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Deciphering the connection between the informal plastic recycling industry and the microplastic pollution in the Buriganga River

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Microplastic pollution poses a significant global threat to ecosystems and human health, yet limited research exists in underdeveloped regions such as Bangladesh. This study investigates microplastic contamination in the Buriganga River, Dhaka, focusing on the impact of the nearby plastic recycling industry. Five different sites on the bank were selected to collect water and sediment samples. The microplastic particles from these samples were separated by density separation and filtration. The particles were photographed under a microscope to obtain length and surface area data by analyzing the microscope images. Shapes were obtained from the microscope images dividing all the particles into three types of shapes: fragment, filament, and fiber, with fragments being the most plentiful. Raman spectroscopy was used to identify the microplastic particles, and polystyrene was found to be abundant. Quantification of these particles showed the intense effect of the recycling industry, with particle counts thousands of times higher than those at the other sites. Most of the particles (53.6% in water and 68.7% in sediment) identified were 1–5 mm in size. The most abundant shape of particles was fragment in both water (67.9%) and sediment samples (85.8%), followed by fiber in water (19.6%) and filament in sediment (13.9%). Polypropylene (48%) and polystyrene (68%) were the most abundant types of plastics in water and sediment, respectively. Polyethylene was also identified in both water (24.5%) and sediment (10.2%). Downstream sites exhibit elevated microplastic levels, likely influenced by the recycling zone, while upstream sites, despite having less external activity, still show substantial microplastic contamination, indicating a complex interplay of factors contributing to river pollution. This study highlights the urgent need for improved waste management and targeted regulatory interventions on unregulated plastic recycling industries to mitigate microplastic pollution in urban rivers.

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Environmental significance

Microplastic pollution in urban rivers, especially near informal plastic recycling industries, is a growing environmental threat. The Buriganga River in Dhaka, Bangladesh, is heavily impacted by microplastics from nearby recycling zones, with plastic fragments and fibers dominating both water and sediment samples. Addressing this pollution is crucial as it poses risks to aquatic ecosystems and public health. Our study highlights a clear connection between disorganized recycling practices and elevated microplastic contamination, with downstream areas exhibiting significantly higher microplastic levels. These findings stress the need for targeted interventions to regulate informal recycling practices and mitigate further pollution.

1 Introduction

Microplastics, plastic particles with a size below 5 mm, have become a major global pollutant and are now ubiquitous in the environment.[1] They pose a significant environmental, ecological and health threat due to their small size and pervasive presence.[2] So far, they have been globally detected in various water bodies,[3–6] air,[7] fish,[8,9] canned foods,[10] honey,[11] sugar, sea salt,[12] and bottled water,[13] raising concerns about widespread contamination through aquatic and air pathways.[14] They can harm marine life by being ingested and can accumulate in the food chain, impacting ecosystems.[15] The persistence of microplastics, coupled with their global distribution, makes them a long-term and widespread issue.[1] Potential entry through food and air into the human body has been confirmed by their presence in human blood,[16] lungs,[17] and breast milk,[18] raising concerns about health impacts, such as inflammation, tissue

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damage, immune system impairment and gut microbiome disruption.[19] The fate, transport and toxicity of microplastics can depend on microplastic characteristics such as size, shape, and polymer types. Therefore, understanding the source, occurrence, and characteristics of microplastics is essential for minimizing the exposure to this contaminant.

Primary microplastics that are synthesized and used for commercial purposes and in consumer products typically enter the environment directly during manufacturing, use, and waste disposal.[20] On the other hand, secondary microplastics are those produced from bigger plastic waste after entering the environment or in waste management scenarios (*e.g.*, landfill).[21,22] Recently, plastic recycling industries have been considered as an important source of secondary microplastic pollution in the environment; however, studies on this topic are very limited. Studies from both Norway and the UK showed a significant contribution of state-of-the-art plastic recycling establishments to microplastic pollution in nearby waterbodies.[23,24] Another study from Vietnam on a mechanical plastic recycling industry showed that recycling without proper wastewater treatment leads to a greater emission of microplastics to the environment despite recycling being a potential means of reducing plastic pollution.[25] This goes to show the importance of further study on the informal plastic industry as a point source of microplastic pollution, especially in the Global South, where informal industries dominate.

