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The Impact of Plastic Waste on Ecosystems and Human Health and Strategies for Managing It for a Sustainable Environment

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Abstract: Over time, the impact of the sharp increase in plastic consumption was not closely monitored by the global community. This has caused an unprecedented volume of mismanaged mixed plastic garbage to enter the ecosystem. One material that is well-recognized and utilized in many different forms in daily life is plastic. Plastic trash has increased dramatically as a result of the widespread use of a variety of plastic products. Toxic plastic use can be caused by a variety of human health issues, including breathing difficulties, liver dysfunction, eye irritation, respiratory problems, vision loss, birth effects, cancers, cardiovascular, headaches, skin diseases, lung problems, genotoxic, dizziness, and gastrointestinal issues. Major environmental pollutants such as water, soil, and air pollution are brought on by the use of plastics. Plastic has been used throughout human history due to its many uses, including great durability, flexibility, inexpensive production costs, and lightweight nature. After the Second World War, plastic became commercially available everywhere in less than a century. Half of the plastic waste produced worldwide comes from packaging plastics. Micro to Nano plastics can break down into smaller particles that are easier for water, soil, and air to disperse. Therefore, a variety of adverse effects, including reduced ingestion, reproduction, ulceration, entanglement, and oxidative stress, affect both terrestrial and aquatic animals. Human health is also harmed by microplastics and nanoplastics because of cancer, birth deformities, chronic kidney disease, cardiovascular illnesses, etc. Polymerization or polycondensation is a biochemical process used to make plastics. If plastic waste generated during post-use is not properly handled and managed, it can have numerous negative effects on the environment. The daily usage of plastic and plastic-derived products has become a global concern due to the pollution they cause to the environment and the health of people and wildlife. It is intrinsically challenging to ascertain the destiny of (micro)(nano)plastics in the environment since there are several sources and pathways for their introduction. The public should be made aware of the dangers of plastic and plastic-related items, which can contribute to several human and animal health issues. Therefore, it is imperative to find biodegradable solutions and efficient regulations and to put them into action. The lifecycle of plastic products according to their various categories will be covered in this paper, along with the issues brought on by improper processing of plastic waste and potential remedies that could be offered to maintain a healthy atmosphere and lessen the factors contributing to climate change, which poses a threat to life as we know it. The lifecycle of plastic products according to their various categories will be covered in this paper, along with the issues brought on by improper processing of plastic waste and potential remedies that could be offered to maintain a healthy atmosphere and lessen the factors contributing to climate change, which poses a threat to life as we know it.

Keywords: Ecosystems, Human Health, Microplastic Waste, Nano Plastic Waste, Plastic Waste, Plastic Waste Management, Pollution, Sustainable Environment.

I. Introduction

Across a wide range of industries, including packaging, building, industry, transportation, and agriculture, plastics have become essential, greatly advancing modern life. Since they first entered the market, the world's consumption of plastic has increased significantly due to its special qualities, which include resilience, durability, affordability, transparency, and lightweight nature. Since the manufacture of disposable plastic products is growing faster than the world can handle, plastic pollution has emerged as one of the most urgent environmental problems. Because municipal waste collection systems are frequently ineffective or nonexistent in developing Asian and African countries, this pollution is most noticeable there.

It is convenient to change the shape of plastics to suit their intended use. Polymers, or "long chains of monomers," are another name for plastics. These subunits are joined to one another to form a polymer. Polymers can come from natural sources, such as cellulose, which is the fundamental building block of plant cell walls and aids in cell adaptation (Qamar et al., 2020).

A polymeric material that may incorporate additional components to enhance performance and/or lower costs is what plastic is defined as by the International Union of Pure and Applied Chemistry. 1860 saw the invention of the first plastic, and 1907 saw the start of the worldwide plastics industry. Nonetheless, the 1920s saw the emergence of industry, and the 1940s saw an increase in the manufacturing of plastic. Around 2 million tons of plastic were produced in 1950.

Early in the 17th century, the Greek word "*plastikos*," which meant "able to be molded" or "fit for molding," was the source of the Latin word "plasticus," which is where the word "plastic" originates (Aisbl et al., 2018). Because of their special qualities, high functionality, and affordability, they have been employed in a variety of ways for a range of purposes, including food packaging (EU, 2019; Thompson et al., 2009; Fobil et al. 2006; Vimal et al., 2020). Plastics are strong concerning their weight (Ncube et

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al., 2021). With the packing material comprising up to as much as 3% of the weight of the packaged product, this leads to a minimal amount of material being used when creating packaging containers (Andrady et al., 2009). Packaging is the largest source of plastic garbage worldwide, accounting for about half of its weight (UNEP., Kenya, 2018).

Plastic is a widely recognized substance that is utilized in many different forms in daily life. It has become a significant aspect of everyone's life. Despite their ease of use and convenience, plastics have detrimental effects on human health that cannot be ignored. Because it is not biodegradable, it continues to accumulate in the environment and contributes to the massive amount of waste that is produced worldwide. Made from materials derived from fossil fuels, plastic is the most practical synthetic "manmade" material. The majority of the technological and industrial revolutions of the 19th and 20th centuries were made feasible by it. Plastic materials have been employed extensively in the shelter, food, transportation, clothing, construction, medical, and recreational industries during the past 30 years due to their low cost, exceptional durability, lightweight, and relative indestructibility (Kumar, 2022). Numerous chemicals and dangerous substances, including bisphenol, thalates, antiminitroxide, brominated flame retardants, and polyfluorinated chemicals, are found in plastics and pose a major risk to human health and the environment. Plastic is not biodegradable since it is designed to be durable and is composed of harmful substances that are known to cause disease.

Soft and flexible polymers have been made from organic molecules, including synthetic or semi-synthetic materials (petrochemical, partially natural). Plastics are generally classified as "bio-based/organic polymers" or "engineered." Coal, combustible gas, and crude petroleum are used to create engineered plastics. Furthermore, the production of plastics uses around 4% of fossil fuels (Pilapitiya & Ratnayake, 2024). Bio-based plastics are also made from sustainable raw materials such as carbohydrates, vegetable fats and oils, microbes, and other natural components (Verma et al., 2016; Alhazmi et al., 2021). The primary causes of the rise of plastic trash are population expansion, urbanization, and economic development. According to Amasuomo and Baird (2016), waste is commonly defined as undesirable chemicals or worthless by-products that are primarily produced during human activities and have detrimental effects on both the environment and people.

II. Literature Review

The widespread use of plastic products in our daily lives has led to the vast global production of polymers. Around 150 million tons of plastic are produced annually on average worldwide. It is used in a wide variety of products, including building materials, shopping and trash bags, fluid containers, toys, apparel, packaging films, and home and industrial goods. Plastics have numerous beneficial ecological qualities and are not intrinsically harmful. A lot of the methods we employ in our designs make specific use of plastic products. Their formulation into glue products enables the production of engineered lumber and sheet products from recycled wood, their durability and low maintenance reduce the need to replace materials, their lightweight lowers shipping energy, and their formulation into superior insulation and sealant products enhances the energy efficiency of our structures. Plastic waste is what happens when plastic is thrown away after its useful life is over. Plastic garbage is known to never break down and to stay on the landscape for many years. The majority of plastic garbage may be recycled, however, recycled goods are worse for the environment since they contain coloring and chemicals. A virgin plastic material can only be recycled two or three times because, following each recycling, heat pressure causes the material to degrade and shorten its lifespan. Recycling is therefore not a long-term or safe way to get rid of plastic garbage. Due to inadequate collection and segregation systems, it has been noted that disposing of plastic garbage is a major challenge.

III. Materials and Methods

The literature was searched using the Scopus Index, PubMed, Academia, Research Gate, and Google Scholar, and the findings of that search as well as any relevant ones were considered. Secondary sources provided the data for this investigation. An intensive offline and online literature review was conducted to collect secondary data. The resources include books, government and international reports, scientific journals, newspapers, and online sites.

IV. Plastics

A variety of synthetic or semi-synthetic organic compounds that are pliable and can be molded into any shape makeup plastic. These are high molecular mass polymers composed of petrochemical-derived monomer units. Their general characteristic is plasticity, which allows them to undergo irreversible deformation without breaking. Long-chain polymers made up of carbon, hydrogen, and oxygen bound together by covalent bonds are called monomers. Lightweight monomers that are frequently utilized in the production of plastics include ethylene and propylene (Hassan et al., 2022). Certain chemical groups may be left out of each monomer during the polymerization process, which causes polymers to irregularly retain the reactivity or chemical characteristics of the original monomer unit. As alternatives to conventional plastic materials derived from petroleum, the industrial sectors are currently actively investigating biomaterials (Khoaele et al., 2023; Tiwari et al., 2023). Vegetable oils and starches (plant-based products) are examples of natural resources that make up all or part of these bioplastics. The usage of bioplastics may lessen environmental effects, particularly the carbon footprint and greenhouse gas emissions linked to the use of polymers. To reduce landfill trash, the development of contemporary bioplastics accelerated in the 1980s (Shah et al., 2021).

