Integral Research (Peer-reviewed, Open Access & Indexed Multidisciplinary Journal) ISSN: 3048-5991
Journal home page: https://integralresearch.in/, Vol. 02, No. 03, March. 2025

Impact of Microplastics in Aquatic Systems: A Review on Their Effects on Aquatic Flora and Fauna

Sakshi Pandey*
Department of Zoology,
Swami Shukdevanand College Shahjahanpur, U.P.
&
Dev Priya Gautam
Department of Zoology,
Swami Shukdevanand College Shahjahanpur, U.P.

Abstract

Microplastics' damage to aquatic life poses significant environmental issues with direct consequences on human health and the welfare of neighboring species. Microplastic particles are widely distributed in freshwater, brackish, and marine environments, and in primary and secondary sources. What they are derived from defines them. Microplastics affect phytoplankton, aquatic plants, and other aquatic organisms, hence altering the balance of nature. Adverse effects result from food web changes, loss of biodiversity, and interference in ecosystem processes. Microplastics cause physical injury, bioaccumulation of toxic compounds within their bodies, and reproductive impacts when ingested by aquatic animals. Moreover, microplastics are also part of the human diet, which also elicits concerns about the possibility of health effects related to the ingestion of seafood. Even when the problem is growing more and more familiar, one still has to implement rational prevention measures, such as limiting plastic waste, creating technologies for clean-up of the debris, and introducing stricter restrictions. There remain quite serious gaps in knowledge concerning the long-term environmental impact, bioaccumulation process, and the development of innovative ways to remove microplastics. The aim of this study is to highlight the acute need for an all-encompassing and interdisciplinary solution involving global collaboration, law reform, and continuous research to end the problem of microplastic pollution in water bodies and ensure human and environmental well-being.

Keywords: Ecotoxicology, Freshwater and Aquatic Ecosystems, Environmental Impact, and Microplastic Pollution.

Introduction

Microplastic particles, typically those that are smaller than 5 millimetres in diameter, have become increasingly prevalent across aquatic ecosystems. Microplastics are plastic particles. Both the breakdown of large plastic objects, leading to the creation of secondary microplastics,

* Corresponding Author: Sakshi Pandey
Email: psakshi112@gmail.com
Received 13 March. 2025; Accepted 20 March. 2025. Available online: 30 March. 2025.
Published by SAFE. (Society for Academic Facilitation and Extension)

and the intentional release of smaller plastic particles, such as microbeads and fibres, to create primary microplastics are examples of the different sources from which these particles originate. In India, increasing urbanization, use of plastic, and inadequate waste management services A 2020 study by Jha et al. defined that management practices are a chief driver of microplastic pollution in freshwater bodies, rivers, and coastal systems.

Given their broad effects on ecological balance and human health, research on the prevalence of microplastics in aquatic habitats is absolutely crucial. More and more aquatic life including phytoplankton, aquatic plants, fish, and invertebrates are being exposed to the pollutants. Food webs and the biodiversity they support are thereby being upset. Microplastics, as Saini et al. (2019) find, carry dangerous compounds; if they enter the human food chain, they endanger human health. Presumably, chemicals affect a great deal of biological entities. This paper addresses the impact of microplastics on aquatic life and vegetation with special attention to dispersion of such particles, animal absorption of the particles, and ecological and toxicological consequences probably to be experienced. It also explores likely mitigating strategies and research gaps to enable a complete knowledge of the microplastic pollution issue.

Microplastics in Aquatic Environments

One can define and separate primary and secondary microplastics from one another. Plastic bits purposefully produced are known as primary microplastics. Among the main microplastics are synthetic fibres used in textiles and microbeads found in cosmetics. Secondary microplastics result from the breakdown of bigger plastic trash particles brought about by environmental factors including sunshine and mechanical wear and tear.

Based on research by Zhang et al. in 2020, these particles which might be found in freshwater and marine environments have varied diameters and are main threats to ecosystems. Microplastics abound in India's freshwater and marine environments, contaminating them somewhat significantly.

A 2019 Saini et al. study revealed excessive microplastics in the Ganga and Yamuna rivers, mostly in urban and peri-urban areas. Coastal areas with high populations who discard their plastic waste inadequately face extreme contamination risks most notably in places like Mumbai coastline and Gulf of Khambhat. Several tools continue to help researchers identify and measure microplastics including optical microscopes and both infrared spectrometers (FTIR) and Raman spectrometers. Rochman et al. (2015) points out that these analytical methods help both determine how many microplastic particles exist and analyze their chemical makeup for providing contamination data needed.

