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A Review of Plastic Threat to Environment

Farjana Islam [a*] and Ruhul A. Khan [a]

[a] Water Analysis Laboratory, Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Due to low weight, great strength, and wide range of applications the invention of plastic has generally been viewed as a blessing for modern living. The world purchases around one million plastic bottles every minute and uses one billion plastic bags every hour. Bangladesh is also witnessing a surge in plastic production employed in our RMG sector, the healthcare industry, and the automobile industry. The amount of plastic pollution in Bangladesh has received very little attention over the years. Plastics are blamed for significant contamination of the air, soil, and water bodies because of their low biodegradability, excessive use, and pervasive mishandling. As a result, plastics are now found in every environmental compartment threatening biodiversity and human health as well. This manuscript discusses plastic pollution as a global environmental issue, offering an in-depth analysis of its effects on soil, water bodies, the atmosphere, and ecosystems. It also emphasizes the consequences for human health, the environment, and the economy, particularly focusing on Bangladesh. Enforcing strict regulations on plastic production and usage is the only way to mitigate its harmful environmental impacts.

Keywords: Plastic pollution; environment; soil; water; air; pollution; plastic.

**Corresponding author: E-mail: farjanaduswe@gmail.com;*

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1. INTRODUCTION

The oceans are swimming in plastic, the rivers are choked with plastic, coastlines are collecting plastic, landfills are clogged with plastic, and our trash cans are filled with plastic – these are the common scenarios of Bangladesh. In recent times plastic is an essential part of everyday living. According to a s of decomposition of these one of the greatest hurdles to environmental conservation is the availability of plastic items. plastics make their disposal extremely hazardous to the environment (Li et al., 2020). That's why recently massive quantities of plastic debris and its limited breakdown disturb the environment greatly. Several types of plastics which are used daily ultimately end up in the trash. This trash gradually covers vast spaces of land (Sharma and Bansal, 2016). "During the previous 50 years, the world's plastic production has grown significantly. Now plastics are used to make a wide range of goods. It has become an essential component of modern life and also the plastics industry is growing interested in this sector increasingly" (Gu and Ozbakkaloglu, 2016). "Conventional plastics are incredibly robust and take a long time to break down in the environment. Globally around 6.5 billion tons of waste plastic and rubber are produced per year worldwide and the long rate plastics do not break down and will always remain in the environment for several years. In normal environmental conditions, polymer degradation takes hundreds of years" (Pol and Thiyagarajan, 2010). "Because plastic waste contains a lot of highly toxic trace elements in its pigment and it is harmful" (Gondal and Siddiqui, 2007). "Therefore, it has been determined that environmental contaminants originating from synthetic plastics are a major hassle" (Zheng et al., 2005). "It has been estimated that 9200 million metric tons (Mt) of plastic have been manufactured worldwide, of which over 6900 Mt have been landfilled which have contributed to environmental degradation. In addition, 368 million metric tons (Mt) of plastic were produced worldwide in 2019 and by 20 years, that amount is expected to triple" (Walker and Fequet, 2023). "Because most consumer plastics are made to be single-use items with little potential for recycling, global production and consumption have skyrocketed, creating previously unheard-of levels of plastic waste and pollution. Among all 9 percent of plastic garbage that has ever been recycled globally, 12 percent has been burned, and the remaining 79 percent has accumulated in natural ecosystems. Moreover, it was assessed that in 2016 about 19–23 Mt of plastic garbage produced worldwide found its way into aquatic environments and that amount is expected to rise to 53 Mt yearly which ultimately disrupt soil or land and the aquatic continuum in various ways by 2030".

Bangladesh is a country that is overpopulated. Its three largest cities, Sylhet, Chittagong, and Dhaka, are all in grave danger. According to a report, Dhaka city discards roughly 14 million polybag fragments daily. The report also mentioned that one of the main reasons for the obstruction of the drainage systems in Bangladesh's urban areas during the floods in 1998 and 2008 was the use of plastic and polythene materials. Out of the top 20 countries in the world for plastic pollution, Bangladesh was ranked 10th in a recent report released by Earth Day Network (2018). Plastic contributes 800,000 tons, or eight percent, of the nation's waste, of which 200,000 tons end up in the nation's rivers and oceans (Hossain and Shams, 2020). Moreover Bangladesh, a developing country having a vast population of 166 million, has satisfactory economic growth including over three thousand small and big plastic industries at present and it has been recognized as the 12th highest export earning sector in the fiscal year 2017-18 (Hossain et al., 2021). Since people turned to single-use plastic out of concern for infection and the virus's spread, the arrival of COVID-19 has made the situation of plastic pollution worse. In Bangladesh, the use of single-use plastic and polythene bags increased dramatically during COVID-19. In 2020, 6,646 tons of waste were produced daily in the Dhaka metropolitan area whereas less than half of the plastic waste is recycled, 48% ends up in landfills, and the remaining portion is either thrown in drains or rivers, or it is just thrown in other parts of the city that time (Khatun et al., 2023). Bangladesh is an agriculture-based nation with 87700 km^2 of arable land. It is home to many rivers along with the country's tropical monsoon environment, which is ideal for the growth of the agricultural industry. In addition to these agricultural sectors, Bangladesh holds a 0.6% market share in the USD 570 billion global plastic industry employing over 2 million people either directly or indirectly. As Bangladesh deals with natural disasters and various forms of solid waste management, improper handling of plastics has become a major concern (Islam et al., 2023). This is right time for policymakers to articulate strict initiative to change the habit of general users and select environment-friendly natural fiber products as practical alternatives. If not, the longer we shall wait, the more difficult it will be to change people's attitude.

