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Characterization and Quantification of Microplastics in Surface Water of Shitalakshya River, Bangladesh

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Abstract

Microplastics (MPs) are a growing environmental concern due to their omni-presence and remarkable durability. The Shitalakshya river, located in the vicinity of industrial areas, faces a significant threat of MPs pollution, which may, in turn, disrupt the ecological balance and human health. In this study, surface water samples (W_1-W_{10}) were collected from the Shitalakshya river for the total counting of MPs with their morphological characterization by stereomicroscope. Chemical identification of MPs was carried out using ATR-FTIR technique and the obtained spectra were compared with the IR library. A total of 381 particles were counted and the abundance of MPs was 0.28 to 2.44 particles/L (average 1.524 particles/L). Examining shapes and colors, a maximum of 68.24% of MPs were fibers and 28.10% of black in color. Regarding particle size, MPs with 0-250 µm were most prevalent in surface water, constituting 56.43% of the total. The findings indicate that the predominant MPs were polyethylene (PE) and other MPs such as polystyrene (PS), polyvinylchloride (PVC), polypropylene (PP), etc. These results indicate that the Shitalakshya river is becoming contaminated by MPs and the pollution poses a risk to organisms in the urban river ecosystem, highlighting the need for immediate attention and corrective measures.

Keywords: Shitalakshya river, Surface water, Pollution, Microplastic, ATR-FTIR spectroscopy, Characterization

I. Introduction

The widespread use of synthetic plastics that break down into smaller particles, including microplastics (MPs) ranging from 0.1µm to 5 mm, are the emerging concern for human beings[1-4]. In 2015, about 8,300 million metric tons of new plastics were produced. By 2018, global plastic production had reached 360 million metric tons annually, showing rapid growth[5,6]. Plastics enter the environment from wastewater treatment plants, urban areas, road runoff, industrial activities, atmospheric pollution, and the breakdown of larger plastic particles[7-9]. MPs are found everywhere in the environment, including all parts of the ecosystem[10]. Plastic waste in land and water ecosystem threatens biodiversity because it is long-lasting and difficult to degrade[11,12]. MPs can also absorb persistent organic pollutants (POPs) and heavy metals[13]. Research shows that MPs harm the environment and ecosystems[14]. Many MPs found in nature do not originate from the sampling site but are transported with rivers being a major pathway[15,16]. Plastics, including MPs, release toxic chemicals into the environment, which can enter the food chain[17]. Humans consume microplastics, and these have been detected in the body[18,19]. Microplastics, as emerging pollutants, threaten water quality and ecosystems. They contain harmful substances like phthalates and can adsorb and release pollutants[20,21]. In fish, MPs can block the gastrointestinal (GI) tract, causing harm, reducing food intake, and leading to death[22-24]. Rivers spread MPs downstream, and smaller particles stay suspended in water for long periods, aiding their dispersal[25].

Extensive research indicates that the prevalence of MPs in rivers is strongly associated with human activities[26]. This correlation underscores the significant impact of anthropogenic factors on the distribution of MPs within freshwater systems[27,28]. As urban areas expand and population densities increase, the influx of MPs into riverine environments tends to rise correspondingly[29], highlighting the need for targeted environmental management and pollution mitigation strategies in heavily populated and urbanized zones[30]. Narayanganj, a significant industrial zone and the second-largest developed industrial area in the country, is situated along the banks of Shitalakshya river. More than 2000 factories are positioned including dyeing and textiles along the riverbanks which are the sources of microplastics[31]. This freshwater system serves as the primary source for drinking water either directly or indirectly. Consequently, we need proper investigations to examine the contamination of MPs in freshwater. This research aimed to characterize and quantify MPs in the surface water of the Shitalakashya river and assess its water quality. Ten surface water samples were collected for analysis. The study focused on quantifying MPs, analyzing their physical attributes using a stereomicroscope, and identifying their chemical composition through Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy. The ATR-FTIR spectra were compared with an IR library using Spectragryph 1.2 software for precise polymer identification. This work aims to provide a comprehensive understanding of MPs microplastic pollution in the river, contributing to water quality assessment and pollution management efforts.

