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**PLASTIC WASTE MANAGEMENT:  
SOURCES, ENVIRONMENTAL AND HEALTH IMPACTS, AND  
SUSTAINABLE RECYCLING STRATEGIES**

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**Article Received: 06 April 2026, Article Revised: 26 April 2026, Published on: 16 May 2026**

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DOI: <https://doi-doi.org/101555/ijarp.8699>

## **ABSTRACT**

Plastics are widely used polymers valued for their durability, light weight, low cost, and versatility across packaging, construction, healthcare, and consumer goods. Global plastic production continues to rise, with projections reaching 1.1 billion tons by 2050, leading to massive accumulation of polymer waste in municipal and industrial streams. Because synthetic plastics are largely non-biodegradable, improper disposal poses serious environmental and health risks, including soil and water contamination, air pollution from incineration, and the release of toxic additives such as bisphenol A, phthalates, and dioxins into ecosystems and the food chain. This review outlines the main sources of plastic waste— industrial scrap and post-consumer domestic waste and evaluates common disposal methods, including landfilling, incineration, and recycling. Landfilling consumes valuable land and risks leachate contamination, while incineration recovers energy but emits hazardous pollutants. Recycling, encompassing mechanical, chemical, and biological processes, offers the most environmentally sound approach by conserving resources, reducing CO<sub>2</sub> emissions, and diverting waste from landfills and oceans. Emerging technologies such as pyrolysis, plasma gasification, and photocatalytic decomposition show promise for converting waste into fuels and value-added products. The review also addresses the health consequences of plastic exposure, particularly through food, water, and inhalation pathways, linking additives like bisphenol A to endocrine disruption, cancer, and reproductive disorders. Effective waste management requires reducing plastic generation at the source, improving collection and recycling infrastructure, and adopting the 3R principles of reduce, reuse, and recycle. With

stronger policy support and technological advances, recycling can become both an environmental solution and an economic opportunity in construction, manufacturing, and design sectors.

**KEYWORDS:** Plastic, Waste, Waste management, Environmental impact, Health impact.

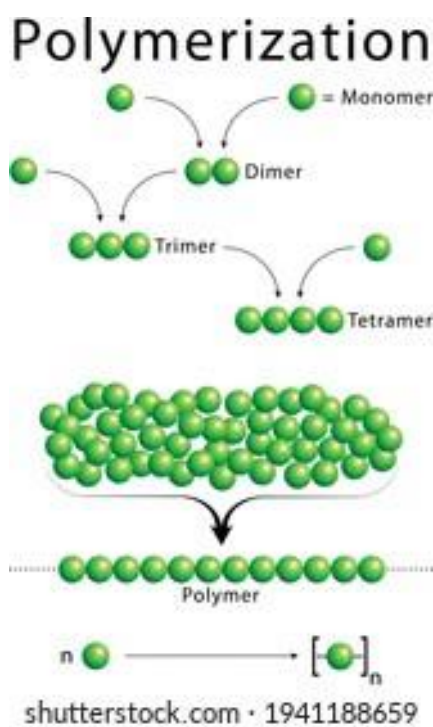
## INTRODUCTION

Plastics are chemically created polymers that are used in a broad range of materials, including clothing, medical supplies, water bottles, food packaging, electrical items and construction materials (Proshad et al., 2018). Polymers have become widely used materials in everyday life due to their special properties such as durability, easy processing, lightweight nature, and low cost of production. Whenever we think about materials that one uses in ones everyday life, one cannot lose sight of the nearly all-encompassing materials called polymers (Jaiswal and Mishra, 2019). Worldwide plastic production is estimated at around 1.1 billion tons of plastic in 2050 (Lai and Lee, 2022). The increase in interest in plastics as raw materials in various sectors comes from its ease of handling, transparency, and cost-effectiveness (Joseph et al., 2021). Plastics have shown extraordinary packaging performance for food, confectioneries, chemical products, and medicinal products (Evode et al., 2021). Nevertheless, massive plastic waste is generated, due to its mass consumption and the application of proper plastic waste management is critical to solving sustainability and environmental issues. Polymeric materials (plastics and rubbers) comprise a steadily increasing proportion of the municipal and industrial waste that is either poorly managed or accumulating in landfills. Since polymeric materials do not decompose easily, disposal of waste polymers is a serious, long-term environmental problem (Damayanti et al., 2022). The disposal of polymeric waste poses severe problems because synthetic polymers are not biodegradable, while natural one can be easily recycled using new technologies that are still under examination. Landfill and incineration are reasonably cheap disposal methods, but these solutions are not environmentally friendly and have to be replaced. Plastic waste management has gained more attention worldwide due to its impact on human life sustainability.