2. CLASSIFICATION OF PLASTIC MATERIAL

In essence, plastics are made of synthetic polymers as long-chain molecules derived from petrochemicals or crude oil. Comparing plastic to many other readily available natural materials, it is more durable, lighter, and more malleable. Plastic has a wide range of uses since it rarely interacts with other materials. It is also used to make the majority of packaging and single-use plastic bags because of its undecomposable manner (Abbing, 2019). Thermoplastics and Thermosetting plastics are two fundamental types of plastic in which Thermoplastics can be remelted and reformed under heat. Examples of thermoplastics are polyethylene (PE), polypropylene (PP), PVC, polyethylene terephthalate (PET), polystyrene (PS), and polyamide (PA). Oppositely, thermosetting plastics are polymers that have stronger bonds so that it cannot be remelted. Consequently, it is difficult to recycle thermosetting plastics as well. Mostly thermoset plastics are used to prepare involve polyurethanes (PUR), unsaturated polyester, silicone, epoxy, melamine, phenolic, and acrylic resins (Geyer, 2020). "In addition plastic debris undergoes degradation resulting in the formation of microplastics (MPs), which are defined as plastic particles smaller than 5 mm. For plastic users and recyclers, a detailed classification of plastic materials was made by the Society of the Plastics Industry (SPI) in 1988. An SPI code or number is marked into the bottom of the plastic product so that the user can easily identify their desired material. In terms of safety, plastic materials are classified into the following seven types, of which type 2, type 4, and type 5 are more compatible to use".

Type 1: Polyethylene Terephthalate (PET or PETE)

PET is an aliphatic polyester. Because of its special qualities—such as its lightweight, toughness, high resistance to heat, grease, and oil, and low permeability to oxygen, carbon dioxide, and water—polyethylene terephthalate (PET) is the plastic used in food packaging applications that are expanding the fastest. Its polymer chain breaks down at a relatively low temperature. Although these plastics are thought to be safe in general, food and drink items can occasionally absorb flavors and odors from them. The primary drawbacks of these polymers are their oxidation susceptibility and lack of biodegradability. PET plastics are utilized in the production of numerous household items, including medicine pots, rope, clothing, and carpet fiber. This plastic is typically recycled into new products. The carpet, pillow, and sleeping bags, among other items, are made from recycled PET materials.

Type 2: High-Density Polyethylene (HDPE)

High-density polyethylene made from petroleum, a type of heat-resistant plastic. Type 2 plastic is used in making milk containers, detergent bottles, refrigerators, toys, various types of plastic grocery bags, etc. High-density polyethylene is relatively strong, irritable and 'heat-prone' in nature. HDPE has a low degree of branching and it is not readily biodegradable. Furthermore, it has very low water absorption capacity. Other notable properties of HDPE are high stiffness, strength, toughness, resistance to chemicals and moisture, and permeability to gas Products made of High-density Polyethylene HDPE are thought to be extremely safe because they prevent chemicals from contaminating food. Due to their lightweight, extremely strong, long-lasting, weather-resistant, and impact-resistant qualities, these materials are being used more frequently these days. HDPE materials are used to make a wide range of everyday products, including soap, detergent, shampoo, oil, and milk containers. Because of health risks, it is not safe to store food or beverages in an HDPE bottle more than once. Typically, these materials are recycled to make trash cans, flower pots, and detergent bottles, among other things.

Type 3: Polyvinyl Chloride (PVC)

PVC comes in two basic forms: rigid (sometimes abbreviated as RPVC) and flexible. It is very dense compared to most plastics with a specific gravity of around 1.4. Polyvinyl Chloride has outstanding tensile strength. The properties of PVC are abrasion-resistance, lightweight tough, and resistant to all inorganic chemicals. Polyvinyl Chloride PVC is utilized in the production of various pipes, tiles, and electronic components. PVC is replacing more conventional building materials because of its many useful qualities, including its ease of use, affordability, durability, resistance to corrosion, and ease of processing. Its main component, chlorine, makes it chemically and biologically resistant. Recycling programs typically do not accept PVC plastic.

Type 4: 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. Since low-density polyethylene (LDPE) is resistant to moisture, and chemicals, it is regarded as a safe and healthy plastic. Due to its strength and flexibility, LDPE is now used more frequently to create a variety of everyday products, including plastic grocery bags, sandwich bags, food wraps, and beverage bottles. As it is rarely recycled, it is better to reuse it instead of discarding it after just one use.

Type 5: Polypropylene (PP)

Polypropylene is a very flexible, soft thermoplastic material with a relatively low melting point. It becomes liquid at their melting point of roughly 130 degrees Celsius. PP can be easily copolymerized with polyethylene to combine into composite plastic. It has strong resistance to water, soap, detergent, acid, and bases Strength and durability are increased by polypropylene because of its strong resistance to water, soap, detergent, acid, and bases. Because it can tolerate higher temperatures, it can be used for a variety of applications. Several products such as lunchboxes, butter receptacles, yogurt pots, sauce bottles, ketchup bottles, plastic bottle caps, and pharmaceutical packaging etc are made by it. Occasionally, PP is recycled and used to make manhole steps, lumber, and car battery cases, among other things.

Type 6: 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. A thermoplastic polymer called polystyrene PS is frequently used to create rigid foam and solid plastic materials. When heated plastic releases potentially harmful chemicals so that it is regarded as dangerous. Different types of items like egg cartons, packing foam, plastic boxes and cutlery, tea and coffee cups etc are made with it. It takes hundreds of years to decompose if it is not recycled. Recycling of polystyrene is common but challenging.