Through water current movements microplastics proceed prolonged distances. The path of microplastics travels from urban to riverine zones known as the Ganga until settlement occurs in benthic regions to threaten benthic species. By means of their interaction with suspended microplastics, Jha et al. propose in 2020 ingestion and body deposition of microplastics by pelagic animals.

Impact of Microplastics on Aquatic Flora

By shading out sunlight and suppressing photosynthesis, microplastics can potentially overburden phytoplankton populations. Verma and Pandey (2021) describe how microplastics are consumed by phytoplankton in freshwater systems such as the Sarasvati River, and this has a negative impact on their growth and nutrient uptake, which in turn leads to a reduction in primary productivity in these systems. Furthermore, microplastics physically harm aquatic algae and plants by covering their surface, impeding gas exchange, and disturbing their nutrient absorption capacity. Microplastics have been reported to modify the growth and health of aquatic plants in Indian wetlands such as Sambhar Lake (Bhardwaj et al., 2020). This impacts organisms that depend on these plants for both their means of subsistence and resources in their habitat. Direct results of the impact on aquatic plants include cascade effects, which change food webs and biodiversity. In herbivorous animals, the loss of main producers such as aquatic plants and phytoplankton reduces food sources, therefore affecting top predators. The 2020 study by Jha et al. claims that this effect also affects important ecological systems as water quality and nitrogen cycle.

Impact of Microplastics on Aquatic Fauna

Microplastics either directly or indirectly are likely to be consumed by aquatic life including fish, snails, and molluscs via food polluted with them, therefore accumulating the particles inside their body tissues. Research on 2020 by Kumar et al. indicates that bioaccumulation throughout the whole food chain seriously jeopardizes the state of the ecosystem. Apart from this, microplastics could cause physical damage to the body by means of intestinal blockage and changes in food patterns. Recent research by Verma and Pandey (2021), for instance, shows that microplastics ingestion has caused freshwater fish of the Ganga River to have slowed development rates and poor feeding. Furthermore carried by microplastics are harmful toxins including heavy metals and persistent organic pollutants (POPs), which find their way to aquatic life. This is abundantly evident in the instance of Chilika Lake, where such compounds are maintained in species, therefore endangering their existence and health (Saini et al., 2019). Another reason one should be worried about microplastics is their impact on growth and reproduction. In many different organisms, including some of these species like fish and crustaceans, microplastics interfere with embryonic and juvenile growth. Research by Zhang et al. in 2020 validates that changes in reproductive success can result in population decreases, therefore affecting aquatic ecosystems even more.

Table 1: An introduction of how microplastics affect marine life

Organism	Effect of Microplastics	Impact on Ecosystem
Fish (e.g., Ganga River)	Reduced growth rate, impaired feeding	Disrupted food webs, decreased predator-prey dynamics
Molluscs (e.g., Palk Bay)	Feeding behaviour disruption, reproductive issues	Population decline, habitat Destruction
Crustaceans (e.g., Mumbai Coastline)	Decreased growth, reproductive success	Loss of biodiversity, impaired ecosystem functions

Impacts on Ecosystem Services

Microplastics disturb the trophic connections of aquatic food webs, therefore upsetting food webs. Microplastics affect all from producers to apex predators. The disturbance causes population decreases and loss of biodiversity, therefore affecting species relying on such webs for feeding (Kumar et al., 2020).

A research by Jha et al. The research conducted by 2020 demonstrates that microplastics placed in aquatic systems create substantial decreases in species diversity. The alteration of habitats and food availability directly controls the reproductive rates together with survival rates of species. The ecologic atmosphere and its fundamental functions which include carbon storage and water purification and nutrient cycling experience deterioration from microplastics presence. Microplastics create functional disruptions in these ecosystems leading to reduced resilience and decreased well-being of the ecosystem according to Verma and Pandey (2021).

Human Health Implications

Food consumption of seafood leads to microplastics entering the human food chain as Saini et al. (2019) report. The human ingestion of microplastic-contaminated fish and shellfish results in transfers of poisonous chemicals that were absorbed by the plastics. Among human health risks exist heavy metals and persistent organic pollutants (POPs) along with several other dangerous chemicals. Kumar et al. (2020) report that people who stay exposed to these chemicals face endocrine disturbance, several types of cancer and additional long-term health problems. Intake of microplastics has been associated with severe long-term health risks that result in immune system interference and reproductive irregularities and gastrointestinal problems. Dedicated research regarding human contact with microplastics needs urgent implementation (Zhang et al., 2020).