II. Materials and Methods

Sampling Area

The Shitalakshya river, a tributary of the Brahmaputra,

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served as the sampling area for this study. Ten sampling sites were strategically selected along the river (Table 1). Sample collection commenced at Kalagachhiya (Latitude: 23.57789; Longitude: 90.55055) and concluded at Raniganj Bazar (Kapasia) (Latitude: 24.07201; Longitude: 90.63311), with an average distance of 7.5 kilometers between each sampling point, covering a total area of approximately 75 kilometers. The sampling sites were designated as W_1 to W_{10} facilitating a comprehensive analysis of microplastic pollution across different environments.

Sample Collection and Preservation

Surface water samples were collected from Shitalakshya river in January, 2023. The geographic positions of the sampling sites were recorded by GPS (MapitGIS App, Android Phone). The detailed record of sample collection is given in Table 1. A 1.0 L pre-washed steel mug was rinsed three to four times with sample water before filling. The mug was filled with sample water and filtered by a 75 µm laboratory test sieve at the sampling sites of the river. 25 L of water from each site was filtered. The residue on the sieve was collected in 150 mL amber glass bottles by washing with deionized water. This sampling method is known as bulk sampling[32,33]. After reducing the volume to about 20 mL, samples were labeled properly for identification. The samples were immediately transported to the laboratory, and were kept at -4 ºC. The samples were taken to room temperature before digestion.

Table 1. Sample collection sites of Shitalakshya river

Sample ID	Sampling area	Latitude	Longitude	Locality
W_1	Kalagachhiya	23.57789	90.55055	Urban
W_2	Narayonganj Launch Ghat	23.61582	90.50768	Urban
W_3	Nobiganj Ghat	23.63312	90.51843	Urban
W_4	Kanchpur Bridge	23.70397	90.51760	Urban
W_5	Ichakhali	23.77486	90.51319	Urban
W_6	Kanchon Bridge	23.83627	90.54614	Urban
W_7	Atlapur Bazar	23.87611	90.57882	Rural
W_8	Ghorashal Railway Bridge	23.94089	90.61764	Rural
W_9	Charshindur	24.01513	90.66005	Rural
W_{10}	Raniganj Bazar (Kapasia)	24.07201	90.63311	Rural

Glassware, Chemicals, and Instruments

The analysis of microplastics in river water involves a set of apparatus, instruments, and chemicals to facilitate a comprehensive examination. The apparatus includes a conical flask, glass petri dish, membrane filter paper, vacuum filter, wash bottle, glass rod, aluminum foil, laboratory test sieve, microscope slides, coverslips, and hand gloves for safe handling. In terms of instruments, a stereo microscope (Euromex Holland, NZ.2P190 2P) is utilized for detailed observation, while an ATR spectrophotometer (IRPrestige 21, Shimadzu Corporation, Japan) is employed for advanced spectroscopic analysis. The chemical components consist of KOH and deionized water, suggesting potential involvement in sample preparation and treatment. This comprehensive set of materials underscores the multi-step nature of the analysis process, encompassing sample collection, filtration, microscopic examination, and potential spectroscopic characterization of microplastics in river water.

Sample Extraction and Isolation of MPs

Approximately 20 mL of the collected sample was taken from amber-colored bottles and again filtered off through a stainless-steel sieve of 75 µm pore into a conical flask by reducing the volume to around 5 mL. The residue was washed with deionized water and subsequently digested with KOH beads. For 1 mL of sample 1 g of KOH was added and all the conical flasks were kept at 60 ºC for 24 hours[34]. Separation of extracted microplastics was carried out through a membrane filter paper (pore size 0.4 µm, diameter 75 mm, Pall Life Sciences, 2500 QAT-UP) by vacuum filtration. The filter paper was washed further with deionized water and collected carefully in a petri dish which was previously treated with distilled water and dried. After covering the petri dish with foil paper, it was kept at room temperature.

Observation, Identification, and Quantification of MPs

A stereo microscope was used to observe the extracted MPs in the filter paper. The magnification was set up to a comfortable level for better view.Various sections of filter paper were selected at random and the overall count of MPs was assessed based on the total observed area. Photos were captured using a camera with a resolution of 3584×2746 pixels, each covering an area of 14.49 mm^2. The quantification of MPs was carried out manually by examining the photos. MP morphotypes were visually identified based on their physical characteristics and details regarding their abundance, shape, color, and size were recorded[35,36]. The assessment of MP length was performed using ImageJ, an image analysis software developed by the

National Institute of Health (NIH) and the Laboratory for Optical and Computational Instrumentation (LOCI).