Type 7: Others

This category includes two well-known plastics, such as polycarbonate and bio-plastic polylactide. Typically, these kinds of plastics are not recycled. Polycarbonate, acrylonitrile butadiene, styrene, fiberglass, and nylon plastics are considered in this category. These plastics are used in mostly plastic CDs and DVDs, baby bottles, large water bottles with multiple-gallon capacity, medical storage containers, eyeglasses, exterior lighting fixtures etc (Padgelwar et al., 2021, Achilias et al., 2008 Akhtar and Amin, 2011).

3. WORLDWIDE PLASTIC PRODUCTION SCENARIO

An important turning point that raised the standard of living for people was the discovery of plastics. Due to their lightweight, robustness, ease of processing, cheap cost, range of applications, and resistance to corrosion by most agents, plastics have largely supplanted other materials, such as wood, metal, and ceramics, in the production of consumer goods since its first synthesized in the early 1900s (Bhattacharyya and Agnew, 2019, Verma and Verma, 2016, ShanShan et al., 2016). Research indicates that plastic-based products contribute to lower production costs across a range of industries, facilitate product diversification, and drive global market expansion. The packaging industry, in particular, has seen the most growth in recent times (Peter, 2018). The world's growing population is driving up the production and consumption of plastics, while increasing per capita income is contributing to higher rates of waste generation and the consumption of various goods. Among other materials, plastic is considered the largest contributor to hazardous waste due to its non-biodegradable nature and the resulting impact on the ecosystem (Braun and Amelung, 2018). It is noted that, while taking into account the global perspective, the average per capita consumption rate of plastic is about 43 kg, with heavily populated, low-income countries being the main producers and users of this enormous number of plastics. Only the EU produced 29.1 million tons (Mt) of plastic garbage in 2018, of which 32.5% was recycled (Rahman and Bhoi, 2021).

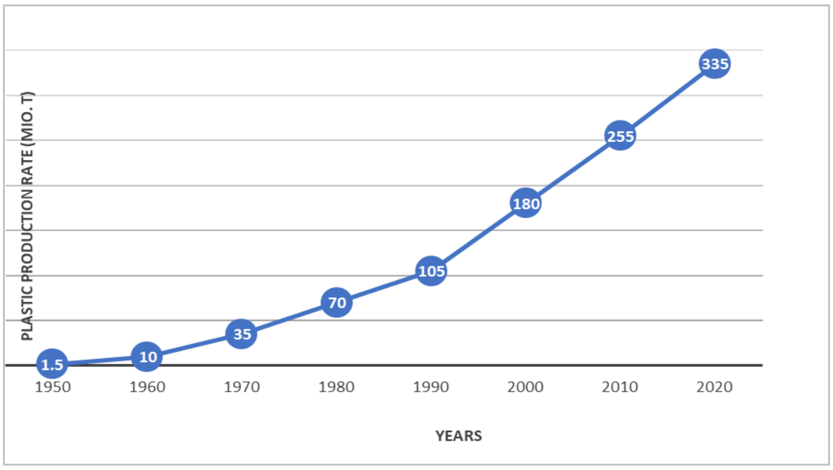

Fig. 1. Plastic production rate from 1950 to 2020 globally

In 2019, the total amount of plastic production worldwide was circa 370 Mt in which Asia accounts for 51%, Europe 16%, North America 19%, Latin America 4%, Middle East and Africa accounts for 7%, Countries of the Commonwealth of Independent States (CIS) 3% (PlasticsEurope, 2021). According to statistics from 2015, plastic consumption amount accounted for 0.13% to 0.75% of the Asia-Pacific region's total material consumption where imported fossil fuels are used to manufacture plastic and depicts how, as per capita income rises, so does plastic usage (Islam et al., 2023). The intensifying Over the past 50 years, the plastics sector has grown. Plastic manufacturing increased throughout this time, rising from 1.5 million metric tons (Mio. t) in 1950 to around 322,00 Mio. t (Fig. 1), and is expected to reach over 600 million tons by 2050. From 1950 until 1990, the generation rate climbed gradually. From that point until 2020, there was a noticeable high peak. Plastic output was 105 million tons in 1990; in just ten years, it climbed to 180 million tons, an increase of around 71.43%. This growth pattern is concerning. In comparison to 2014, there was a 3.4% increase in global plastic manufacturing in 2015. From 1950 to 2015 the compound Annual Growth Rate (CAGR) of plastic was about 8.6% (Jambeck et al., 2015). The top 10 countries in the world by production of plastic are distributed as follows namely 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). Mostly due to single-use plastics plastic waste is generated being dumped after their initial application (Ayeleru et al., 2020).

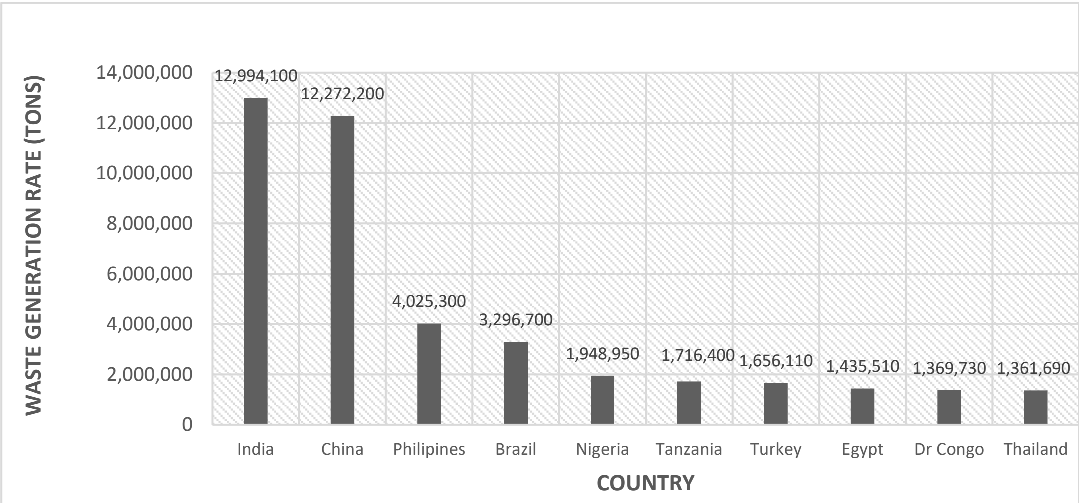

Fig. 2. Ten (10) countries with the most plastic pollution

The Fig. 2 illustrates that India is the nation which produces the greatest amount of plastic waste (PW) whereas China comes in second position followed by the Philippines, Brazil, Nigeria, Tanzania, Turkey, Egypt, Dr. Congo, and Thailand.