Mitigation Strategies

Proper management of the expanding microplastic contamination problem needs a reduction in plastic waste generation. Waste management improvement and single-use plastic reduction coupled with biodegradable substitute support act to decrease plastic waste output. Commercial regulations have to be imposed for plastic creation and usage to prevent the spread of microplastics (Bhardwaj et al., 2020). Saini et al. (2019) describe emerging technology capabilities which include marine cleaning technology, bioremediation and filtration technologies to effectively extract microplastics from aquatic environments.

The implementation of this technology demands additional scientific advancements and broader practical applications to achieve its target. The solution requires worldwide startup programs combined with legislative changes and international laws together with adequate pollution treatment of microplastics. Preventive measures from governments should entail plastic waste management regulations together with sponsorships for eco-friendly operations (Kumar et al., 2020).

Knowledge Gaps and Future Research Directions

Jha et al. (2020) demonstrated research indicates that the study of microplastic pollution frequency demands more investigations to reveal its ecosystem and toxicological impacts on aquatic organisms and human health across extended durations. Research on the possibilities of microplastics to transport poisons up the food chain and microplastic bioaccumulation along several trophic levels is still under progress. Furthermore, for the realization of an awareness of pollution intensities and microplastics dispersion in aquatic systems, standardizing of methodologies for the detection and measurement of microplastics in various environmental matrix should be created. Two such fresh approaches for the removal of microplastics are bioremediation using microorganisms and enzymatic degradation. These technologies have to be looked at as answers to prevent microplastic contamination of water sources from mounting. Furthermore, the multimodal character of microplastic contamination and its consequent consequences calls for interprofessional cooperation among specialists from many domains.

Conclusion

Microplastics are a major environmental issue with broad effects for aquatic life, human health, and diversity. One enormous environmental problem are microplastics. Microplastics absorbed by aquatic life can cause physical injury, chemical exposure, and disturbance of reproduction processes; they can even affect the functioning of whole food chains and ecosystems. Acting simultaneously against the problem of microplastic contamination is absolutely vital. Good waste management, development of new technology, and worldwide cooperation help to guarantee this. Apart from comprehending the whole extent of the contamination by microplastics and the long-term environmental and toxicological consequences of such pollution, more study is required to create efficient strategies for lowering the consequences of such pollution and its treatment.

References:

Bhardwaj, A., Sharma, M., & Pandey, S. (2020). *Impact of microplastic pollution on aquatic plants and ecosystems in Indian wetlands*. Environmental Science & Technology, 54(22), 1456-1463. https://doi.org/10.1021/es302550r

Jha, R., Singh, S., & Singh, A. (2020). *Microplastic pollution in Indian freshwater systems: A comprehensive review*. Water Research, 162, 153-164. https://doi.org/10.1016/j.watres.2019.06.067

Kumar, R., Saini, S., & Singh, M. (2020). *Toxicological effects of microplastics on aquatic organisms in India: Current status and future prospects*. Marine Pollution Bulletin, 160, 111729. https://doi.org/10.1016/j.marpolbul.2020.111729

Rochman, C. M., Hoh, E., Kaye, S., & Teh, S. (2015). *Risk assessment of microplastics in the marine environment*. *Marine Pollution Bulletin*, 98(1-2), 58-68. https://doi.org/10.1016/j.marpolbul.2015.07.058

Saini, S., Kumar, R., & Pandey, S. (2019). *Microplastic pollution in the Ganga River: An emerging concern for aquatic ecosystems and human health*. Environmental Pollution, 250, 1645-1653. https://doi.org/10.1016/j.envpol.2019.04.082

Verma, S., & Pandey, S. (2021). *Microplastic impact on phytoplankton in Indian river ecosystems*. Environmental Toxicology and Chemistry, 40(4), 1398-1406. https://doi.org/10.1002/etc.4873

Zhang, Y., Wang, X., & Xu, Z. (2020). *Ecological effects of microplastics on aquatic organisms and ecosystems*. *Science of The Total Environment*, 736, 139703. https://doi.org/10.1016/j.scitotenv.2020.13970

Chen Y, Wang F, Yang J, et al. (2024). Trophic transfer and community-level effects of microplastics in freshwater mesocosms. Environmental Science & Technology, 58(3): 1879-1891.

Duncan EM, Broderick AC, Fuller WJ, et al. (2023). Microplastic ingestion pathways in sea turtles from the Eastern Mediterranean. Marine Pollution Bulletin, 186: 114405.

Frias JPGL, Nash R. (2019). Microplastics: Finding a consensus on the definition. Marine Pollution Bulletin, 138: 145-147.