The economic growth in South and Southeast Asia has led to increased plastic consumption and production, contributing to the widespread existence of microplastics.[26] Bangladesh, one of the fastest-growing economies in the world, has an increasing demand for plastic products and there are around 5000 plastic industries that employ roughly 2 million people, and 300 of them recycle plastics.[3,27] In 2016, plastic recycling industries contributed about 280 million BDT to the economy of Bangladesh.[3] But the amount of informally recycled plastics is much higher than that of formally recycled plastics.[3,27] In our previous review, we talked about some of the recent studies on identifying microplastics from Bangladesh.[28] The Buriganga River, one of the four major rivers that surround the capital with a huge impact on the people and the environment, plays a critical role in the city's transportation, wastewater discharge, and industrial activities. The region experiences a tropical monsoon climate, characterized by an average annual rainfall of approximately 200 mm.[29] Average temperatures range from 18 °C in winter to 29 °C during the summer months.[30] The hydraulic behavior of the Buriganga is influenced by seasonal monsoon flows[31] and anthropogenic modifications; flow rates vary significantly, with dry season flows often reduced due to upstream withdrawals and tidal backflow from the Shitalakshya River.[32] The river's hydrology is further complicated by encroachment and siltation, which reduce its carrying capacity and alter sediment dynamics. Pollution sources along the Buriganga are diverse and densely clustered. Major contributors include tanneries, textile dyeing units, plastic recycling factories, domestic sewage discharge points, and informal dumping zones.[33] The Hazaribagh and Kamrangirchar industrial zones, located near the riverbank, are particularly notorious for releasing untreated waste directly into the water. This industrial clustering, combined with limited regulatory enforcement, has led to persistent chemical and physical pollution.

Microplastic research in Bangladesh is still emerging, with most studies conducted in the past few years. Initial investigations have primarily focused on marine and coastal regions.[28] Several recent studies have been conducted throughout the country to investigate microplastic contamination in different water bodies in Bangladesh: Buriganga River,[34] Rupsha River,[35] Karnaphuli River,[36] Mohamaya Lake[37] and waterbodies in the western region.[38] But a growing number of studies are now targeting urban rivers, particularly the Buriganga River in Dhaka.[28] Studies have found microplastics in aquatic species,[39] sediment[34,39–42] and water[34,39,40] samples of the Buriganga River. Islam *et al.*, 2022, showed microplastic abundance in water and sediments of different sites of the river.[34] However, most of the current work has been descriptive, focusing on occurrence rather than source identification or transport dynamics. Moreover, the influence of local anthropogenic activities—especially informal plastic recycling industries—has been understudied, leaving critical gaps in understanding pollution pathways and point sources in river systems. The Buriganga River is surrounded by small-to-medium scale informal plastic recycling industries.[43] Therefore, it is important to investigate the relationships between the abundance of microplastics and the presence of plastic recycling industries that are situated on the bank of this river.

This study aims to assess the situation of microplastic pollution in the Buriganga River and determine the impacts of informal plastic recycling industries on the extent of the microplastic pollution scenario. Islambag, situated on the bank of the river Buriganga in Dhaka, is one of the largest informal plastic recycling zones in the country, and there are different sites on the riverbank where plastic products and pelletized plastics are washed and dried. The mismanagement of these recycling products and the unregulated recycling process contribute a big share of the plastic pollution in the Buriganga River and the surrounding area. The quantity of microplastic particles present in water and sediment samples from four different sites was compared with that of the recycling zone. Quantification, size analysis and identification of the particles were done to evaluate the extent of microplastic pollution in the river that resulted from the plastic recycling.

2 Materials and methods

2.1 Selection of sampling sites

All the samples were collected at the banks or near to the banks of different points of the Buriganga River. Five sites were selected for sample collection. The location of the sites is shown in Fig. 1. The recycling zone (referred to as 'RZ') in Chandir Ghat is located in the Islambag area. This area is situated near the middle of the river. This area was selected because of the high activity of the nearby industries and to determine the impact of the recycling shops. The area marked as 'ORZ' in Fig. 1 is the opposite bank of RZ. A few dump yards and small shops are present here. This site is around 300 m in the waterway from RZ.

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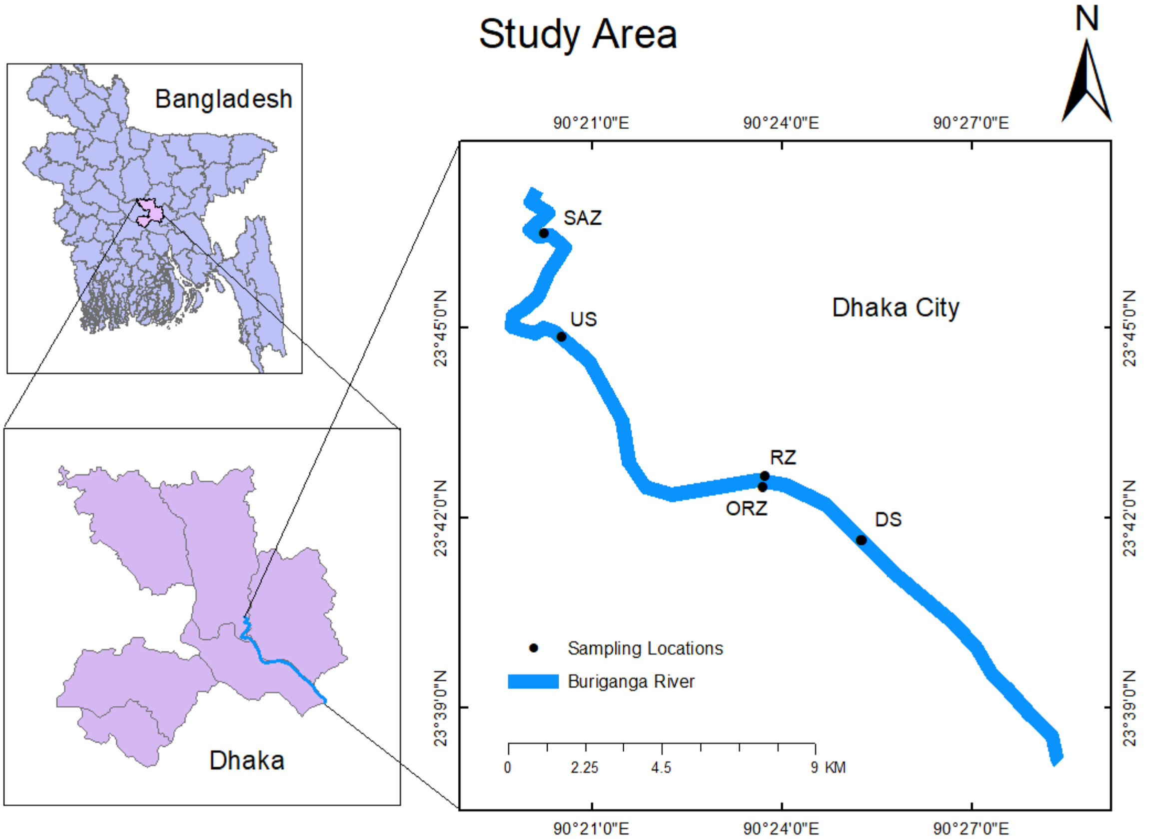