4. PLASTIC WASTE AND ENVIRONMENT

Although the broad availability of plastic products makes human life easier, it causes long-term environmental damage as a result of increasing trash output from overproduction and consumption. Because the most widely used plastics are disposable and non-biodegradable, they end up in landfills or the environment when left unchecked, contaminating the air, soil, and water among other environmental compartments. Here, Fig. 3 illustrates the percentage distribution of the ultimate fate of plastic waste globally in 2019, showing that only a small portion of plastic waste was recycled. The irreversible use of plastic and its careless disposal have poisoned environmental bodies, endangering not only human existence but also that of other living things and ultimately putting humankind in danger. Many industries, including packaging, consumer goods and home applications, building and construction, textiles, transportation, electrical and electronic equipment use a lot of plastic materials whereas very little portion of that material is recycled and the remainder is either burned or dumped in a landfill. It was reported that in total 6300 Mt plastic was produced globally in between 1950 and 2015 in which only about 9% was recycled, 12% was burned, and over 79% was dumped in landfills or left in their natural settings (Geyer et al., 2017). Furthermore, mismanagement of plastic waste is also responsible for soil, air, and water pollution. Intentional or inadvertent open burning of plastic waste is thought to have the greatest negative impact on air quality. In Bangladesh, burning solid waste is a common way to reduce the quantity of litter in cities and landfills. But because there was insufficient awareness and separation, plastic items were also burned in these wastes. In the winter, incinerators become more common in the communities because impoverished people burn their waste to stay warm. Among these wastes is a notable quantity of plastic waste that is carelessly discarded on the sides of roads (Hossain et al., 2021).

4.1 Effect of Plastic on Soil

The dispersion of micro plastics damages soil aggregation ability, bulk density, water retention capacity, mineralization, stabilization, and dissolution of soil aggregates; this is expected to hurt the evolution of soil microorganisms (Machado et al., 2018). By creating a hydrophobic barrier in the soil micro plastics found in phytotoxic chemicals may negatively affect plant roots and soil fauna (Zhang et al., 2021). Furthermore, toxicity is produced by the chemical bisphenol A (BPA), which is released by plastic once it seeps into the soil (Bläsing and Amelung, 2018). Furthermore, plastic mulching, which is frequently used in agricultural fields, appears to be a major contributor to the decline of soil health, nutrition, and carbon stock and releases toxic additives that promote soil infertility. Micro plastics also affect soil bacteria and ultimately disrupts the rates of mineralization and influences the root-colonizing by changing soil pH (Rillig et al., 2019). This following Fig. 4 exhibits impacts of microplastics in soil ecosystems. In addition to causing minor changes in bulk density, texture, and structural integrity of the soil, the transportation of MPs on agricultural soil also increases the evaporation of soil water and reduces nutrient contents through microbial immobilization. In addition, micro plastics directly harm root growth. It is also quickly incorporated into various soil layers, altering the soil's chemical composition and affecting microorganism development. The dispersal of microplastic into deeper soil layers impacts the health of earthworms and contributes to groundwater contamination (Chae and An, 2018). Micro plastics (MPs) can infiltrate the soil ecosystem and accumulate in soil invertebrates. A previous study found that polybrominated diphenyl ethers (PBDEs), derived from polyurethane foam particles (less than 75 mm), can be deposited in earthworm bodies. Therefore, it can be concluded that micro plastics significantly affect soil organisms, which in turn impacts the soil biota. As a result, when plastic waste pollutes the soil, the production and quality of agricultural products decrease (Gaylor et al., 2013).

4.2 Effect of Plastic on Water Bodies

Bangladesh is home to one of the largest river networks in the world, with over 700 rivers and watercourses, and tributaries approximately 24,140 km in total. Mishandled plastic waste is considered one of the main sources of pollution among various types of solid waste that is why Bangladesh ranks 10th among the top 20 nations in the world for mishandled plastic waste generation (Chowdhury et al., 2021). In Dhaka, 22 out of 65 canals have been transformed into dumping zone because of plastic pollution (Hossain et al., 2021). Nearly all abandoned plastic wastes (PWs) eventually find their way into aquatic bodies (ponds, lakes, rivers, and eventually the ocean), either by seeping from landfill sites or being directly dumped. Various types of plastic accounted for between 50% and 80% of the total garbage that was collected from the ocean's surface, bottom, and coastline (Barnes et al., 2009). Plastic contamination accounts for more than 60% of the waste litter found on four large beaches of Bangladesh — Laboni, Inani, Ananda Bazaar, and Patenga (Qi et al., 2018). To preserve the biodiversity of expanding maritime tourism sector proper plastic waste management should be addressed. Among different types of plastic litter, plastics in microform usually release hazardous organic pollutants like dichlorodiphenyltrichloroethane, polybrominated diphenyl ethers etc., that are found in water during manufacturing, consequently increasing their concentration in water (Issac and Kandasubramanian, 2021). Additive-free MPs have a detrimental effect on human health over time even though it is not chemically hazardous to aquatic species (Udayakumar et al., 2021). The next stage involves the infiltration and subsequent direct discharge of MPs, which have broken down or decreased in size during wastewater treatment, into water resources. Consequently, the following are adverse effects of MP pollution on the environment: reduced growth and changes in the feeding habits of species due to the high number of MPs consumed. Low growth and variation in the species' eating habits as a result of the high number of MPs consumed (Horton et al., 2018). If hazardous materials and additives (such as plasticizers, antioxidants, flame retardants, colors, etc.) are properly left untreated before being dumped into the marine environment, they may find their way into the body tissue of aquatic organisms (Botterell et al., 2019). Because of weathering, a longer shelf-life, and hydrophobic properties, Micro plastics surface may absorb additional contaminants at a higher concentration. Ultimately, this allows MPs to operate as a transporter of pollutants into aquatic animals (O'Donovan et al., 2018). Additive chemicals, such as phthalates used as plasticizers, enhance the properties of polymers; however, their presence in biological organisms can lead to carcinogenic effects and disruption of the endocrine system (Teuten et al., 2009). MPs could serve as a carrier of a variety of hydrophobic organic substances into marine organisms, rendering them more susceptible to the accumulation of persistent organic pollutants (POPs). Micro plastics also can spread far with other pollutants and cause problems for the aquatic ecology because of their lightweight nature (Bakir et al., 2014).

