Identification, seasonal abundance and human impacts of microplastics in lakes and river of Jammu & Kashmir, India

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ABSTRACT
Microplastics are microscopic plastic particles that are now common contaminants in freshwater and marine environments, endangering human health, wildlife, and ecosystems. The study was conducted on Jhelum river in Kashmir and Mansar & Surinsar lakes in Jammu, India aimed at identifying and classifying the microplastics, determining seasonal variations in abundance and composition, and health impacts on humans. A total of 36 surface water samples were collected (3 samples from each waterbody in each season) using a Neuston net and grab sampler. A questionnaire was prepared to study the effects of microplastic on human health which took an account of 200 respondents in total around the waterbodies. Fragments were found to be the most prevalent microplastic type, with 100-300 µm particles being the most abundant. Seasonal trends showed highest concentrations during summer while winter recorded the lowest levels. Tourism and agriculture in the lakes, as well as industrial trash in the Jhelum River, were the main sources of microplastics. Areas with higher pollution levels, especially those close to the Jhelum River, have noticeably higher health effects, including respiratory, skin, and gastrointestinal disorders. In order to address microplastic pollution and the hazards that come with it, the study emphasizes the necessity of focused mitigation measures such as better waste management, industry restrictions, and public awareness campaigns.
Keywords: Microplastic; water pollution; Jhelum; Mansar Lake; Surinsar lake; health impacts; abundance; temporal variations

1. INTRODUCTION

Microplastics (MPs), defined as plastic particles smaller than 5 mm [1], have emerged as a significant global environmental issue due to their widespread presence in aquatic and terrestrial ecosystems. These particles are categorized into primary microplastics—intentionally produced particles such as microbeads in cosmetics and personal care products—and secondary microplastics, which result from the fragmentation of larger plastic debris through physical, chemical, or biological processes, accelerated by environmental weathering and UV radiation [2] [3]. Currently, polystyrene (PS), polyethylene tetra acetate (PET), polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), and polyvinyl chloride (PVC) comprise the majority of plastics [4].

One significant contributing factor to the production of MPs is believed to be the breakdown of plastic trash [27]. Urbanized and industrial regions, in particular, are hotspots for microplastic contamination, as inadequate waste management systems and high human activity exacerbate the load of microplastics entering freshwater ecosystems [24]. Microplastics have recently been found at varying depths in a variety of marine and lake sediments, including the Tokyo Bay, the Gulf of Thailand, the Southern Ocean, and China's Wuliangsuhai Lake [23]. According to studies, deep sediment may include microplastics, and their concentrations may even surpass those found in surface sediment and adjacent seas [38].

Advanced spectroscopic techniques, such as Fourier Transform Infrared (FTIR) and Raman spectroscopy, have become standard tools for determining the morphology, size distribution, and polymer composition of microplastics [15]. Complementary methods, such as Scanning Electron Microscopy (SEM) for surface morphology analysis and Pyrolysis-GC-MS for chemical characterization, enable researchers to trace the sources of microplastics and study their persistence in complex environmental matrices [32]. Microplastics in water, sediment, and biota samples can be measured using a variety of techniques, each with unique advantages and disadvantages. Water is filtered using a filter, the filter is dried, and the microplastics are weighed as part of gravimetric procedures [5].

Microplastics pose significant threats to freshwater ecosystems and the organisms inhabiting them. These particles tend to accumulate in sediments, which act as long-term sinks, and are ingested by various aquatic organisms, including zooplankton, invertebrates, and fish [12] [4]. Human exposure to microplastics has become a growing concern due to their ubiquitous presence in water, food, air, and even drinking water sources [10]. Humans primarily ingest microplastics through contaminated water, seafood, agricultural produce, and plastic-packaged food, while inhalation of airborne microplastic fibers has emerged as an additional exposure pathway [37]. Once inside the body, microplastics can cross biological barriers, accumulate in tissues, and trigger inflammatory responses, oxidative stress, endocrine disruption, and immune system dysregulation [28] [10].

Microplastic pollution in freshwater and marine environments is on the rise in India, according to studies. Microplastics have been discovered in rivers such as the Ganga and Yamuna, especially in urbanized and busy areas [29]. Although significant research has been conducted on marine microplastics, the understanding of their prevalence, behavior, and impact in freshwater and terrestrial ecosystems remains limited. The study is aimed at identifying and classifying the microplastics, determining the source of contamination, seasonal abundance, temporal variations, and effects on human health.