According to Ilyas et al. (2018) and Pan et al. (2020), plastics have several advantageous qualities, including low weight, toughness, high strength, good stiffness, versatility in fabrication, design capabilities, good insulation, poor electrical and thermal conductivity, and corrosion resistance. Plastics have a wide range of applications in manufacturing, electronics, furniture, toys

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and leisure products, transportation, building, agriculture, packing, medicine, and heat insulation (Oehlmann et al., 2009; Pan et al., 2020). According to Ilyas et al. (2018), plastics are currently used in the production of 85% of medical equipment, including joint replacement, sterile packaging, disposable syringes, and intravenous bags, because of their lightweight and biocompatible nature.

Due to a lack of raw materials in the current day, plastics are gradually replacing traditional materials including metal, wood, glass, and paper (Chandran et al., 2020). Consequently, the current pattern of plastic consumption has led to an increase in worldwide plastic output (Panda et al., 2010). Furthermore, at the current rate of expansion, plastic manufacturing is predicted to treble over the next 20 years (Lebreton and Andrady, 2019). A number of characteristics, including polymerization mechanism, structure, origin, molecular forces, temperature-dependent behavior, and preservation methods, can be used to categorize plastics (Pilapitiya & Ratnayake, 2024).

To produce high-quality plastics, the polymer can be processed in a variety of ways. These techniques fall into three main categories, such as (i) primary processing techniques, which include extrusion, injection, compression, and compression, blow, extrusion blow, and transfer molding; (ii) secondary processing techniques, which include thermoforming, fabrication, calendaring and roto-coating, casting, and coating; and (iii) tertiary processing techniques, which include bending, drilling, cutting, and welding.

V. Resin-Based Plastic Naming

A lot of polythene bags don't even have a numerical code to identify the kind of resin that was used in their production; as a result, they either end up in the trash or are recycled as mixed plastic. It finds its way to mixed plastic throughout the recycling process if it does not carry a number code. Cross-contamination with various resin types is the other recycling difficulty. If 10 kg of PP is combined with 1000 kg of PET during the sorting process, the entire recycled PET lot may become contaminated. These combined polymers might not be safe to use, especially when it comes to storing food. Thus, it is crucial to classify the plastic according to its type and code when recycling. Because plastic is a lengthy polymer of monomer hydrocarbon units, its chemical structure becomes extremely complicated and stable as plasticizers, stabilizers, colors, and other additives are added during manufacturing. This is the cause of plastics' detrimental effects on the environment and their non-biodegradable nature (Haritash, A.K., 2019).

Table 01: Plastic nomenclature according to resin *(Nature: Recyclable)*. (Source: Haritash, A.K., 2019, Page: 6)

Number Code	The name of the resin and its acronym	Symbol
1	Polyethelene terpthalate (**PET**)	
2	High density polyethelene (**HDPE**)	
3	Poly vinyl chloride (**PVC**)	

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4	Low density polyethylene (**LDPE**)	
5	Polypropylene (**PP**)	
6	Polystyrene (**PS**)	
7	Mixed Plastic	

VI. Emissions of Greenhouse Gases from Plastics Worldwide

The waste that winds up in our rivers and oceans is the most obvious effect of plastic on the ecosystem, claims Hannah Ritchie (2023). Its role in climate change is another issue. According to OECD estimates, 1.8 billion tons of plastics were released during their life cycle, which includes both production and disposal. This considers the varying warming effects of various greenhouse gases and is expressed in carbon dioxide equivalents. The graphic below shows how these emissions are broken out (Figures 01, and 02). The majority originate as carbon dioxide during the production phase. Approximately 3.3% of worldwide emissions, or

54.6 billion tons of CO_2eq, were caused by plastics. Although it's not the sole greenhouse gas, carbon dioxide is the most significant. Researchers express greenhouse gas emissions in "carbon dioxide equivalents" (CO_2eq) to account for all of them. This includes all greenhouse gasses, not just CO_2 (Hannah Ritchie, 2023).

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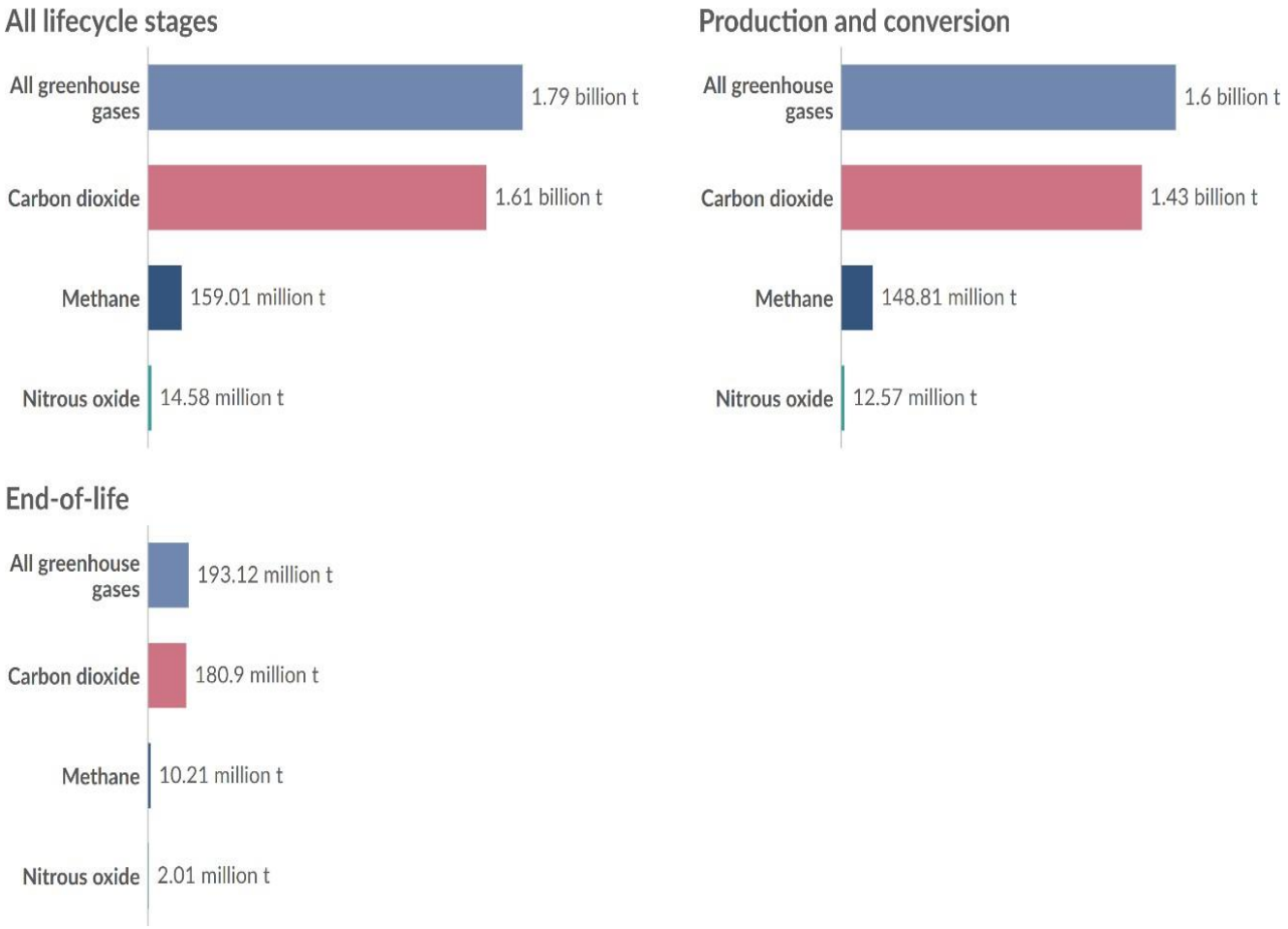


Figure 01: Plastic-related greenhouse gas emissions, 2019 (Source: https://ourworldindata.org/ghg-emissions-plastics#article-citation)/(https://creativecommons.org/licenses/by/4.0/)