Typical plastic waste management strategies include landfills, incineration, microbial decomposition, thermal decomposition, mechanical pulverization, and recycling. Therefore, plastic waste is mainly disposed of in landfills and discharged into the environment. These wastes, particularly plastic packaging, end up in rivers and seas, posing a significant hazard

to aquatic habitats (Prajapati et al., 2021). Landfill is becoming increasingly costly, as the volume of waste increases and landfill capacity decreases. More importantly, dumping plastic waste in a landfill could waste valuable resources and causes a series of problems, such as additive leaching and land occupation. Meanwhile, incineration is commonly used in the energy recycling of plastic waste, since a significant amount of energy can be recovered, and the energy can be utilized to generate electricity, combined heat, power, or for other operations. However, incineration can be harmful, because various toxic components, which may cause toxic effect are released. Among these methods, plastic waste recycling simultaneously offers an acceptable and environmentally friendly approach (Tejaswini et al., 2022).

The recycling of conventional synthetic polymers is a more environmentally friendly process than sending a biopolymer to incinerated, composted, or dumped in a landfill. Among the main environmental benefits of polymeric recycling are energy conservation, saving depleting landfill space, and reducing petroleum use and CO<sub>2</sub> emissions. However, managing the waste composed of these materials is one of the most significant environmental issues confronting us in the present day. Recycling polymeric waste is the most important action currently available to reduce environmental impacts worldwide and is one of the most dynamic areas in industry today. (Prajapati et al., 2021).



**Figure 1: Polymerization reaction.**

Source: Lai and Lee (2022).

### **Sources of Polymer Waste**

Waste plastics consist of plastic resin or product that must be re-processed or disposed of and they consist mainly of industrial plastic waste and domestic plastic waste (Figure 3). Industrial Plastics waste is a plastics waste generated by various industrial sectors (Figure 2). Postconsumer plastics waste is a plastics waste generated by a consumer. Nuisance plastics (NP) are wastes plastics that cannot be reprocessed under the existing techno-economic conditions. Scrap plastics (SP) are waste plastics that are capable of being reprocessed into commercially acceptable plastic products (Jaiswal and Mishra, 2019).

### **Generation of Industrial Plastics Waste**

Industrial Plastics waste is a plastics waste generated by various industrial sectors. Industrial plastic scrap, being reprocessed by the industry and thus often considered an "avoidance of waste" is usually omitted by those researching the subject. Approximately 4.7% of total plastics production is recycled by reprocessor and over 8% is recycled in plant. The amount of plastics waste generated by the manufacturers of commodity resins depends on such factors as the complexity of the polymerization process, the number of grades produced in a plant, and the number of manufacturing steps. The least waste is generated in the manufacturing of polyethylene, the most in the manufacturing of PVC. Plastics waste is generated during the polymerization process (reactor scrapings, unsuccessful runs, etc.), and shipment and storage (Jaiswal and Mishra, 2019).

### **Domestic Plastic Waste**

Domestic plastic waste is a waste generated from households and the majority of Plastic Solid Waste is generated from households and commercial sources, which combined, are referred to as municipal plastic waste. This type of plastic waste mainly consists of the following plastic resin types: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl alcohol (PVC). Municipal plastic waste is typically thermoplastics, which are thermally recyclable due to their non-resistance to heat (Miandad et al., 2017).

