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Review

The Devastation of Waste Plastic on the Environment and Remediation Processes: A Critical Review

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Abstract: The devastating effect of plastic waste on the ecosystem due to the rapid increase in population has been a concern. Although stakeholders and governments invested in efforts to mitigate plastic waste, their exertions have limited to no effects as the demand for plastic increases annually. Emerging practical advancements in recycling plastic have been critical for achieving a sustainable circular economy. This study reviews the adverse effect of plastic waste on the environment and the inhabiting creature, the regulation for managing plastic waste, and their limitations. This scoping review also provides information on the current route for reducing plastic waste by defining its sources and their applications. After identifying the generation of plastic waste, the plastic polymers are categorized according to the hazard ranking of their monomers according to their environmental toxicity, damaging the inhabiting creature. The discharge pathways of plastic waste into the environment and aquatic systems leading to white pollution and climate change were also determined. Conversion of plastic waste through the remedial channel by manufacturing value-added products using techniques such as reusing, recycling, and energy recovery, reducing the disposal of plastic waste in landfills is outlined. The information on remedial processes provided in this study will help reduce plastic waste from the environment. In addition, correctly applying these suggestions may help reduce environmental pollution and the death of inhabiting creations. Further research is necessary to convert plastic waste as raw materials into high-value products to achieve a circular economy.

Keywords: plastic waste; environmental pollution; human health; circular economy

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1. Introduction

From 1950 to now, worldwide plastic pollution is estimated to be 8.3 billion million tons. With the emergence of the COVID-19 outbreak, the world has seen a massive increase in home plastic garbage, culminating in a global waste management catastrophe [1]. Improper plastic waste management could adversely impact the environment, animals, and inhabiting creatures [2]. As a result, innovative recycling technologies for reducing plastic waste are critical for discovering novel recycled materials with advantageous qualities that can improve industrial operations while assisting every country in meeting global sustainability goals [1].

Plastics are chemically manufactured polymers [3], which may be thermoset or thermoplastic. Thermoset polymers are petrochemical products called irreversible polymers hardened by a curing agent that can not be reformed or recycled. At the same time, thermoplastic is a petrochemical-based substance that can be shaped when soft into many different forms to a desired shape for different applications. They are recyclable and reused as raw materials for developing other value-added products [1]. This review only focuses on thermoplastic due to the havoc on the environment and their recyclable benefits. The benefits of plastics in our daily life, production, clothing, footwear, food packaging, medical supplies, telecommunication, logistics construction material, agriculture, electrical objects, and manufacturing owns up to its wide application [4,5]. They have extraordinary properties such as low cost, durability, stability, and lightness [6–8]. These properties increased their usage for several applications, including but not limited to food and medicine packages. The plastic material demand for different applications has increased with a compound annual growth of 4.2% from 2021–2028 [9]. Due to this demand, more significant quantities of disposable plastic, such as garbage bags, shopping plastic bags, plastic lunch boxes, and tableware, are dumped in the environment. Dumping waste plastics led to biodiversity loss and severe ecosystem destruction, making plastic pollution a significant global challenge begging for urgent solutions [10].

Consequently, the alarming impact of plastic litter on the ecosystem is of grave concern in the scientific literature and environmental health management due to white pollution [4,6]. Based on the United Nations Environment Programme (UNEP), worldwide plastic waste generation in 2018 was approximately 360 million tonnes. Plastic is a high molecular polymer having a stable composition that is difficult for microorganisms to degrade naturally [10]. It is a type of solid pollutant that poses critical environmental threats in the following ways: (i) animals' longevity is compromised; (ii) soil's functionality and agricultural manufacturing; (iii) induces diseases; (iv) yield to microplastics and cause ecological issues; (v) results in white pollution.

White pollution is an image term for waste plastic pollution in the environment. It denotes the environmental pollution caused by dumping manufactured plastic products [6,11]. The robustness and durability of plastics pose an ecological hazard to the environment, destroying inhabiting creatures due to their resistance to natural forces such as biodegradation, ultraviolet (UV) degradation, mechanical abrasion, and oxidation [6,12]. These processes weaken the quality of the polymer integrity, which disintegrates into the fragmentation of smaller pieces than 5 mm called "primary microplastics" [8,12,13].

2. Plastics and Their Applications in Daily Lives

Plastic is derived from the Greek word "plastikos" and was used from the early 17th century. This material describes substances that can be molded or are suitable for molding [7,14]. Plastics, either thermoplastics or thermosetting polymers, are organic chemicals made up of large molecules, primarily a product of synthetic oil derivatives [11]. They are affordable, user-friendly, have high impact strength, are lightweight, flexible, rigid, colorful, malleable, and can resist heat, corrosion, UV light, and chemicals [3,15]. They exhibit varying primarily due to their source, production process, or additives. However, they are a repetition of polymerized monomer units and are classified into natural, semi-synthetic, bioplastics, and virgin or synthetic plastics [16].