2. METHODOLOGY

2.1 Description of the study area

The study was conducted on three water bodies: The Jhelum River in Kashmir and Mansar & Surinsar Lakes in Jammu (Figure 1). The Jhelum River, originating in Jammu and Kashmir, is a major waterway in the region, vital for irrigation, agriculture, and drinking water. It flows through the Kashmir Valley into Pakistan before merging with the Chenab. However, pollution from industrial runoff, sewage, and waste, along with climate change impacts like glacier retreat and shifting rainfall, threaten its health [17] [31]. Mansar Lake, in Jammu's Trikuta foothills, is a religiously significant natural lake surrounded by forests and wildlife. It faces pollution from tourism, sewage, and agricultural runoff, with rising microplastic contamination from plastic waste [18] [34]. Similarly, nearby Surinsar Lake, valued for its ecology, suffers from urbanization, deforestation, and waste influx, leading to deteriorating water quality and increasing microplastic pollution [18].

Figure 1: Location map of study area

2.2 Collection of samples

Samples were collected during December 2023 to November 2024 from various sites to ensure representative microplastic analysis, selecting points based on accessibility and human activities like agriculture, tourism, and industry. To record seasonal variations in microplastic abundance, surface water samples were collected throughout the year across the four seasons: spring (March – May), summer (June – August), autumn (September – November), and winter (December – February). Three surface water samples samples were collected from each water body in a particular season making a total of 36 surface water samples. A neuston net with mesh size of 0.30 mm and van dorn sampler was used to collect surface water samples.

2.3 Data collection

Water samples were collected using a 20-liter polyethylene container. The water was filtered through a 1-mm mesh sieve to remove large debris, followed by filtration through a 0.45 µm cellulose nitrate membrane filter to isolate microplastics. The filters were then rinsed with distilled water to remove any contaminants. For further analysis, microplastics were extracted from the filters using a density separation method. A solution of sodium chloride (NaCl) with a density of 1.2 g/cm³ was prepared, and the filters were placed in this solution. Microplastics, being less dense than the solution, floated to the surface, where they were collected and stored in sterile containers for further identification. Microplastics were identified and classified under a stereomicroscope (Leica M205C) with a camera attachment. The microplastics were categorized based on their morphological types, including fragments, fibers, beads, films, and foams. The size of each microplastic particle was measured using the microscope's calibrated scale. The microplastics were further classified based on their size. The size categories used were less than 100 µm (small), 100–300 µm (medium), 300–500 µm (large), 500–1000 µm (very large), and greater than 1000 µm (extremely large). Each microplastic type was counted and categorized by size to assess the size distribution within each water body. The abundance of each type was recorded as the percentage of the total microplastics identified.

To identify the sources of microplastics, a combination of visual surveys, interviews, and literature review was used. In each study site, a survey was conducted to identify potential pollution sources, including: industrial waste, tourism activities, sewage and runoff, agricultural activities, and fishing nets. Interviews were conducted with local residents, fishermen, and tourists to assess the impact of human activities on microplastic pollution in the lakes.

To determine the effects of microplastics on human health, a self-structured questionnaire was designed. The questionnaire included questions about respondents' health symptoms and their proximity to the water bodies. Key areas of focus included gastrointestinal issues such as abdominal pain, diarrhea, nausea, and vomiting; skin irritations like rashes, redness, itching, and dry skin; respiratory problems such as breathing difficulties, wheezing, and cough; neurological symptoms including headaches, fatigue, and dizziness; allergic reactions like swelling, itching, and watery eyes; and long-term health concerns such as suspected hormonal imbalance and organ damage. The questionnaire also included demographic data, such as age, gender, occupation, and frequency of exposure to the water bodies. It was distributed to local residents and visitors around each waterbody, with a total of 200 questionnaires being distributed (approximately 66 for each waterbody). Participants were asked to recall symptoms they had experienced over the past year and indicate their frequency of exposure to the water. The responses were collected and analyzed to identify patterns of health symptoms associated with exposure to microplastic-polluted water.

2.4 Data analysis

The collected data were analysed using SPSS (Statistical Packages for Social Sciences) and MS-Excel for basic descriptive statistics including percentage, mean, standard deviation and standard error.