Fig. 1 Sampling sites locations (abbreviations used in the map image are SAZ: secondary active zone, US: upstream site, RZ: recycle zone, ORZ: opposite of recycle zone, and DS: downstream site).

This spot was selected to determine the pollution spread caused by the recycling zone across the width of the river. The location marked as 'US' in Fig. 1 is the upstream site of Bosila. There is a bend in the river before this bank. The secondary active zone, Gabtoli, marked as 'SAZ' in Fig. 1, is another active zone for microplastic pollution, situated 11.5 km away from RZ. There are slums, dump yards, brickfields, small to large shops, and high population density present close to the bank. Also, the waterway is an active route of transportation for small- to medium-sized water vessels. Even though it is an upstream site, there might be a significant amount of microplastic pollution present because of the high amount of anthropogenic activity. The upstream site, Bosila, is marked as 'US' in Fig. 1. This is located about 8 km away from RZ and 6 km from SAZ. No external source of pollution is present here. This site was selected to determine the existing amount of microplastic, where there is no major external source. The downstream site Postogola is marked as 'DS' in the figure (Fig. 1). There is a bridge nearby and it is a rather less active zone. However, there might be effects of the hotspots present before this one as it is in a downstream location and 4.5 km away from the hotspot (Table 1).

2.2 Sampling method

All the samples were taken between the timeframe from July 2022 to January 2023. Water was collected in a triple-rinsed stainless steel bucket,[4,5] following the grab sampling protocol.[6] The bucket was closed using a metal lid and sealed with nylon tape after collection. 10 L of water was collected from 15 cm to 50 cm in depth from the surface of the water. Sediment samples were collected from an approximate depth of 5–10 cm from the water surface using a shovel.[8] For every location, sediments were collected from different points and mixed homogeneously for better representativeness. Around 1 kg of sediment was taken on multiple layers of aluminum foil from each site. Then, the full package was transported to the lab using a jute bag.

The water samples were filtered through a Tyler series 4 sieve (4750 μm) on top of a Tyler series 200 sieve (75 μm). The smallest particle considered for our study is 75 μm. Residues over the Tyler 4 sieve were discarded. The particles from the top of the Tyler 200 sieve were taken for further analysis.

300 g of sediment[9] was taken from the well-mixed samples. Smaller and lighter particles were isolated from the sample by density separation using a saturated NaCl solution.[6,9,16–18] 1 L of saturated NaCl solution was prepared in a beaker and the 300 g sample was mixed thoroughly and left steady for the layers to separate. After 2–3 hours, when the layers were properly separated, particles floating on the top layer were collected. These separated particles were then placed on the Tyler series 4 and 200 sieve setup and rinsed with distilled water to isolate the smaller particles. The bottom layer in the salt solution was

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Table 1 Sampling sites descriptions (W = water and S = sediment)

Site number	Site name	Site category	Site descriptions	Coordinates	Sample codes
1	Chandir Ghat	Recycling zone (RZ)	Located in the Islambag area which is the largest informal plastic recycling zone in Dhaka. This site is a recycling zone and is located almost in the middle of the Buriganga River	23°42′41.2″N 90°23′27.4″E	RZ-W, RZ-S
2	Opposite bank of Chandir Ghat	Opposite of recycling zone (ORZ)	Opposite bank of the recycling zone, some waste dumps, and small shops are present	23°42′30.0″N 90°23′29.1″E	ORZ-W, ORZ-S
3	Gabtoli	Secondary active zone (SAZ)	Another active zone of the river. There are slums, brickfields, and other small businesses present close to the bank, and the water path is an active route for small ships and boats	23°46′56.8″N 90°20′09.2″E	SAZ-W, SAZ-S
4	Bosila	Upstream site (US)	An upstream site. A bend before the sampling site is present	23°44′42.1″N 90°20′44.9″E	US-W, US-S
5	Postogola	Downstream site (DS)	Close to a bridge, but without recycling activities	23°41′24.7″N 90°25′33.0″E	DS-W, DS-S

again stirred and the density separation and sieving steps were repeated 2–3 times for every sample to ensure that all of the small particles were separated from the sample. The separated particles were collected from the top of the Tyler series 200 sieve and then dried in an oven at 40 °C.

