Assessment of Microplastics Contamination in Freshwater Ecosystems at Gomti River

Priyanshu AP[1], Dr Arif Siddiquie[2]
[1]*P.G. Student, Department of Civil Engineering, Amity University, Uttar Pradesh, Lucknow, India*
[2]*Associate Professor, Department of Civil Engineering, Amity University, Uttar Pradesh, Lucknow, India*

Abstract- Microplastic contamination in freshwater ecosystems has emerged as a significant environmental concern due to its pervasive presence and potential ecological and human health impacts. This paper provides a comprehensive assessment of the sources, distribution, and ecological consequences of microplastic pollution in freshwater environments The study examine the pathways through which microplastics enter these ecosystems, including urban runoff, wastewater effluents, and atmospheric deposition. The paper highlights the detrimental effects of microplastics on aquatic organisms, ranging from physical harm to chemical toxicity, and discusses the implications for biodiversity and ecosystem services. Additionally, we evaluate current methodologies for detecting and quantifying microplastic contamination, identifying key challenges and areas for improvement. A critical analysis of existing remediation strategies is conducted, encompassing physical, chemical, and biological approaches to mitigate microplastic pollution. We also explore innovative technologies and policy frameworks aimed at reducing microplastic release and enhancing ecosystem resilience. The findings underscore the urgent need for integrated management practices and collaborative efforts to address the multifaceted issue of microplastic contamination in freshwater ecosystems. This paper contributes to the growing body of knowledge essential for developing effective solutions to safeguard aquatic environments and public health from microplastic pollution.

Keywords: Microplastics Contamination, Freshwater River Ecosystems, Environmental Impacts, Remediation Strategies

I INTRODUCTION

Microplastics are synthetic, high-molecular-weight compounds that have been reduced to particles smaller than 5 mm. Due to their low biodegradation rate, these particles persist in the environment and can negatively impact human health as they move through the food chain. They are typically formed from the breakdown of larger plastic items, such as packaging materials, that are improperly discarded. These microplastics are prevalent in oceans, remote islands, and polar regions, posing significant threats to ecosystems due to their role as environmental pollutants. Current data on the sources and total amounts of microplastics in terrestrial and marine environments is insufficient. Various human activities and products, including laundry, tire wear, urban dust, road paint, maritime activities, and cleaning agents, contribute to microplastic pollution. Despite reports of microplastic contamination in marine and freshwater ecosystems, the atmosphere, and human bodies, further research is needed to pinpoint their origins and assess their impacts.

Due to their small size, microplastics are easily ingested and can travel through the food chain, persisting in the environment due to their resistance to biodegradation. Their minute size, ranging from micro to nano levels, makes them nearly impossible to remove once they have entered the environment. This persistence poses hazards to both humans and wildlife. Marine organisms, for example, can suffer physical and mechanical harm from ingesting microplastics, which may also introduce ecotoxic substances such as unreacted monomers, impurities, additives, dyes, lubricants, or plasticizers. Microplastics can enter the human body if they are not effectively filtered out by sewage treatment processes or can end up in the ocean, affecting both ecosystems and human health.

1.1 Microplastics: Sources, Types, and Characteristics

Microplastics, encompasses both primary microplastics, manufactured as small particles, and secondary microplastics resulting from the breakdown of larger plastic items. Based on their size and origin, microplastics can be classified into primary microplastics like microbeads, microfibers and secondary microplastics such as fragmented plastic debris.

1.1.1 Sources of Microplastics

Microplastics enter freshwater ecosystems through various pathways, including:

- Fragmentation of plastic debris: Larger plastic items such as bottles, bags, and packaging materials break down over time due to mechanical, chemical, and environmental processes, releasing microplastic particles.
- Microbeads in personal care products: Many cosmetics, personal care, and cleaning products contain microbeads made of plastic polymers, which are washed down the drain and enter waterways. [21]
- Synthetic textile fibers: Synthetic fabrics like polyester, nylon, and acrylic shed microfibers during washing, which are discharged into wastewater and eventually reach freshwater bodies.
- Plastic pellets and nurdles: Raw plastic pellets used in manufacturing processes and nurdles (pre-production plastic pellets) are transported via rivers or accidental spills, contributing to microplastic pollution.
- Municipal and industrial wastewater effluents: Microplastics are present in effluents discharged from wastewater treatment plants, industrial facilities, and agricultural runoff, entering freshwater ecosystems.