Natural materials with plastic characteristics, such as being reshaped with heat and molten, are considered natural plastic, such as amber (a pine tree resin), used to make ornaments. The semi-synthetic are natural materials blended with chemicals, such as cellulose acetate (cotton fibers or wood pulp), used for movie films. Bioplastics are synthesized from renewable materials such as cellulose, vegetable fats, lactic acid, starch, etc. Synthetic plastics, referred to as virgin plastics, are acquired from carbon-based materials such as decomposed or cracked gas or coal [16]. Plastics are classified according to their composition, the starting materials used for production, application, degree of recyclability, and recyclability, as shown in Figure 1 [3].

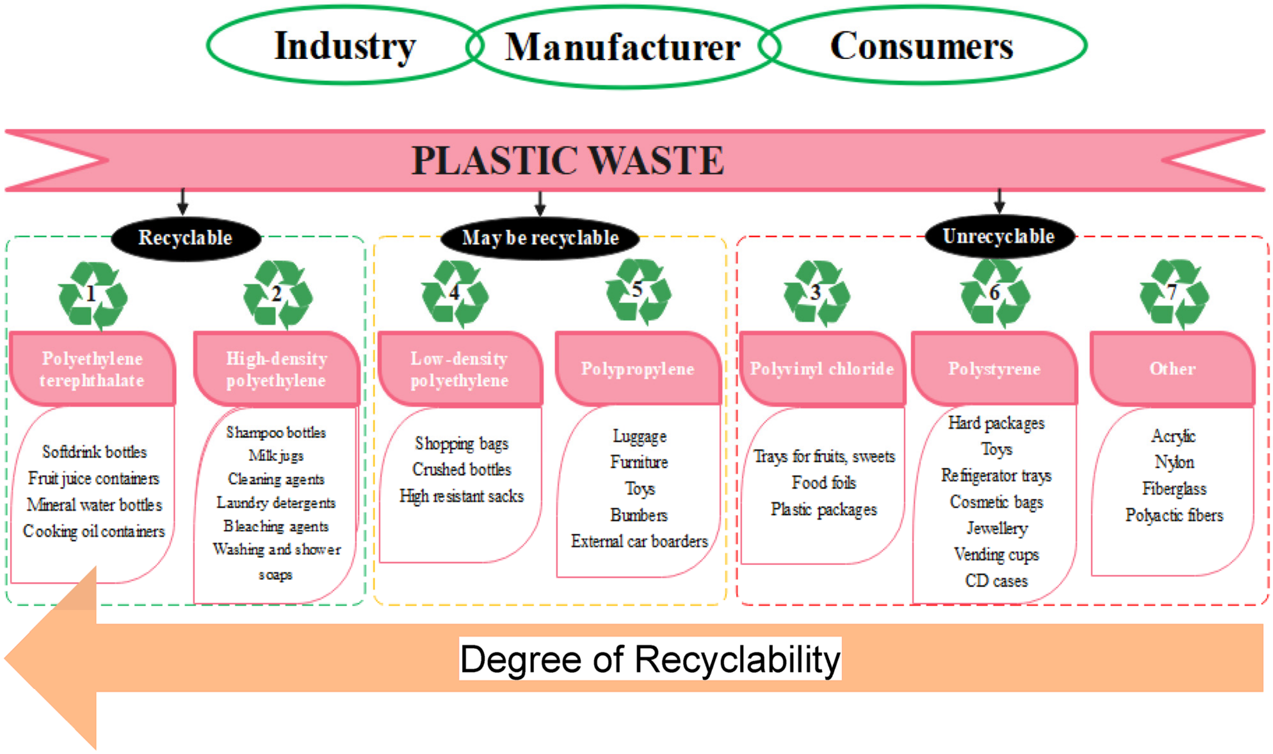

Figure 1. Typical classification of plastic waste generated during daily activities.

3. Environmental Regulation of Plastic Waste

The conventional and ancient management of plastic waste in most countries is by landfilling and burning. Burning plastic waste is not environmentally friendly as smoke, carbon monoxide, carbon dioxide, and nitrous oxide release contribute to global warming [14]. Landfilling plastic waste is undesirable due to its non-biodegradable nature, thus having the potential to leach into the environment [17]. Moreover, the livestock may eat, choke with plastic waste, and die. Waste plastic in gutters also serves as breeding bases for mosquitoes that infect the general population with malaria and other health issues such as dysentery and epidemic cholera [15,18]. Because of the rapid increase in solid waste and the scarcity of suitable waste disposal land, many countries are running out of landfill space. Stakeholders and governments seek to reduce the amount of waste accumulated in landfills [3]. A hazard rating model was established for the hazard classes in the EU classification and labeling (CLP) regulation, founded on the United Nations Globally Harmonized System. The polymers were ranked according to monomer hazard categorization. Hazard categorization data were for materials identified as used in the production of polymers presented in Table 1 [19].