To remove the organic matter, the sieved particles were oxidized using hydrogen peroxide (H_2O_2). Each sample of separated particles was kept in 30% H_2O_2 solution for 72 hours in a fume hood.[14,16,17,34] After 72 hours, the mixture was again filtered using a Tyler 200 sieve, washed with distilled water, and then dried in an oven. All the separated particles were then placed in a Petri dish (Fig. 2).

2.3 Observation and identification of MPs

The particles were examined under an optical microscope ZEISS Primovert (Zeiss, Germany) running in phase contrast. Photos were taken using a "Tucsen ISH500" camera and TCapture (Tucsen, China) software. The total number of microplastic

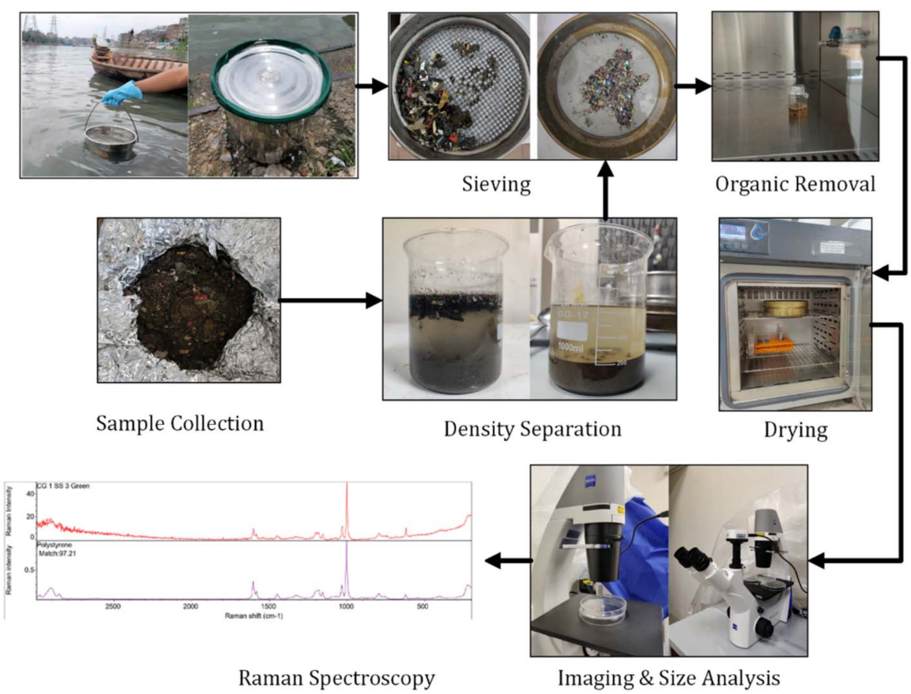

Fig. 2 Workflow diagram of microplastic extraction.

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particles present in different samples was counted from the images manually through observation. However, the hotspot sediment samples had too many microplastic particles and to make the quantification process easier, the sample was diluted in water making a homogeneous mixture (mixing them and then separating them immediately) and particles were counted using 1/20 of the total volume of that mixture. There is no established methodology to classify microplastics by their shapes.[44,45] However, shape is an important characteristic of microplastics. We have classified all the particles found in our study into three types of shape: fragment, filament, and fiber.[46] Microplastic particles with an aspect ratio (length/width) larger than 4 are considered filament or fiber in this study as suggested by Edo *et al.*[46] Fibers are differentiated from filaments by their thickness along the length and sharp ends.[46] Fibers normally come from various kinds of textile fabrics.[4,7,47–49]

The length and surface area of the individual particles were determined from the images using ImageJ (National Institutes of Health, USA) software. The software was calibrated at 500 pixels = 1000 μm and the length and surface area of the particles were measured using the software. A Thermo Scientific DXR3 Raman Microscope (Thermo, USA) was used for chemical

Table 2 Numbers of microplastic particles found in sediment and water samples taken from different samples

Different sample sites	Recycling zone (RZ)	Opposite of recycling zone (ORZ)	Secondary active zone (SAZ)	Upstream site (US)	Downstream site (DS)
Sediment sample (particles per kg)	40 000	373	110	7	40
Water sample (particles per m^3)	3100	100	1600	300	500