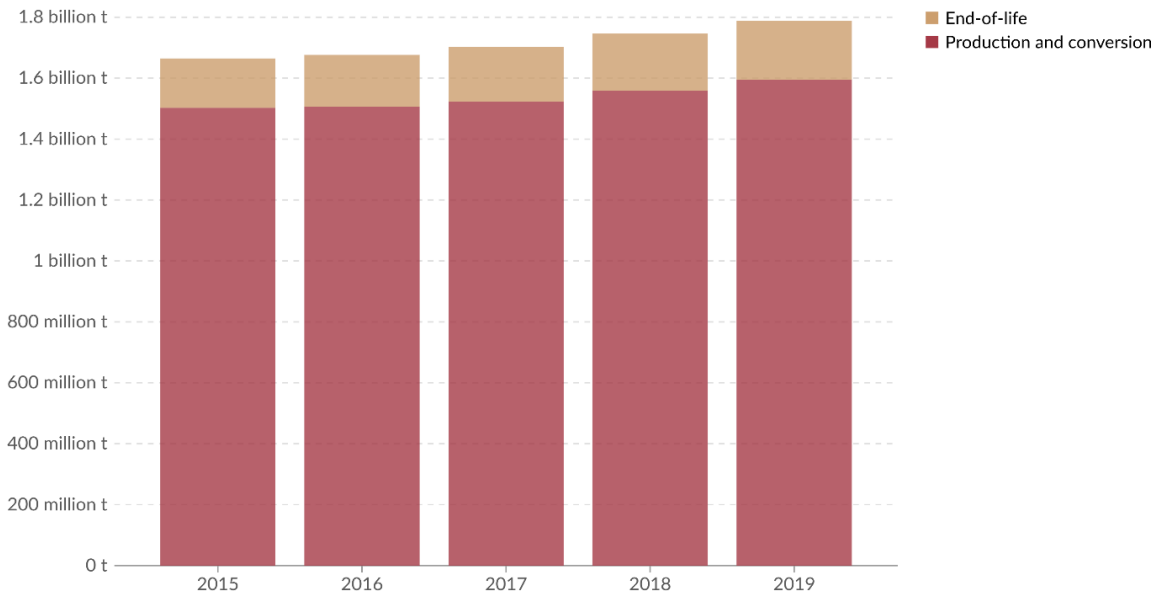


Figure 02: Emissions of greenhouse gases from plastic by stage of life, 2015–2019

(Source: https://ourworldindata.org/ghg-emissions-plastics#article-citation)/ (https://creativecommons.org/licenses/by/4.0/)

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Tons of carbon dioxide equivalents are used to measure emissions. "End-of-life" describes waste management techniques like landfill emissions, recycling, and incineration.

VI. Health Effects of Plastic on Human

Because plastic has become so prevalent in our surroundings, we are exposed to dozens, if not hundreds, of industrial chemicals every day, endangering our health. Both humans and animals are suffering from the biological impacts of the chemical compounds included in plastics. The chemicals included in plastics, such as vinyl chloride, phthalates, and bisphenol-A, or BPA, are extremely harmful to human health (Pilapitiya & Ratnayake, 2024).

a) BPA, or bisphenol A:

Polycarbonate plastics, especially food packaging, are synthesized using it. Common, indestructible objects like water bottles, dinnerware, CDs, DVDs, even eyeglasses and lenses contain it. Bisphenol A has the potential to seep into the liquids or substances that are stored in plastic containers. BPA is a fundamental component of polycarbonate plastics, which are used in food packaging, bottled water, and other products. Since the 1940s, BPA has been identified as a substance that disrupts hormones and interferes with normal hormonal activity. It is a hormone disruptor used in the production of durable, clear polycarbonate plastic.

Sippy cups, water bottles, baby bottles, and cans of food liners all contain bisphenol A. The main ways that humans are exposed are by ingestion—through food, by sucking or mouthing plastics, and by skin contact. Bisphenol A has also been linked in studies to increased rates of diabetes, heart disease, birth malformations, early puberty, low sperm count, hyperactivity, aggression, and elevated liver enzyme levels. Women who often come into contact with this chemical may be more likely to experience ovarian cysts, breast cancer, prostate cancer, alopecia, miscarriages, and polycystic ovarian syndrome, which is known to cause infertility (Kumar, 2022).

b) Vinyl chloride:

PVC, or toxic plastic, is produced using it. Window frames, carpets, school lunchboxes, medical tubing, upholstery, and shower curtains all contain it. According to research conducted as early as the 1930s, lab animals and manufacturing workers' livers were harmed by even brief exposure to vinyl chloride. Vinyl chloride is a documented human carcinogen that affects not just the liver but also the brain, lungs, and lymphatic and hematological systems, according to the National Toxicology Program's 1980 list (Kumar, 2022).

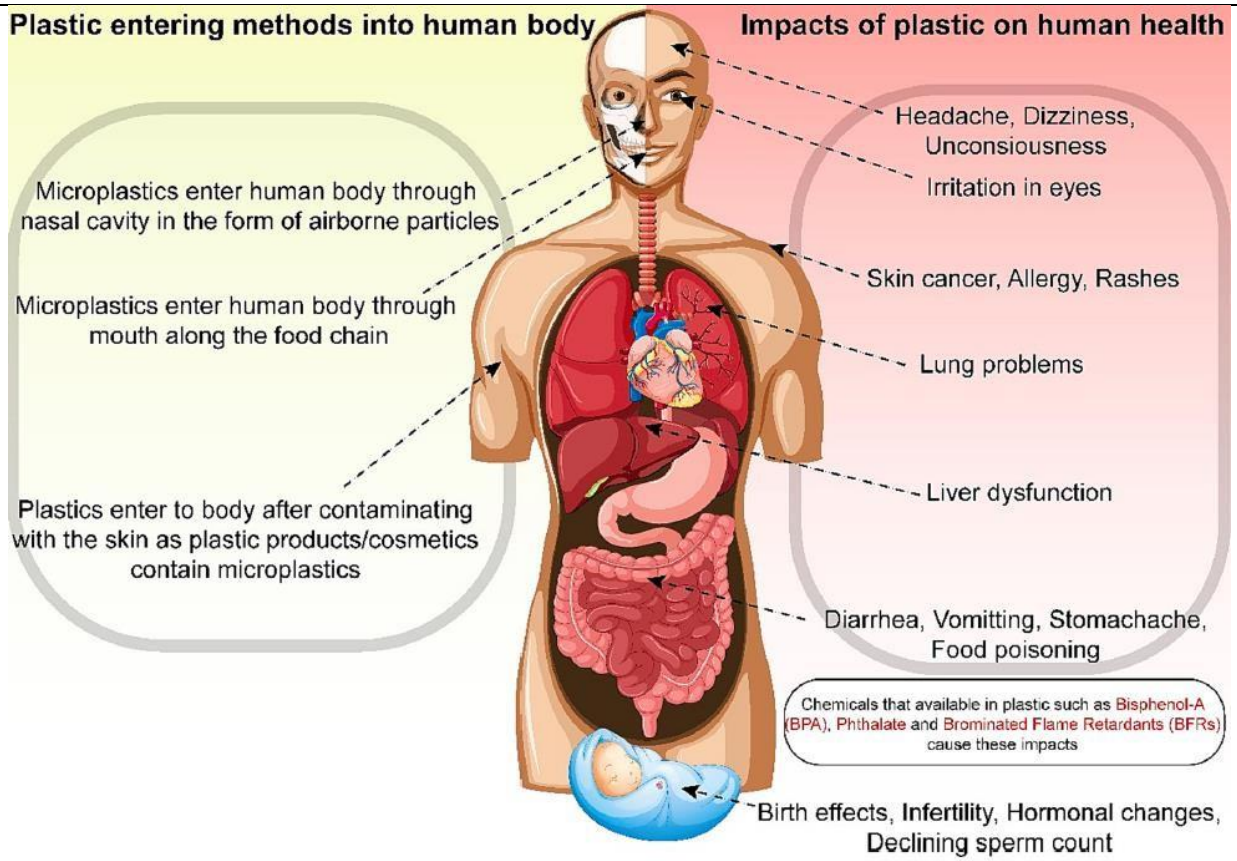


Figure 03: The ways that plastics enter the body and how they affect people's health (Source: Pilapitiya & Ratnayake, 2024, Page: 9).

