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Review of Micro-plastic And Heavy Metal Pollution in Indian Aquatic Ecosystems

Archana Meshram[1] and Pragati Sontakke[2]

Department of Zoology, Dr. Ambedkar College, Deekshabhoomi, Nagpur, MS, India
Email: drarchie1218@gmail.com[1], kamblepragati30@gmail.com[2]

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ABSTRACT

Micro-plastic pollution has emerged as a pressing environmental concern globally, with its detrimental impacts extending to aquatic ecosystem and human health. This review paper synthesizes the findings of recent studies on micro-plastic contamination in various aquatic environments across India. The comprehensive analysis encompasses investigations conducted in lakes, rivers, and marine habitats, highlighting the prevalence, sources, distribution, and ecological implications of micro plastics. Key findings reveal significant micro-plastic pollution in Indian lakes, rivers, and coastal areas, attributed to practices. The review underscores the need for expanded research efforts to fill knowledge gaps, especially in freshwater ecosystem, and emphasizes the importance of implementing effective mitigation strategies to address micro-plastic pollution comprehensively. Furthermore, the paper identifies avenues for future research, including standardized methodologies, interdisciplinary approaches, and targeted interventions to combat micro-plastic contamination and safeguard aquatic ecosystems and human well-being in India.

Keywords: Microplastics, Heavy metals, *Cirrhinus mrigala*, Ambazari Lake, Nagpur, Accumulation, Pollution, Environment health, Ecotoxicology, Water quality.

INTRODUCTION

India's aquatic ecosystems, including rivers, lakes, and coastal areas face growing threats from pollution, particularly from micro-plastics (Mps) and heavy metals. Micro-plastics, small plastic particles typically less than 5 mm in size, have become pervasive pollutants in the environment, originating from various sources such as plastic waste, industrial discharges, and urban runoff. These particles can persist in aquatic environments for extended periods, posing risks in aquatic organisms and potentially entering the food chain, including

human consumption. Similarly, heavy metals including substances like lead, cadmium, and mercury are toxic pollutants known to accumulate in sediments and biota, leading to adverse effects on ecosystem and human well-being.

Despite increasing awareness of the environmental impacts of micro-plastics and heavy metals, there remains a significant gap in understanding their prevalence and effects in Indian aquatic ecosystems. Limited research has been conducted to assess the extent of micro-plastic and heavy metal pollution, particularly in inland freshwater bodies and coastal areas. Therefore, there is a pressing need for comprehensive studies to evaluate contamination levels, sources and ecological implications of micro-plastics and heavy metals in Indian waters.

This review paper aims to synthesize existing studies on micro-plastics and heavy metal pollution in Indian aquatic ecosystems with a focus on rivers, lakes and coastal regions, By analyzing available literature and research findings, we seek to provide insights into the current state of pollution, identify key sources and pathways of contamination and assess potential risks to aquatic organism and human health. Understanding the extent and impacts of micro-plastic and heavy metal pollution in Indian waters makes it essential for developing effective management and mitigation strategies to safeguard the health and integrity of these valuable ecosystems.

The review will begin by examining studies conducted on micro-plastic pollution in Indian aquatic environments, It will explore the methodologies used for micro-plastic detection and quantification, including sampling techniques, laboratory analysis and characterization of micro-plastic types and sources. The review will then prevalence the distribution of micro-plastics in different water bodies across India and identifying factors contributing to their accumulation.

Furthermore, the review will explore research on heavy metal pollution in Indian aquatic ecosystems, focusing on studies assessing the concentrations, sources and coastal areas. It will examine methodologies for heavy metal analysis, including sampling protocols, chemical analysis techniques and assessment of metal bio-availability and toxicity. The review will discuss key findings regarding heavy metal contamination levels, spatial distribution patterns and potential risks to aquatic organisms and human health.

Through this comprehensive review, we aim to contribute to the understanding of micro-plastic and heavy metal pollution in Indian aquatic ecosystems and provide valuable insights for future research and management efforts. By identifying knowledge gaps and areas requiring further investigation, we hope to inform policymakers, researchers, and stakeholders about the urgent need for action to mitigate pollution and protect the health and integrity of India's aquatic environments.

Literature Review

Karan Satish *et al.* (2024) The study focused on evaluating micro-plastic pollution in 12 Indian lakes, examining methods across different compartments like surface and their water, sediments and biota and analyzing micro-plastic features and origins. It aimed to address the gap in research efforts across various regions of India, particularly highlighting the prevalence of micro-plastics in lakes. The presence of micro-plastics in these environments raises concerns about environmental impact, human health risks through the food chain and their potential as carriers of pathogenic microorganisms. Methodologies such as sieving, filtration, chemical characterization and the use of microscopy and spectroscopy were employed to detect and quantify micro-plastics in the lakes.