The CLP hazard classes for health and environmental hazards were categorized into five levels (I–V). Each level was allocated an estimated hazard grade, increasing by ten. This factor does not reflect an absolute variation in hazard between the categories. The formula for calculating the hazard score (i.e., sum) for the polymer is according to the classifications of the monomer(s) which make the polymer. If the material has multiple classifications, e.g., it is classified as mutagenic class 2 (IV) and acute toxic class 3 (III), the hazard grades (1–10,000) for both classifications were summarised to generate a hazard score for the material. This method results in a material with a higher hazard rating when it is both mutagenic and acutely toxic (i.e., 1000 + 100 = 1100) compared to only mutagenic material (i.e., 1000). If more than one monomer is required to manufacture the polymer, the average weight fraction of each monomer in the polymer is multiplied by the monomer's hazard score [19].

Table 1. Categorization of the plastic polymer according to hazard ranking of monomers [19].

Class V		**Class IV**		**Class III**		**Class II**		**Class I**		**Not Classified**
Polymer	S	Polymer	S	Polymer	S	Polymer	S	Polymer	S	
Polyurethane (PUR)	13,844	Polyoxymethylene (POM)	1500	Polyphenylene ether (PPE)	400	Polyamide 6-Nylon 6	50	Polyvinyl acetate (PVAc)	1	Polylactic acid (PLA)
Polyacrylonitrile (PAN)	12,379	Phenol formaldehyde resins (PF.)	1500	Polyacrylic acid (PAA)	230	Polystyrene (PS.)	30	Polypropylene (PP.)	1	Polybutylene terephthalate (PBT)
Polyvinyl chloride (PVC)	10,551	Unsaturated polyester (UP)	1414	Polyoxymethylene (POM)	103	Low-density polyethylene (LDPE)	11			Polytetrafluorethylene (PTFE)
Acrylonitrile-butadiene-styrene (ABS)	6552	Polycarbonate (PC.)	1177	Polyamide 6.6-Nylon 6.6	63	High-density polyethylene (HDPE)	11			Polyvinylidene fluoride (PVDF)
Epoxy resin	4226	Unsaturated polyester (UP)	1117	Polyamide 6.10-Nylon 6.10	47	Linear-low-density polyethy-lene(LLDPE)	10			Polyamide 11-Nylon 11
Styrene-acrylonitrile (SAN)	2788	Thermoplastic polyurethanes (TPU)	1094	Expanded polystyrene (EPS)	44	Polyethylene terephthalate (PET)	4			Polyamide 12-Nylon 12
High-impact polystyrene (HIPS)	1628	Polymethyl methacrylate (PMMA)	1021							
		Polyphenylene sulfide (PPS)	897							

4. Discharge Pathways of Plastic Waste into the Environment

A significant amount of plastic waste has been dumped into the environment around the world, contributing to the recent white pollution crisis [6,20]. White pollution produced from polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), and additional high molecular polymers dumped as solid waste, such as disposable tableware packaging bags, plastic bottles, agricultural mulch film, and so forth is discharged to the environment [6,11]. Discharge pathways of plastic waste are illustrated in Figure 2.