1.1.2 Types of Microplastics

Microplastics can take various forms, including:
- Microbeads: Spherical or irregularly shaped plastic particles used in cosmetics, personal care products, and abrasive cleaners.
- Microfibers: Thin strands of plastic released from synthetic textiles during washing, drying, or wear and tear.
- Microfragments: Small fragments of degraded plastic materials originating from larger plastic items through mechanical or chemical processes.
- Microfilms: Thin layers or coatings of plastic materials formed on the surface of freshwater bodies due to weathering and degradation of plastic debris.

1.1.3 Characteristics of Microplastics

Microplastics exhibit diverse physical and chemical properties, influenced by factors such as polymer composition, size, shape, density, and surface characteristics. These properties play a crucial role in their transport, fate, and interactions within freshwater ecosystems. [3] Common polymers found in microplastics include polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC). Additionally, microplastics can adsorb and accumulate various pollutants such as heavy metals, organic contaminants, and microbial pathogens, further exacerbating their environmental impacts. [21]

1.2 Distribution and Fate of Microplastics in Indian River system

India is endowed with diverse freshwater ecosystems, [4] including rivers, lakes, reservoirs, ponds, wetlands, and groundwater aquifers, which play vital roles in supporting biodiversity, agriculture, fisheries, and human livelihoods. The major river systems in India, such as the Ganges, Yamuna, Brahmaputra, and Godavari, serve as lifelines for millions of people, providing water for drinking, irrigation, and industrial purposes.

Rivers act as conduits for transporting microplastics from upstream sources to downstream reaches, where they can accumulate, degrade, or be transported further downstream or to marine environments. . [1] [10] [14] [15] In India, major rivers such as the Ganges, Yamuna, Brahmaputra, and their tributaries are highly susceptible to microplastic pollution due to anthropogenic activities along their banks, including urbanization, industrialization, agriculture, and improper waste management practices. Studies have reported the presence of microplastics in various Indian rivers, with higher concentrations observed near urban centers, industrial zones, and wastewater discharge points. The distribution of microplastics in rivers is influenced by hydrological factors such as flow velocity, sediment dynamics, and seasonal variations, as well as the input of microplastics from point sources and non-point sources. [10][22]

1.3.Factors Influencing the Fate of Microplastics

The fate of microplastics in Indian freshwater [6] ecosystems is influenced by a complex interplay of physical, chemical, biological, and hydrological processes, including:
- Transport pathways: Microplastics can be transported via surface water flow, sediment transport, atmospheric deposition, and biological vectors such as aquatic organisms and migratory birds.
- Deposition and sedimentation: Microplastics can settle and accumulate in sediments, where they may undergo burial, resuspension, or re-sedimentation processes.
- Sorption and desorption: Microplastics can adsorb and desorb contaminants such as heavy metals,

organic pollutants, and microbial pathogens, altering their environmental fate and bioavailability.
- Biofilm formation: Microplastics can serve as substrates for microbial colonization, leading to the formation of biofilms that facilitate the transfer of pollutants and nutrients in aquatic ecosystems.
- Trophic transfer: Microplastics can enter the food web through ingestion by aquatic organisms, leading to bioaccumulation and biomagnification of plastic-associated contaminants.
- Weathering and degradation: Microplastics can undergo physical and chemical weathering processes such as abrasion, photodegradation, and hydrolysis, resulting in size reduction, surface alteration, and fragmentation over time

1.4 Impacts of Microplastics Contamination on Indian Freshwater Ecosystems

The following are the major impacts of microplastic Contamination on Indian freshwater ecosystems:

1.4.1 Physical Impacts

Microplastics can cause physical harm to freshwater organisms through ingestion, entanglement, abrasion, and obstruction of digestive tracts. In Indian freshwater ecosystems, microplastics have been found to affect a wide range of organisms, including fish, crustaceans, mollusks, amphibians, and aquatic insects. Studies have reported instances of fish ingesting microplastics, leading to intestinal blockages, reduced feeding efficiency, altered behavior, and reproductive impairment. Microplastic fibers can entangle and suffocate aquatic organisms such as turtles, birds, and mammals, leading to injury or death. Additionally, microplastics can act as carriers for other pollutants such as heavy metals, pesticides, and pathogens, exacerbating their physical impacts on freshwater organisms. [23]

1.4.2 Chemical Impacts

Microplastics can serve as vectors for transporting and releasing various chemical pollutants into freshwater ecosystems, including persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), phthalates, bisphenol A (BPA), and heavy metals. These pollutants can adsorb onto the surface of microplastics or partition into their polymer matrix, leading to the accumulation and bioavailability of contaminants in aquatic environments. In Indian freshwater ecosystems, microplastics have been found to sorb and desorb a wide range of chemical pollutants, posing risks to aquatic organisms and human health. Studies have documented the presence of POPs such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) associated with microplastics in Indian rivers, lakes, and wetlands, highlighting the potential for long-range transport and biomagnification of toxic compounds in freshwater food webs. [8]

1.4.3 Biological Impacts

Microplastics can exert biological impacts on freshwater organisms through direct and indirect mechanisms, including ingestion, toxicity, immune suppression, reproductive impairment, and alteration of microbial communities. In Indian freshwater ecosystems, microplastics have been found to affect the physiology, behavior, and ecological interactions of aquatic organisms, leading to population-level effects and ecosystem-wide consequences. For example, microplastic ingestion can cause nutritional deficiencies, energy depletion, and growth inhibition in zooplankton, leading to cascading effects on higher trophic levels such as fish and birds. Furthermore, microplastics can disrupt microbial communities in sediments and water columns, affecting nutrient cycling, carbon sequestration, and ecosystem functioning in Indian wetlands and lakes. [7] [9]

1.4.4 Ecological Impacts

Microplastic contamination can have profound ecological impacts on Indian freshwater ecosystems, including changes in species composition, community structure, ecosystem dynamics, and ecosystem services. Invasive species such as water hyacinth (Eichhornia crassipes) and water lettuce (Pistia stratiotes) can serve as vectors for microplastics, facilitating their transport and accumulation in Indian water bodies. Microplastic pollution can alter habitat availability, food availability, and reproductive success for native species, leading to shifts in community assemblages and trophic interactions. Additionally, microplastics can affect the functioning of freshwater ecosystems, including nutrient cycling, primary production, and carbon storage, with implications for water quality, fisheries, and recreational activities. [24]

1.5 Analytical Techniques for Microplastic Detection and Quantification

The analytical techniques for microplastic detection and quantification include the following:

1.5.3 Visual Inspection

Visual inspection is a simple and cost-effective method for detecting and quantifying macroscopic microplastics (>1 mm) in environmental samples such as water, sediment, and biota. In India, visual surveys have been used to assess the abundance and distribution of microplastics on beaches, riverbanks, and urban landscapes, providing valuable insights into sources, hotspots, and seasonal variations of plastic pollution. However, visual inspection is limited to larger particles visible to the naked eye and may underestimate the abundance of microplastics below the detection threshold.

1.5.2 Spectroscopic Analysis

Spectroscopic techniques such as Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy are commonly used for identifying and characterizing microplastics based on their chemical composition, molecular structure, and surface functional groups. In India, FTIR analysis has been widely employed to identify polymer types and additives in microplastic samples collected from freshwater ecosystems, providing information on sources, pathways, and fate of plastic pollution. Raman spectroscopy offers complementary capabilities for microplastic analysis, enabling rapid and non-destructive identification of polymer particles in complex matrices.