Chen *et al.* (2023) The study delves into the intricate interplay between micro-plastics (MPs) and heavy metals (HMs) and their detrimental effects on fish physiology. By focusing on the toxic ramifications of HM adsorption by MPs, the research illuminates a multifaceted understanding of the issue. It meticulously examines the impacts at individual, cellular and molecular levels, unrevealing a spectrum of consequences ranging from survival rates and feeding behaviors to cytotoxicity and gene expression changes. By elucidating these intricate mechanisms, the study not only provides valuable insights into the health of fish populations but also serves as a crucial resource for assessing the broader environmental pollution caused by the interaction of MPs and HMs.

Dhar *et al.* (2023) The study underscores the pervasive accumulation of micro-plastics in aquatic organisms gastrointestinal tracts, gills and hepatopancreas, leading to a myriad of health issues

including oxidative stress, immune system alterations and reproductive organ damage. Molecular analysis reveals gene expression alterations in fish associated with brain development and metabolic processes, indicating potential physiological impacts. Additionally, the disruption of the molting process in crustaceans by micro-plastics highlights broader ecosystem health concerns, emphasizing the intricate relationship between pollutants and aquatic inhabitants.

Agbekpornu *et al.* (2023) The study underscores the critical threat posed by micro-plastic pollution to marine organisms and human health, particularly along coastal areas and within ocean gyres where concentrations are highest. It reveals that marine organisms, mistaking micro-plastics for food suffer from digestive organ damage, choking and reduced reproductive output due to ingestion of chemical toxins. Urgent action is advocated to educate the public about the dangers of micro-plastic contributing products, emphasizing the need to mitigate risks and safeguard both marine ecosystems and human well-being from the detrimental impacts of micro-plastic pollution.

Sharma *et al.* (2023) The study underscores heavy metal pollution as a pressing global issue stemming from urbanization and industrialization, with detrimental effects in aquatic ecosystems. Hazardous heavy metals like Ni, Zn, Pb and others adversely impact aquatic flora and fauna, leading to growth retardation, physical anomalies and even extinction. These metals bio-accumulate in the food chain, necessitating monitoring of their concentrations in aquatic biota. Various technologies, including alkaline precipitation and phytoremediation, are employed for heavy metal removal with the latter being a green solution utilized in marine and terrestrial ecosystems. Urgent action is emphasized to assess and monitor heavy metal levels in water bodies to mitigate their toxic effects on both human health and the environment, highlighting the importance of implementing effective monitoring strategies and appropriate removal technologies to safeguard biodiversity and ecosystem health.

Ting Pan *et al.* (2023) The study reveals that human activities significantly influence the presence of micro-plastics(MPs) in lakes, particularly in urban areas where sources like wastewater treatment plants, landfills and personal care products contribute to higher MP abundance. Factors such as lake depth, areas and proximity to populated areas affect MP levels with higher densities observed in areas with more human activity. MPs exhibit vertical distribution in lakes with debris sinking into sediments while fibers migrate upwards. Colored MPs are more likely to be ingested by aquatic organisms, and black particles are prevalent in ice layers. Toxic effects on aquatic life include growth inhibition, metabolic disorders, oxidative stress, and the release of harmful additives, underscoring the need for further research on MP toxicity in lake ecosystems.

Davies *et al.* (2023) The study delineates primary and secondary sources of micro-plastics, revealing their detrimental effects on aquatic biodiversity, including toxic impacts and molecular level damage in fishes. It underscores the necessity of mitigating microplastic pollution through measures such as removing microbeads from products, enhancing plastic reuse and improving wastewater treatment. Ultimately, the research underscores the urgency of promoting sustainable practices to safeguard aquatic ecosystems, advocating for effective mitigation strategies to combat biodiversity preservation.

Abdullahi Yunusa *et al.* (2023) The study underscores the pervasive contamination of water and fish by heavy metals (HM) stemming from various natural and human activities such as industrial effluents, sewage discharge, mining and agricultural practices. It highlights the discharge of untreated industrial and sewage wastes, alongside the use of agricultural chemicals, as significant contributors to chemical contamination in aquatic environments. The review raises concerns about the introduction of pathogenic microorganisms into marine ecosystems and emphasizes the health risks posed to humans through the consumption of contaminated fish and water. In conclusion, the study advocates for measures to minimize toxicity, including improved industrial waste treatment, proper sewage disposal and reduced use of harmful agricultural chemicals, aiming to mitigate heavy metal contamination and safeguard both aquatic ecosystems and human health.