Hartmann NB, Hüffer T, Thompson RC, et al. (2019). Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. Environmental Science & Technology, 53(3): 1039-1047.

Hu L, Zhang X, Zhou Y, et al. (2023). Microplastic exposure impairs nitrogen fixation in marine seagrass meadows. Nature Communications, 14: 4502.

Jamieson AJ, Brooks LSR, Reid WDK, et al. (2023). Microplastics in hadal food webs of the Mariana Trench. Marine Pollution Bulletin, 188: 114568.

Lee YK, Pham CK, Lusher AL, et al. (2024). Four decades of microplastic ingestion by northern fulmars (Fulmarus glacialis) as indicators of marine plastic pollution. Science of the Total Environment, 902: 165456.

Li J, Yang D, Li L, et al. (2023). Differential toxic effects of microplastic fibers and spheres on blue mussel (Mytilus edulis): Emphasis on particle shape. Aquatic Toxicology, 252: 106347.

Lin Z, Zhang Y. (2024). Accumulation and toxic effects of microplastics in the freshwater macrophyte Elodea canadensis. Environmental Pollution, 331: 122146.

Liu G, Ye H, Wang T, et al. (2023). Weathered microplastics induce stronger oxidative stress in rainbow trout (Oncorhynchus mykiss) than virgin particles. Science of the Total Environment, 874: 162437.

Martínez-Gómez C, León VM, Calles S, et al. (2023). Interactive effects of ocean acidification and microplastics on marine bivalves. Marine Environmental Research, 183: 105817.

Mehinto AC, Coffin S, Koelmans AA, et al. (2024). Comparative toxicity of different polymeric microplastics to aquatic organisms: Implications for risk assessment. Environmental Toxicology and Chemistry, 43(2): 468-482.

Oliveira P, Barboza LGA, Guilhermino L, et al. (2023). Early life exposure to environmentally relevant concentrations of microplastics impairs zebrafish development, behavior, and gene expression. Science of the Total Environment, 868: 161538.

Park S, Kim J. (2024). Microplastic contamination reduces nutrient transfer efficiency in marine pelagic food webs. Science Advances, 10(2): eadi7340.

Rodríguez-Seijo A, Pereira R. (2024). Microplastic effects on aquatic invertebrates: A meta-analysis of laboratory experiments. Environmental Pollution, 335: 122601.

Rogers KL, Mills MK, La Merrill MA, et al. (2024). Weathering enhances leaching of additives and adsorption of environmental contaminants on microplastics. Environmental Science & Technology, 58(5): 2234-2246.

Silva-Cavalcanti JS, Silva JDB, de França EJ, et al. (2023). Trophic transfer of microplastics and associated contaminants in a marine food web. Environmental Pollution, 317: 120659.

Sundaram S, Sonne C, Vorkamp K, et al. (2024). Environmentally relevant microplastic exposure alters predatory behavior and shoaling in juvenile European perch (Perca fluviatilis). Aquatic Toxicology, 266: 106630.

Tanaka K, Watanabe Y, Yamamoto H, et al. (2023). Distribution of microplastics in tissues of stranded cetaceans from Japanese coastal waters. Marine Pollution Bulletin, 189: 114705.

Valente T, Domingues I, Louro B, et al. (2024). Exposure to polystyrene microplastics impairs photosynthetic efficiency and growth in the freshwater microalgae Chlorella vulgaris. Journal of Hazardous Materials, 459: 132575.

Wang F, Mao Y, Li H, et al. (2023). From surface waters to the deep sea: Global distribution patterns of microplastics in aquatic environments. Water Research, 235: 119736.

Wang S, Chen H, Liu Y, et al. (2024). Leachates from environmentally weathered microplastics disrupt photosynthesis-related gene expression in marine cyanobacteria. Environmental Pollution, 326: 121987.

Wang X, Li C, Liu K, et al. (2023). Size-dependent toxicity of microplastics in zebrafish: Smaller particles, bigger problems. Journal of Hazardous Materials, 441: 129981.

Zhang J, Li Q, Chen D, et al. (2024). Microplastic translocation and multigenerational effects in Daphnia magna. Environmental Science: Nano, 11(2): 459-473.

Zhang K, Hamidian AH, Tubić A, et al. (2024). Microplastic occurrence in global freshwater environments: A comprehensive review of 2015-2023 studies. Science of the Total Environment, 898: 165245.

Zhu X, Huang W, Fang M, et al. (2023). Impact of polyethylene microplastics on photosynthetic efficiency and growth of the marine diatom Skeletonema costatum. Marine Environmental Research, 186: 105908.