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c) Styrene:

Building polystyrene plastics is one of its uses. It is present in single-use polystyrene cups and bottles used for food packaging. Studies on mice exposed to styrene through ingestion or inhalation show that it causes lung cancer, and the International Agency for Research on Cancer (**IARC**) has classified styrene as a potential carcinogen. Human styrene carcinogenicity is more restricted, and the most vulnerable human organ to styrene toxicity is thought to be the central nervous system. Chronic exposure at work can lead to fatigue, a slower rate of invention, and problems with focus, color vision, and balance (Kumar, 2022).

d) Phthalates:

PVC plastics are the main material that it softens. It can be found in car interiors, medical tubing, infusing bags, vinyl upholstery, rubbery toys, raincoats, and food wrappers and containers. Phthalates are a group of compounds that are used as solvents and fixatives in items like nail polish, to soften plastics like PVC (polyvinyl chloride), and to bind chemicals' scents. Exposure to this by humans can happen in a variety of ways, including inhaling vapors from solvents and fixatives or scents. When children chew on plastic toys, tiny holes are made in the material, which allows chemicals like perfumes, and deodorants to seep into the child's mouth.

Hormone disruption, issues with development and reproduction, preterm birth, asthma, undescended testes, early puberty, genital deformities, and the emergence of certain cancers are among the negative health impacts. Reduced lung function, increased weight gain, increased insulin resistance, reduced sperm count, and sperm DNA damage are some of the negative health effects of these substances. Additionally, research indicates that male infants exposed to this toxin have impaired reproductive development (Kumar, 2022).

VII. Impact of Plastic Waste on The Environment

Different types of plastic have different effects. The ecology may be negatively impacted by microplastics directly or indirectly. The term "direct impact" describes situations where life is immediately in danger, such as when birds erroneously swallow plastic pellets because they believe they are food. Indirect impacts occur when invading organisms are incorporated into the system and cause ecological imbalance. Another important factor contributing to plastics' detrimental effects on the environment is the discharge of toxic chemicals during manufacturing. Standard materials and waste products of plastic production include a wide range of chemicals that are carcinogenic, neurotoxic, and hormone-disrupting. These chemicals eventually enter the environment through water, air, and land contamination.

a) Impact on the Land:

Plastics are usually segregated for treatments such as recycling and waste-to-energy, while a larger portion is sent to landfills. Processes such as UV decomposition and microbial degradation, generate small pieces of plastics known as microplastics which seep into the soil thereby creating an impermeable barrier against water and fertilizer movement. Furthermore, the buildup of these plastics during the rainy season has even more negative consequences. When soil erosion or flooding occurs, the tiny plastic particles often wind up in canals and drainage systems, which ultimately lead to water bodies and the ocean. However, harmful compounds released by chlorinated plastics tend to spread to neighboring ecosystems or leak into groundwater (Haritash, A.K., 2019).

b) Impact of plastic waste on aquatic ecosystems:

Ocean waves abrasive properties, microbes, and ultraviolet light all aid in the breakdown of plastics. Financial losses for small fisheries businesses can result from vessels being damaged by marine debris, which not only raises maintenance costs but also reduces the number of days at sea. The fishing industry has suffered significant losses as a result of unfavorable environmental circumstances, particularly in terms of fewer shellfish caught (Balogun et al., 2019). Currency depreciation, decreased revenue, and expensive upkeep are typically the ways that the effects are most noticeable (Haritash, A.K., 2019).

c) Effect on Air Quality:

One of the main effects of plastic bags on the environment is air pollution, which is brought on by the release of CO_2 and hazardous chemicals during production. Poisonous chemicals are released when plastic is burned outdoors, polluting the ecosystem. When humans and animals breathe in dirty air, it can lead to respiratory issues and other health issues. When plastic bags are burned, dioxins, furans, chlorine dioxide, and other dangerous, poisonous chemicals, acids, and gasses are released. After being emitted, persistent organic pollutants travel great distances before accumulating and eventually making their way into the food chain by settling in polar ice caps and oceans. The harmful, mutagenic, and carcinogenic bromine chemicals eventually make their way into crops, waterways, and the human body. The connected contaminants imperil the species by putting fish and other communities at risk.

d) Microbiological Degradation of Polymers:

Under typical circumstances, both biodegradable and nonbiodegradable plastics contribute to the garbage that tends to build up in the environment and create harmful conditions. Since the water-immiscible and water-soluble chains of the polymers tend to accumulate in water bodies because they cannot be recycled or burned, their breakdown is crucial (Shah et al., 2008). Plastic

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biodegradation is one of the inexpensive and environmentally beneficial methods of assisting in the removal of plastic trash. A wide range of microorganisms, including fungi, bacteria, and algae, are engaged. Nine (09) different fungal species and seventeen

(17) different bacterial species have so far been shown to be effective in breaking down plastic. Microbe-assisted plastic breakdown primarily involves the hydrolysis or oxidation of the lengthy polymer chain into smaller ones with the help of extracellular and intracellular enzymes.

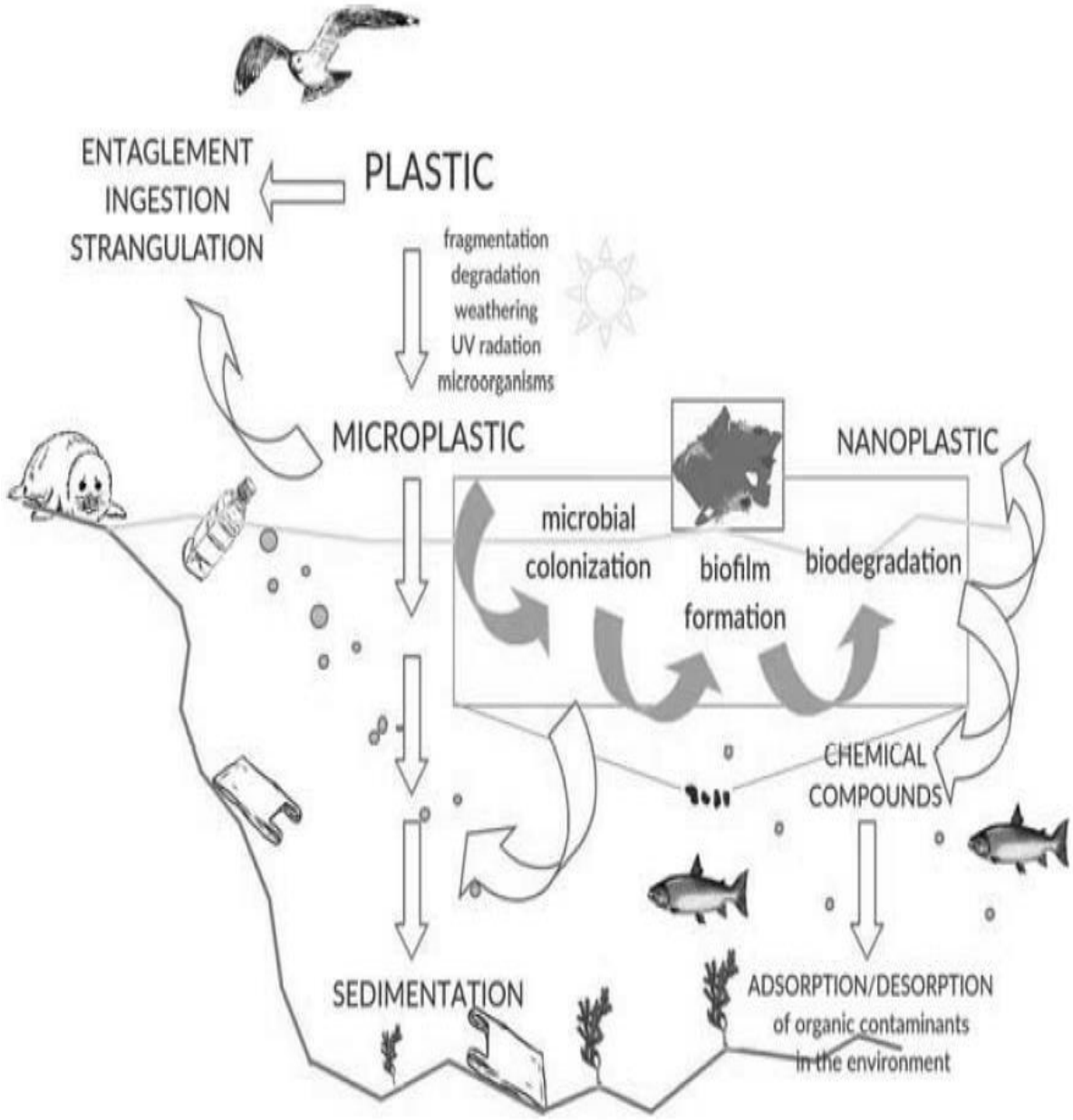


Figure 04: Possible interactions between marine microplastics and microorganisms (Source: Urbanek *et al.,* 2018)

The process via which microbes break down plastics is multi-step (Haritash, A.K., 2019). According to Lucas et al. (2008), the phases are linked to terms like degradation, assimilation, mineralization, bio-deterioration, and bio-fragmentation.

e) Plastic waste's effects on the quality of water:

Acid rain is acknowledged as a major hazard to both natural and man-made settings, especially in areas that have historically depended significantly on coal. Another well-known and serious issue, especially about human health, is smog. Current plastic packaging techniques have an unparalleled impact on water quality, and industrialization demands greater concern, which is why water contamination is beginning to garner significant scientific attention (J. Chu et al., 2021). Water, found in lakes, rivers, and oceans, makes up the majority of the planet's ecology (70 percent). Water pollution happens when dangerous materials, mostly chemicals, and microbes, are dumped into streams, rivers, lakes, seas, or other bodies of water, deteriorating their quality and making them hazardous to people or the environment (M. Bilal et al., 2020).

