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Microplastic Pollution in the Environment: Sources, Impacts, and Mitigation Strategies – A Review

Ashish Sambhaji Uzgare[1*] and Fakeha Mohammed Rehan Shaikh[2]

[1, 2] Department of Chemistry, Faculty of Science, Wilson College (Autonomous), Mumbai-400007, Maharashtra, India.

*Corresponding Author: ashish.uzgare@wilsoncollege.edu

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***Abstract*: The widespread pollution of the environment with microplastics (particles smaller than 5 mm) is considered a global problem. This literature review examines published studies written between 2004 to 2026 in order to get a general idea about the sources, consequences, and ways of combating this pollution. The review identifies that microplastics originate from two primary sources: primary microplastics, which are intentionally manufactured for products such as cosmetics, personal care items, and industrial abrasives, and secondary microplastics, which result from the environmental degradation of larger plastic waste. These particles have been ubiquitously detected in aquatic, terrestrial, and atmospheric ecosystems, with documented pathways into the human body via ingestion, inhalation, and dermal contact. Analysis of recent literature reveals that human exposure to microplastics occurs through diverse routes, including drinking water, dairy products, disposable paper cups, and contaminated food items. Potential health implications identified include oxidative stress, chronic inflammation, endocrine disruption, and an increased risk of carcinogenesis, although the need for further long-term studies is emphasized. To address this challenge, this review evaluates control and mitigation strategies, ranging from source reduction (e.g., plastic production limits, bans on microbeads) and improved waste management to technological interventions such as advanced oxidation processes, biological degradation, and adsorption techniques. While source reduction and policy governance are identified as the most effective long-term solutions, technological methods currently face limitations including high energy demands, incomplete degradation, and material saturation. This review concludes that mitigating microplastic pollution requires an integrated, global strategy combining preventive policies, circular economy principles, and continued innovation in remediation technologies.**

Keywords: Microplastic, Environment, Health, Plastic, Pollution

I. Introduction

The development of plastics after the mid-20th century has had profound impacts on contemporary society, offering remarkable advantages in packaging, building, electronics, health care, and many other uses. Nevertheless, these advantages have been accompanied by severe environmental costs (Geyer *et al.,* 2017). The fast growth in the production and use of plastics during the past few decades has caused plastics to build up in large amounts in the environment. The ability of plastics to withstand wear and tear and remain resistant to breakdown makes them last for years before decomposing into tiny pieces called microplastics, which measure less than 5 mm (Andrady, A.L., 2011). This microplast definition covers particles with a range of sizes from a few micrometers up to 5 millimeters in diameter, thereby forming a very wide class of pollutants. The use of the term "microplastic" in scientific works dates back to about 2004 (Li *et al.,* 2023). The spread of these particles is now ubiquitous in the aquatic, terrestrial, and atmospheric environment, thus showing the widespread nature of microplastics. Current research have found that the particles can be found not only in water, but also in soils and atmosphere, thereby suggesting their ability to be incorporated into the food chain of humans (Cole *et al.,* 2011). Sources of microplastic contamination are extremely varied, ranging from anthropogenic sources to natural sources, with the former being much more common as the leading contributors to microplastic generation worldwide. It is important to understand the different sources of microplastics, as efforts should focus on reducing microplastic generation rather than removal once they have entered the environment (Napper *et al.,* 2016, Browne *et al.,* 2011). Microplastics are generated by many different industries and consumers through various means, and their entry point into environmental systems ranges from atmospheric transport to stormwater and wastewater discharge, direct disposal, and even mechanical breakdowns in nature. Sources of microplastics can be divided into two major groups, namely the primary sources of microplastics, which include cosmetics and personal care products, plastic beads used by industries, synthetic clothing, and tire debris, and secondary sources, which include all types of plastics that break down into microplastics (Browne *et al.,* 2011; Wagner *et al.,* 2018). Microplastics have been identified as an important problem for the environment in the last twenty years, with the scientific community, policy makers, and environmental groups identifying the pressing requirement for a solution to the problem (Thompson *et al.,* 2004).

The data employed in this study have been sourced from scientific databases such as Google Scholar, ScienceDirect, PubMed, and Scopus to generate e literature that discusses microplastics and its impact on the environment. This literature review comprises research articles, review articles, and observational studies ranging from 2004 to 2026. Keywords like microplastics, plastic pollution, primary and secondary microplastics, environmental contamination, impact on human health, and detection technologies have been applied in order to search for relevant sources. The purpose of this literature review is to give a broad understanding of the microplastics, its sources and impacts on ecosystems as well as human beings. The paper also focuses on discussing major strategies to minimize microplastic pollution.