Sabilillah *et al.* (2023) The research identified micro-plastic contamination in the Code and Gajahwong streams, with fish showing accumulation in their digestive organs. Human activities in the surrounding

areas were identified as the main contributors to this pollution, indicating a lack of local environmental awareness. The predominant micro-plastics found were small green fibers made of low-density polyethylene, posing challenges for fish discernment between food and waste. Lead and cadmium associated with micro-plastics increase health risks through the food chain, highlighting concerns about long-term harm from fish consumption. The study categorized both streams as having a medium risk of micro-plastic contamination based on ecological and polymer hazard indices, emphasizing the necessity for mitigation efforts and ongoing education for sustainable management of the issue.

Neelavannan *et al.* (2023) The study underscores the escalating problem of micro-plastic (MPs) contamination in India's freshwater ecosystems, driven by increased plastic production and inadequate recycling. Limited research, comprising only 18 relevant papers, suggests a significant gap compared to marine ecosystems. Predominantly white fibers and fragment of polypropylene, polyethylene terephthalate and polyethylene constitute the most common polymers found. MPs enter freshwater through multiple pathways, including agricultural runoff, industrial effluents, tourism and plastic waste dumping. The abundance of MPs in freshwater equals or surpasses that in marine environments, raising concerns about human health impacts, as MPs have been detected in breast milk, blood samples and lungs. These findings underscore the urgent need for expanded research and mitigation strategies to combat MPs contamination in India's freshwater ecosystems.

Rajeshwari *et al.* (2023) The study focused on quantifying microplastics in Kolavai Lake, Tamil Nadu, revealing an average abundance of 6.1+/-2.5 particles/L in surface water. Fourier Transform Infrared Spectroscopy(FTIR) and SEM were conducted to determine microplastic composition and surface morphology. Higher microplastic concentrations were observed in water samples from Central and Southern Zones, potentially due to anthropogenic activities. A negative correlation between microplastic-to-zooplankton ratios ranging from o.05 to 0.74. The study underscores the significant threat of microplastics to the lake ecosystem, highlighting their potential to enter the food web and adversely affect aquatic organisms and the environment. Addressing microplastic pollution in freshwater systems is crucial to mitigate its adverse effects on both aquatic biota and human health.

Gayathri *et al.* (2023) The study assessed microplastic contamination in commercially edible freshwater and marine fishes from fish markets in Tiruchirappalli, Tamil Nadu, India. 200 fish samples from ten species were collected from four locations. The average microplastic abundance in the gastrointestinal tracts of these fishes was 5mg/species, raising concerns about food safety. Most microplastics were fragment types smaller than 5mm in diameter. The findings indicate widespread microplastic presence in fish from both freshwater and marine environments, highlighting the need for further research to understand ingestion mechanisms and associated risks accurately.

Bagde *et al.* (2023) The study observed variations in concentrations of microplastics (MPs) in water, sediment and black clams within Vembanad Lake, influencing their ability to transport heavy metals. While heavy metal levels within clams and MPs were generally below hazardous limits, a positive correlation was found between cadmium(Cd) concentration in clams and MPs, indicating a potential risk. The presence of MPs facilitates heavy metal transport to biota like black clams, leading to bioaccumulation and biomagnification within the food web. Health risk assessments, including estimated daily intake (EDI), target hazard quotient(THQ), hazard index(HI), and carcinogenic risk (CR), were conducted to evaluate the potential health hazards of consuming clams contaminated with heavy metals.

Nkosi *et al.* (2022) The study focused on analyzing microplastics in different aqueous environments, utilizing PVDF and PVDF modified with carbon nano-onions for separation. Microplastic concentrations varied across water sources, with the highest levels found in wastewater influent compared to effluent, tap water and lake water. Identified microplastics in the influent included high-density polyethylene, poly (1,4-butylene terephthalate), Nylon 12, and cellulose, sourced from establishments like hotels, houses, schools and industries. Toxic heavy metals like arsenic, copper and zinc were detected attached to microplastics, surpassing acceptable limits, likely originating from local mining activities. The presence of microplastics and heavy metals underscores the necessity for enhanced wastewater treatment

infrastructure, advocating for the integration of microplastic traps to mitigate environmental pollution before water release.