### **Consequences of Improper Polymer Waste Disposal on the Environment**

More plastic has been produced in the last years than was produced in the previous years and his implies that plastic waste is rapidly increasing its damage on all ecological systems and life. Invariably, plastics have affected man's daily living and its continued usage and production especially in most low-income nations is now worrisome, since they may not be

able meet up with the advanced techniques of plastic waste management (Proshad et al., 2018). Moreover, the qualities of plastics such as light weight and durability that make them so unique have in turn becomes a disposal problem. For instance, when used plastic products are trashed into the environment (landfill), they endure for long time in the surrounding due to the fact that they are durable, while those thrown into water bodies continue to float on the surface because they are of low density. Thus, the damage these wastes are getting to life and the ecosystem is increasing thereby causing severe environmental hazards such as water pollution, soil pollution and air pollution (Kehinde et al., 2020). Plastics waste released into the aquatic environment releases harmful chemicals such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDTs) which are toxic to aquatic organism. This pollutant then enters the tissue and skins of aquatic organism or can also be consumed by aquatic-life and progresses up the food ladder to man's as consumers by eating this contaminated seafood (Sidorov et al., 2016). Contaminated plastics can discharge toxic substances into the soil, which could later flow into underground and other water sources in the surroundings. This can cause severe damage to the organisms consuming it water. With several types of plastics, landfill areas are constantly piling up large. There are also many bacteria and pathogens in these landfills that promote the biodegradation of plastics. Land filling and pollution occurs when plastic wastes are not properly disposed of, they are carried by wind or animals and fill up land spaces, drainages, pipes and this chemical then get deposited into the soil, thus contaminating crops (Bui et al., 2020). The side-effects of plastic waste burning are air pollution which release soot and solid residue ash (black carbonaceous colour) which can travel thousands of kilometers, depending on prevailing atmospheric conditions and enter the food chain possess a high potential of causing health and environmental concerns (Kadapakkam and Sukhman, 2020). There are increasing concerns about the possibility of hazardous chemicals, such as halogenated additives and polyvinyl chloride because the combustion of plastics releases dioxins, furans and polychlorinated biphenyls (PCBs) into the atmosphere during the process some compounds released include acetaldehyde, benzaldehyde, formaldehyde, phosgene, polychlorinated dibenzo-dioxin, hydrochloric acid, propylene and vinyl chloride, among others. Some of the health effects of these compounds include damaging the nervous system, causing lesions, eye and respiratory tract irritation and carcinogenic effects adversely affecting the bone marrow, the liver and the immune system. In addition, the released substances settle on the soil and plants as black carbon, ashes, and many powders, with the potency to drift to the marine environment and when rain falls, some of these toxic composites permeate the soil, pollute the aquifers, or

plants cultivated around this soil absorb them and further integrate them into the food chain (Adeniran and Shakantu, 2022).

### Health Consequences of Improper Polymer Waste Disposal

Plastics have affected man's daily living and its continued usage and production especially in most low-income nations is now worrisome, since they may not be able meet up with the advanced techniques of plastic waste management. When used plastic products are trashed into the environment, they endure for long time in the surrounding due to the fact that they are durable, while those thrown into water bodies continue to float on the surface because they are of low density. Thus, the damage these wastes are getting to life and the ecosystem is increasing thereby causing severe environmental health hazards such as water pollution, soil pollution and air pollution (Kehinde et al., 2020). When plastic waste reaches the sea, it either strangulates, kill or contaminate seafood. Animals can easily be poisoned by plastic pollution and thereafter contaminate water sources and human food. Also, by skin absorption, human beings may get infected when they get in contact with chemicals used in plastic production. During most of the plastic production processes, some synthetic substances such as Bisphenol A, phthalates and fire retardants are usually added to give it certain special properties (Zhang et al., 2020). Meanwhile human health risks can arise from their monomeric building blocks (e.g., Bisphenol A), their additives (e.g., plasticizers) or from a combination of the two (e.g., antimicrobial polycarbonate). Food and inhalation are considered the main source of exposure to BPA in the human body. Research also shows that Bisphenol A increases the risk of breast cancer, prostate cancer, pains, metabolic disorders, etc. while in women it impaired it can lead to health issues like obesity, endometrial hyperplasia, recurrent miscarriages, sterility, and polycystic ovarian syndrome (Wu et al., 2021). Figure 4 below shows the structure of Bisphenol A.