Quality Control and Chemical Characterization

Glass apparatus was used over plastic to prevent contamination during the analysis. The stereomicroscope inspection area was thoroughly cleaned before the analysis of the sample filter papers. Filter paper with samples was placed in a petri dish covered with foil paper to prevent the influence of air. Chemical characterizations of visually identifiable MPs were conducted through ATR-FTIR analysis, obtaining infrared spectra of the samples within the range of 4000-500 cm^{-1}. The FT-IR spectrum depicted in Fig. 1 represents a microplastic found in the extracted water samples.

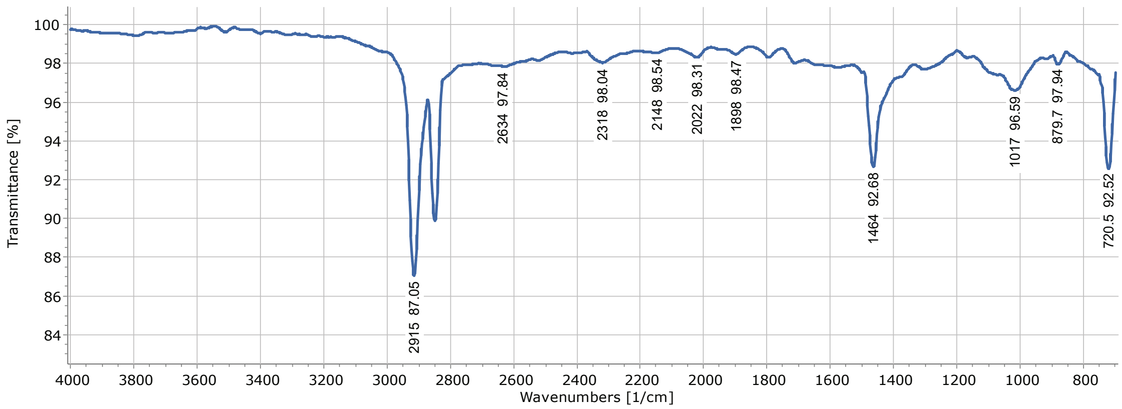
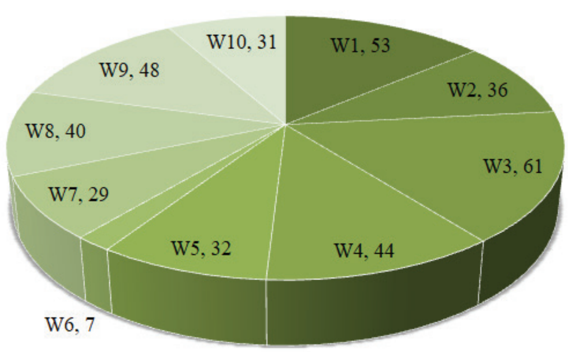


Fig. 1. FT-IR spectrum of a visually identified microplastic in water sample

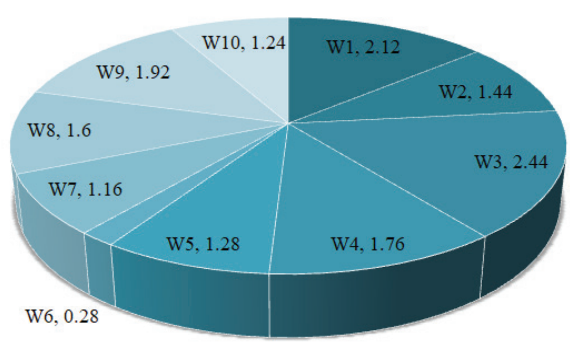
III. Results and Discussion

Abundance of Microplastics

The abundance of microplastics in surface water varied from 0.28–2.44 particles/L with an average value of 1.524 particles/L. W_3 was the highest and W_6 was the lowest abundant samples. The order of MPs abundance in percentage is shown in a pie chart (Fig.2). The order of microplastics abundance was $W_3 > W_1 > W_9 > W_4 > W_8 > W_2 > W_5 > W_{10} > W_7 > W_6$. Islam et al. (2022) reported a range of 4.33-43.67 particles/L of MPs in the Buriganga river[37], whereas Hossain et al. (2022) and Alam et al. (2019) reported higher concentrations of 2.11 particles/L and 5.85 particles/L in different rivers respectively[35,38], compared to the current study. The excessive presence of MPs in the river is attributed to the densely populated surroundings of the sampling sites. Previous research by Ding et al. (2019), Mani et al. (2015), Wang et al. (2018), and Wen et al. (2018) have indicated that human activities and agriculture are significant contributors to MPs contamination in densely populated regions[39-42]. According to Kataoka et al. (2019), the global variation in microplastic abundance in rivers is influenced by factors such as geographical location[43] of the river, hydrodynamic characteristics, and the sources of polluting materials[44].