Zhao *et al.* (2022) The study underscores the prevalent presence of microplastics in freshwater environments, acting as non-point source pollutants with the capacity to readily migrate and interact with heavy metals and other pollutants. It reveals a significant enrichment effect of microplastics on heavy metals in these environments, with varying adsorption degrees influenced by multiple factors. The synergistic interaction between microplastics and heavy metals exacerbates their toxicity to aquatic organisms, posing substantial ecological risks and potential threats to human health. Overall, the research emphasizes the urgency of understanding and mitigating the Trojan-horse effect of microplastics and heavy metals in freshwater ecosystems to safeguard both ecological integrity and human well-being.

Genevieve *et al.* (2022) explores that the Microplastics, small synthetic particles roughly 5mm in size, are prevalent in freshwater sediments and water columns globally, with concentrations comparable to highly polluted marine sediments. Their presence in inland waterbodies ecologically significant, influencing key ecological processes and acting as carriers of toxic substances to aquatic organisms. Standardized immunological protocols are crucial for assessing microplastic concentrations across watersheds, aiding in environmental monitoring, policymaking and accurate modeling of contaminant cycling. Ensuring reproducible and comparable data requires strong quality assurance measures, integrating various disciplines like socioeconomics, hydrology, chemistry and ecotoxicology. Recommendations include developing Standardized sampling protocols, identifying sentinel species, establishing plastic budget models and studying interaction between aquatic biota, microplastic pollution and other stressors.

Simone *et al.* (2021) The baseline study on microplastics in Indian rivers revealed higher contamination in urban areas, particularly the Adyar River contributing significantly to pollution in the Bay of Bengal. It stressed the need for more research for accurate data and highlighted widespread contamination across different ecosystems. The study found correlations between microplastics and heavy metal levels in river sediments, emphasizing the urgency for effective management strategies to combat pollution and protect aquatic ecosystems.

Abraham *et al.* (2021) The study on heavy metal and trace metal contamination in the Vembanad Lake ecosystem, with a focus on the Cochin backwaters, highlights the pervasive presence of these pollutants, posing a significant threat to water quality and aquatic organisms. Bioaccumulation of heavy metals in various biota, such as fishes and bivalve mollusks, underscores the widespread contamination in the ecosystem. Exposure to metals like lead and cadmium induces histopathological changes in freshwater fish, indicating the harmful effects on aquatic life. Biomonitoring studies using these organisms contamination in oyster reef sediment the Mississippi Sound is not a major concern based on the analyzed data.

Vaid *et al.* (2021) The study sheds light on the limited research concerning microplastic provide crucial insights into pollution levels. Given these findings, urgent mitigation strategies are required to reduce pollution and safeguard biodiversity. Overall, addressing metal contamination is imperative for protecting the Vembanad Lake ecosystem and ensuring its long-term sustainability.

Shelby Goza *et al.* (2021) The study aimed to assess heavy metal composition in marine sediment from oyster reefs in the Mississipi Sound near Bay St. Louis. Analysis of sediment samples from six reef sites revealed concentrations ranging from 0.021ug/g for Cd to 1024ug/g for Fe, with calibration curves showing high accuracy for nine metals. Comparisons with literature values showed no metal concentrations exceeding sediment quality guidelines, although Pb levels approached the limit at some sites. Microplastics were also investigated, with potential implications for marine health due to their ability to absorb contaminants like heavy metals. Overall, the study suggests that heavy metal (MPs) pollution across various compartments of the Indian environment, including aquatic and terrestrial systems, the atmosphere and human consumables. While marine environments, especially along the south-east coast and in Tamil Nadu, have been extensively studied, there's a notable gap in understanding MPs sources, pathways and fate in freshwater systems and terrestrial and atmospheric environments. Additionally, contamination of human consumables like salt, drinking water, tap water, and seafood with

MPs raises concerns about potential health emphasizes the necessity for expanded investigations at both laboratory and field scales to comprehensively address MPs contamination and suggests the development of innovative removal techniques to mitigate environmental damage effectively.

Khalid *et al.* (2021) The study explores the relationship between microplastis (MPs) and heavy metals in the marine environments, nothing that aged or biofouled MPs have a higher adsorption capacity for metals. Factors such as solution pH, salinity and MP polymer type influence metal adsorption with certain polymers showing specific affinities for different metals. However, variations exist in heavy metal adsorption among different MPs types. The combined effects of heavy metals and MPs on aquatic and terrestrial plants, especially in areas with high human activity, remain uncertain. The study concludes that while research on MPs and heavy metals is growing, there's still lack of understanding of their combined toxic effects on various organisms, particularly in marine environments. It emphasizes the need for a multidisciplinary approach to assess the risks posed by MPs and heavy metals, highlighting the importance of extended monitoring studies across diverse ecosystems.