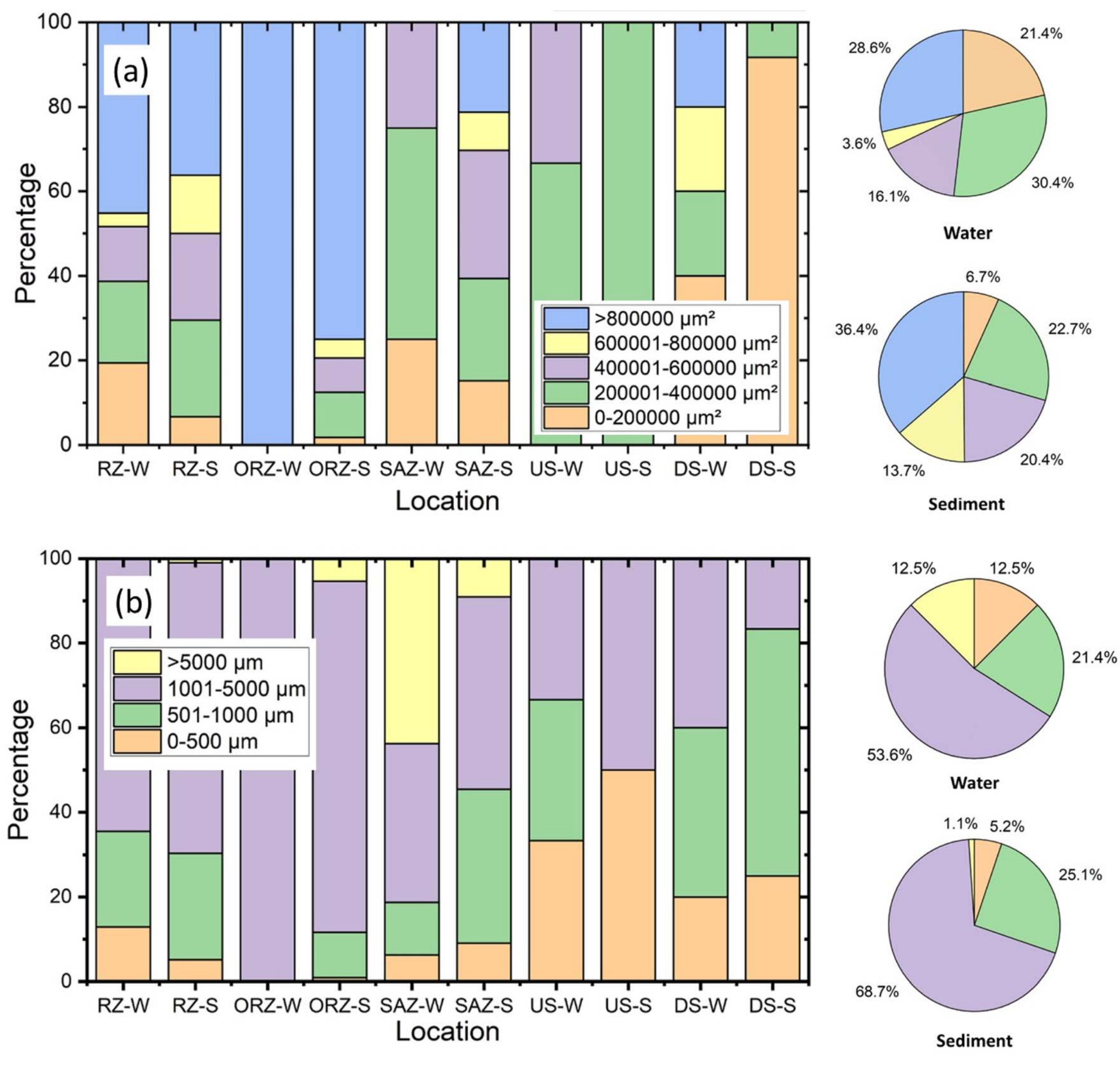

Fig. 3 Microplastic (a) size and (b) surface area in different collection sites and distribution in water and sediment samples.

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characterization[19] and identification of the polymer types of the particles present in the samples after final segregation. The dried microplastic particles were put on a quartz plate (ALPHA Nanotech UV-Grade Fused Quartz Plates, size: 75 mm × 25 mm × 1 mm; acid, base and organic solvent-resistant; spectral range: 190–2500 nm). A 785 nm full-range grating excitation laser with 400 lines per mm grating and 11 mW power was used in the DXR3 Raman spectrometer coupled with an optical microscope. The aperture was 25 μm and the estimated spot size was 3.1 μm. The allowed wave number range was 6 to 3365 cm^{-1}, and a minimum range limit of 200 cm^{-1} and a maximum range limit of 3000 cm^{-1} were set. Representative particles from each sample were taken based on their shape, size, and color and then identified.