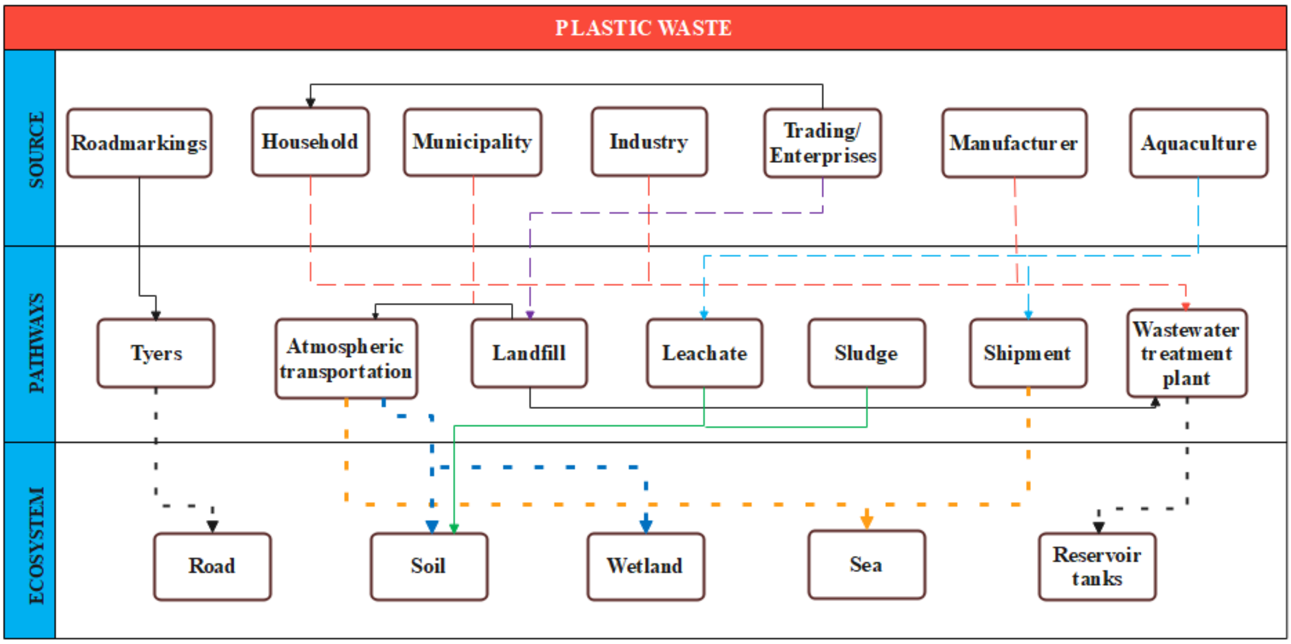

Figure 2. Discharge pathways related to manufacturing and utilization of plastics.

Statistics revealed that 322 million tons of plastics were manufactured worldwide in 2015, a 40% increase from five years before 2018, from 359 million tons of global production to 385 million tons of global consumption respectively [21]. From 2 million metric tons (MT) produced in 1950 to 322 million MT manufactured in 2015, manufacturing has traditionally grown faster than almost all other produced materials. As of 2017, 8.3 billion MT of plastic had been generated worldwide [22]. Africa is the world's second most contaminated continent, having over five hundred shipping garbage containers imported monthly [5]. According to data on thirty-three African countries, the continent imported approximately 172 metric tons of plastic waste and polymers valued at $US 285 billion between 1990 and 2017. Tunisia (7%), Morocco (9.6%), Algeria (11.3%), South Africa (11.7%), Nigeria (17%), and Egypt (18.7%) had the highest share of imports among African countries. Each year, 90,000 to 250,000 tons of plastic enter South Africa via the sea. It is also predicted that plastic imports to Africa will double in the next five years, significantly adding to the global temperature rise [5,23]. About 80 % of the 59 million tons of waste produced accumulates on the shorelines, while only 12 % of the waste gets recycled, and the remaining pollutes the shoreline [24].

5. Impact of Plastic Waste on Humans, Animals, and the Environment

5.1. Human and Animal Health Effects

Although plastic polymers are non-toxic, they do, however, they pose a threat to society. Different additives and residual monomers preserved from polymers cause health risks. Plastic additives are endocrine disruptors and carcinogens, and these chemicals primarily harm humans through skin contact (linked to dermatitis), intake, and inhalation [3]. Microplastics are pervasive environmental contaminants that humans unavoidably ingest [25]. Due to microplastics in products, foodstuffs, and air, exposure can occur through ingestion, inhalation, and dermal contact [26]. Microplastic exposure may cause particle toxicity in all biological systems, including oxidative stress, inflammatory lesions, and increased uptake or translocation, abnormal chromosome rearrangements shown by a, b, c, d in Figure 3 [14,27]. The immune system's inability to remove synthetic particles may cause chronic inflammation and increase the risk of neoplasia.

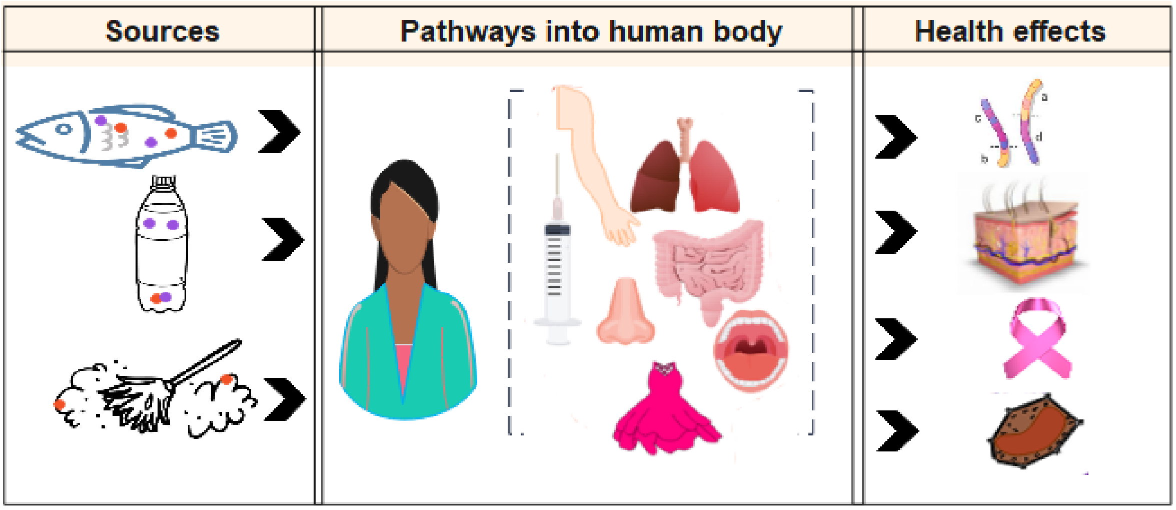

Figure 3. Possible threats of microplastics on human health.