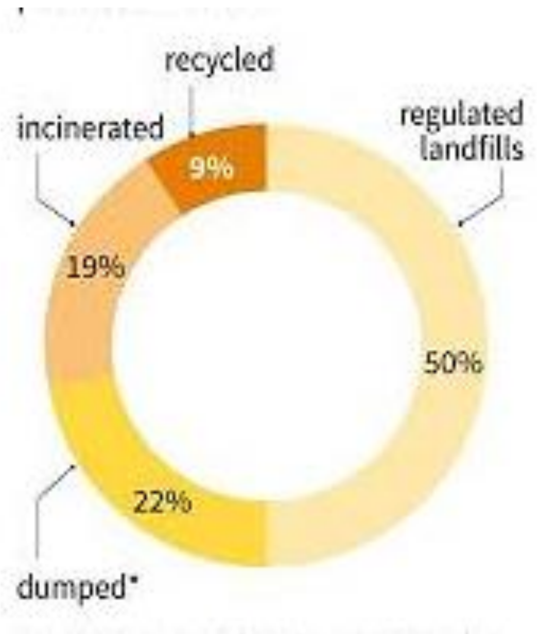

Fig. 3. Fate of plastic waste in percentage worldwide in 2019

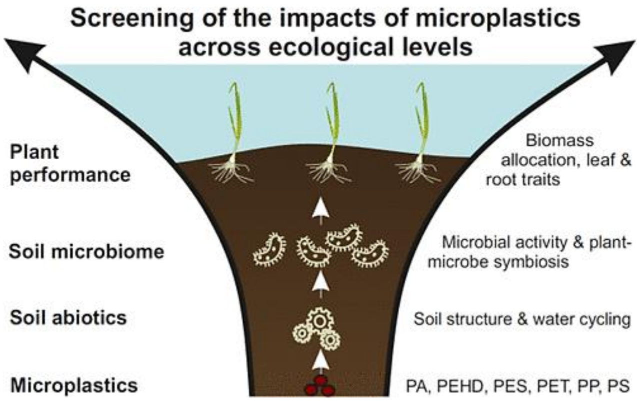

Fig. 4. Impacts of microplastics in soil ecosystems

4.3 Effect of Plastic on Air Quality

The majority of standard plastic waste management involves burning waste and operating open landfills without doing any form of sorting to separate recyclables and reusable materials, which has the worst possible impact on the environment and air quality. One popular method for treating materials with a high volume and mass of mixed plastic content is incineration or open burning. However, this method uses fossil fuels to burn the materials and releases a significant amount of greenhouse gases into the atmosphere, which can lead to air pollution and climate change. Burning plastic releases toxic smoke into the atmosphere and creates extremely dangerous gasses (Hossain et al., 2021). Moreover, toxic heavy metals (Cd, Pb, Cr, Ni, Cu, Zn) and lithophilic metals (Ca, Si, Na, Mg, Al, P, Fe), accelerate many fatal diseases in living creatures (Valavanidis et al., 2008). Similarly, poisonous gases are released as a result of the combustion of Plastic wastes, which are reduced to ash and ink in the form of tiny particles. Burning of the vinyl chloride releases phosgene (up to 2 mg/g Poly Vinyl Chloride) which is considered a serious health deteriorative agent while breathing. Irritation of the skin and eyes, respiratory tract infections, nervous system abnormalities, brain and gastrointestinal tract damage, and a decline in disease immunity ultimately led to cancer (Nagy and Kuti, 2016). In addition, methane is released in huge quantities during the decomposition of landfilled plastics by a variety of microorganisms, bacteria, and flavo-bacteria (such as Pseudomonas, a well-known nylon-eating bacteria). Methane is regarded as one of the primary greenhouse gas emissions. Lead-acid and Li-ion battery boxes are occasionally burned and discarded, which spreads aqua regia from the batteries into the soil and seriously damages the soil. There is growing concern over the unintentional and unregulated open combustion of plastic materials and its carcinogenic effects. In underdeveloped nations like Bangladesh, open-burning solid waste management is primarily conducted by local vendors or the informal sector, which is substantial relative to the waste management industry as a whole.