(a) Number of MPs per 25 L of water



(b) Number of MPs per L of water

Fig. 2. Abundance of MPs in the surface water of Shitalakshya river

Characterization of MPs

Visual sorting, tagging method, spectroscopy, and chromatography are the four possible methods of MP identification[45]. Among them spectroscopy is the most widely used technique for the detection of microplastics due to several reasons like directness, reliability, non-destructive approach[46].Visually identified 9 particles were selected from the ten extracted water samples for ATR-FTIR analysis. Different types of polymers e.g. polyethylene, polypropylene, polystyrene, HDPE, and PVC were identified by stereomicroscope and ATR-FTIR spectral analysis. The spectral bands were confirmed from literature and IR spectra library. Only first particle is shown for the probable identification of the microplastic (Fig.3) and similar technique was followed for the other particles too.

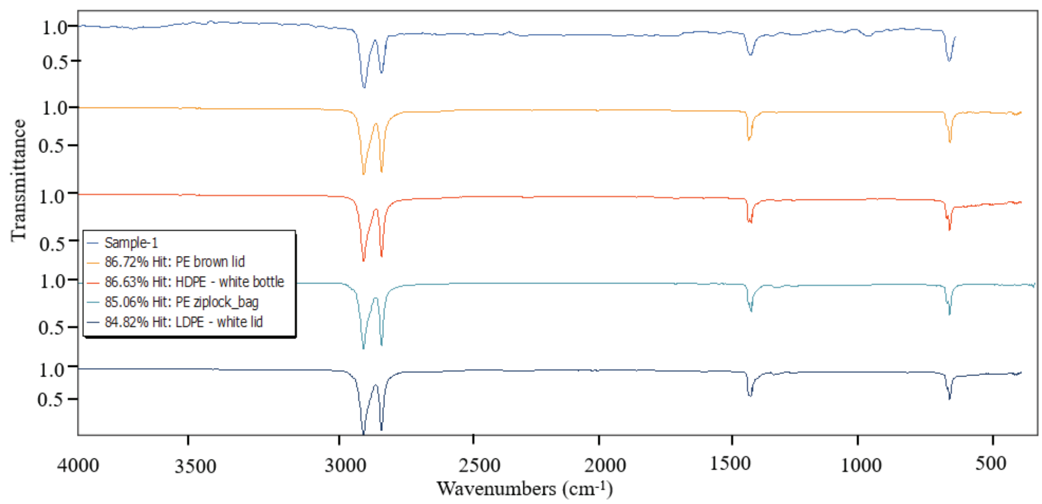


Fig. 3. Spectra of polyethylene in sample matched with standard polymers

Among the 9 particles, three of the particles showed almost the same result, the particles being different variations of polyethylene. The primary diagnostic peaks of significance include the C-H stretching peak indicative of sp^3 carbon in the range 3000-2840 cm^{-1} (<3000 cm^{-1}). The presence of two adjacent peaks in the absorption below 3000 cm^{-1} confirms the occurrence of sp^3 C-H stretching. Additionally, a weak peak in the region 1000-650 cm^{-1} suggests potential CH_2 OOP bending, while the absorbance at ~1465 cm^{-1} may be attributed to CH_2 in-plane bending (scissoring)[47]. Despite slight deviations from standard polymer peaks, the characteristic <3000 cm^{-1} peaks and library matching collectively support the classification of the sample as polyethylene-type.