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f) Effects of plastic pollution on the deep seafloor ecology, mangroves, and seagrasses:

The nitrogen released by seagrass litters is influenced by plastic pollution, which may have an impact on the biogeochemical and nutrient cycles along the shore. Plastic contamination reduced the rate of eelgrass breakdown by 36%, claim Walther and Bergmann (2022). Around 50% of the plastics from municipal waste are denser than seawater and sink straight to the deep bottom, making the deep seafloor a potential sink for plastic litter like this.

Plastic pollution poses a serious threat to the Sundarbans, the world's biggest mangrove forest, which is found in Bangladesh and India. Plastic garbage that leaks through rivers has made the Sundarbans into a landfill (Adyel and Macreadie, 2021). According to Kane et al. (2020), microplastics sink more quickly in deep waters because of their higher surface-to-volume ratio, which causes more fouling. This effect is more noticeable when these particles are mixed with feces and aggregates.

g) The effects of plastic waste on general health:

The disruption of human lives by plastics extends beyond environmental bounds. Chemical additives found in plastics, including phthalates, bisphenol A (BPA), and brominated flame retardants (BFRs), have the potential to seriously harm public health (Pawar et al., 2016). Although BPA can be found in the air, dust, and water, eating is the primary way that people are exposed to it (Kang et al., 2006; Katyal et al., 2020). High temperatures and a range of pH levels cause BPA to hydrolyze and break down (Chouhan et al., 2014; Campanale et al., 2020). Pregnant women's blood, amniotic fluid, placental tissue, and cord blood can all contain BPA, which suggests fetal exposure. Using feeding bottles made of plastic exposes young newborns to BPA often (Kumar, 2018). Human health problems such as cancer, birth defects and developmental disorders, chronic respiratory diseases, cardiovascular disease, and chronic renal disease can all be brought on by bisphenol A (Rezg et al., 2014; Campanale et al., 2020).

h) Degradation by bacteria and fungi:

The fungus contributes to the breakdown of plastics as well. The presence of strains from species including Aspergillus niger, A.glaucus, and Chaetomium spp. has been strong and aids in the degradation of plastic. Plastic sheets cultivated using strains of Penicillium Chrysogenum NS10 and Penicillium oxalicum NS4 were utilized in a study by Ojha et al. (2017) to degrade HDPE and LDPE, respectively. Because of the fungal action, there are cracks, depressions, and rough surfaces. Additionally, the fungi function by secreting certain enzymes that aid in breakdown by forming filamentous structures. Plastics floating along the shoreline of Lake Zurich, Switzerland, were found to be degraded by saprotrophic fungus strains Cladosporium cladosporiodes, Xepuculopsis graminea, Penicillium griseofulvum, and the plant pathogen Leptoshaeria spp. in another study (Brunner et al., 2018). Common examples include Arthrobacter, Bacillus brevis, Phanerocheate chrysosporium, Pseudomonas sp., and Aspergillus spp. The production of oxygenase enzymes by bacteria aids in the breakdown of plastic by upsetting the stability of lengthy polymer chains (Haritash, A.K., 2019). Gram-negative and Gram-positive bacteria are among the various taxa from which the strains that aid in the breakdown of plastics originate (Kathiresan, 2003).

Table 02: Bacteria's capacity to break down plastic (Source: Raziyafathima et al., 2016).

SL Number	The Microbes	Varieties of Plastic	Where do the germs come from	Degradation rate (percent)
01.	Aspergillus Aryzae	HDPE	Buried HDPE In the ground	72%
02.	Streptomyces spp.	LDPE	Soil from garbage	46.7%
03.	Bacillus cereus	Polyethylene	Soil dumping	7.2% and 2.4%
04.	Aspergillus Glaucus	Polyethylene	Soil from mangroves	20.8% and 7.26%
05.	Pseudomonas spp.	Polyethylene	Textiles, sewage, and households	8.16% and 46.2%

i) The impact of plastic waste on wildlife:

Inadequate waste management can have a variety of effects on animals, including chemical toxicity and the spread of diseases and parasites (K.R. Vanapalli et al., 2021). Their presence in the atmosphere allows for the stoichiometric calculation of the enormous plastic water and plastic-air partition coefficients of water and airborne hydrophobic contaminants or pathogens (Y. Liang et al., 2021). Animals' physiological processes are impacted in many ways by plastic debris, and the animals' digestive systems are unable to break down the plastics when it is mixed with other antigens or foreign bodies in animals like cattle (Evode et al., 2021).

j) The effects of airborne plastics on public health:

Both natural and manufactured polymers make up airborne microplastics. The bulk of airborne microplastics are around 20 μm in size, although they can range from 20 to 500 μm (Wang et al., 2021a, b). According to Wang et al. (2021a, b), airborne microplastics come in a variety of colors (black and white) and shapes, including fiber (the most common), film, fragment, foam,

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granule, and sphere. Other sources of airborne microplastics include industrial emissions and the breakdown of bigger plastic objects (Pilapitiya & Ratnayake, 2024). Indoor airborne microplastic concentrations are generally significantly greater than outside concentrations (Wang et al., 2021a,b).