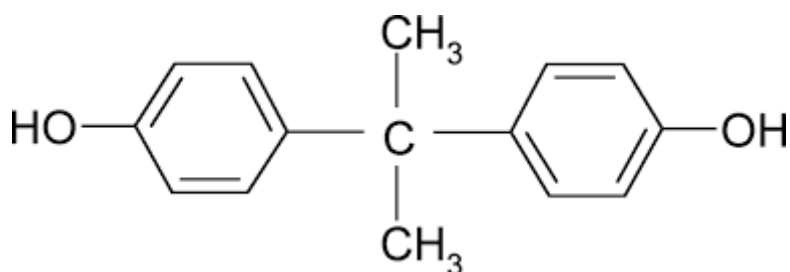


Figure 4: Structure of Bisphenol A.

### **Polymer Waste Remedies**

Various remedies have been implemented for polymer waste removal and they include the following mechanical recycling, chemical recycling, energy recovery, landfill disposal and biodegradation. The three solid waste management strategies are the 3R (Reduce, Reuse and Recycling). Polymer wastes are disposed mainly in three ways which are by landfill, burning (incineration) and recycling (Kehinde et al., 2020). Landfill is the most common method of municipal solid waste disposal.

There are two main techniques for landfilling: open dumping and sanitary landfill. In the process of landfilling, a number of potentially valuable components are lost. Open dumping was the original method of waste disposal. In this method waste is deposited in an open area and allowed to decompose. Its sole advantage, a relatively low disposal cost, is far outweighed by the disadvantages which is odour, the scattering of lightweight wastes by the wind, and the presence of pests such as rats and mice (Verma et al., 2016). Open dumping is still being practiced, but its importance is diminishing. Sanitary landfill is a modern method of landfilling. Sanitary landfill is a method of disposing of waste on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary (Jaiswal and Mishra, 2019).

An alternative to landfilling of plastic waste is burning, but growing concerns exist about the potential atmospheric release of hazardous chemicals during the process. Plastic waste fumes release halogenated additives and polyvinyl chloride, while furans, dioxins, and polychlorinated biphenyls (PCBs) are released from burning of plastics into the environment (Barone et al., 2021). The disadvantage of combustion of plastics is the air pollution caused by the noxious fumes and hazardous halogens released into the atmospheres which pollutes air climate change. Compounds of low molecular weight can vaporize directly into the air thereby polluting the air and based on their varieties, some may form a combustible mixture, while others may oxidize in solid form (Alabi et al., 2019). The most damaging effect by plastic litter to surrounding air can be attributed to intentional or incidental open-fire burning. In most cases, burning of the plastic wastes is done to reduce the volume which causes not only environmental pollution but also energy loss since valuable fuel could be extracted from plastics through pyrolysis (Gebre et al., 2021).

Plastic waste recycling refers to the waste management process that collects plastic waste materials and turns them into raw materials reused to produce other valuable products (Figure

5). Recycling is not only a method for disposing of plastic waste, but it is also an effective process to minimize the need for virgin plastics, which can help lessen global warming and the recycling of plastic waste helps to conserve natural resources due to polymeric materials being made from oil and gas (Ayele et al., 2020). Plastic recycling can be categorized as primary, secondary, tertiary and quaternary recycling. Based on the mechanism of the methods, plastic waste recycling is often classified as mechanical, chemical, and biological recycling (Prajapati et al., 2021). Mechanical recycling is often classified as primary or secondary recycling, and chemical and biological recycling is commonly classified as tertiary and quaternary recycling. Each method has its advantages and disadvantages, depending on the user needs. Mechanical recycling turns polymeric waste into new polymer products, chemical recycling such as catalytic and thermal processes, can convert plastic waste into feedstock for chemicals/monomers/fuels i.e it converts waste polymers into feedstock for chemicals/monomers/fuels production. This process is a potential method to reduce plastic waste as a primary source of environmental issues and energy recovery process releases the energy contained within plastics through combustion (Damayanti et al., 2022). Primary recycling is the processing of scrap plastic into the same or similar type of product from which it has been generated, using standard plastics processing methods. Secondary recycling is the processing of scrap plastic into plastic products with less demanding properties. Tertiary recycling is the recovery of chemicals from waste plastics. Quaternary recycling is the recovery of energy from waste plastics (Jaiswal and Mishra, 2019).