Sources and Impact of Microplastics

Industrial and Commercial Contributions to Microplastic

Microplastic contamination has become one of the most serious problems in today's world since there are about 1.7 million tonnes of plastic waste that find their way into the seas each year, and the amount of microplastics in drinking water has risen to 4.34 particles per liter (Ibrahim *et al.,* 2025). Discharge from industries related to plastics is thought to be an important contributor to the input of microplastics (Long *et al.,* 2021). Mitu *et al.,* (2026) conducted a study on microplastic pollution in 15 dairy products both commercially available and traditionally produced. In their study, microplastic particles were found in all samples analyzed. Fibrous microplastics prevailed in the samples (78%-90%), while polyethene and polypropylene polymer compounds accounted for the majority of the microplastics, increasing health risk. Lee *et al.,* (2023) have examined microplastics' origins, distribution, and possible adverse health effects on humans. They stressed the ubiquity of microplastics in the marine and terrestrial environment. The researchers pointed out that microplastics could affect human beings through various channels, but scientific data about their impact on human health is insufficient at the moment. There is some information about the links between microplastics' effects and oxidative stress, inflammation, and other negative phenomena, and these effects seem to differ depending on microplastics' size, form, type, and level. Pilapitiya *et al.,* (2024) discussed the global challenge of plastic waste pollution. Study focuses on the widespread use of plastics and their effects on the environment and human health. As such, the researchers explain that micro- and nanoplastics are polluting the air, water, and soils, thus posing a threat to both the ecosystem and humans. Ashrafy *et al.,* (2023) conducted a review on sources, dispersion, and ecological effects of Microplastic (MPs) in the aquatic environment. It should be noted that environmental conditions like UV exposure and low temperatures result in degradation of plastic materials, thus forming MPs. These MPs then get washed away by runoff to water bodies. The MPs were found to have higher accumulation levels close to urban settlements with considerable amounts observed in aquatic life forms. Additionally, MPs act as transport agents for dyes, heavy metals, and other chemicals. Ahmad *et al.,* (2025) studied the sources, effects, and degradation of microplastics (MPs) in marine ecosystems. This research paper mentions plastic waste, land-based activities, tourism, ships, and deposition of pollutants from the atmosphere as the main sources of microplastics. MPs tend to build up in marine ecosystems and have many negative effects on different types of species like planktons, invertebrates, fishes, and humans by affecting their physiological, reproductive, behavioral, and genetic processes.

Daily Essentials Contributions to Microplastic

Products that are deemed necessary to use every day and cosmetics are identified as key sources of primary microplastics. Cosmetic products such as face scrubs, shower gel, toothpaste, shampoo, sunscreen lotions, lipstick, and glitters in other cosmetics may contain artificial microplastics or microbeads, which act as exfoliates and provide a glossy finish (Sun *et al*., 2020). These particles are generally smaller than 5 mm and can pass through wastewater treatment systems, eventually entering rivers, lakes, and marine ecosystems Singh, & Mishra, 2023). Based on the findings from Liu *et al.,* (2024) microplastics have become an increasing concern as an indoor pollutant since kitchens have been identified as one of the sources of microplastic pollution owing to the extensive use of plastic food packaging, cooking equipment, storage materials, among others in homes. This study points out that microplastics may cause health problems through ingestion and inhalation mechanisms and some of the health problems associated with ingestion and inhalation of microplastics include inflammation, oxidative stress, metabolic problems, and so forth. Dzierżyński *et al*., (2024) explored recent literature on the presence of microplastics within human bodies and the possible influence of microplastics on carcinogenesis. It was found that humans have microplastics in their bodies due to microplastics ingestion, inhalation, and skin contact with microplastics, thus, accumulating the particles inside different body tissues and organs. According to the researchers, microplastics can cause such conditions as oxidative stress, chronic inflammation, cell injury, and endocrine disorders, which are considered risk factors for cancer. However, more research is necessary in this area. Agarwal *et al.,* (2025) highlighted that disposable paper cups, widely used for beverages, can release microplastic particles due to the degradation of their internal plastic lining. The study emphasized that frequent use of such products may contribute to daily human exposure to microplastics, raising concerns about potential environmental and health impacts. Stapleton and Hai (2023) recognized microplastics as an important environmental pollutant coming from different sources such as personal care products, man-made textiles, packing materials, and even the breakdown of large plastics, the prevalence of microplastics in all kinds of ecosystems raises major environmental and human health issues due to their persistence, possible toxicities, and capacity to carry dangerous chemicals. Jayavel *et al.,* (2024) explore the effect of micro- and nanoplastics on human health, emphasizing the growing prevalence of these substances in the environment and their possible pathways of entry into humans via ingestion, inhalation, and skin contact, micro- and nanoplastics have the ability to be deposited within human body tissues and lead to oxidative stress, inflammation, damage to the immune system, among other negative health effects. Campanale *et al.,* (2020) discussed the impact of microplastics and their associated chemicals on human health. Microplastics were shown to be able to carry toxins and could find their way into the body through ingestion, inhalation, and dermal contact. Microplastics could lead to inflammation, oxidative stress, and even disrupt endocrine and immune systems; however, more research needs to be conducted in order to determine long-term impacts. Mir *et al.,* (2025) investigated the presence of microplastics in food items and emphasized the rising incidences of microplastics being identified in various types of food products. In their investigation, the authors stated that the presence of microplastics in the food supply chain occurs through environmental pollution, food package material, and food processing techniques. In addition to the above, the study discussed novel artificial intelligence-based techniques for detecting microplastics in foods. Based on their study, the authors concluded that exposure to microplastics through foods is risky to human health, emphasizing the need for improved monitoring and mitigation strategies. Pop *et al.*, (2025) explored microplastics in their occurrence within daily activities and noted a number of less apparent sources such as household items, packages, textiles, and personal care goods. As is pointed out by the authors, such particles become released to the environment because of regular domestic activity and wastewater systems. It is important to mention the fact that there are simple means for decreasing microplastics occurrence, such as decreased use of single-use plastics and raising public awareness.