Furthermore, microplastics can release constituents, contaminants, and pathogenic organisms [28]. Microplastics are ubiquitous in the environment and consumer products, and human exposure to these particles is unavoidable [27]. The route for potential adverse effects of microplastics in the human body focusing on exposure and toxicity pathways is shown in Figure 3 [14,27].

Ingestion is deemed the main pathway of human exposure. Considering the consumption of foodstuffs, the intake of microplastics is projected at 39,000–52,000 particles of person^{-1} year^{-1} microplastics [27]. Microplastics are toxicants that, after consumption by a variety of marine and freshwater life, can form complexes in the food chain, causing a wide range of health problems [29]. Animals exposed to plastic additives and microplastics can be harmful to humans if ingested, and biomonitoring studies on human tissues have revealed that plastic components are present in the human species through the identification of environmental contaminants [3,30].

Animals are easily exposed to plastic waste on the ground or in the water when feeding, resulting in animal death in some cases [31]. Plastic waste in aquatic streams exhibits hydrophilic and high charge characteristics relative to land, and the occurrence of microorganisms may convert the plastics into microplastic. The accumulation and adhesion of bacteria on plastic waste could develop microcolonies, harming aquatic organisms [32,33]. Particles may enter the gastrointestinal system via contaminated foods or mucociliary clearance following inhalation, potentially causing an inflammatory response, increased permeability, and changes in gut microbe composition and metabolism [34]. Dermal interaction with microplastics is thought to be a less critical route of exposure. Once considered inert particles without toxicity, microplastics are potentially hazardous to organisms, depending on susceptibility and exposure [27].

The large surface area of microplastics can cause cytotoxicity, oxidative stress, and translocation to other tissues. Simultaneously, their persistent nature limits their removal from the organ system, resulting in chronic inflammation and an increased risk of cancer [26]. As part of particulate matter, microplastics may contribute to the rising prevalence of neurodegenerative and immune diseases. An overabundance of antioxidant responses can lead to oxidative stress [35]. Microplastics may also cause metabolic changes, either directly or indirectly, through their effects, such as negative energy balance. Following exposure, microplastics may act locally or translocate, exposing distant tissues. Because epithelial barriers are more permeable during inflammation, translocation is more probable [12]. Microplastic is termed plastic particles having a size of less than 5 mm. Due to their smaller particle size, microplastics are more likely to adsorb other pollutants and cause toxic effects when combined.

Microplastic is a polymer that takes over 100 years to deteriorate in the natural environment. Microplastic's toxic effects gradually build up in the food chain, threatening the ecosystem's stability [36]. The term "toxic effect of plastic wastes" means adverse reactions caused by the introduction of plastic into living things. Inhibiting the transcription of genes related to oxidative stress and transmembrane transport in the plant's body can harm its growth [31]. Microplastics impair cellular transporters' extracellular transmission and lead to metabolic disorders in people [37].

5.2. Environmental Consequences

Plastics and plastic products made primarily from crude oil derivatives have risen in the last six decades due to continuous technological progress, relatively low production costs, and "incomparable" usability features [3]. Regardless of how it was made, most plastic waste is/was incinerated, landfilled, littered, or recycled after its useful life, resulting in carbon or methane emissions over time [38]. As a result, it is not surprising that researchers have predicted that by 2050, there will be a scarcity of fish as a result of plastics in the oceans, based on an annual estimated 13 million tonnes of the 500 billion plastic bags which end up in the shoreline have killed over 100,000 aquatic organisms [3]. The weathering of plastics on the ocean's surface emits the toxic greenhouse gases ethylene and methane [39]. The rapidly growing population influences the availability of plastic waste, which can eventually result in pollution of the environment, as evidenced by the decline of the natural environment, mortality of aquatic organisms, and blockage of sewage systems [40,41].

The potency of organic phosphorus and nitrogen reduces due to the interference of plastic waste on the humus [42]. Additionally, plastic waste in soil blocks the pores of the plant root cell walls. Consequently, there is a decrease in the absorption of nutrients and water [43]. The partial-permanent stability of plastics in aquatic ecosystem potentially lead to marine pollution, which can affect aquatic animals [41].

