



# Environmental and Health Impacts of Plastic Pollution: Innovative Mitigation Strategies

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## Abstract

The overuse and non-biodegradable nature of plastic has created a global crisis on our ecosystem and the environment. The sources of single used plastics in various forms such as packaging material, containers, plastic bottles, carry bags, straws, cutlery, etc. have been increasing the problems in routine life of the society. The smaller plastic fragments less than or equal to 5 mm in length are referred to as microplastics. Microplastics can enter into the food chain in different ways. Microplastics possess the ability to absorb organic contaminants and act as vectors of hazardous chemicals in living systems. Human health is severely affected due to inhalation and ingestion of microplastics in various ways. Degradation of plastic by physical and chemical processes may prone to health hazard. In order to save the flora and fauna of the earth from microplastic hazards, the potential sources of microplastics should be identified and use of plastics be controlled, and plastic litters should be recycled and reprocessed. To minimize our dependency on plastics, the suitable alternatives should be identified and adopted. This paper highlights the effect of plastic pollution on environment and human health, and evaluate mitigation strategies to reduce plastic pollution in order to restore sustainability.

**Keywords:** Microplastic, sustainability, ecosystem, health hazards, food chain, global crisis

## Introduction

Plastic pollution refers to the accumulation of plastic waste in the environment, particularly in oceans, rivers, lakes, and on land. Plastic pollution occurs when plastic products are not properly disposed of or recycled. It has emerged as one of the most crucial environmental challenges of the 21st century. The problem is further amplified due to the excessive use of single use plastics in the form of packaging material such as carry bags, food packaging, containers, plastic bottles, cutlery and straws (Singh and Mathur, 2019). As per estimation in 2017, it was reported that 348 million tons of plastic was produced globally, of which over 10 per cent was intended for single use and then disposed of as waste and only a fraction of it (about 3 percent) was recycled (Verla *et al.*, 2019).

The most common sources of plastic pollution include improper disposal of plastic waste, inadequate recycling infrastructure, littering, and microplastics produced from the breakdown of larger plastic items. These small particles of plastic which increased enormously over the years were termed as 'microplastic' from around mid-2000. Plastics (including microplastics) constitute major part of marine litter and became a major environmental issue (Bujnicki *et al.*, 2019; Barrett *et al.*, 2020; Gola *et al.*, 2021; UNEP, 2021).

Plastic pollution has long lasting impacts, including entanglement and ingestion by marine animals, contamination of food and water sources, disruption of ecosystems, and even the release of harmful chemicals during plastic degradation. Addressing plastic pollution needs a combination of efforts, including reducing plastic consumption,

improving waste management practices, promoting recycling and reuse, and developing alternative materials that are less harmful to the environment (Barrett et al, 2020). From aquatic to terrestrial ecosystems, plastic pollution poses significant threats to biodiversity, ecosystem integrity, and human well-being (Bank and Hansson, 2019). Plastics are synthetic materials made from polymers, containing long chains of molecules. They are mainly derived from petrochemicals; however, bioplastics are also made from renewable sources such as corn starch or cellulose. Due to their durability, plastics can persist in the environment for hundreds of years, causing significant harm to wildlife and ecosystems (Abbott and Sumaila, 2018).

In the 1960s and 1970s, researchers and environmentalists began to raise concerns about the accumulation of plastic waste in the environment. The first documented instance of plastic pollution in the ocean was reported in the 1970s, highlighting the impact of plastic debris on marine ecosystems. The awareness of plastic pollution increased in the late 20th and early 21st centuries, driven by scientific research, grassroots activism and media coverage. In recent years, several initiatives were aimed at reducing plastic pollution, including bans on single-use plastics, promotion of recycling and waste reduction, and development of alternative materials and packaging solutions. Despite all efforts, plastic pollution remains a major environmental challenge, with millions of tons of plastic entering the oceans each year and severely impacting ecosystems, wildlife, and human health.