3. RESULTS AND DISCUSSIONS

3.1 Identification and classification of microplastics

The analysis of samples collected from Jhelum River, Mansar Lake, and Surinsar Lake identified five primary categories of microplastics vis-à-vis fragments, fibres, beads, film, and foam. Fragments were the most prevalent type in all three water bodies, accounting for 60% in the Jhelum River, 50% in Mansar Lake, and 40% in Surinsar Lake (Table 1). This aligns with previous studies indicating that fragments, primarily derived from the breakdown of larger plastic debris, are the most common form of microplastics in aquatic environments due to continuous degradation processes [2] [3]. Fibers constituted the second most abundant microplastic type, particularly prominent in Mansar (30%) and Surinsar (25%) lakes. These fibers likely originate from textile laundering, fishing nets, and synthetic ropes, consistent with reports by Su *et al.* (2022) [33], who found that fiber microplastics are widely dispersed in freshwater systems due to their lightweight nature and slow degradation. The elevated fiber presence in the lakes suggests significant anthropogenic influence, including domestic wastewater discharge and fishing activities. Beads, films, and foams were observed in smaller proportions, with beads comprising 10% in Jhelum River, 6.67% in Mansar Lake, and 15% in Surinsar Lake. The presence of beads suggests potential inputs from personal care products and industrial sources, as noted in earlier studies [11]. Films (5–10%) and foams (5–10%) were also detected, likely originating from plastic packaging, agricultural mulch films, and food containers [5]. Their relatively higher percentage in Surinsar Lake indicates possible contributions from tourism and recreational activities around the waterbody. The dominance of fragments and fibers aligns with global trends observed in freshwater ecosystems, highlighting the persistent nature of secondary microplastics derived from larger plastic debris and synthetic textiles [40].

Table 1: Percentage composition of microplastic types found across the waterbodies

Category of Microplastic	Jhelum River (%)	Mansar Lake (%)	Surinsar Lake (%)
Fragments	60.00	50.00	40.00
Fibers	20.00	30.00	25.00
Beads	10.00	6.67	15.00
Films	5.00	6.67	10.00
Foam	5.00	6.67	10.00

3.2 Size distribution of microplastics

The microplastics found were categorized into five size ranges: less than 100 µm, 100–300 µm, 300–500 µm, 500–1000 µm, and greater than 1000 µm. The analysis showed a clear dominance of small-sized particles, with the majority falling within the 100–300 µm range (Table 2). This size category accounted for 50% of the microplastics in the Jhelum River, 60% in Mansar Lake, and 55% in Surinsar Lake. These findings align with previous research indicating that microplastics in freshwater environments are predominantly within this range due to fragmentation of larger plastic debris and their high mobility within aquatic systems [15] [36]. Microplastics in the 300–500 µm range were the second most abundant, constituting 20% in the Jhelum River and 25% in both Mansar and Surinsar lakes. This distribution suggests that intermediate-sized microplastics are also significant contributors to pollution, likely originating from synthetic fibers, degraded plastic films, and secondary breakdown of larger plastic items [40]. Particles smaller than 100 µm were found in lower proportions, comprising 10% in the Jhelum River and 5% in both lakes. Their lower abundance may be attributed to difficulties in capture due to their small size and potential interactions with suspended sediments [3]. However, their presence is concerning, as microplastics in this size range have a higher potential for ingestion by plankton and other aquatic organisms, leading to trophic transfer and bioaccumulation [20]. Larger microplastics (500–1000 µm) were less common, with their highest percentage recorded in the Jhelum River (15%), followed by Surinsar Lake (10%) and Mansar Lake (7%). The presence of larger particles suggests contributions from direct plastic littering and insufficient degradation processes, as larger microplastics tend to settle more rapidly due to their size and density [7]. The least common category was microplastics exceeding 1000 µm, representing only 5% in the Jhelum River and Surinsar Lake and 3% in Mansar Lake. These larger particles likely originate from incomplete degradation of plastic materials or improper disposal of plastic waste [16]. Their lower abundance is consistent with studies indicating that larger microplastics undergo mechanical breakdown, forming smaller, more abundant secondary microplastics [26].