3 Results and discussion

3.1 Contribution of informal plastic industries to MP pollution

Table 2 presents the total numbers of microplastic particles in sediment and water samples collected from different sampling locations along the Buriganga River. The number of microplastic particles present in the sediment sample collected from the recycling zone (RZ) is 40 000, which is overwhelmingly larger than the number found in other samples and other locations. The water sample here also had a significantly higher number of particles than other samples. The significantly higher microplastic numbers in the RZ site can be attributed to the contributions from all the informal plastic recycling industries around the bank of the Buriganga River in this region. The higher number of particles in the downstream sites (DS) could be an effect of the recycling zone (RZ). The sediment samples collected from the opposite site of the recycling zone (*i.e.*, location ORZ) showed a comparatively high number of microplastic particles indicating the immediate effect of the hotspot. However, the water sample present here at ORZ had a much smaller number of microplastic particles than RZ. The secondary active zone (SAZ) showed a large number of microplastic particles present in both water and sediment samples though it is upstream. Such numbers can be a result of pollution caused by the brickfields, slums, dump yards, heavy traffic in the waterway, *etc.* Gabtoli (SAZ). being one of the most active piers of the Buriganga River, experiences a lot of human activity. On top of that, littering and the poor waste management system caused a lot of debris to enter the water. Both the upstream (US) and downstream (DS) sites have very little activity near the river. As a result, the amount of pollution is low in these cases. The existing pollution can be traced back to SAZ for the upstream and to RZ for the downstream. The amount of pollution is higher in the downstream than the upstream as the RZ has way higher pollution than the SAZ.

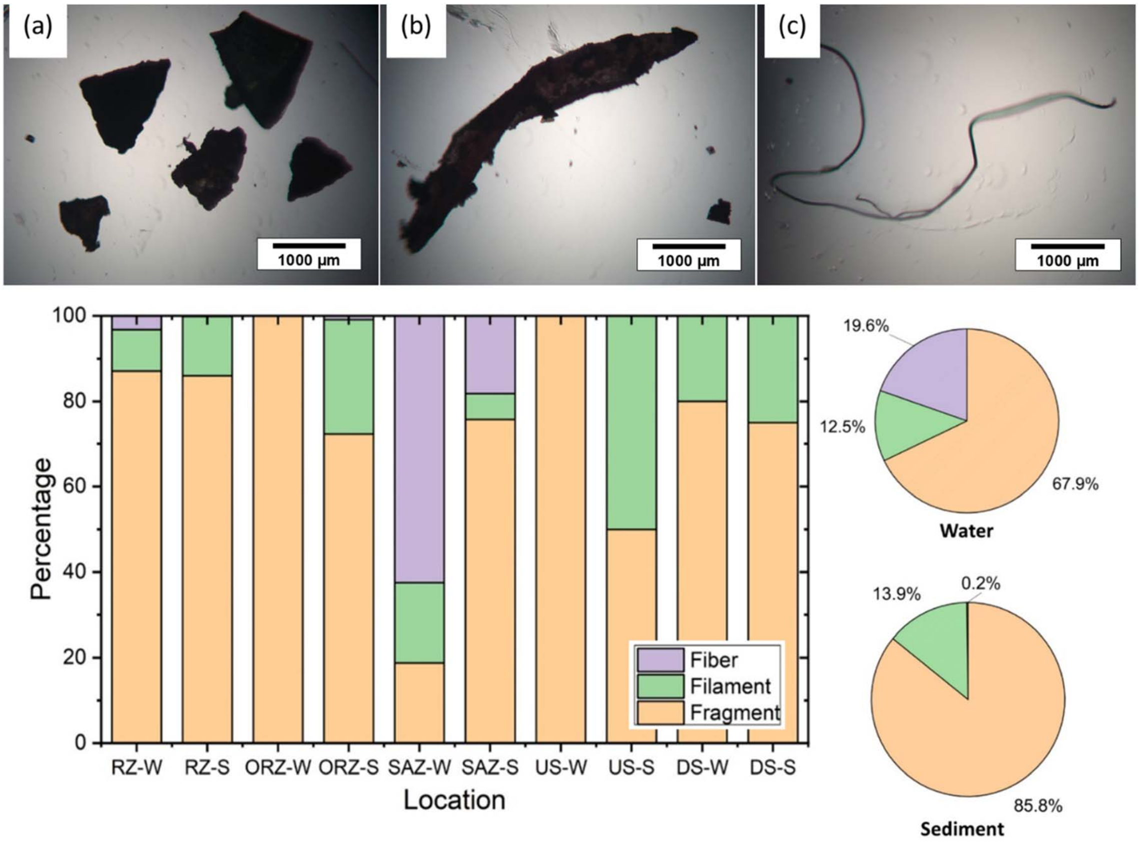

Fig. 4 Examples of different types of shapes: (a) Fragment, (b) filament, and (c) fiber and microplastic shapes in different collection sites and distribution in water and sediment samples.