4.4 Effect of Plastic on Marine Life

Microplastics smaller than five millimeters, are known to be a major global hazard to the marine environment. As a result, laws have been put in place to monitor and research the issue of this tiny plastic waste. These particles originate from two sources: the direct release of micro- or nanosized plastics into the environment (primary microplastics), which are used in applications such as pre-production pellets, personal care products, cosmetics, and cleaning agents; and the gradual fragmentation or wear of larger objects during use, which leads to their loss in the environment (secondary microplastics). Their low density and small size allow them to move over large distances (Barboza et al., 2020). Over 80% of all marine litter is made up of plastics. Studies have suggested that approximately 5.25 trillion plastic waste particles are present in the ocean, of which 269000 are floating on the surface while the majority around 4 billion are estimated to be beneath the surface. In addition, per year about 100 million marine species are killed by plastic pollution (Islam et al., 2023).

Marine organisms are affected by plastic pollution due to entanglement, absorption, bioaccumulation, and changes in the integrity and function of their habitats. Although wastes made of microplastics are seen as a significant

Table 1. Ecotoxicity of plastic waste

Item	Availability	Effect
Car Tyre Rubber (CTR)	Land	Harmful to the overall environment as it contains chemical substances such as carbon black, clay, silica, sulfur, etc.
Bisphenol A (BPA) and phthalates	Land and water both	Endocrine disruptive substances have the potential to alter hormone regulation in both wildlife and people. Shows harmful effects on aquatic species also
Leachate Exposure	Water	Negative effects on a variety of organisms, including fish, photosynthetic bacteria, and Daphnia spp., brown mussels, barnacles

cause of entanglement, ingesting MP and macro pollutants by numerous marine species (Vegter et al., 2014). It is anticipated that every year, up to 13 million metric tons of various polymers will remain in the ocean. Plastic items that have leached phthalates and bisphenol A (BPA) are classified as implicit endocrine-dismembering agents because they can interfere with the control of hormones in both people and wildlife. Among the substances that are harmful to aquatic life include BPA, phthalates, and BFRs (Islam et al., 2023).

Additive leaching from plastic materials is influenced by several factors, including the permeability of the polymer matrix, gaps between polymer molecules, the physical and chemical characteristics of the additives, the surrounding medium's characteristics (such as salinity, temperature, and pH), and time. However, exposure to leachate harms a range of species, such as fish, photosynthetic bacteria, Daphnia species, brown mussels, and barnacle nauplii etc (Tetu et al., 2019). Aqueous leachates derived from plastic materials affect the growth of microalgae such as Raphidocelis subcapitata and Skeletonema costatum, Mytilus galloprovincialis as well (Fabbri et al., 2014).

4.5 Effect of Plastic on Climate Change and Global Warming

Polythene is the most common synthetic plastic material which is used in worldwide and it is the main contributor to the production of methane gas, especially when it comes into contact with sunlight (Royer et al., 2018). This type of hydrocarbon emission is determined by its average molecular weight, which varies with the length of the polymer chain, the amount of exposed branching molecules, shape and density (Mohanan et al., 2020). Apart from vehicle emissions, coal stockpiles, MSW disposal sites, and mines producing gas and oil are regarded as essential sources of methane production in Bangladesh. Every step of the plastic life cycle, including the extraction and transportation of raw materials, plastic manufacturing, waste treatment, and environmental release, results in greenhouse gas emissions. The production facilities themselves are primarily responsible for controlling greenhouse gas emissions during manufacturing; these emissions are often determined by the efficiency, configuration, and equipment's service life. Moreover, plastics that are discharged into the environment also gradually emit greenhouse gasses, and the ocean's concentration of (micro)plastics will significantly impair the ocean's ability to repair carbon. The present state of plastics production will result in 1.34 gigatons of greenhouse gas emissions annually by 2030 and 2.8 gigatons by 2050. This will drastically deplete the world's remaining carbon budgets, endangering the ability of the international community to prevent global temperatures from rising by more than 1.5 or even 2 degrees Celsius by the year 2100. The issue will get worse since the plastics industry intends to increase manufacturing on a big scale. According to World Economic Forum projections, the production and consumption of plastics would increase at a 3.8% annual growth by 2030 and then decrease to a 3.5% annual rate between 2030 and 2050 (Shen et al., 2020).

5. SCENARIO OF BANGLADESH REGARDING PLASTIC WASTE

Since Bangladesh has one of the highest densities of population in South Asia including 1265 people per square kilometer, the country generates about 87,000 t of single-use plastic waste annually, of which 86% is still dumped in landfills. Nearly 80% of total single use plastic waste over the country comes from municipal areas and rural areas is accountable for about 22% amount of single-use plastic due to rapid advancement in agricultural sectors. Mismanaged plastic production and use in offices, business sectors, and various industries—primarily packaging—made Bangladesh one of the most plastic-polluted nations. Almost 3000 plastic manufacturing industries are located in Dhaka and Chittagong; among them, 98% belong to the Small-Medium Enterprises (SMEs) with around USD 74 million of domestic market size (Islam, 2012).

The below-mentioned bar chart demonstrates that in 2020 the waste generation rate was higher for Dhaka, the capital of Bangladesh compared to other cities namely Chittagong, Khulna, Rajshahi, Barishal and Sylhet. It has been evaluated that Bangladesh contributes nearly 8% of the world's total debris generation and Dhaka uses about 14 million polythene materials in a day. In addition, about 250 t of non-recyclable goods like straws and plastic cutlery are sold in Old Dhaka daily. The improper management of waste systems often results in their disposal in rivers and oceans, endangering marine biodiversity. As of recent estimates about 73000 tons of plastic waste are produced daily in Bangladesh and end up in the Bay of Bengal. Polythene bags and plastic waste have been posing a serious threat to the nation's entire environmental system. Approximately 80% of Bangladeshis use plastic bags daily even though they are aware of the negative effects they have, which come from the lax enforcement of laws and regulations (Islam et al., 2023). The following Fig. 6 exhibits that in Bangladesh the average loss of revenue in terms of tourism, aquaculture, and fisheries due to plastic pollution were respectively USD 11.5 million and USD 1.8 million in 2020.