Table 2: Size distribution of microplastics across the waterbodies

Size Range (µm)	Jhelum River (%)	Mansar Lake (%)	Surinsar Lake (%)
< 100 µm	10.00	5.00	5.00
100–300 µm	50.00	60.00	55.00
300–500 µm	20.00	25.00	25.00
500–1000 µm	15.00	7.00	10.00
> 1000 µm	5.00	3.00	5.00

3.3 Seasonal abundance of microplastics

Microplastic abundance varied across seasons and study sites, with the Jhelum River showing the highest mean concentration (92 ± 12.09 particles/L), followed by Mansar (54 ± 7.08 particles/L) and Surinsar Lakes (42 ± 6.96 particles/L) (Table 3). Seasonal trends revealed peak microplastic levels in summer (82 ± 17.20 particles/L) and the lowest in winter (40.33 ± 10.26 particles/L), likely due to increased surface runoff, human activity, and plastic fragmentation during warmer months [3] [33]. Jhelum River exhibited consistently higher microplastic loads due to its larger catchment area and urban inputs [30]. Mansar and Surinsar Lakes, being more enclosed, had lower concentrations, influenced by local waste management and recreational activities. The results align with global studies showing seasonal fluctuations in microplastic pollution, with higher concentrations in warm months and lower levels in winter due to reduced runoff and sedimentation [16] [36].

Table 3: Abundance of microplastics (particles/L)

Waterbody	Spring	Summer	Autumn	Winter	Mean ± SE
Jhelum River	98	121	86	63	92 ± 12.09
Mansar Lake	58	69	54	35	54 ± 7.08
Surinsar Lake	47	56	42	23	42 ± 6.96
Mean ± SE	67.67 ± 13.42	82 ± 17.20	60.67 ± 11.37	40.33 ± 10.26	

Note: SE = Standard Error

3.4 Seasonal composition of microplastics

The seasonal variation in microplastic composition showed that fragments were the dominant type across all seasons, with the highest percentage recorded in summer (60%) and the lowest in winter (40%) (Table 4). The increased presence of fragments in warmer months is likely due to enhanced plastic degradation from UV exposure and higher human activity, consistent with previous studies [3] [33]. Fibers were the second most abundant type, peaking in winter (35%) and reaching their lowest percentage in summer (20%). The higher fiber proportion in winter may be due to increased indoor textile use and reduced runoff, which limits dilution [16]. The proportions of beads remained stable across all seasons (10%), indicating consistent sources such as personal care products and industrial wastewater [11]. Films and foams were also relatively stable but showed a slight increase in winter (10% each), possibly due to reduced degradation rates in colder conditions [5].

Table 4: Seasonal variation in microplastics composition

Season	Fragments (%)	Fibers (%)	Beads (%)	Films (%)	Foams (%)
Spring	55.00	25.00	10.00	5.00	5.00
Summer	60.00	20.00	10.00	5.00	5.00
Autumn	50.00	30.00	10.00	5.00	5.00
Winter	40.00	35.00	10.00	10.00	5.00

3.5 Sources of microplastic in the waterbodies

The study identified 5 potential sources of microplastics in the waterbodies (Table 5). Those sources are industrial waste, sewage and runoff, tourism activities, agriculture, and fishing nets. Industrial waste was the major contributor in the Jhelum River (30%), whereas its impact was significantly lower in Mansar (10%) and Surinsar (5%) lakes. This aligns with previous studies indicating that rivers receive higher industrial discharges due to their proximity to manufacturing units and urban centers [3] [30]. Tourism activities were the primary source of microplastics in Mansar (30%) and Surinsar (40%) lakes, surpassing their contribution in the Jhelum River (20%). The increased microplastic pollution in these lakes is likely linked to recreational boating, littering, and plastic waste disposal from visitors [5]. Sewage and runoff were consistent sources across all sites, contributing 25% in Jhelum and Mansar and 20% in Surinsar. This suggests continuous microplastic input from household wastewater and urban runoff, a trend observed in other freshwater ecosystems [16]. Agricultural activities contributed 25% in Surinsar Lake, higher than in Mansar (20%) and Jhelum (10%). The higher proportion in lakes could be due to runoff from nearby farmlands carrying plastic mulches and pesticide packaging waste [26]. Fishing nets were a notable source in all three water bodies, contributing 15% in Jhelum and Mansar and 10% in Surinsar. The presence of synthetic fibers from fishing gear has been widely documented in aquatic environments [33].