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3.2 Classification of different types of MPs

The length and surface area of each microplastic particle found were measured using ImageJ software for size analysis. Length and surface area are two important characteristic properties of microplastic research. Size data are crucial for studying the aggregation, settlement, transportation, degradation, bioactivity, bioaccessibility of microplastics, as well as their impacts on the environment, ecology, and human health.[28,50–52]

Fig. 3(a) shows the distribution of microplastic samples by size. We found that most of the particles (54% in water and 69% in sediment) are in the 1001–5000 μm length range. This result is consistent with the study done in the Buriganga River sediment by Islam *et al.*[34] The second most dominant size range is 501–1000 μm, being present in more than 20% of both types of samples. However, the DS sediment sample has a more dominant length range of 501–1000 μm. The RZ sediment sample, the ORZ sediment sample, and the SAZ water and sediment sample have particles greater than 5000 μm, which are fiber-shaped. The SAZ site has a significantly large number of particles with lengths greater than 5000 μm, which are all fibers because if they were not, all of those would have been filtered in sieves. Such differences in size can be a result of the external activities happening around the sites, such as industrial discharge, urban runoff, solid waste mismanagement wastewater treatment, and recreational activities.

Fig. 3(b) shows that the surface area range between 200 001 and 400 000 μm^2 is mostly abundant (30%) in water samples with the second most abundant (29%) range being greater than 800 000 μm^2. Particle surface area greater than 800 000 μm^2 is mostly abundant (36%) in the sediment samples. The downstream site (DS) sediment sample has mostly the smallest

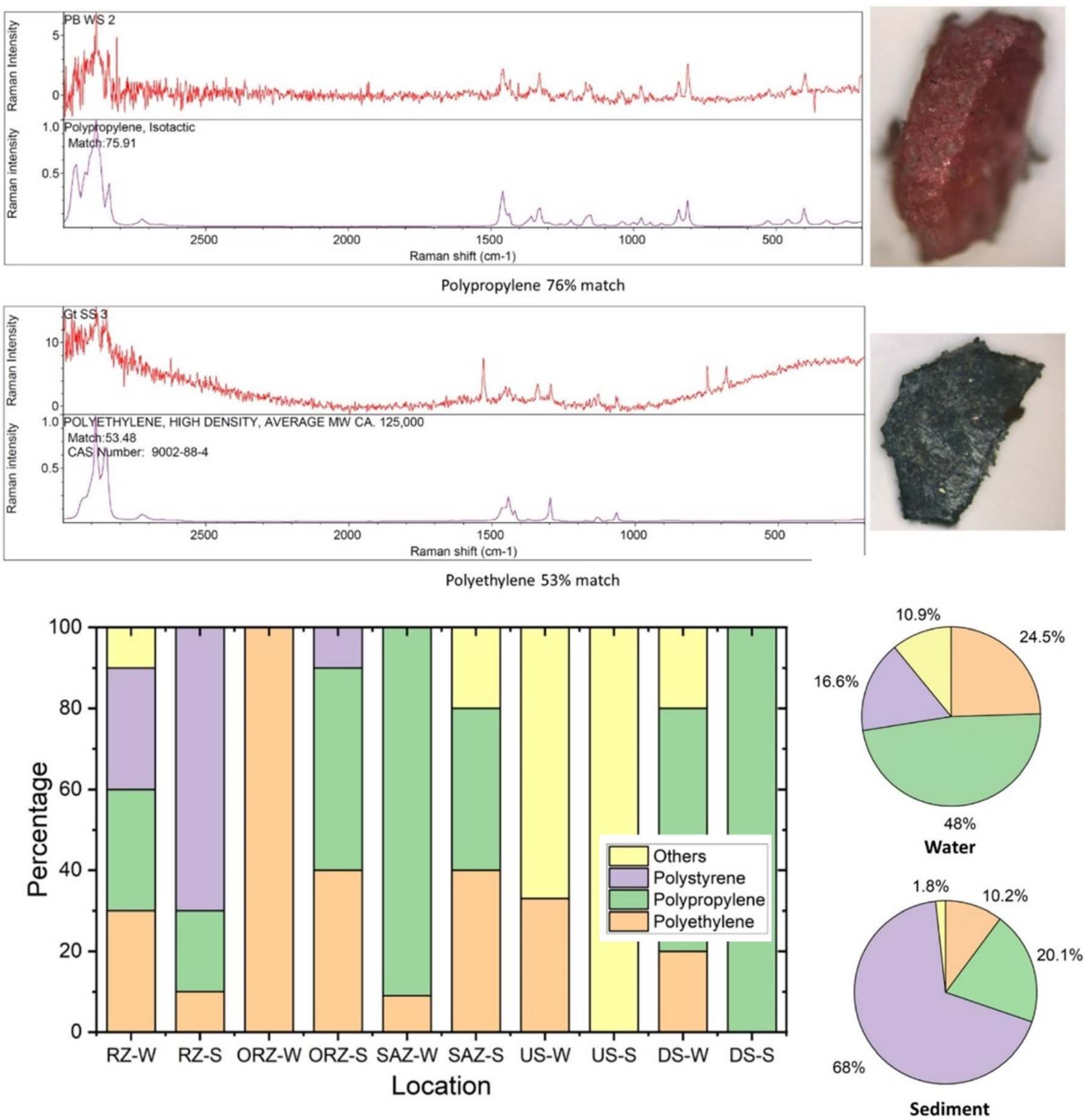

Fig. 5 Polymer types in different collection sites and distribution in water and sediment samples.