### **Challenges and Solutions of Polymer Waste**

Huge amounts of plastic production (millions of tons) is carried out all around world every year. Recycling rate of plastic wastes is now around 32.5% and the rest end up on their journey in landfills and oceans, where they degrade very slowly and cause pollution which is a crucial environmental problem that needs to be addressed immediately with efficient ideas to solve them. Thus, efficient and environmentally-friendly solutions can be urgently and practically implemented (Kibria et al., 2023).

Polymers should be recycled or thermally processed by applying thermal decomposition techniques such as pyrolysis, plasma gasification, and photocatalytic decomposition rather than being burned or dumped in landfills. These processes have shown great potential for more effective treatment processes and energy recovery from the wastes. In pyrolysis process, long, heavy polymeric chains of plastics such as polyethylene terephthalate (PET)

are decomposed into smaller and non-harmful molecules under high temperature and pressure in the presence of catalysts (Chawla et al., 2022).

On the other hand, inorganic materials present in the plastic wastes (i.e. Polypropylene (PP)) are successfully removed along with the ash by applying plasma gasification approach. They can also be converted to simple molecules and fuels by photocatalytic methods. These plastic wastes can also be used for the production of value-added products (Rhodes, 2018).

### **Future of Polymer Waste Remedies**

For many years incineration and landfill was the main, if not the only, methods of solid waste disposal. Because of the drive toward energy and material conservation, as well as the concern about the environments, new waste disposal options are being developed and implemented. The improved collection procedures and more stringent government legislation will result in an increase in the percentage of collected waste (Jaiswal and Mishra, 2019). Open dump and open burning will be drastically reduced. Sanitary landfill will be the main method of waste disposal, but resource recovery and thermal treatment (incineration and pyrolysis) will become economically significant disposal methods. Wastes from various activities come as solid wastes (effluents) and gaseous wastes, all putting heavy burdens on the environment. In the coming years approximately 30% of solid refuse will be recycled, large quantities of waste plastics (possibly up to 1 million tons a year) will become available for processing into secondary products (Blettler et al., 2018).

### **Economic Advantage of Recycled Polymer Waste**

There are numerous advantages to plastic recycling, including energy conservation and greenhouse gas emissions reduction also known as Gasification. It also protects resources such as oil and gas that are not renewable. In addition, recycling provides livelihood in developing countries for millions of people and families, ranging from white collar employments to casual economic activities. Recycling plastic waste products is the most resourceful approach to managing solid waste, and it could also be perceived as a recent illustration for actualizing the concept of industrial ecology (Kehinde et al., 2020). It can be seen as a business opportunity and used as a solution to creating health. However, before investing in the plastic recycling business, a thorough research comprising of all factors that may directly or indirectly influence the business is necessary. Recycled plastic waste has economic benefits in the following sector: construction, architecture, clothing, art and design,

income generation (Olukanni et al., 2018; Turukmane et al., 2018; Ogundiran and Olanipekun, 2019).

## CONCLUSION

Plastic waste has become a menace in our society with a lot of increasing challenges every day which cannot be over emphasized alongside her stupendous accelerated threat in the environment. Thus, the first and perhaps the best way of managing any kind of waste is not to generate or create it, rather to extend efforts to minimize waste by reducing it right at its source. The most efficient way of managing plastic waste is through recycling which has several potential benefits in various industries like construction and clothing amongst many others.

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