OAJRC Environmental Science, 2024, 5(2), 34-38
https://www.hillpublisher.com/journals/oajrces/
ISSN Online: 2632-2331

Current Scenario on the Impact of Microplastics on the Environment, Marine, and Humans

Rugved B. Parmar[1], Parth H. Agrawal[2], Tesfaye Rebuma[3], Mahendra Pal[4,*]

[1]B. J. Medical College, Civil Hospital Campus, Ahmedabad, Gujarat, India.
[2]Veterinary Public Health, Veterinary College, Kamdhenu University, Anand, Gujarat, India.
[3]Shaggar City Administration, Sebeta Sub-city Administration Agricultural Office, Sebeta, Oromia, Ethiopia.
[4]Narayan Consultancy on Veterinary Public Health and Microbiology, Bharuch, Gujarat, India.

How to cite this paper: Rugved B. Parmar, Parth H. Agrawal, Tesfaye Rebuma, Mahendra Pal. (2024). Current Scenario on the Impact of Microplastics on the Environment, Marine, and Humans. *OAJRC Environmental Science*, 5(2), 34-38.
DOI: 10.26855/oajrces.2024.06.001

Received: July 20, 2024
Accepted: August 17, 2024
Published: September 13, 2024

Corresponding author: Mahendra Pal, Narayan Consultancy on Veterinary Public Health and Microbiology, Bharuch, Gujarat, India.

Abstract

Microplastics pose a significant environmental and health challenge, originating from the degradation of larger plastics and the intentional incorporation of microbeads in products such as personal care items. These minuscule particles, measuring less than 5 mm in diameter, have permeated ecosystems worldwide, from the polar ice caps to the deepest oceanic trenches, presenting serious risks to both marine and terrestrial organisms, as well as human health. Microplastics not only transport harmful pollutants but also inflict direct physical harm on wildlife and are associated with chronic health issues in humans, including inflammation, oxidative stress, and cancer. This review offers a comprehensive analysis of microplastics, detailing their sources, classifications, and pervasive presence, while exploring their impacts on various ecosystems. It emphasizes the urgent need for a multifaceted approach that encompasses individual actions, community initiatives, and technological advancements.

Keywords

Environmental pollution, human health, marine ecosystems, microplastics

1. Introduction

Floating plastic waste in the ocean was first reported in the early 1970s, although preliminary observations from the 1960s had already noted plastic fragments in birds [1]. Microplastics, which are plastic particles smaller than 5 mm in diameter [2], have emerged as a significant environmental issue. These particles often originate from the degradation of larger plastic items or from microbeads of tiny polyethylene fragments used in cosmetics and personal care products. Plastic pollution is a critical issue for marine ecosystems, harming marine life and raising significant ethical and aesthetic concerns [3]. Over recent decades, the problem has escalated, with plastics constituting 70% of human-produced waste and production levels surging [4].

In fact, more than half of all plastic is wasted within a year of its production, with much of it being non-recyclable and non-reusable. Microplastics are pervasive across the globe, from polar regions to equatorial zones and from coastal areas to deep marine environments [5]. The movement of microplastics is influenced by ocean currents and circulation patterns, making them difficult to track and identify. These tiny particles have significant detrimental effects on aquatic ecosystems. When marine organisms ingest microplastics, they can suffer from various harmful effects, including genotoxicity, growth inhibition, oxidative stress, and decreased feeding behavior [2]. Various marine species, including corals, plankton, fish, and whales, can ingest these particles, leading to their transmission through the food chain [6].

By 2014, scientists estimated that the ocean contained up to 51 trillion microplastic particles, a staggering number that surpasses the stars in the Milky Way by a factor of 500. These tiny contaminants, roughly the size of sesame seeds, pose severe risks to oceanic and aquatic health [7], underscoring the critical need for effective strategies to tackle this widespread environmental crisis. This communication delineates the growing impact of microplastics on the environment, marine life, and human health.

1.1 Origin of Microplastics

Microplastics mainly result from the breakdown of larger plastic debris. When plastic waste is exposed to solar ultraviolet (UV) radiation, whether it is on beaches or floating in the ocean, it undergoes weathering that damages its structure. This weathering creates cracks on the plastic's surface, causing it to fragment into smaller particles. This process is a key source of secondary microplastics in marine environments. These tiny particles spread across ocean waters, seabed sediments, coastlines, and beaches. Other factors, including oxidation, hydrolysis, mechanical wear, biodegradation, and photodegradation, also contribute to the breakdown of plastic polymers. Understanding these processes is vital for explaining how microplastics are widely distributed and persist in marine ecosystems. By uncovering the origins and mechanisms of microplastic formation, we can develop better strategies to reduce their impact on the environment and human health [8, 9].