6. Regulation Policies of Plastic Waste

Although plastic bag regulation has received attention, current efforts focus on reducing plastic straws, plastic cutlery, and polystyrene products such as cups and microbeads [44]. Even though multilateral agreements and United Nations rulings were implemented, especially since 2007, their effect appears to have been very restricted thus far [45]. The primary rights-based tool is called extended producer responsibility (EPR). EPR gives producers of plastic goods property rights and obligations regarding handling and disposing of their products after use. The objective was to promote waste minimization, decrease the usage of virgin materials, and advance the recycling industry [46].

In the European Union, governments demand increased plastic recyclability in product design, e.g., lesser polymers in products, lesser mix-polymer composite merchandise (such as chip bags), fewer artificial ingredients, and increased transparency regarding preservatives. The EPR strategy is being put into practice. By 2030, all plastic items sold in the European Union should be recyclable [47]. In South Africa and Indonesia, private companies offer direct payments for returning empty plastic bottles and bags [47]. Private businesses provide pay-out for the return of empty plastic bags and bottles. The United States and Australia have implemented the same incentives [47].

Regulating the commercial market with, for example, bans is an effective way of reducing the consumption of plastic items, but it usually comes at a significant social expense. Among the most well-known case studies is the ban on plastic bags in Kenya, Rwanda, Mauritius, and China, enacting total bans on single-use plastic bags [48–50] Rwanda is a prime example of a strict ban accompanied by severe sanctions that have motivated others to implement, including Malawi (2013). Rwanda's hard stance involves airport luggage searches, a $150 fine for transporting a plastic bag, and a year of imprisonment for retailers selling plastic bags. Kenya punished more harshly for using, producing, and retailing plastic bags [51]. China regulates only thinner plastic bags to restrict plastic pollution [52]. Senegal and Australia banned lightweight plastic bags <50 microns [47]. The regulation does not apply to all plastic carrier bags. Countries, including Italy, France, Vietnam, and the United States, accept biodegradable bags. The thickness of plastic bags is also essential. The severity of bans differs, varying from extremely strict to partial bans [51]. Technological advancement is critical for the reduction of plastic pollution. Innovation could influence the quality and quantity of plastics manufactured and how plastics are discarded [53,54]. Although R&D can be endorsed, investment in it is not a political tool in and of itself but instead the result of a well-designed policy mix. A tax on single-use plastics, for example, combined with changes in consumer preferences and awareness programs, can stimulate investment in selecting appropriate alternative solutions [47].

7. Challenges to Plastic Waste Management and Improvements

There are three main challenges to plastic waste management and recycling:

(i) People—The behavioral patterns of people include the high usage of plastic containers, which may get contaminated and undesirable to be recycled or reused [55]. Lack of awareness of waste separation from the source. These include a lack of education regarding recycling and knowledge of plastic products that are recyclable [55];
(ii) Legislation—A lack of regulations requiring plastic manufacturers to print identification codes for plastic resin on plastic containers is needed for effective recycling [55]. Insufficient financial incentives for recycling plastic waste;
(iii) Infrastructure—Inefficient waste collection management. In many societies, only the local government and waste pickers gather recyclable waste and sell it to waste

shops/recyclers [55] gradual growth of private investors and insufficient insight from the financial sector. The final phase of burning plastic in landfills demands significant financial resources [56].

Educating people about waste segregation, including detailed information on waste management strategy and proper waste disposal procedures, is another critical issue in raising awareness of the need to reduce plastic consumption. To raise public awareness, attractive compensation measures should be implemented to reduce waste mobility to landfills [55]. Reassurance of plastic waste management research could improve collaboration between key stakeholders, including central governments, local governments, research institutes, non-governmental organizations (NGOs), plastic manufacturers, plastic purchasers, and waste dispersers or separators.

Consequently, plastic waste can be recirculated back into the system, lowering usage and the environmental impacts of plastic disposal [55]. The government should encourage businesses in the plastics sector to adopt the principles of the circular economy. The project will bring together influential stakeholders to reconsider and remodel the use of plastics in the future. The circular economy model advocates the optimal usage of resources by recycling, reusing, repairing, remanufacturing, and refurbishing products [57]. A collaborative effort with all stakeholders is crucial to advancing the circular economy of plastic waste management.

7.1. Remediation Strategies for Plastic Waste

The key to long-term sustainability is converting waste into electricity, energy, and value-added products (chemicals). Pollutants can be converted into hydrogen [58], biomass into biofuels [59], greenhouse gas into green energy [60], and plastics into bricks [61]. Waste from one manufacturer could serve as a source of raw materials for another or a third manufacturer, for instance, waste tires to pyrolysis plants. The linear economy uses the model; of take, manufacture, utilize, dispose, and pollute, whereas the circular economy uses a sustainable model; of take, manufacture, utilize, reuse, and recycle, as shown in Figure 4 [62]. As part of a sustainable development strategy, circular economies should be accelerated, and linear economies should be minimized [63].