In Fig.3, the first particle exhibited approximately 86.72%, 86.63%, and 84.82% match with polyethylene, HDPE (High-Density Polyethylene), and LDPE (Low-Density Polyethylene) polymers. Similarly, the second particle aligned with the standard spectra of PE or HDPE, showing a similarity of approximately 90%. The third particle exhibited a significant resemblance to the standard spectra of PE or HDPE or LDPE with a match of around 70%. These formulations were identified in the forms of brown lid, white lid, white bottle, and zip-lock bag. The material in particle 4 exhibited ~76% similarity with PVC and aligned with the spectral bands of CH St. of CHCl and CH_2 below 3000 cm^{-1}. Particle 5 corresponded to 62.15% PVC and 60.59% polystyrene, while particle -6 closely aligned with 64.83% PVC and 63.29% PS. The similarity in values suggests that both samples could potentially be either PS or PVC, based on the information available in the database library. Two particles among 9 (Particle-7 and Particle-8) exhibited approximately 50% resemblance to both PVC and PS. The percentages of polystyrene are higher in these samples. Consequently, these particles are more likely to be polystyrene than PVC considering the substantial deviation observed. The spectrum of the last particle corresponded to 63.24% polypropylene, 62.6% PS, and 60.99% PVC. Although the highest match is with polypropylene, it is not definitively confirmed leaving some uncertainty regarding the identification of the particle. Some deviations in all sample spectra might arise from the use of alkali digestion, leading to various effects such as color change, structural damage, and degradation[45].

Shapes of Microplastics

The outcomes of the shape analysis of MPs are presented in Table 2. Among the total water samples (n=10), five distinct morphological shapes of MPs were identified, namely fragment, foam, fiber, pellet, and film as shown in Fig.4. A stereo microscope was used at a consistent magnification to analyze random sections of filter paper for MPs, with photos captured at 3584×2746 pixels covering 14.49 mm^2 each. Fibers, the main MPs in this study, primarily stem from synthetic and natural materials in everyday items, released through abrasion and wear.[48] It is likely associated with various sources such as cleaning activities, fishing-related purposes (nets, rods, gear, ropes), industrial and household discharges and direct cloth washings[49,50].

Table 2. Number of MPs having different shapes in the collected samples

Sample ID	Microplastic Type				
	Fiber	**Fragment**	**Foam**	**Film**	**Pellet**
W_1	49	1	2	1	Absent
W_2	24	5	3	1	3
W_3	36	19	1	2	3
W_4	27	11	2	1	3
W_5	26	3	Absent	Absent	3
W_6	5	2	Absent	Absent	Absent
W_7	15	2	1	4	7
W_8	20	14	2	4	Absent
W_9	34	5	6	3	Absent
W_{10}	24	3	2	1	1
Total (n=10)	260	65	19	17	20

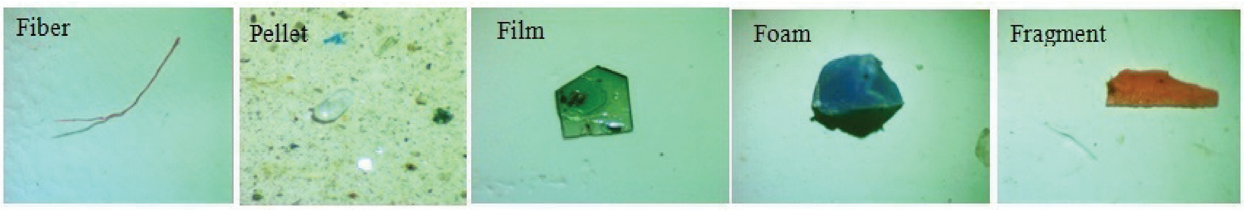


Fig. 4. Shapes of microplastics in the water samples

It can be seen that fiber was the most abundant shape. W_1 and W_6 had the highest and the lowest number of fibers, respectively. Fragment was the second highest abundant MP. Film and foam were absent in samples W_5, and W_6. Pellet was absent in W_1, W_6, W_8 and W_9 water samples. Film and foam were the least abundant shapes among all other shapes in the surface water samples (Table 2 and Fig.5). In various water samples, the microplastic abundance was observed as follows: fiber>fragment>pellet>foam>film. Hossain et al. (2022) reported a significant presence of fiber, constituting 83% of the microplastics in the surface water of the Karnaphuli river[35]. Several other studies examining river water including those conducted by Alam et al. (2019) and Qu et al. (2018), identified fiber as the predominant shape type[38,51]. On the other hand, Islam et al. (2022) observed 72.7% fragment in the surface water of Buriganga river[37]. Fiber microplastics pose the highest risk and can lead to adverse effects on the gastrointestinal tract, resulting in health issues and physical harm to aquatic and other organisms[52,53]. The bioaccumulation of these fibers in the food chain raises concerns about long-term ecological disruption and potential health risks for organisms and also humans who may be exposed through contaminated seafood.