Table 2. Effects of plastic waste treatment on global greenhouse gas emission

Treatment	Advantages	Disadvantages	Greenhouse gas emission
Recycling	Recycling and reusing waste plastic can both treat white pollution and save oil resources. Increased recycling can lead to negative greenhouse gas emissions by reducing raw material use and avoiding emissions from producing the same number of raw materials.	Only a small percentage of “recyclable” plastic wastes are recycled into the original products, even the most easily recycled plastics. Challenges lie in the use of colorants, additives and fillers in the plastic production process, pollution from consumer use, and loss of production during recycling. Low-grade plastic waste, such as multi-layer plastic packing, is particularly difficult to separate and dispose of.	The carbon footprint of 1ton recycled PET tray containing 85% of recycled content from cradle to grave was 1.538 tons CO_2e. 3.17 million tons of plastic waste recycled in 2014 could save approximately 3.2 million tons of CO_2e, equivalent to 670,000 cars on the road in a year, and plastic packing recycling into new products could save 1.4 million tons of CO_2e.
Incineration	Incineration has recently been considered a simple solution to large-scale contamination of land-based plastics. It is not only effectively manage plastic pollution but also provide energy and heat.	Greenhouse gases, usually CO_2, can be produced during plastic waste incineration. With this energy conversion occurring, the incineration of plastic packing waste will become one of the main sources of greenhouse gas emissions.	Each ton of plastic packing waste generally contains approximately 79% combustible carbon, which will release 790 kg of carbon into the atmosphere, or about 2.9 tons of CO_2.
Sanitary landfill	The sanitary landfill has the advantages of mature technology and low treatment cost, which is the main way of centralized disposal of urban plastic wastes.	The landfill refuse has not been treated innocuously. There are hidden dangers such as biogas and heavy metal pollution. Its waste leakage liquid will pollute groundwater resources for a long time.	Up to now, there is no record of greenhouse gas emissions from plastic landfills. However, this does not exclude the possibility of greenhouse gas emissions from plastic landfills.

Treatment	Advantages	Disadvantages	Greenhouse gas emission
Others (open burning)	Simple treatment and low treatment cost.	It has a serious impact on climate and human health since it occurs at lower temperatures and is performed without any air pollution control than in a waste incinerator.	Plastic packing waste can emit 2.9 million tons of greenhouse gas per ton of plastic packing waste when it is burned in the open air.

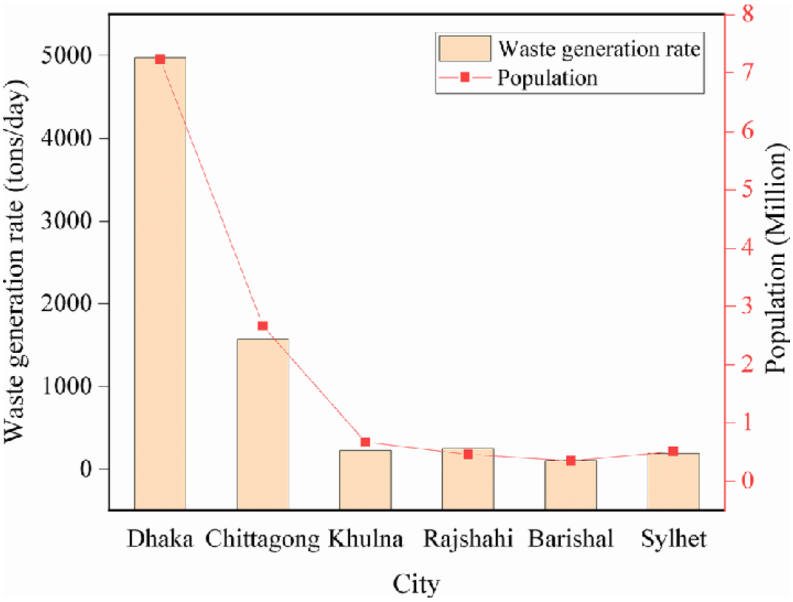

Fig. 5. Different types of plastic waste generation in Bangladesh in 2020

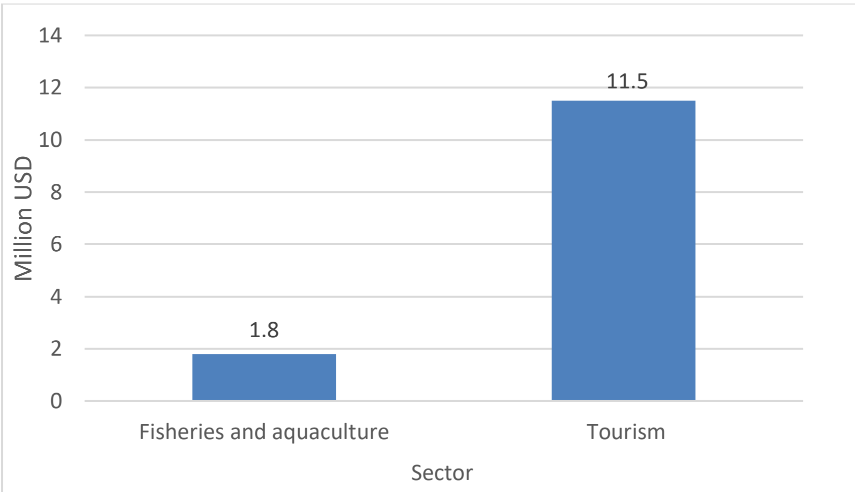

Fig. 6. Average estimated annual loss in revenue as per 2020 in Bangladesh

In Bangladesh, tourism is a growing industry that was significantly affected due to the initial wave of the pandemic. Besides, Bangladesh earned USD 1157 million from the tourism sector during the 2009-2018 period. Each year, 0.55 million tourists (on average) visit Bangladesh in the same period. Moreover, it creates 2.23 million jobs each year. The travel and tourism sector contributes 4.4% of the GDP each year and this is projected to ascent to 4.7 percent in 2027