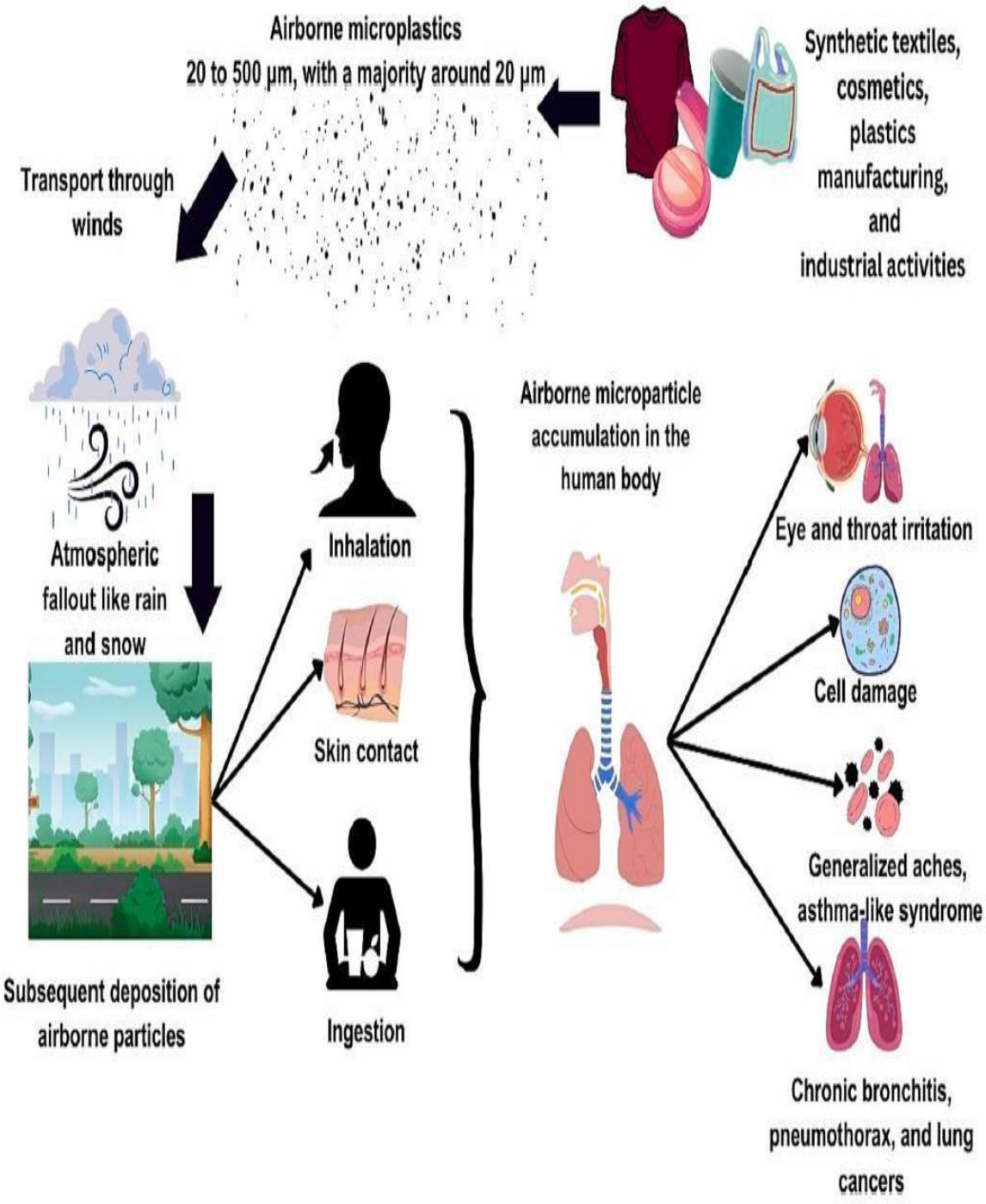


Figure 05: Airborne plastics and their effects on human health (Source: Pilapitiya & Ratnayake, 2024, Page: 7).

k) Plastics are a new issue for the Sundarbans (the largest mangrove forest in the world is turning into a plastic cesspit):

Plastic pollution is a serious threat to the Sundarbans, the biggest mangrove forest in the world and a UNESCO Marine World Heritage site that lies between Bangladesh and India. The Sundarbans, a Ramsar site and a Class 3 Tiger Conservation Landscape of global priority for endangered and flagship species Royal Bengal Tigers (Panthera tigris), have historically faced numerous threats, including overexploitation, commercial farming and development activities, hazards brought on by climate change, and natural disasters (Sen, 2019; Mukul et al., 2020). According to Jambeck et al. (2015), Bangladesh and India, the countries that share benefits and management of the Sundarbans, are among the top twelve countries that generate plastic waste that is not properly managed. They are also releasing plastic waste downstream through rivers and coastlines, turning the Sundarbans into a

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landfill. According to a recent study, the Bay of Bengal may receive up to 3 billion pieces of microplastics every day from the combined flows of the Ganges, Brahmaputra, and Meghna rivers (Napper et al., 2021). Additionally, every year, roughly 4 million tonnes of plastic debris are released into the Bay of Bengal by all of Bangladesh's and India's river systems. With 177 rivers that receive water from three major rivers and run via them to the Bay of Bengal, Bangladesh's Sundarbans serve as a basin for the long-term buildup of plastic garbage (Banglapedia, 2012). The Bay of Bengal is the world's largest bay, and its resources are used by several littoral nations, including Bangladesh, Myanmar, Sri Lanka, Thailand, Indonesia, and India. These nations' various river systems also discharge plastics into the Bay of Bengal. Plastics are primarily transported to bays and oceans by rivers (Lebreton et al., 2017; Meijer et al., 2021).

VIII. The Improper Handling of Plastic Waste

Preventing pollution now is always preferable to waiting to deal with the garbage later (Ncube et al., 2021). As of 2010, the global percentage of plastic garbage that was improperly disposed of is depicted in Figure 06. Any plastic trash that is not adequately contained in disposal locations, such as uncontrolled landfills or dumps, is referred to as inadequately disposed of plastic garbage. This garbage has little trouble migrating into the surrounding ecosystem or entering the ocean. The cause of this waste issue is inadequate waste management systems.

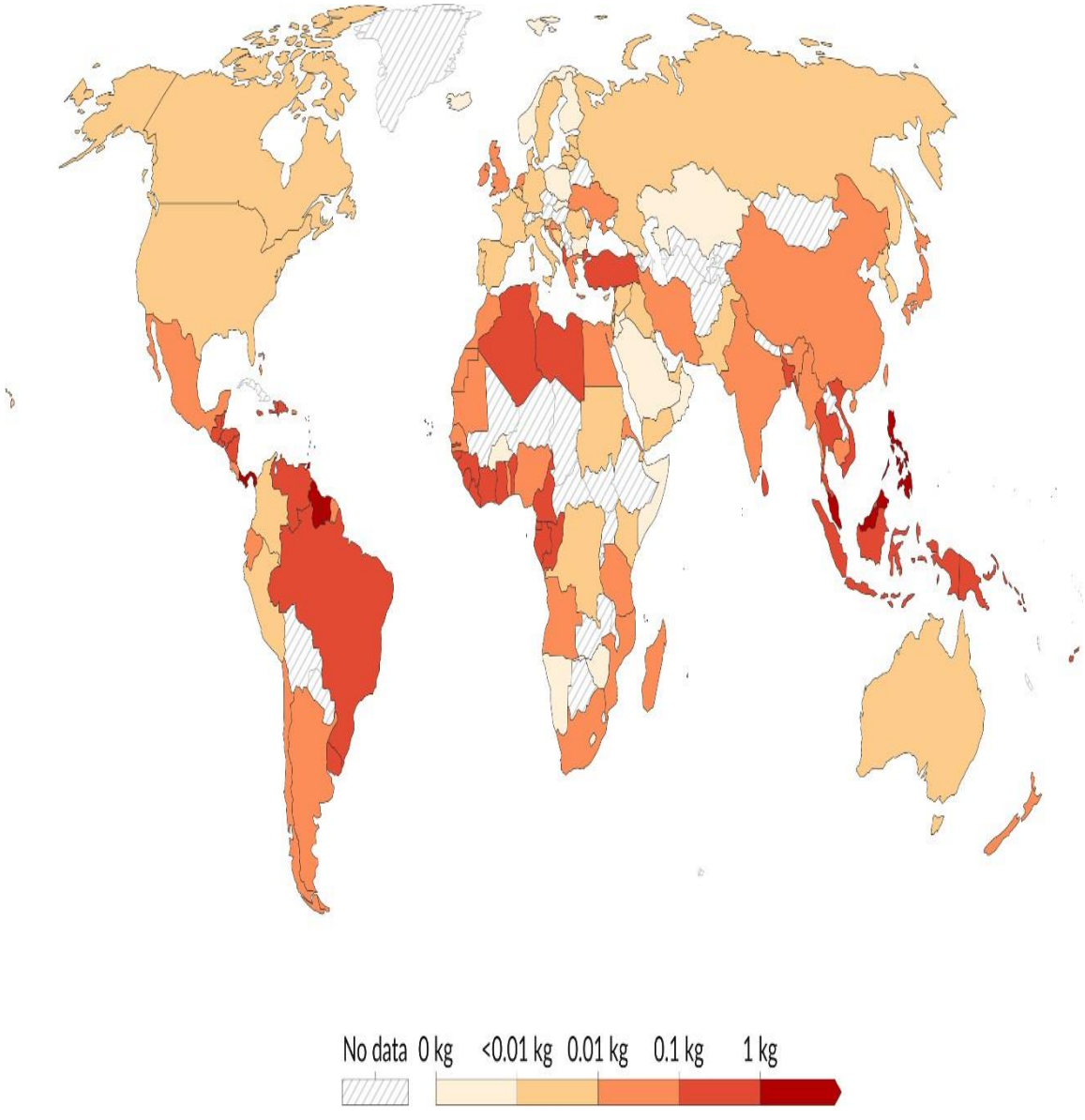


Figure 06: Per capita amount of plastic debris dumped into the ocean in 2019

(Source: https://ourworldindata.org/plastic-pollution) /(https://creativecommons.org/licenses/by/4.0/)

Plastic emissions are estimated to be this high each year. Waste shipped abroad, which has a higher chance of ending up in the ocean, is not included in a nation's total.