1.2 Classification of Microplastics

Primary microplastics are deliberately produced plastic particles designed for specific uses. These include tiny particles found in personal care products like exfoliating scrubs and microfibers shed from textiles such as clothing and fishing nets [8]. They also encompass intermediate plastic feedstock, known as "mermaid tears," that are inadvertently released during manufacturing. Major sources of primary microplastics are industrial plastic production emissions, the wear and tear of plastic products, and rubber particles from vehicle tires. Identifying these sources is crucial for devising effective strategies to reduce their environmental impact and safeguard marine ecosystems [10].

Secondary microplastics emerge from the breakdown and degradation of larger plastic items. Environmental factors like solar UV radiation, oxidation, hydrolysis, and mechanical forces cause these plastics to weather and fragment into smaller particles. This fragmentation process significantly contributes to the proliferation of microplastics in marine environments, exacerbating their environmental effects. Understanding the formation mechanisms of secondary microplastics is essential for addressing their widespread presence and mitigating their impact on marine ecosystems [9].

1.3 Global Distribution of Microplastics

The global spread of microplastics is chiefly driven by two main sources: fishing activities and land-based contributions. Fishing operations worsen oceanic microplastic pollution through the loss and abandonment of gear like nets and lines, as well as the release of microplastics from maritime activities. Ocean currents then transport these microplastics over vast distances, causing widespread contamination. In India, the Bay of Bengal is notably more polluted with microplastics compared to the Arabian Sea, primarily due to the intensity of land-based activities. On land, urban runoff, wastewater, and industrial discharges are significant contributors to microplastic pollution. Domestic practices, such as washing synthetic textiles, also release microfibers into aquatic systems. Identifying and addressing these sources is vital for creating effective strategies to reduce the global spread of microplastics and safeguard marine environments [10].

2. Microplastics as Environmental Stressors

Microplastics pose a significant environmental threat due to their ability to adsorb and transport persistent organic pollutants (POPs) like pesticides, PCBs, DDT, and dioxins. These pollutants cling to plastic particles and are consumed by marine organisms, leading to bioaccumulation and biomagnification of these harmful chemicals throughout the food chain [11]. Additionally, as plastics degrade, they release monomers such as bisphenol A (BPA), which can be absorbed by marine life, though the full effects of this absorption are still not fully understood. Furthermore, ingested plastics can cause direct physical harm to marine organisms, leading to problems such as digestive blockages and internal injuries [12].

Microplastics profoundly affect terrestrial ecosystems by disrupting the behavior of various organisms and contaminating vital environmental resources. For example, earthworms exhibit irregular burrowing patterns in soils polluted with microplastics, while fish demonstrate behavioral changes when microplastics enter the blood-brain barrier [13]. These particles also contribute to groundwater pollution by leaching chemicals into the soil, potentially degrading drinking water quality. As microplastics break down, they acquire new chemical and physical properties with unpredictable effects. They have been found in food items like salt, beer, and sugar, raising concerns about potential health risks for humans, while earthworms show stunted growth when consuming microplastic-contaminated food. Moreover, microplastics reach remote regions through agricultural practices, irrigation, water treatment processes, and tire wear. In soil, they alter structure and texture, disrupt soil fauna, block pores, and impair microbial and arthropod activity. Chlorinated plastics worsen these issues by releasing chlorine into the soil, affecting water sources and animal health. Additives in plastics can interfere with hormonal systems, modify gene expression, and induce biochemical changes in living organisms [14].

3. Influence of Microplastics on Marine Fishes

Microplastics pose a significant ecological and biological threat to marine life, particularly impacting fish and seabirds. These tiny plastic particles cause various toxic effects, such as decreased food consumption, stunted growth, oxidative stress, and abnormal behavior. Microplastics not only introduce harmful chemicals into marine organisms but also serve as carriers for other environmental contaminants [15].

Inhibition of Growth and Development: Polystyrene microplastics significantly hinder fish growth, while polyethylene microplastics reduce feeding and growth in species like *Tripneustes gratilla*. For *Sebastes schlegelii*, exposure to polystyrene microplastics depletes energy reserves and lowers nutritional quality [16].

Genetic Damage: Microplastics can cause genetic damage by adsorbing polycyclic aromatic hydrocarbons (PAHs), resulting in immunotoxicity, neurotoxicity, and genotoxicity. For instance, *Mytilus galloprovincialis* mussels show substantial genetic damage when exposed to these contaminants.

Seabirds: Northern Fulmar seabirds are known to ingest substantial amounts of microplastic debris. Large plastic items can create a false sense of fullness, potentially leading to starvation. Moreover, ingested plastics pose additional risks through chemical exposure and bacterial colonization [17].