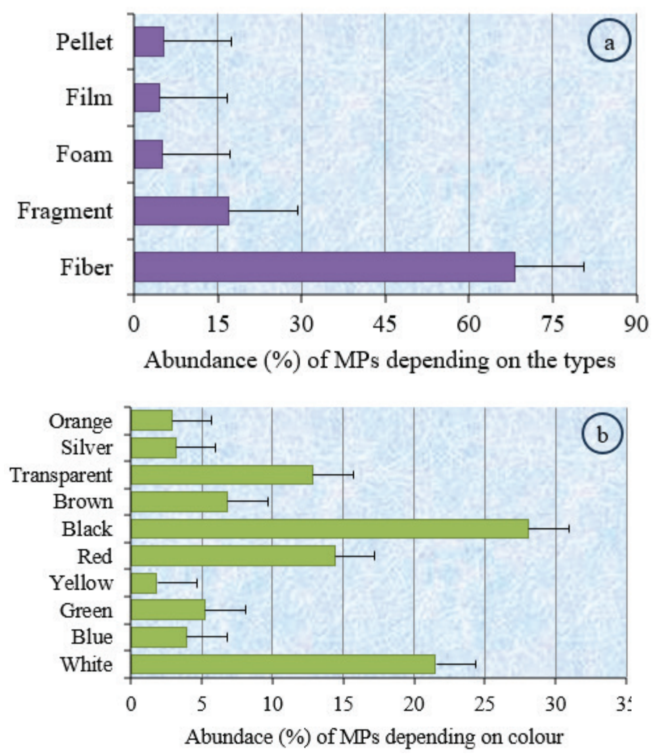


Fig. 5. Abundance of microplastics depending on (a) typesand (b) color

Sizes of Microplastics

The various microplastic samples were classified into five distinct categories based on their observed size types. The categories were <250 µm; 250-600 µm; 600-1000 µm; 1000-1500 µm; and >1500 µm (Table 3).

Table 3. Data for the different sizes of microplastics in the water samples

	Microplastic size (µm)				
Sample ID	**<250**	**250-600**	**600-1000**	**1000-1500**	**>1500**
W_1	24	18	7	1	3
W_2	20	13	2	1	Absent
W_3	34	24	Absent	1	2
W_4	32	10	2	Absent	Absent
W_5	19	9	2	2	Absent
W_6	4	1	2	Absent	Absent
W_7	13	14	Absent	Absent	2
W_8	23	9	Absent	3	5
W_9	30	15	2	1	Absent
W_{10}	16	13	2	Absent	Absent
Total (n=10)	215	126	19	9	12

The length of the microplastics was found to vary from <250 to >1500 µm. The value of the length may differ from other perspective assessment because there is no given estimation for the size of the MPs. Only W_1 and W_3 samples contained all 5 categories of particles. Sample W_2 and W_{10} had the same number of MPs within the range of 250-600 µm. Sample W_7 contained almost the same numbers of MPs size in 250-600 µm followed by <250 µm. Most of the samples had no microplastics having a length >1000µm. Some of the plastics larger than 1500 µm were found in samples W_1, W_7, and W_8, and these microplastics were visually identifiable. The most abundant size of MP was <250 µm and 1000-1500 µm was the least abundant.The distribution of microplastic sizes was observed in Table 3 as follows: <250 µm accounted for 56.43%, followed by 250-600 µm at 33.07%, 600-1000 µm at 4.99%, 1000-1500 µm at 2.36% and greater than 1500 µm at 3.15%. Alam et al. (2019) reported that microplastics within the range of 50-100 µm were more prevalent[38]. Additionally, Hossain et al. (2022) and other studies have identified the group of microplastics measuring less than 1000 microns as the most abundant[35].The tiny size of microplastics was a result of processes such as fragmentation, degradation caused by mechanical forces, variations in hydrodynamics, diverse climate conditions, and interactions with tides[54]. Exposure to environmental factors such as sunlight and moisture weakens the plastic polymers, leading to the formation of smaller particles. While some microplastics result from intentional manufacturing, many are the byproducts of the breakdown of larger plastic particles and the abrasion of synthetic materials.

Analysis of Microplastics Coloration Type

The microplastic particles observed from surface water samples were categorized into ten types of color. The classes include: white, blue, green, yellow, red, black, brown, transparent, silver, and orange. Data for the microplastic coloration type from the water samples are shown in Table 4 and Fig.5.