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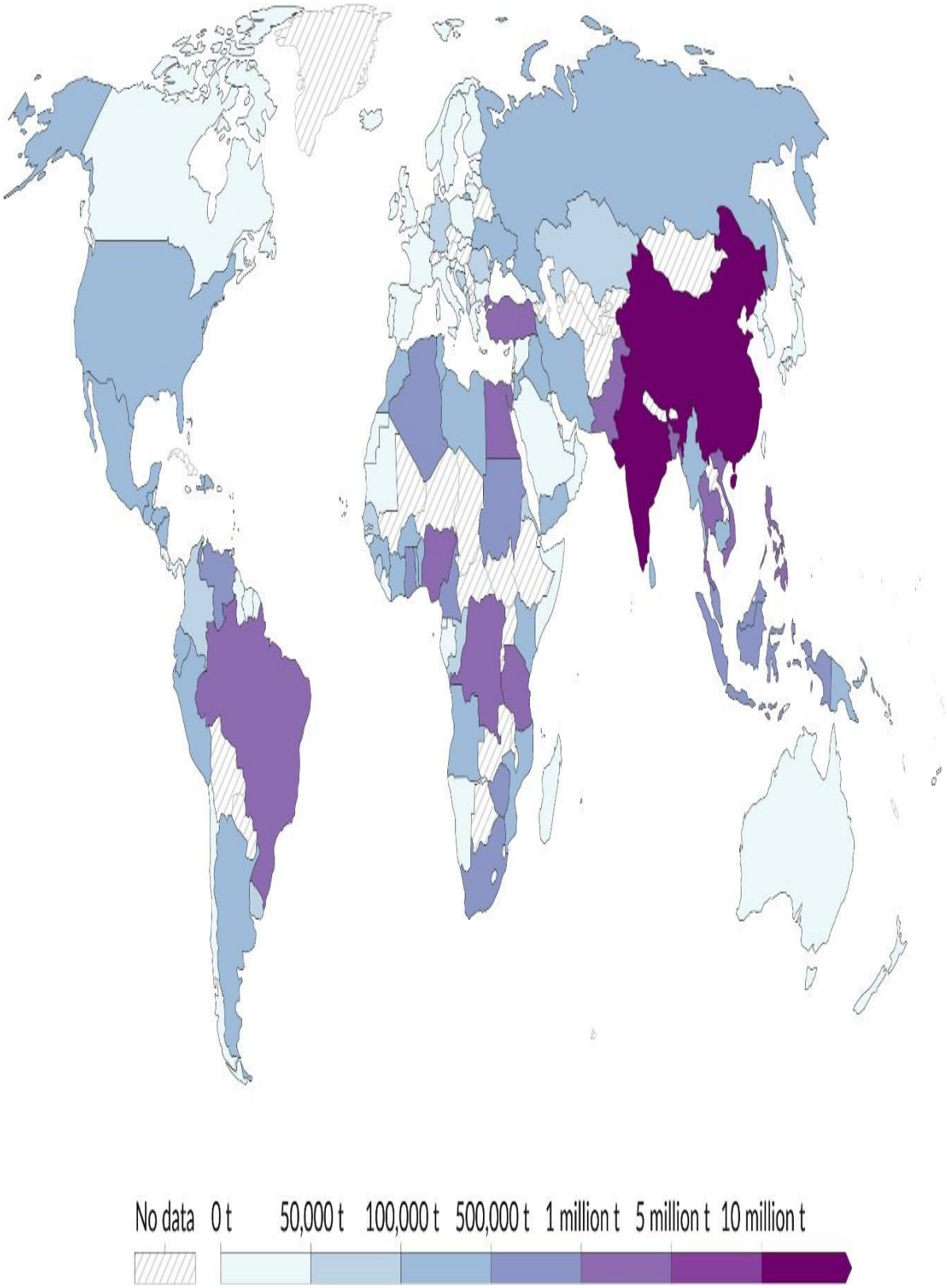


Figure 07: Poorly handled plastic waste, 2019 (Source: https://ourworldindata.org/grapher/plastic-waste-mismanaged),/ (https://creativecommons.org/licenses/by/4.0/)

Waste made of plastic that is not recycled, burned, or stored in sealed landfills is considered mismanaged. It comprises materials that are burned in open pits, disposed of in unclean landfills and dumpsites, or dumped into open waters or seas.

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Waste Management Techniques For Plastic And Microplastics

Economic development and environmental preservation are both essential components of raising living standards in the twenty- first century. Waste management is crucial to reducing the negative impacts of fast industrialization, resource exploitation, and depletion (Haritash, A.K., 2019). Selecting the right plastic treatment process is essential due to the rise in plastic waste, the non-biodegradable nature of plastic components, and their potential for injury.

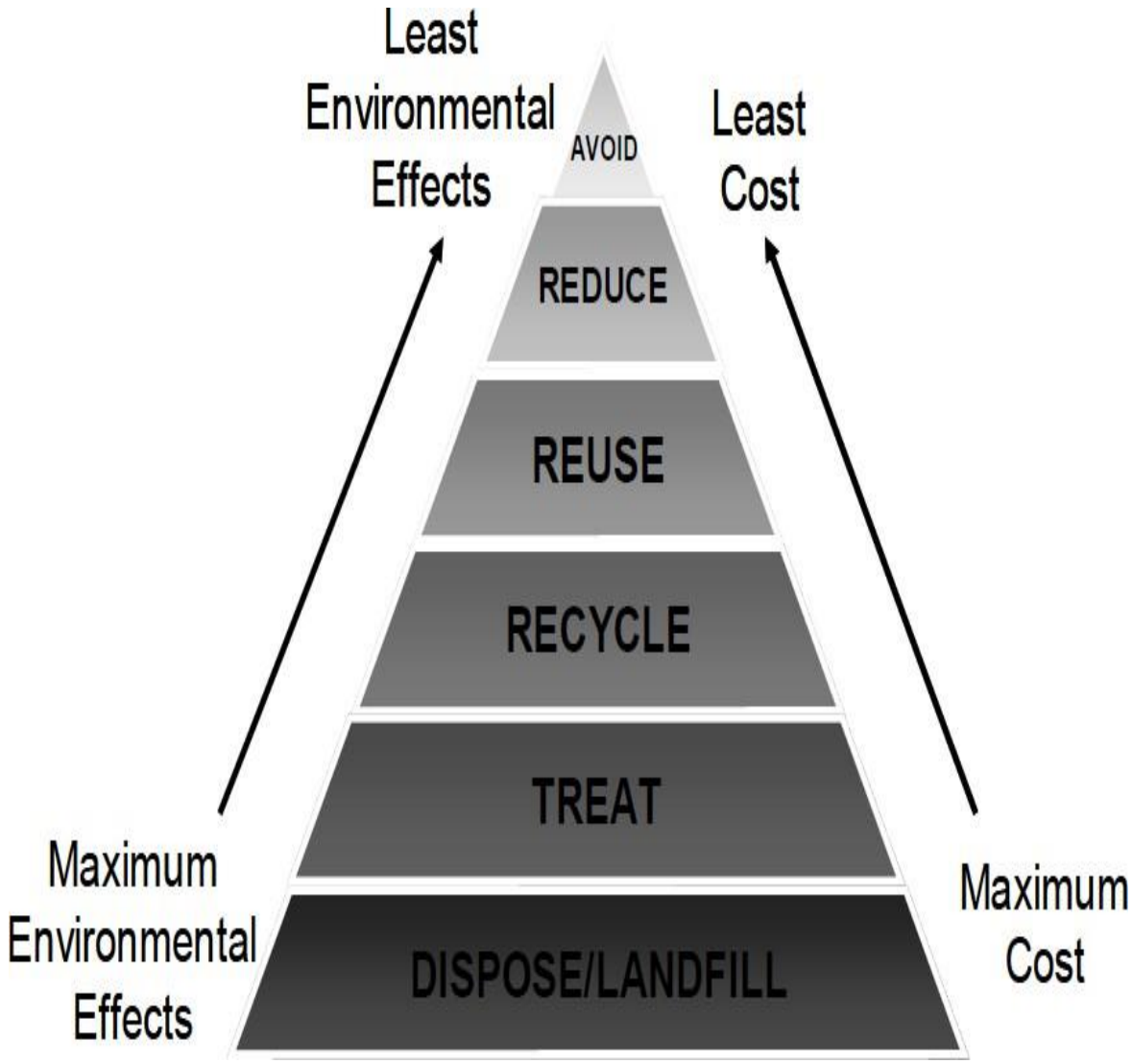


Figure 08: An approach to managing plastic garbage that is hierarchical (Source: Haritash, A.K., 2019, p: 16).