Table 5: Potential sources of microplastics and their relative contribution

Source	Jhelum River (%)	Mansar Lake (%)	Surinsar Lake (%)
Industrial Waste	30.00	10.00	5.00
Tourism Activities	20.00	30.00	40.00
Sewage and Runoff	25.00	25.00	20.00
Agriculture	10.00	20.00	25.00
Fishing Nets	15.00	15.00	10.00

3.6 Effects of microplastics on human health

The survey of respondents living near the Jhelum River, Mansar Lake, and Surinsar Lake revealed a range of health issues potentially linked to microplastic exposure (Table 6). Gastrointestinal issues were the most commonly reported symptoms, affecting 52% of respondents overall, with the highest prevalence near the Jhelum River (60%). These symptoms, including abdominal pain, diarrhea, nausea, and vomiting, may be associated with the ingestion of contaminated water or food containing microplastics, as previous studies suggest microplastics can act as carriers of toxic chemicals and pathogens [27]. Skin irritations such as rashes, itching, and dryness were reported by 32% of respondents, most frequently in communities near the Jhelum River (40%). This aligns with studies indicating that prolonged exposure to water contaminated with plastic particles and associated pollutants can trigger dermatological reactions [37]. Respiratory problems, including coughing, wheezing, and breathing difficulties, were more common in Jhelum River communities (35%), followed by Mansar (20%) and Surinsar (15%). The presence of airborne microplastics and fibers, particularly in areas with high pollution levels, has been linked to lung irritation and inflammatory responses [8]. Neurological symptoms such as headaches, fatigue, and dizziness were reported by 10% of respondents overall, with a higher occurrence near the Jhelum River (15%). Research suggests that exposure to plastic-associated chemicals like phthalates and biphenyl may have neurotoxic effects [36]. Allergic reactions, including swelling, itching, and watery eyes, were less common (8% overall), but their presence suggests potential immune system responses to microplastic contaminants [13]. Long-term health concerns, such as suspected hormonal imbalances and organ damage, were reported by 3% of respondents, with slightly higher reports near the Jhelum River. Endocrine-disrupting chemicals associated with microplastics have been linked to reproductive and metabolic disorders [40].

Table 6: Health issues reported by the respondents

Health Issue	Symptom Description	Jhelum River (%)	Mansar Lake (%)	Surinsar Lake (%)	Overall (%)
Gastrointestinal Issues	Abdominal pain, diarrhea, nausea, vomiting	60.00	50.00	45.00	52.00
Skin Irritations	Rashes, redness, itching, dry skin	40.00	30.00	25.00	32.00
Respiratory Problems	Breathing difficulty, wheezing, cough	35.00	20.00	15.00	23.00
Neurological Symptoms	Headaches, fatigue, dizziness	15.00	10.00	5.00	10.00
Allergic Reactions	Swelling, itching, watery eyes	10.00	8.00	7.00	8.00
Long-term Health Concerns	Suspected hormonal imbalance, organ damage	5.00	3.00	2.00	3.00

4. CONCLUSION

The study revealed significant spatial and seasonal variations in microplastic composition, size distribution, abundance, sources, and associated health impacts across the Jhelum River, Mansar Lake, and Surinsar Lake. Fragments were the most dominant type of microplastic, particularly in the Jhelum River, followed by fibers, beads, films, and foams, indicating secondary degradation of plastic waste and textile pollution as primary contributors. The majority of microplastics were within the 100–300 µm size range, highlighting their potential for bioavailability and ingestion by aquatic organisms. Seasonal analysis showed that summer had the highest microplastic abundance, likely due to increased tourism, agricultural runoff, and plastic degradation under high temperatures, whereas winter recorded the lowest concentrations, attributed to reduced anthropogenic activity and sedimentation. Among sources, industrial waste was a major contributor in the Jhelum River, while tourism activities and agriculture were more prominent in Mansar and Surinsar Lakes, reflecting localized pollution dynamics. Health assessments indicated a strong correlation between microplastic exposure and gastrointestinal, dermatological, respiratory, and neurological symptoms, with the highest prevalence among communities near the Jhelum River. The presence of endocrine-disrupting chemicals linked to microplastics raises concerns about long-term health effects such as hormonal imbalances and organ toxicity. Urgent mitigation measures, such as better waste management, stricter regulations, and public awareness, are needed to reduce microplastic pollution and its risks. Further research is essential to assess long-term effects and improve freshwater protection strategies.

5. ACKNOWLEDGEMENT

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