As a result of plastic pollution, various harmful chemicals leaches into the environment. Additionally, micro plastics have been found in drinking water, seafood, and even in the air we breathe, raising concerns about potential impacts on human health (Farady, 2019). Plastic waste is ubiquitous, found in oceans, rivers, forests, and even remote areas. Its widespread presence highlights the extensive reach of human activities and the scale of the pollution problem. Plastic pollution severely affected natural landscapes and iconic landmarks, impacting tourism and cultural heritage sites (Bao et al, 2018).

The objective of this paper was to comprehensively analyze the scope, scale, and impact of plastic pollution on human health, ecosystems, wildlife, and the environment. This involves measuring the amount of plastic waste generated, its distribution and intensity in different environments (water, air and land), and its ecological and health impacts. Further, it was aimed to generate knowledge and suggest effective measures that ultimately contribute to mitigating the environmental, ecological, and health impacts of plastic pollution.

## **Results and Discussion**

Plastic pollution poses a major threat to ecosystems and biodiversity. It contaminates soil, water bodies and oceans, causing significant harm to wildlife through ingestion, entanglement, and habitat destruction. Understanding plastic pollution helps us to measure the extent of environmental degradation and the urgency of addressing it to protect ecosystems. Plastic pollution has implications for human health. Plastics can leach harmful chemicals into the environment, potentially entering the food chain and posing risks to human health through the consumption of contaminated seafood or water. Understanding these health risks is extremely important for safeguarding human well-being.

Plastic pollution impacts industries such as tourism, agriculture, fisheries, and affecting livelihoods and economic development. Plastic pollution disproportionately affects vulnerable communities living in coastal areas, low-income neighbourhoods, and developing countries with inadequate waste management infrastructure. Understanding the social dimensions of plastic pollution highlights the importance of addressing environmental justice issues and ensuring equitable access to clean environments.

## **Causes of Plastic Pollution**

Microplastics originate from various sources. Primarily microplastics are directly released in the environment from abrasion of large plastic objects while manufacturing, abrasion of textile materials while washing and erosion of tyres while driving. Secondary microplastics originate due to degradation of larger plastic pieces, photo degradation and mismanaged wastes like discarded plastic items, fishing nets etc. Over the last seventy years the use of plastic has been increased exceptionally. The production of plastic has gone up from 300 million metric

tons to 360 million metric tons annually in the last five years (half of which is of single use). Indeed, we are literally dumping the earth with plastic garbage. It is estimated that only 9% of the total plastic produced has been recycled (Geyer *et al.*, 2017), 4.8 to 12.7 million metric tons of microplastics enter the ocean (Jambeck *et al.*, 2015). Large plastics in spite of being readily visible have negative impacts on ecology (Thevenon *et al.*, 2014), society and economy. Depending on its density, the microplastics can either float or sink to the ocean floor. As a result, significant amount of microplastics will accumulate in the deep seas and even invade the food chain (Seltenrich *et al.*, 2015).

Insufficient waste management systems, particularly in various developing countries, result in improper disposal of plastic waste. A significant portion of plastic waste ends up in oceans, rivers, and natural environments due to the lack of recycling facilities, landfill space, and incineration capabilities. Weak regulations or inadequate enforcement of existing regulations allow industries to continue producing excessive plastic without sufficient accountability for its disposal (Thelma *et al.*, 2024). The globalization of supply chains often involves extensive packaging and transportation of goods using plastic materials. Addressing plastic pollution requires a coordinated effort across borders to regulate production and waste management practices. The prevalence of single-use plastics, such as disposable water bottles, straws, and food packaging, contributes to the great extent to plastic pollution. The convenience and low cost of these items have fostered a culture of disposability, encouraging excessive consumption and disposal.

### ***Health and Environmental Impacts of Plastic Pollution***

One of the biggest challenges faced today is the disposal of plastic waste that persists in soil for longtime about 1000 years in environment. Methods like incineration, recycling and landfills are used for disposal but incineration releases harmful chemicals and greenhouse gases in environment and causes harmful diseases, recycling is difficult process and releases harmful chemicals in the environment, and land filling is the best method but increase in the plastic created trouble. Many fishes die by ingesting the plastic in marine water (Boerger, 2010). On burning plastic waste releases harmful chemicals and affects respiratory systems that leads to asthma, nausea, head ache and damages nervous system. Marine organisms especially sea turtles eat plastic considering them as jelly fish and leads to death (Derraik, 2002). Burning of plastic is another practice that release harmful chemicals like furan, dioxins into the air and causes environmental pollution and affects human endocrine system. Using toxic plastic waste can cause headache, lung infection, cancer, skin diseases, loss of vision, gastro intestinal diseases, birth defect, cardiovascular and reproductive diseases.

