



# Microplastics in Freshwater Ecosystems in India: A Comprehensive Review

**Bandana Kumari Soni, Assistant Professor**

Department of Zoology

Jai Prakash University, Chapra, Bihar

## Abstract

Microplastics—plastic particles smaller than 5 mm—are now recognized as pervasive pollutants with potential ecological and health consequences. In India, freshwater ecosystems such as rivers, lakes, and wetlands serve as critical lifelines for biodiversity, agriculture, and drinking water. However, these ecosystems are increasingly contaminated by microplastics derived from diverse anthropogenic sources. This review synthesizes existing research on the sources, distribution, ecological effects, and management strategies of microplastic pollution in Indian freshwater ecosystems. It also identifies key research gaps and policy needs to address this emerging environmental challenge.

## 1. Introduction

India faces severe plastic waste management challenges due to rapid urbanization, industrialization, and population growth. Plastics constitute a significant portion of municipal solid waste, much of which is mismanaged and ultimately enters aquatic environments. Once in the environment, these plastics degrade into microplastics through physical, chemical, and biological processes.

Freshwater ecosystems—rivers like the Ganga and Yamuna, lakes such as Dal and Loktak, and numerous wetlands—are vital for ecological stability and human livelihoods. However, increasing evidence indicates that these water bodies are now repositories for microplastic pollutants, which may disrupt aquatic food webs and threaten water quality. This review consolidates the current understanding of microplastic contamination in India's freshwater systems and explores its ecological and public health implications.

## 2. Sources and Pathways of Microplastics

Microplastics in Indian freshwater systems arise from two main sources:

### 2.1 Primary Sources

Personal care products: Microbeads used in toothpaste, exfoliating scrubs, and cosmetics.

Industrial processes: Abrasive blasting media, textile fibers, and plastic pellets (nurdles).

### 2.2 Secondary Sources

Fragmentation of larger plastics: Breakdown of bottles, packaging, and fishing gear.

Tire wear particles: Significant in urban runoff.

Synthetic textile fibers: Released during laundry and discharged through wastewater.

## 2.3 Pathways into Freshwater Systems

Urban runoff carrying litter and stormwater waste.

Discharge from wastewater treatment plants (WWTPs) that are often inefficient in microplastic removal.

Industrial effluents from textile, paint, and plastic manufacturing sectors.

Agricultural runoff from mulching films and fertilizers containing plastic residues.

Atmospheric deposition of airborne microplastics, particularly in urban areas.

## 3. Distribution in Indian Freshwater Ecosystems

Numerous studies have confirmed widespread microplastic contamination:

Ganga River: High microplastic concentrations in Varanasi and Kolkata regions (Sarkar et al., 2020).

Yamuna River: Abundant fibers and fragments linked to untreated domestic and industrial discharge.

Dal Lake (Jammu & Kashmir): Tourism-driven plastic waste contributes to notable microplastic levels.

Kolavai Lake (Tamil Nadu): Microplastic abundance up to  $6.1 \pm 2.5$  particles/L (2024 study).

Kumaraswamy Lake (Coimbatore): Microplastic load index indicates heavy pollution (2023 study).

Ousudu Lake (Puducherry): Preliminary studies report substantial microplastic occurrence (Varshini et al., 2025).

## 4. Ecological Impacts

Microplastics pose multiple threats to aquatic organisms and ecosystems:

Ingestion by aquatic species causes intestinal blockage, reduced feeding efficiency, and altered energy budgets.

Adsorption of pollutants: Microplastics can carry persistent organic pollutants (POPs), heavy metals, and pathogenic microorganisms.

Bioaccumulation and biomagnification: Contaminants move up the food web, impacting fish, birds, and mammals.

Habitat alteration: Sediment-bound plastics modify benthic habitats and reduce oxygen exchange.

## 5. Human Health Implications

Humans are exposed to microplastics primarily through:

Consumption of contaminated freshwater and seafood.

Inhalation of airborne microplastics.

Potential health effects include inflammation, oxidative stress, endocrine disruption, and possible carcinogenicity. Although quantitative exposure data in India are limited, the risks underscore the need for monitoring and preventive measures.

## 6. Mitigation and Management Strategies

### 6.1 Policy Interventions

Enforcement of Plastic Waste Management Rules (2016) and amendments to curb single-use plastics.

Implementation of Extended Producer Responsibility (EPR) across industries.

Development of microplastic-specific regulatory standards for water quality monitoring.

### 6.2 Technological and Infrastructural Measures

Upgrading WWTPs with membrane bioreactors and nanofiltration systems.

Promoting biodegradable plastics and circular economy models.

Enhancing solid waste collection and segregation at the community level.

### 6.3 Public Awareness and Education

Nationwide campaigns to reduce single-use plastics.

Promoting behavioral change toward sustainable consumption.

Supporting community-based clean-up initiatives for lakes and rivers.

### 6.4 Research and Monitoring

Standardization of sampling and analytical methodologies.

Establishing long-term microplastic monitoring programs.

Interdisciplinary research integrating ecology, toxicology, and socioeconomics.

## 7. Research Gaps

Limited geographical coverage—most studies focus on large rivers, ignoring smaller water bodies.

Insufficient understanding of toxicokinetics and dose–response relationships in local species.

Lack of longitudinal studies to assess temporal trends.

Need for modeling studies to predict microplastic transport and fate under Indian climatic conditions.

## 8. Conclusion

Microplastic pollution in India's freshwater ecosystems is an emerging environmental crisis with implications for biodiversity, water security, and human health. While research efforts are increasing, substantial gaps remain in understanding sources, dynamics, and long-term impacts. Integrated efforts—combining policy reform, scientific research, and public engagement—are essential to mitigate this growing threat and safeguard India's freshwater resources.

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