1.5.3 Microscopic Techniques

Microscopic techniques such as optical microscopy, scanning electron microscopy (SEM), and transmission electron microscopy (TEM) are essential tools for visualizing, counting, and measuring microplastics in environmental samples. In India, optical microscopy has been extensively used to quantify microplastics in water, sediment, and biota samples from freshwater ecosystems, allowing researchers to assess particle size, shape, and color characteristics. SEM and TEM provide higher resolution imaging of microplastics, enabling detailed morphological analysis and surface characterization for individual particles. However, microscopic techniques require sample preparation, image processing, and expertise in particle identification, which can be time-consuming and labor-intensive.

1.5.3 Chemical Analysis

Chemical analysis techniques such as gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS) are used to quantify organic pollutants associated with microplastics in environmental samples. In India, GC-MS analysis has been employed to measure concentrations of POPs, PAHs, phthalates, and other chemical contaminants sorbed to microplastics collected from freshwater ecosystems. LC-MS techniques offer high sensitivity and selectivity for analyzing complex mixtures of organic compounds in microplastic samples, providing valuable information on pollutant profiles, partitioning behavior, and environmental risks. However, chemical analysis requires specialized instrumentation, sample extraction, and quality assurance procedures, which may pose challenges for routine monitoring and large-scale studies in resource-limited settings.

II. STUDY OF GOMTI RIVER IN LUCKNOW

2.1 Site Description:

Lucknow, the capital of Uttar Pradesh, is situated along the Gomti River. The study area encompasses a segment of the Gomti River within Lucknow city, extending from 80.899893 to 80.968180 N latitude and 26.886799 to 26.833321 E longitude. In order to comprehensively assess the physical, chemical parameters, and heavy metal content of the Gomti River in Lucknow, eight distinct sites were carefully chosen for sampling and analysis. Sampling activities are conducted monthly from January to February.

Four eight sites were strategically selected to represent different segments of the Gomti River. Samples are collected from each designated point located in the middle of the river, and the coordinates of these sampling points are meticulously recorded in the field using GPS technology.

Table 1: Selected Site locations

S. No.	Locations	Latitude	Longitude
1	Kudia Ghat	80.909700	26.878021
2	Hanuman Setu	80.93344	26.86001
3	Barrage	80.93627	26.85904
4	Pipra Ghat	80.96759	26.83310

2.2 Sampling Procedure

The water samples were gathered using pre-cleaned polyethylene bottles or containers with a capacity of 1000 mL, following the prescribed procedure outlined by APHA AWWA WEF (23rd edition) to ensure the integrity of the samples and accurate analysis of selected parameters, thus preventing any potential contamination during collection, storage, and subsequent analysis.

After collection, each sample was tightly sealed to prevent leakage and safeguard against contamination from external pollutants during handling and transportation. The bottles were meticulously labeled with the date, location, and water source to facilitate identification during chemical analysis. All collected samples were promptly preserved in a cold environment and transported to the laboratory, where they were stored at 4 °C until ready for final chemical analysis. For the analysis of heavy metals, separate samples were taken in 500 mL tarson bottles, diluted with concentrated nitric acid, and subsequently analyzed for heavy metal content.