The physical effects of plastic debris when ingested by animals (terrestrial or marine) are quiet well understood. The risk perspective of microplastics in humans is yet to be studied and ascertained and there isn't sufficient evidence to quantify the hazards of microplastics yet. However, researches are going on to study the effect of microplastics on aquatic animals. Various types of plastics have the capacity to absorb organic contaminants (pesticides, bisphenols). When these contaminated microplastics accidentally (with increase of microplastic load these accidents become common incidents) enter human system, they can disrupt hormonal system, and even induce genetic changes and cause cancer. In case of humans, a study by researchers at the University of New Castle in 2019 reported that humans on an average ingest 5 g of plastic weekly (Wit *et al.*, 2019). Though direct impact of these microplastics is yet to be assessed but the chemicals used in plastic certainly can cause cancer, heart problem, poor foetal development, oxidative stress, respiratory distress and inflammation.

Due to the large surface area of microplastics, the toxic chemicals such as heavy metals and organic pollutants get adsorbed on its surface and are carried into the environment. There are three probable mechanisms by which chemicals are adhered onto microplastic particles (Verla *et al.*, 2019) which includes adsorption onto microplastics as hydrophobic adsorbents, biofilm growth assisted, and plastic additives and related chemicals contained with resins. Studies have shown that microplastics sustain up to years after being disposed of, creating a havoc in waste management on land (Prasad *et al.*, 2023). Also, the attempt of microbial biodegradation of plastics leads to increased release of methane gas (a dangerous ozone depleting gas). The prolonged deposition of single-

use plastic on the land affects the animals as well who mistakenly eat them in search of food. Improper waste management and recycling techniques as well as the lack of awareness is worsening the situation (Jambeck *et al.*, 2015; Hermabessiere *et al.*, 2017). The process of disintegration from the landfills expectedly delivers up to 20 million tons of CO<sub>2</sub> in the atmosphere. All this adds on to global warming (Eriksen *et al.*, 2013).

Life threatening impacts like infertility, movement impairment, and ulcers have been reported in about 260 species of aquatic life (such as fishes, turtles and seabirds) due to ingestion of plastic debris (Laist *et al.*, 1997; Derraik *et al.*, 2002; Gregory *et al.*, 2009). Ocean life is affected by over exploitation, dumping of waste as well as global climatic change. This is because of the downstream disposal of rivers that collect the undesired waste products throughout their route from the polluted banks (Beatley *et al.*, 1991; Ormond *et al.*, 1997; Snelgrove *et al.*, 1999). Micro plastics can settle and accumulate in sediments, where they may persist for long time. This can affect benthic organisms living in or on the seafloor, disrupting their feeding, burrowing, and reproduction behaviour. Microplastics can serve as vectors for transporting pathogenic microorganisms in aquatic environments. Bacteria and other pathogens can attach to microplastic surfaces, facilitating their dispersal and potentially increasing the risk of disease transmission among aquatic organisms.

### **Mitigation Strategies**

To tackle the super polluting micro and nano plastic problem we have to focus on controlling plastic pollution. This apparently has to be done through three simultaneous approaches:

1. Reducing or terminating use of plastic.
2. Cleaning up plastic litter and recycling it.
3. Finding alternatives to plastics.

Education and awareness are another strategy that involves raising awareness about the environmental impacts of plastic pollution through educational campaigns. Inform the public about proper waste management practices, the importance of recycling, and the benefits of reducing plastic consumption. Encouraging innovation is a strategy in which governments support research and development into alternative materials that can replace plastics or biodegradable plastics that are less harmful to the environment. Encourage innovation in packaging design to minimize waste and environmental impact (Abt Association, 2019). Community clean-up initiatives is a strategy where government through relevant local authorities organize community clean-up events to remove plastic waste from beaches, rivers, and other natural environments. These events not only help to clean up existing pollution but also raise awareness about the issue.