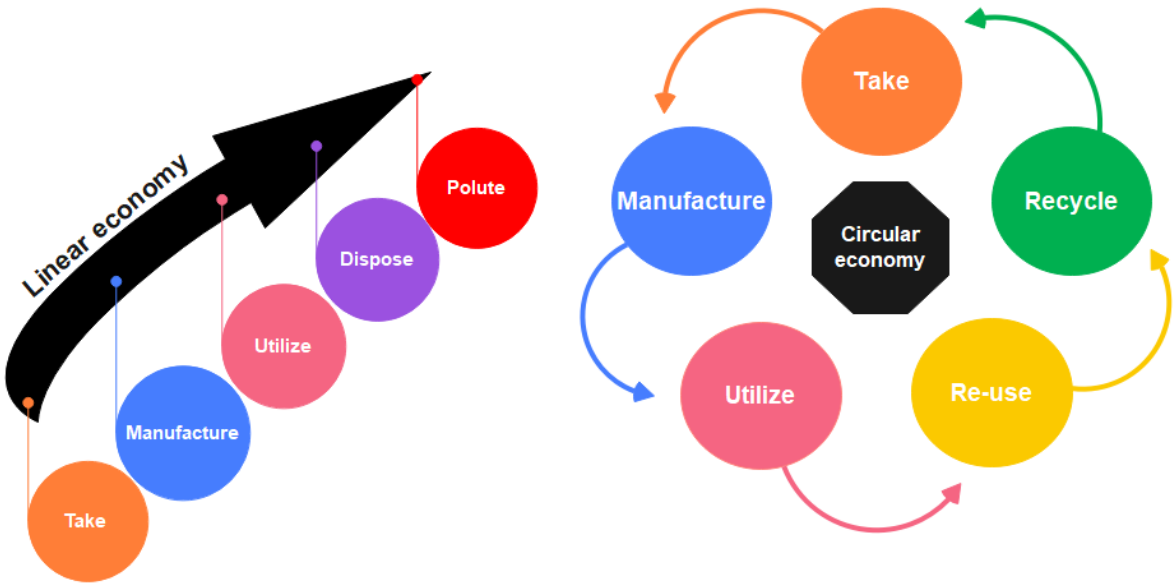

Figure 4. Linear vs. circular economy strategies for plastic utilization and remediation [63].

Waste reduction is a direct approach following the hierarchy of waste minimization in the conventional plastic waste treatment process. It can be described as a strategy for waste management that involves designing and producing products with a minimal volume and low toxic content to ensure a longer product life [64]. Another application is to utilize the product reuse technique, where a product is used for a different purpose from what it may have been designed for. Reducing waste also entails making more robust products with longer expected lifespans than their less robust and less expensive counterparts [63]. Some examples of benefits linked with the utilization of plastic waste are listed:

- ✓ To decrease the use of natural resources in bricks, such as clay. Plastic has been added recently to serve as a binder for brick development.
- ✓ To reuse and reduce the generation of plastic waste, water degradation, and subsequent pollution.
- ✓ It might assist in lowering the amount of space needed for dumping, which increases more landscape for farming and other agricultural activities.
- ✓ It is suitable for regular construction because of its high compression strength.
- ✓ Environmental pollution is less during the production process.
- ✓ Offer an exceptional approach to utilizing plastic waste.
- ✓ The final product recovered is cost-effective.
- ✓ Products constructed using plastic extend the product lifespan.

7.2. Reusing, Recycling, and Energy Conversion

Treatment processes such as reusing, recycling, energy recovery, and landfilling have been employed to reduce environmental pollution due to plastic waste [15,65]. Brick is among the most common concrete slabs used in construction. Because of the high demand, waste has been investigated for brick incorporation. As a result, bricks come in various forms in the construction sector, including foam bricks, concrete bricks, fly ash bricks, and clay bricks [66]. Applying plastic waste to make bricks increases their strength and lowers costs so people can afford them [66,67].

Ordinary household plastic waste such as Tupperware containers, laundry detergent bottles, and plastic bags from plastic recycling grades such as polypropylene, high-density polyethylene, and low-density polyethylene, respectively, are used as raw materials for manufacturing 2D graphitic carbon nanosheets (2D g-CNS), and the resulting 2D g-CNS consists of an ultrathin thickness with sub-1 nm [1]. Regarding reusing marine plastic waste, 3D printing technology has been employed to create needles to repair fractured nets utilizing marine plastic waste (fishing nets made of petroleum-based polyamide) as a filler [68].