Table 4. Data for different colors of MPs in water samples

Sample ID	Microplastic colour									
	White	**Blue**	**Green**	**Yellow**	**Red**	**Black**	**Brown**	**Transparent**	**Silver**	**Orange**
W_1	7	2	2	Absent	13	21	2	4	2	1
W_2	6	2	2	4	4	10	2	3	3	1
W_3	28	3	1	Absent	4	13	2	9	1	Absent
W_4	5	2	7	1	4	7	8	7	1	2
W_5	8	Absent	Absent	Absent	4	13	2	1	1	2
W_6	Absent	Absent	Absent	1	3	2	Absent	1	Absent	Absent
W_7	7	2	Absent	Absent	3	3	5	6	Absent	3
W_8	8	1	1	1	2	12	2	8	3	1
W_9	10	1	5	Absent	9	18	Absent	5	Absent	Absent
W_{10}	3	2	2	Absent	9	8	2	5	Absent	Absent
Total (n=10)	82	15	20	7	55	107	25	49	11	10

Green-colored microplastics were mostly found in samples W_4 and W_9. Almost all of the samples had red, black, white and transparent microplastics. Black colored microplastics were the most abundant in the collected samples containing 28.1% of the total MPs. Yellow-colored MPs were the least abundant. Orange, brown, blue, and silver colored MPs were also found. The color variations of microplastics in water can be attributed to factors such as polymer composition, additives, environmental weathering, biofilm accumulation,etc[55]. These influences can lead to a diverse range of colors among microplastic particles, reflecting their complex interactions with the environment.The abundance of different coloration types of MPs followed the order: black>white>red>transparent>brown>green>blue>silver>orange>yellow. Colored MPs accounted for 65.62% whereas white and transparent microplastics were 34.38% of the total microplastics. These different colored microplastics may have originated from the solid waste of domestic work and daily use such as clothes, fishing nets, bags, etc. Islam et al. (2022) found a higher percentage of red (31%) and transparent (24%) MPs in the surface water of the Buriganga river which is quite different from the present study[37]. Napper et al. (2021) and Hossain et al. (2022) found blue as the most dominant colour in the surface water of Ganges river and Karnaphuli river respectively[56,37] which also showed dissimilarity with this study.

Policymaking, Public Health, and Mitigation Strategies

This research highlights the abundance, types, and sources of MPs in the Shitalakshya river. MPs like polyethylene, polypropylene, and polystyrene were detected. Urban areas, such as Kalagachhiya, Narayanganj, and Nobiganj, show high contamination levels of MPs. Poor recycling and waste disposal systems worsen the issue. Policies should control plastic waste, regulate uses and production, and promote biodegradable alternatives. Collaboration among governments, industries, and communities is crucial to prevent plastic pollution in rivers. Microplastic fibers from textiles and domestic activities threaten human health as they can bioaccumulate in aquatic organisms and enter the food chain[57]. Harmful polymers like PVC and polystyrene pose long-term exposure risks[58]. Public awareness campaigns are needed to highlight these dangers. Promoting reduced use of single-use plastics and proper disposal practices can help. These steps are vital to mitigate health risks and protect vulnerable populations. Community-based waste management and recycling can lower plastic waste. Industries along rivers should follow extended producer responsibility frameworks to manage plastic waste. Periodic cleanup drives and habitat restoration, such as reforestation along riverbanks, help reduce pollution. Research on biodegradable materials and eco-friendly alternatives should be promoted. Public-private partnerships can support innovative waste-to-energy technologies for sustainable solutions. The findings have regional significance, as rivers in South Asia face similar plastic pollution challenges. Lessons from this research can inform transboundary initiatives under frameworks like the South Asian Association for Regional Cooperation (SAARC), promoting joint efforts to tackle riverine MPs pollution.

IV. Conclusion

This study reveals the presence of microplastic pollution in the Shitalakshya river. The abundance of microplastics ranged from 0.28 to 2.44 particles per liter in surface water. The predominant microplastics were in the 0-250 µm size range in surface water mostly appearing as black-colored fiber shapes. Notably, PE, PS, and PVC polymer types were the most prevalent. Overall, these findings emphasize the contamination of the Shitalakshya river by microplastics, providing essential data for future research. To better understand microplastic pollution, future studies should explore distribution patterns during different periods and water conditions. Additionally, implementing measures such as developing eco-friendly materials, reducing plastic usage, and improving plastic waste management are crucial steps in mitigating microplastics pollution in water. In addition to waste management and public awareness campaigns to assist reduce pollution, future studies could concentrate on the local sources and effects of MPs in the Shitalakshya river.

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