Another potential approach of reusing plastic is turning it into an energy carrier or feedstock for fuels. By heating waste plastic with air or steam (gasification) valuable industrial gas mixtures called synthesis gas (syngas) can be produced which can be used to produce diesel and petrol or directly be burned in boilers to generate electricity (Saebea *et al.*, 2020).

### **Alternatives to Plastic**

It is very difficult to control plastic waste as many of the goods we use are made of plastic. With due course of time many environments friendly plastics have been developed that does not cause harm to the environment. Bioplastics are made from natural substances like corn starch, and does not produce carbon dioxide upon brake down. They can be decomposed easily within weeks and compostable. Bioplastics are manufactured from plant waste especially powders of fruits and vegetables and becomes alternative for fossil derived plastics. Biodegradable plastics consist of additives that made them to decompose easily in presence of light and oxygen. Recycled plastics are the plastics made from old plastic materials by recycling and the same item cannot be generated.

Examples of many ecofriendly plastics include bamboo tooth brush, green bags, green bee wraps, reusable coffee cups and safety razors. Eco-friendly innovative were developed based on the technology to curb the problem but

even though the problem continued due to lack of individual participation in the society. Innovative like compostable pizza boxes and biodegradable packaging vessels are used. Many plant-based products are used for packaging of food and take away containers to control harmful effects on the environment. Bagasse, a byproduct of sugarcane processing can easily be molded into packaging for food services and delivery due to its malleability and sustainability. It is a compostable biodegradable alternative to polystyrene. It can also be used as reinforcements in composites (Hajiha *et al.*, 2015; Liu *et al.*, 2020).

Bioplastics that are biodegradable and recyclable are being made from lignocellulosic material (Xia *et al.*, 2021; Leowa *et al.*, 2022). Corn starch and sorghum are used to make biodegradable odor free and static free loose fills which are used for packing. Stone paper, as the name suggests is paper made from stone, calcium carbonate in particular. Stone papers can be used to make certified food-grade packaging, grease proof paper wraps, zip lock bags etc. (Chu *et al.*, 2019; Indriati *et al.*, 2020). A sustainable alternative of cellophane has been made from FSC certified wood pulp (Nature Flex). These are uncoated and semi permeable and can be used as wraps for chocolates, confectionary, dairy, tea, coffee, bakery products etc.

Increasing awareness about the environmental impacts of plastic pollution through educational campaigns can foster behavioural change and promote responsible consumption habits. Plastic pollution is a global issue that transcends national boundaries. Understanding its global interconnectedness emphasizes the need for international cooperation and collective action to mitigate its impacts effectively. By integrating these solutions and engaging various stakeholders, we can effectively mitigate plastic pollution and move towards a more sustainable future.

## Conclusion

Plastics are destroying nature due to their harmful effect and plastic bags have become the major cause of land pollution today. The plastic bags entering into the water bodies are a major cause of water pollution and these are deteriorating our environment in every possible way. The practice begins at home where the use of plastic related items especially the single use plastic should be completely avoided. Also, if using plastic, the reusable ones should be preferred. Use of blue dustbin for the purpose of recyclable (non-biodegradable) waste should be promoted on high scale. The practice will only happen if education is done correctly among the common people regarding the threats of plastics to the environment. Hence, improving the public awareness about bad garbage disposal practices would really help. Other activities that may be performed to reduce the environmental impact of plastic bags include participating in neighborhood clean-ups, voluntarily recycling home garbage, and avoiding littering. By adopting regulatory measures, technological solutions, and behavioral changes, society can mitigate the impacts of plastic pollution and can make transition towards a more sustainable and circular economy. Government should take initiative to provide research opportunities and education to youth and encouraging them to come up with innovative ideas regarding plastic waste removal, recycling and reusing, and producing eco-friendly plastic alternatives.

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