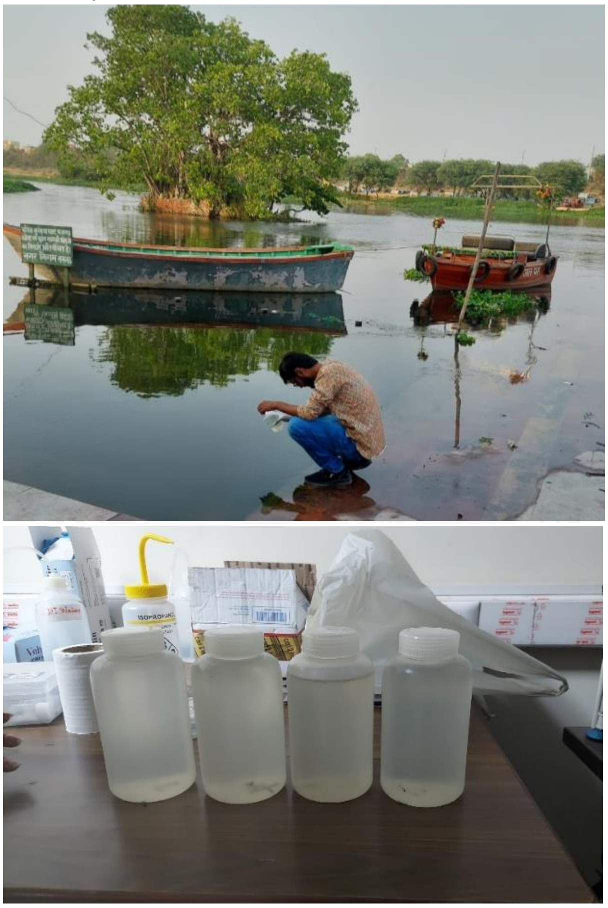

Figure 1; Collection of Sample

III RESULT AND DISCUSSIONS

The collected samples analysed for microplastics content revealed the following:

S.No.	Locations	Average number (±SD) of plastic particles (pcs/ m3)
1	Kudia Ghat	1.1 ± 0.1
2	Hanuman Setu	1.9 ± 0.4
3	Barrage	0.7 ± 0.2
4	Pipra Ghat	0.8 ± 0.1

The results indicate that microplastics are pervasive in various environmental compartments, with significant ecological and human health implications. While advancements in detection and mitigation provide a basis for addressing the issue, comprehensive strategies encompassing policy, technology, and public engagement are essential for effective management and reduction of microplastic contamination. Further research is needed to understand the long-term impacts and develop innovative solutions to this global challenge.

IV CONCLUSION

Policy and regulatory interventions are essential for addressing microplastic pollution through measures such as legislation, enforcement, monitoring, and stakeholder engagement. In India, policy frameworks such as the Plastic Waste Management Rules, 2016, and the Extended Producer Responsibility (EPR) framework provide legal mechanisms for regulating the production, use, and disposal of plastic products, including microplastics. State governments, municipal authorities, and environmental agencies play key roles in implementing and enforcing plastic waste management regulations, conducting pollution monitoring, and promoting sustainable practices in industries, municipalities, and communities. Additionally, international agreements such as the Stockholm Convention on Persistent Organic Pollutants (POPs) and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes provide frameworks for addressing global plastic pollution and its impacts on human health and the environment. Collaborative efforts between government agencies, research institutions, NGOs, industries, and civil society are essential for developing and implementing effective policy solutions to microplastic contamination in Indian freshwater ecosystems.

However, there are technical and economic constraints in dealing with the management of microplastics. The technical challenges in addressing microplastic pollution include limitations in detection and quantification methods, complexity of pollution pathways, and lack of standardized protocols for sampling and analysis. In India, limited infrastructure, expertise, and resources for microplastic research and monitoring pose challenges for assessing the extent and impacts of plastic pollution in freshwater ecosystems.

Furthermore, variability in microplastic characteristics, spatial heterogeneity, and temporal dynamics of pollution sources complicate efforts to develop effective remediation strategies and management practices.

Economic constraints in addressing microplastic pollution include costs associated with research, monitoring, remediation, and compliance with regulatory requirements. In India, competing priorities for funding, investment, and resource allocation limit the capacity of government agencies, research institutions, and NGOs to tackle plastic pollution effectively. Additionally, reliance on conventional waste management practices, lack of incentives for sustainable practices, and inadequate infrastructure for waste collection, recycling, and disposal contribute to the persistence of plastic pollution in freshwater ecosystems.

It can be concluded that microplastics contamination poses significant environmental, economic, and public health challenges for Indian freshwater ecosystems, requiring urgent action from policymakers, researchers, industries, and civil society to address this complex issue. By assessing the extent of microplastic pollution, analysing its impacts on the environment and human health, and proposing effective remediation strategies, we can safeguard the ecological integrity, water quality, and sustainable development of Indian freshwater resources for future generations.

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