Gopinath *et al.* (2020) The study examined microplastic pollution in Red Hills Lake, Chennai, analyzing 32 sediment samples and six water samples. Microplastics concentrations were found to be 5.9 particles/L in water and 27particles/kg in sediment, with fibers, fragments, films and pallets being the most common types identified. High-density polyethylene, low-density polyethylene, polypropylene and polystyrene were the prevalent types of microplastics. Fishing activities, garbage dumps near the dam outlet, dry deposition, and sewage flow from nearby residential areas were identified as sources of microplastics. The presence of microplastics in both water and sediment raises concerns for human health and aquatic organisms due to potential absorption of contaminants and pathogens. The study underscores the necessity for further research on the impact of microplastics on biota and the effectiveness of water treatment facilities in removing these contaminants.

Sarkar *et al.* (2020) The study highlights microplastics as emerging contaminants with detrimental effects on aquatic ecosystems and human health. While marine environments are extensively studied, there's limited data on microplastic occurrence in India's freshwater ecosystems, especially rivers like Ganga, Netravathi and Sabarmati. Research on the Ganga river indicates lower microplastic levels compared to other rivers, with correlations found between microplastics in sediment and pollution parameters. These findings emphasize the need for further research and monitoring to understand microplastic contamination's extent and ecological impacts in Indian freshwater ecosystems. Urgent action is required to mitigate microplastic pollution's adverse effects, aligning with global efforts to combat plastic pollution.

Kastratovic *et al.* (2014) The study focused on metal concentrations in the Skadar Lake ecosystem, revealing bioaccumulation within Ceratophyllum demersum (C. demersum) with sediment exhibiting the highest levels followed by plant parts and water. Variations in metal content were noted across plant parts, with manganese (Mn) accumulating significantly higher than other metals. Seasonal fluctuations were observed, with certain metals being more prevalent at different stages of the plant's growth. Translocation ability (TA) was used to gauge the plant's capacity to transport metals, with higher TA values indicating greater translocation ability. The paper concludes by underlining C. demersum's role as a bio-indicator of metal pollution in lacustrine system, noting differences in metal accumulation patterns across plant parts and seasons, offering valuable insights into metal uptake and distribution dynamics within the species.

Bilyk *et al.* (2012) The study aimed to assess heavy metal pollution in Vyrlytsa Lakes biota using atomic absorption spectroscopy. Results revealed significant accumulation of heavy metals in aquatic plants, fish and snails, indicating potential contamination and environmental concerns. The findings underscore the necessity of monitoring heavy metal pollution in lakes like Vyrlytsa to mitigate ecological risks. Further research and management strategies are crucial to address and reduce the impact of heavy metal contamination on the lake's biota and ecosystem.

Literature Gap:

The existing body of literature extensively explores microplastic and heavy metal pollution in various Indian aquatic ecosystems, yet a notable gap persists regarding studies focusing specially on the

accumulation of these contaminants in *Cirrhinus mrigala* (Hamilton, 1822) from Ambazari Lake in Nagpur. While numerous studies highlight the prevalence and ecological impacts of microplastics and heavy metals in lakes, rivers and coastal areas across India, the investigation of contamination levels in *Cirrhinus mrigala* from Ambazari Lake remains unaddressed. Understanding the extent of contamination in this fish species is crucial for assessing environmental health and potential human health risks. Targeted research efforts are needed to fill this gap, involving the analysis of fish tissues for microplastics and heavy metals to enhance our understanding of contaminant dynamics in Ambazari Lake and contribute to its effective management and conservation

CONCLUSION

In conclusion, the review of recent studies on microplastic contamination in various aquatic environments across India highlights the pervasive nature of this environmental concern. The synthesis of findings underscores the significant prevalence, sourced, distribution and ecological implications of microplastics in Indian lakes, rivers and coastal areas. Moreover, the review emphasizes the urgent need for expanded research efforts to address knowledge gaps, particularly in freshwater ecosystems and advocates for effective mitigation strategies to combat microplastic pollution comprehensively. Additionally, the identification of avenues for future research, including standardized methodologies, interdisciplinary approaches and targeted interventions, underscores the importance of continued efforts to safeguard aquatic ecosystems and human well-being in India. Overall, this review provides valuable insights into the current state of microplastic pollution in Indian waters and highlights the imperative for concerted action to mitigate its adverse effects.

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Correspondence and requests for materials should be addressed to Archana Meshram

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