Different policies and environmental safety laws have been implemented by local authorities, government municipalities, and social groups to help people dispose of plastic garbage after use (N.U. Benson et al., 2021). Among these waste management techniques, landfills, recycling, incineration, and bioremediation are a few that have scientific backing. The purpose of these techniques is to dispose of plastic garbage properly and maintain a clean environment (A. David et al., 2018; P.O. Awoyera 2020).

a) Landfills:

Landfills are any locations where we dispose of all disposable plastic waste after it has been used and before it is buried beneath the surface of the ground (Evode et al., 2021). Many precautions should be taken throughout this manual disposal procedure to prevent secondary adverse effects, such as soil degradation and groundwater pollutants, which might arise from inadequate processing (Y. Zheng et al., 2005). It requires a lot of effort to be done in the surrounding area, such as excavating a lengthy hole or dumping it deep and allowing the garbage to break down. This process can take over a year to complete, hence it is done extremely slowly (Y. Liang et al., 2021). The processing of these landfills involves the biodegradation and decomposition of every organic molecule. It can take ten to a hundred years for plastic bags and other long-polymer wastes to break down in landfills (T. Thiounn et al., 2020). Due to their unique biochemical characteristics and environmental or climatic elements, such

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as sunlight, wind, and temperature change, certain plastic wastes might take a long time to decompose (C. Zhou et al., 2014).

b) Bioremediation:

The field of biotechnology known as "bioremediation" is similarly characterized by its primary concepts of decontamination and detoxification by the use of microorganisms to biodegrade natural substances that can be treated through the biodegradation of bacteria, fungi, algae, and plants (M. Asgher et al., 2020). As a chemical catalyst, enzymes in the bioremediation process function by lowering the activation energy and turning the substrate into the product (Evode et al., 2021). The enzymes that are most likely to be employed in the process include hydrolases, laccases, microbial oxygenase, peroxidases, microbial lignin peroxidases, microbial manganese peroxidases, microbial oxidoreductase, and microbial lipases (S. Jaiswal et al., 2020).

c) Reduce, Reuse, and Recycle (3R):

By reducing the amount of plastic used for packaging and minimizing the use of plastic in the material, plastic manufacturers can make a substantial contribution to waste reduction (Evode et al., 2021). Another crucial factor in encouraging the reuse of plastic materials is lowering the toxicity of the substance. A polycarbonate container containing "Bisphenol A" may be more difficult to dispose of than a BPA-free container. Reusing the material is simple because it has no associated toxicity (Haritash, A.K., 2019).

Recycling is a waste management technique that gathers waste and transforms it into raw materials that may be used again to create other useful products. The six phases involved in this process are as follows: gathering waste plastics, classifying or sorting them, washing them to get rid of contaminants, shredding and resizing, identifying and separating plastics, and compounding (E. Szostak et al., 2021). Additionally, it supports the national economy and encourages a sustainable way of living. It has certain drawbacks as well. Certain chemicals are discharged into the environment during the recycling process. Plastics must be melted using heat, which also produces carbon(C), sulfur(S), and other gases that are released into the atmosphere. These gases have various negative effects on the environment, including acid rain, greenhouse gas emissions, and global warming (L. Shen et al., 2014).

d) Pyrolysis:

The process of recovering crude petrochemicals and obtaining hydrocarbons by converting gasses and fatty oils is known as pyrolysis. Plastic garbage is also utilized to produce renewable energy and recover crude petrochemicals. There are three types of temperature-based media: high, medium, and low (Evode et al., 2021). According to the range of temperatures required to break down the plastic structure, medium and high temperatures are used. Despite the potential high capital costs, this scientific approach to waste management is effective (S.D.A. Sharuddin et al., 2016).

e) Incineration:

The combustion of organic molecules can also produce energy which is known as fuel. The fuels can be presented in different physical states like liquid, solid, and gas used by vehicles and airplane propulsion. This method of incineration has several different positive impacts on society rather than energy production (Evode et al., 2021). It also has huge contributions in minimizing waste and producing electricity from the waste, which is highly needed in modern industrialization (L. De Weerdt et al., 2020). Some of the disadvantages of the incineration process include expensive setup compared to other waste management methods. It pollutes the environment and can damage public health. It releases ash waste that can harm people and the environment (C. Netzer et al., 2021).

Reducing The Quantity Of Plastic Waste

The two actions listed below should be followed to reduce the amount of plastic waste.

a) Alternatives to plastic:

It can be challenging to collect, sort, and direct plastic garbage in an appropriate manner. About 15% of the plastic garbage produced each year gets recycled, despite recycling's steady growth during the past 30 years (Eze et al., 2021). The globe is once again turning to traditional or alternative materials to replace plastics with natural polymers because plastic waste management procedures are not entirely satisfactory.

b) Raising public awareness of the problem of plastic pollution:

Raising public awareness of plastic pollution is crucial. Governments may help consumers shift their purchase patterns toward plastic, sustainable material use, and disposal practices by putting awareness programs and campaigns into action with the help of international stakeholders. World Environment Day celebrates a variety of locally led campaigns around the world to reduce plastic pollution, including beach clean-ups in Mumbai, workshops for stitching cloth bags in Ghana, concerts in Atlanta that use no plastic waste, etc. To create a legally binding global agreement to eradicate plastic pollution, the World Wildlife Fund (WWF) has started a public campaign called "No Plastic in Nature."

Recommendations For Future Research On Plastic Waste Recycling

The environment has been negatively impacted by the growing manufacture of plastic products and the creation of plastic garbage. The crushing of plastics during mechanical recycling produces microplastics and nanoplastics, even though recycling

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may lessen plastic pollution. The worldwide microplastic population is expected to rise from 41 kt in 2000 to 1397 kt in 2060. Emissions of microplastics will rise from 17 kt in 2000 to 749 kt in 2060. Nearly every microplastic and nanoplastic released in untreated wastewater is the result of mechanical recycling. To reduce microplastic discharges, non-OECD (Organization for Economic Cooperation and Development) Asia will be crucial. In many nations, reducing the usage of plastic items and improving wastewater treatment will be necessary to reduce the discharge of microplastics (Suzuki et al., 2024).

The amount of microplastic and nanoplastic contamination from point sources, like plastic recycling facilities, is not well understood or evaluated worldwide. It is advised to include extra filtering in the wash water management system to eliminate the smaller microplastics before wash discharge. During mechanical recycling, plastics are crushed, producing microplastics and nanoplastics. It might be crucial to include microplastics in water quality laws, according to some evidence of microplastic pollution of wash water. To improve understanding of microplastic and nanoplastic pollution from plastic recycling processes, further research should be done.

Conclusion

Plastic waste is a threat to the environment because it has negative environmental impacts, although plastic is an essential component of society and has been crucial to growth. Because of their fundamental uses in domestic tasks and the industrial packaging of several final goods, plastics have a positive influence on our daily lives. Because of their physicochemical makeup, plastics play several vital roles in our daily lives, but if their post-use disposal is not properly managed, they can pose a threat to both human health and the environment. Although there is current understanding regarding the impacts and ways to mitigate them, the infrastructure needed to treat plastic trash is inadequate, especially in poor nations.

To enable cyclical plastic life, we have demonstrated various approaches that can be used to treat plastic trash. By recycling materials and reusing plastics, these techniques will save a significant amount of money while also protecting the lives of humans, animals, and the environment. When their useful lives are coming to an end, these plastics readily wind up in the environment. Because they contaminate land and water sources and can even enter the food chain, plastics have a detrimental impact on the health of both humans and animals. Few people are aware of the negative consequences of illegally disposing of plastic waste, and even those with higher education are insensitive to environmental issues. Investing in research to create alternative materials that are affordable, environmentally friendly, and readily available is long overdue. The only ways to combine a country's technological and social development are through the collection, management, and efficient recycling of plastic trash. This leads to the conclusion that a well-executed plan at the institutional, governmental, and consumer levels can eventually integrate plastics into daily life.

Although plastics have a lot to offer in the future, it is clear that the way we currently produce, consume, and dispose of them is not sustainable for both human health and wildlife. To eliminate current plastic waste in the environment and prevent plastic discharge downstream, periodic plastic clean-up programs must be reinforced. Strong incentive and monitoring programs for plastic recycling organizations must be promoted. A functional society can reduce the environmental issues caused by plastic use by implementing efficient waste management systems that lead to a circular economy. The best course of action is to raise awareness and stop the overuse of plastic products, including trash bags. By consuming fewer plastic products and converting to alternatives, plastic pollution can be decreased. Reduced plastic use is now the focus of another crucial aspect of eco-friendly living.

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