The development and implementation of effectively mitigating and remediating microplastics in the environment are essential to enhance technologies that enable recycling or energy recovery of plastics already in landfills to put into practice a workable option to encourage landfill mining in the long run, thereby lowering the number of landfilled plastics and, therefore, the production of microplastics and implementing waste minimization, reusing [69,70]. Waste-to-energy explores strategies to prevent plastic landfilling and runs purchaser behavior change campaigns to get people to avoid disposable items such as single-use plastics. One concern is that plastic in bricks and concrete may diminish compressive strength (CS). However, research dispels concerns about the CS of plastic embedded.

The cost of concrete and bricks remains significant [71]. Herki and Khatib (2017) reported no variation in CS in concrete consisting of up to 30% stabilized polystyrene. Adding waste plastic improves energy efficiency and lowers the density of the building materials while not drastically reducing the CS [72]. Plastic waste can also be converted into fuel using gasification, which involves anaerobic heating at 350–600 °C. The plastic waste is transformed into liquid oil and combustible gas by applying thermal energy to achieve the activation energy needed for polymer cracking [10].

In comparison, thermochemical conversion is a standard and feasible option for plastic recycling. Compared to biological recycling, thermochemical recycling can handle unsorted and polluted waste [73,74].

Table 2 illustrates the main characteristics of plastic waste conversion techniques. Pyrolysis has lately acquired popularity among thermochemical processes due to its ability to convert plastic waste into high-value chemicals and fuels in an environmentally friendly way [75]. Unlike gasification and incineration, pyrolysis is conducted without oxygen, resulting in lower carbon dioxide emissions and fewer hazardous contaminants. Remarkably, polychlorinated dibenzofurans (PCDF) and polychlorinated dibenzo-para-dioxins (PCDD) can be significantly reduced under pyrolytic conditions (less than 600 °C and with no oxygen) [76–78]. Moreover, pyrolysis offers distinct benefits in environmental management, operational expenses, product value, and renewable energy generation. According to a techno-economic study, generating petroleum intermediates from plastic waste has tremendous economic prospects [79].

Table 2. Energy recovery techniques and operation of plastic waste [73,79,80].

Process	Definition	Operational Parameter
Chemical/feedstock	Plastic waste is broken down chemically into component monomers, oligomers, solid, liquid, and gaseous hydrocarbon mixtures.	Plastic waste could be dissolved using different solvents, e.g., PLA dissolves in acetone
Depolymerization	The process of melting waste plastic produces the monomers and oligomers that make up plastic, which can subsequently be used in other polymerization reactions.	Operated at a pressure and temperature above a solvent's critical point
Gasification	Syngas is a gaseous combination rich in hydrogen and carbon monoxide produced when plastic waste is broken down using heat, regulated steam, oxygen, and/or air content.	It is operated mainly under atmospheric pressure, between 850 °C and 1200 °C.
Hydrocracking/ hydrogenation	This process is achieved by producing liquid, solid, and gaseous hydrocarbons by breaking the carbon-to-carbon bonds and adding hydrogen in an inert, hydrogen-rich environment.	High pressures up to 100 bars, with reaction temperatures between 350 °C and 490 °C.
Incineration	Rapid burning of plastic garbage produces heat and power. This heat is trapped and utilized to produce energy indirectly or directly to heat structures. Over stoichiometric, the air is utilized extensively as an oxidizing agent and is occasionally known as waste-to-energy (WTE).	It is operated mainly under atmospheric pressure, between 850 °C and 1200 °C.
Mechanical	This process involves melting down used plastic waste and forming plastic pellets using separation processes, such as extrusion, heat, and crushing.	
Pyrolysis	The breaking down of hydrocarbon bonds in plastic trash with heat in an oxygen-poor environment yields a variety of solid, liquid, and gaseous hydrocarbon compounds. For an inert atmosphere, use a vacuum or nitrogen and helium	Open outlet pressure slightly beyond atmospheric, at a temperature between 300 °C and 900 °C.

8. Conclusions

The concern over plastic waste in the environment is critiqued as a disruption from issues endangering the environment with climate change and killing the inhabiting creatures. The rapid growing plastic production leading to plastic waste is outpacing environmental waste management and available landfills for waste disposal, contributing to climate change. Climate change has adversely affected the environment and its inhabiting creatures in recent years. Burning plastic waste has contributed to carbon emissions, causing global that has claimed many lives and properties and ecosystem damage. It is evident that the role of plastics in the environment is complex, and resolutions will demand creative and sustainable strategies. Due to the valuable properties and our reliance on plastics, complete banning, and replacement is not a quick and easy solution. Global utilization is undoubtedly growing, and plastic waste's mismanagement and discharge into the environment, leaching and disintegrating into microplastics, are causing severe environmental problems. According to the circular economy prospect, we recommend a solution to mitigate the pollution caused by plastic waste. Reclamation strategies such as reuse, recycling, and energy recovery are three valuable strategies for reducing plastic waste. The reuse, recycle, and energy conversion strategies entail using waste plastic and converting it into a different product with different applications, which extends the lifespan of the plastic.

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