eco-friendly poly bags, paper bags, cotton bags, jute bags, and other alternatives to polythene and plastic bags.

CONCLUSION

Due to several advantages plastic is globally one of the most produced materials which have different applications all over the globe. Suddenly reduction of plastic production is difficult but with some proper initiatives, unnecessary PWs can be minimized and can lessen environmental pollution as well as reduce the health issues on humankind. 3Rs (Reduce, Reuse, Recycle) could be a great initiative. Additionally, the generation of alternative sources of plastics, lessening single-use plastics, and finally converting the PW into energy through various thermochemical processes are possible solutions that can lead towards sustainable development goals (SDGs) and also ensure a cleaner, greener and safer environment. Local recycling industries need to grow rapidly and to do that government, policymakers, social activists, and common people need to work together. In this way, PW will be reduced and the world will move towards sustainability.

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