(Hossain and Wadood, 2020). Bangladesh's tourist industry has enormous potential to increase the GDP of the nation and supply employment for millions of people. Besides aquaculture and seafood industries in Bangladesh are expanding so rapidly and serving as an essential source of revenue and food for rural communities (Shamsuzzaman et al., 2020). Unfortunately, mishandled garbage disposal or plastic pollution harms the tourism, fishing, and aquaculture sectors. Tourists may find coastal locations less appealing due to the ongoing buildup of plastic waste and the stench of decaying vegetation. Moreover, the growing incidence of fish polluted by microplastics make marine life unfit for human consumption (Khatun et al., 2023).

6. EXISTING POLICIES IN BANGLADESH TO CONTROL PLASTIC POLLUTION

In 2002, Bangladesh implemented a ban on plastic shopping bags in compliance with the Environment Act of 1995. However, the prohibition proved ineffective due to a lack of substitutes and insufficient regulatory enforcement (MoEFCC, 1995). The Mandatory Jute Packaging Act, introduced in 2010 and effective from 2013 in Bangladesh whereas the ultimate goal was to discourage the use of plastic bags and promote alternatives. It supported the jute industry and reduced reliance on plastic packaging. The National 3R Strategy for Waste Management was enacted in 2010 to promote an efficient waste management system. But practically all families do not segregate their waste due to a lack of enforcement and weak institutional infrastructure. Later in 2015, the Plastic Park Project was introduced which relocated old plastic factories from old Dhaka to a new location and then the Clean Dhaka Master Plan (2018-2032) was developed which aimed to prepare an integrated approach to address the growing urban population and the associated rising urban wastes under the Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC). The three components of the 3R strategy were integrated into the master plan whereas appropriate waste collection, disposal and trash reduction were guaranteed achieved by the establishment of incineration and treatment plants. A policy known as the "National Plastic Industry Development Policy 2021 (Draft)" was introduced by the Ministry of Industries in 2020, and it emphasized the significance of lessening the environmental effects of plastic waste. This policy also emphasized the need to standardize recyclable items, guarantee the quality of recycling, and reach zero waste associated with plastic and packaging by 2030. The guideline also highlighted how important it was to gather waste from plastic packaging so that it could be recycled. Additionally, DNCC and Narayanganj City Corporation (NCC) were aiming to build a 42.5-megawatt (MW) waste-to-energy facility power station in DNCC and a 5MW power plant in NCC which used incineration to convert garbage into electricity to limit the amount of landfill material. In 2020, the High Court issued an injunction to strictly implement the national ban on plastic bags. The implementation of such enforcement measures might involve the regular monitoring of markets, the shutdown of companies producing polythene bags, and the seizure of equipment. The High Court also banned the use of single-use plastics in hotels and restaurants near beaches, including straws, cotton swabs, cutlery, bottles, food containers, and plastic plates, as well as the carrying, selling, and advertising of these items. To comply with the Bangladesh Environment Protection Act of 1995, the government released the Solid Waste Management Regulations in December of 2021. Now the Eighth Five-Year Plan (July2020-June2025) is going on in Bangladesh issued by the Bangladesh Planning Commission whereas stipulations to improve the management of solid waste in urban cities are included. Additionally, there are no programs specifically addressing plastic waste in the Eighth Five-Year Plan; instead, concerns about solid waste in general are addressed. Furthermore, a sizable portion of plastic can also be found in electronic trash. As a result, legislative efforts should be created to allow for the easy recycling of electronic items and the safe separation of plastic components (Khatun et al., 2023).

7. CONCLUSION

The tiny particles end up in the human body and cause severe health consequences. Meanwhile, burning plastic items (which is a common practice in Bangladesh) releases toxic gases and particles into the air. The Country and Climate Development Report published by the World Bank Group in 2022 says that around 32 percent of human deaths every year are associated with environmental degradation, specifically outdoor air pollution, inadequate water, sanitation, and hygiene standards, and lead exposure among adults linked with plastic pollution. The estimated annual loss for environmental health amounted to Tk 4.4 trillion in 2019. Plastic waste is also responsible for clogging drainage systems and developing breeding grounds for mosquitoes that result in incidents of vector-borne diseases such as dengue, chikungunya, and malaria. Recycling plastic waste is an economically and environmentally viable way to address plastic pollution though the progress of this is not significant in Bangladesh. In 2020, the nation consumed 977,000 tons of plastic and recycled only one-third of the total. In Dhaka, around 646 tons of plastic waste are generated every day and only 37.2 percent is recycled. A large amount of plastic waste remains in the environment. High costs associated with recycling, lack of technology, and lack of public awareness about the consequences of plastic pollution are key factors which hinder recycling in Bangladesh. Despite our country's strides in policy and legislative arrangements, the effective implementation of these policies and laws is still lacking. In addition to the need for effective regulation and enforcement from the government, individual-level awareness is also crucial in addressing this problem. A strong focus on the circular use of plastic, based on the 3R strategy (reduce, reuse, recycle) will result positively in creating new value chains of plastic, green skills, jobs, and innovative products, while also addressing social and environmental challenges that occur due to our widespread use of plastic. More research and knowledge processes, as well as engagement of stakeholders in multisectoral actions, will driving factors in successfully curbing plastic pollution. Now is the time to act together and save our world from this impending crisis.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT,COPILOT etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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