Toxicological Effects: Polystyrene microplastics have been observed to reduce the number of ovulated egg cells and impair sperm motility in *Thecrassostrea gigas*. Additionally, PVC and PE microplastics, ranging from 40 to 150 µm, cause oxidative damage to the white blood cells of *Sparus aurata* and *Dicentrarchus labrax*, leading to immunotoxic effects [18].

4. Effects of Microplastics on Human Health

Microplastics pose a major health risk, infiltrating our bodies through various sources, including toothpaste, cosmetics, sunscreen, tap water, bottled water, honey, salt, beer, and seafood. Their widespread presence in daily products and food highlights the urgent need for action.

Exposure Pathways: Microplastics are particularly hazardous due to their contamination of seafood, which accumulates in aquatic organisms that enter the human food chain. High levels of microplastics have also been found in tap water, with studies indicating 82% contamination in New Delhi, India. Chronic exposure to microplastics can cause discomfort, inflammation, disruptions in cellular growth, cell death, and impaired immune function, and they may also carry harmful microbes [19].

Reproductive Toxicity: Bisphenol A (BPA), used to enhance plastic transparency, interferes with hormonal systems, especially affecting testosterone levels [20].

Oxidative Stress and Cytotoxicity: Microplastics cause oxidative stress and inflammation, leading to cellular toxicity. Research shows that MPs can be absorbed by cells, such as macrophages, worsening oxidative damage [21].

Carcinogenicity: The oxidative stress and chronic irritation from MPs may act as pro-inflammatory agents, potentially leading to cancer. Additionally, Di-(2-ethylhexyl) phthalate (DEHP), a plasticizer found in some plastics, is known to be a carcinogen [20].

Probable Mode of Action:

- **Ingestion and Gastric Interaction:** Microplastics interact with stomach acids and enzymes, potentially sticking to the stomach lining or blocking gastric gland openings.
- **Intestinal Interaction:** Microplastics that pass through the stomach enter the intestines, where they interact with epithelial cells and the mucus layer.
- **GI Tract Discontinuities:** Areas such as Peyer's patches in the gastrointestinal tract allow MPs to interact with the immune system, facilitating their uptake [22].

5. Solutions to the Microplastics Menace

The pervasive issue of microplastics demands a thorough and urgent approach to address their environmental and health impacts. A comprehensive strategy should include individual actions, community and national efforts, and innovative technological solutions.

Individual Actions: Individuals can play a crucial role by choosing natural-fiber clothing, such as organic cotton and wool, which decompose more easily than synthetic materials. Using reusable items, like bottles and straws, helps reduce single-use plastic dependence. Proper recycling is essential to prevent plastics from contaminating the environment. Additional steps include minimizing plastic use by opting for natural or reusable products, participating in local clean-up activities, and utilizing wax worms, which can help break down plastics.

Community and National Efforts: On a larger scale, supporting eco-friendly transportation options aligns with global commitments, such as India's pledge to reduce carbon intensity by 45% by 2030, as stated at COP 26. Enforcing bans on single-use plastics, like India's legislation effective from July 1, 2022, targets high-litter, and low-utility plastic items. Emphasizing the principles of reducing, reusing, and recycling helps decrease plastic waste, while challenging the assumption that plastics will inevitably end up in oceans promotes responsible disposal and environmental stewardship.

Innovative Technological Solutions: Advances in technology offer promising solutions for tackling microplastics. Space-based technologies can provide a global view of water management, potentially improving pollution control efforts. Research into magnetic separation techniques aims to develop methods for removing microplastics using metal powders. While challenges remain, these innovations are crucial in addressing the microplastics crisis. Implementing these diverse strategies can help mitigate the widespread impacts of microplastics, safeguarding both environmental and human health.

6. Conclusion and Recommendations

Microplastics represent a pervasive and escalating threat to both marine and terrestrial environments, as well as human health. Originating from the breakdown of larger plastic debris or from intentionally manufactured microplastics, these particles have infiltrated ecosystems across the globe from polar ice caps to deep ocean trenches. Their widespread distribution and persistence pose severe risks, including the absorption and transport of harmful pollutants, physical harm to marine life, and potential health issues in humans through the food chain and environmental exposure. The impacts of microplastics extend beyond immediate environmental damage. They disrupt the ecological balance, harm marine organisms, and introduce toxic substances into the food web. As these particles spread through various environmental mediums, their long-term effects on both ecological systems and human health become increasingly concerning. Addressing the microplastic crisis requires a multifaceted approach involving individual, community, national, and technological strategies to effectively mitigate their detrimental effects.