Control and Mitigation Strategies for Microplastics

Table 1 indicates control and mitigation strategies for microplastics with limitations. Mitigation of microplastic pollution calls for an all-encompassing strategy starting with the prevention process. Source minimization approaches, which involve minimizing the production and consumption of plastics, constitute the most effective mitigation strategy since they avoid microplastic creation even before they enter the environment (Osman *et al.,* 2023).

TABLE 1
Control and Mitigation Strategies for Microplastics with Limitations

Strategy Category	Method	Mechanism	Effectiveness	Limitations	References
Source Reduction (Primary Control)	Reduction of plastic production and use	Prevents formation of microplastics at source	Considered the most effective long-term strategy because prevention avoids downstream pollution	Requires major industrial change and policy enforcement	Osman *et al.,* (2023)
Product Regulation	Ban on microbeads in cosmetics & personal care products	Eliminates intentional microplastic inputs	Proven success in several countries (policy-driven reduction)	Does not address secondary microplastics	Kumar *et al.,* (2025)
Waste Management Improvement	Recycling, proper waste collection systems, extended producer responsibility (EPR)	Reduces leakage of plastics into environment	Strong reduction in macro- and microplastic generation	Inefficient in developing regions	Kumar *et al.,* (2025)
Advanced Oxidation Processes (AOPs)	UV, photocatalysis, oxidation	Degrades polymer structure	Can partially degrade microplastics	Energy intensive; incomplete mineralization	Al Alwan *et al.,* (2024)
Biological Treatment	Microbial degradation (bacteria, fungi, algae)	Enzymatic breakdown of polymers	Promising but currently slow degradation rates (0–15%)	Requires optimization of conditions	Pérez-García, *et al.,* (2025)
Adsorption Techniques	Biochar, activated carbon	Adsorbs microplastics onto surfaces	Low cost, flexible application	Saturation limits, regeneration needed	Priyadarshini *et al.,* (2026)
Policy & Governance Strategies	Plastic bans, circular economy, public awareness	Reduces generation and improves management	Essential for systemic reduction	Requires global coordination	Onyena *et al.,* (2022)

Policies such as the Microbead-Free Waters Act of 2015 (USA) and similar bans implemented in countries including the United Kingdom and Canada have been effective in reducing primary microplastic pollution from cosmetic products, but they do not address the issue of secondary microplastics (Kumar *et al.,* 2025). Moreover, technological measures will be necessary in dealing with already formed contamination of water bodies with microplastics. The advanced oxidation processes including ultraviolet radiation and photocatalysis may help in partial degradation of microplastic polymers; however, such methods are characterized by extremely high energy expenses and poor mineralization (Al Alwan *et al.,* 2024). In turn, biological decomposition by means of microorganism and enzyme action presents a more eco-friendly option; nevertheless, currently applied decomposition rates prove to be insufficient, which calls for optimization (Pérez-García *et al.,* 2025). Furthermore, adsorption with the use of biochar or activated carbon proves to be an economically efficient method; however, its performance is significantly hindered by such factors as saturation and need for material regeneration (Priyadarshini *et al.,* 2026). In addition to that, governance approaches involving restrictions concerning plastic usage and development of the circular economy strategy should also be incorporated; however, in order to be fully effective, those measures will have to be globally coordinated (Onyena *et al.,* 2022).

II. Conclusion

The existence of microplastics has become one of the common forms of environmental pollutants that are present everywhere in aquatic, terrestrial, and atmospheric environments. It is apparent from the literature review that microplastic contamination is sourced both from primary sources like personal care products, synthetic fibers, pellets, and tire particles, as well as secondary sources resulting from the breakdown of plastic materials. Human activities are the major source of microplastic pollution. Microplastics can be found in food, drinking water, and even within human tissue. The presence of microplastics poses health risks related to oxidative stress, inflammation, endocrine disorders, and potentially cancer.

One of the major research gaps is associated with the inadequate knowledge about the long-term effects on human health and the impacts of continuous exposure to plastic nanoparticles. Another research gap is related to the absence of a standardized system of detecting microplastics and measuring their impact, making comparison of the results obtained through various studies difficult. The directions for future research would include such aspects as creation of advanced systems for microplastics detection using AI and nanotechnologies, as well as developing efficient alternatives that could easily degrade. Policy actions will be focused on increasing international cooperation with regard to implementation of circular economy practices.

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