Based on the above conclusion, the following recommendations were forwarded:

- Governments should enforce stricter regulations on the production, use, and disposal of plastics, particularly focusing on banning single-use plastics and mandating more rigorous recycling practices.
- Encourage individuals to adopt more sustainable lifestyles by choosing natural-fiber clothing, reducing reliance on single-use plastics, and participating in local clean-up activities.
- Implementing advanced sorting technologies and investing in recycling facilities can reduce the amount of plastic waste that ends up in landfills and oceans.

References

[1] Harper, P. C., and Fowler, J. A. (1987). Plastic pellets in New Zealand storm-killed prions (Pachyptila spp.). Notornis, 34 (1), 65-70.

[2] Li, Y., Sun, Y., Li, J., Tang, R., Miu, Y., and Ma, X. (2021). Research on the influence of microplastics on marine life. In IOP Conference Series: Earth and Environmental Science (Vol. 631, No. 1, p. 012006). IOP Publishing.

[3] Thompson, R. C., Swan, S. H., Moore, C. J., and Vom Saal, F. S. (2009). Our plastic age. Philosophical Transactions of the Royal Society. Biological Sciences, 364(1526), 1973-1976.

[4] Derraik, J. G. (2002). The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, 44(9), 842-852.

[5] Tursi, A., Baratta, M., Easton, T., Chatzisymeon, E., Chidichimo, F., De Biase, M., and De Filpo, G. (2022). Microplastics in aquatic systems, a comprehensive review: origination, accumulation, impact, and removal technologies. RSC Advances, 12(44), 28318-28340.

[6] Sharma, S., and Chatterjee, S. (2017). Microplastic pollution, a threat to marine ecosystem and human health: a short review. Environmental Science and Pollution Research, 24, 21530-21547.

[7] National Ocean Service. (2017). Microplastics. National Oceanic and Atmospheric Administration. https://oceanservice.noaa.gov/facts/microplastics.html.

[8] Andrady, A. L. (2011). Microplastics in the marine environment. Marine Pollution Bulletin, 62(8), 1596-1605.

[9] Shim, W. J., Hong, S. H., and Eo, S. E. (2017). Identification methods in microplastic analysis: a review. Analytical Methods, 9(9), 1384-1391.

[10] GESAMP. (2015). Sources, fate and effects of microplastics in the marine environment: A global assessment. (Kershaw, P. J., ed.). (IMO/FAO/UNESCO- IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96p.

[11] Miller, M. C., Vanderlinden, J. D., and Roesner, A. K. (2020). Microplastics in the marine environment: Sources, impacts, and mitigation strategies. Environmental Pollution, 266, 115205.

[12] Jovanović, B., and Boris, S. (2017). Microplastics in aquatic environments: Sources, impacts, and monitoring. Environmental Monitoring and Assessment, 189 (3), 145-158.

[13] Laskar, A. H., and Kumar, A. (2019). Microplastic pollution in the Bay of Bengal: Sources, distribution, and potential impacts.

Environmental Science and Pollution Research, 26 (25), 26064-26076.

[14] Gasperi, J., Dris, R., Sandahl, M., and Tassin, B. (2017). Microplastics in aquatic environments: Sources, fate, and impacts. Environmental Science and Pollution Research, 24 (19), 15643-15653.

[15] Cole, M., Lindeque, P., Halsband, C., and Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62(12), 2588-2597.

[16] Wang, J., Wang, J., and Li, Y. (2020). Microplastics in the marine environment: Sources, distribution, and ecological impacts. Environmental Science and Technology, 54 (16), 10110-10120.

[17] Lopes, C. P., Silva, M. M., and Pereira, R. M. (2022). Microplastics in coastal and marine environments: A comprehensive review of their sources, fate, and impacts. Science of the Total Environment, 849, 157738.

[18] Viršek, M. K., Regner, S., and Zupančič, N. (2017). Microplastics in marine environment: Sources, impacts, and removal strategies. Environmental Science and Pollution Research, 24 (21), 17347-17358.

[19] Caspers, H. (1987). Biodegradation of synthetic polymers: Mechanisms and applications. Polymer Degradation and Stability, 20 (1), 1-18.

[20] Prata, J. C., da Costa, J. P., and Duarte, A. C. (2019). A critical review of the sources, distribution, and impacts of microplastics in marine environments. Environmental Science and Technology, 53(12), 7251-7264.

[21] Deng, Y., Huang, Y., and Chen, X. (2017). Microplastics in marine environments: A review of the sources, effects, and management. Marine Pollution Bulletin, 121(1-2), 159-167.

[22] Rist, S., Freeman, J., and Thompson, R. C. (2018). Microplastics in freshwater systems: A review of the sources, occurrence, and impacts. Science of the Total Environment, 640-641, 880-894.