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particles under 400 000 μm^2 surface area. The recycle zone (RZ) and opposite of recycle zone (ORZ) have a significant number of large particles because RZ is likely to be the source of microplastics in the river. Downstream sites mostly have smaller particles. A possible explanation is that larger particles are decomposed into smaller particles because of ultraviolet light, heat, wind, waves, weathering and sand abrasion in the river.[53,54]

As seen in Fig. 4, fragments are the most dominant shape in both water (68%) and sediment (85.8%) samples. Filaments are present in most samples except ORZ and US. SAZ has a significant portion of fibers (63% in the water sample and 18% in the sediment sample) in both samples, with fibers being by far the most dominant shape in the water sample. It can be conjectured that there are textile industries or landfills containing textile waste near this location. RZ and ORZ also have a few fibers present. Other studies done in Bangladesh[28] as well as in the Buriganga River[34] match this result. Even studies done on fish[55] and marine[44] samples are similar to this result. Fibers have a significant presence (20%) in water samples. However, these are least present (0.2%) in sediment samples.

Fragments are assumed to originate from larger plastics.[4,14,44,51,53,55,56] Fiber or filament shaped microplastic particles are more buoyant and difficult to settle,[57] which might explain the presence of filaments in DS and less presence in all the sediment samples combined. Hoellein *et al.* found out through a simulation experiment that the settling rate of fiber shaped microplastics is less than that of fragments in fresh water.[58] However, a secondary movement reduces the settling velocity of irregularly shaped fragment particles causing them to sink slower than other shapes of microplastic particles of the same sizes.[59] Microplastic particles can travel great distances driven by surface currents and wind forces.[51] These explain why fragment shape is the most dominant in almost all the samples (except the SAZ water sample) and in the results of all the water samples combined and all the sediment samples combined.

A total number of 63 particles were characterized by Raman spectroscopy. 10 different types of polymers were found. Among them, polyethylene, polypropylene and polystyrene were mostly dominant. The other polymers include poly(dimethylsiloxane), poly(ethylene-*co*-vinyl acetate), poly(propylene glycol), poly(vinyl alcohol), poly(4-methyl-1-pentene), poly(vinyl ethyl ether), and poly(lauryl methacrylate-*co*-ethylene glycol dimethacrylate). The RZ sediment sample has 70% polystyrene in the sample. The overall data for the sediment samples show about 68% polystyrene in the samples, which might be an indication of possible pollution from the recycling zone. According to Fig. 5, polypropylene (PP) is the most abundant (48%) in the water samples, polyethylene comes second. A possible explanation for this result can be the increase of use of non-woven fabrics, locally known as "Tissue fabric", used to make disposable bags and face masks. Such single use plastic products create a lot of waste, which is mostly mismanaged and disposed of on the ground and in landfills, that may later enter the river ecosystem.[60] As PP (0.90–0.91 g cm^{-3}) and PE (0.91–0.97 g cm^{-3}) both have a lower density than water (1 g cm^{-1}), they are generally buoyant in freshwater.[20] Chemical characterization can help trace the source of these particles, *i.e.*, from what industry these plastic products originated. A previous study on the Buriganga River shows that polypropylene is mostly abundant here, which matches the water sample results in this study; however, that study did not consider the hotspot area.[34]

4 Conclusion

This study revealed a significant correlation between microplastic pollution in the Buriganga River and surrounding anthropogenic activities, particularly in informal plastic recycling zones. Among the five studied sites, the recycling zone showed the highest concentration of microplastic particles in both water and sediment, with most particles being fragment-shaped. Polypropylene (48%) was the dominant polymer in water samples, while polystyrene (68%) prevailed in sediments. Upstream sites had lower concentrations, while downstream sites reflected the impact of upstream pollution sources, demonstrating spatial variation influenced by both river flow and local activities.

The strong spatial correlation between high microplastic abundance and the presence of informal recycling operations strongly implicates these industries as major point sources of secondary microplastic pollution. These facilities, often operating without proper environmental controls, discharge plastic particles directly into the river during washing, shredding, and drying processes. The prevalence of polymer types such as polypropylene and polystyrene—commonly found in consumer packaging and disposable goods—points to inadequate segregation and containment practices. This finding underscores the urgent need for formal regulation and environmental monitoring of such industries, particularly those operating in close proximity to ecologically sensitive waterways. Without targeted policy interventions and infrastructure investment in waste management, these informal sectors will continue to exacerbate plastic pollution in urban rivers. As a key waterway in the capital city, the Buriganga River requires immediate attention from governmental and environmental authorities to mitigate ongoing pollution and to safeguard water quality, ecosystem health, and public well-being.

Author contributions

Md. Ridwan Mahfuz: data curation, formal analysis, investigation and writing – original draft; Mohammad Yousran Fargab: data curation, formal analysis, investigation and writing – original draft; Zaki Alam Pushan: conceptualization, methodology, and writing – review & editing; Nafisa Islam: supervision, funding acquisition, and writing – review & editing; Shoeb Ahmed: conceptualization, supervision, funding Acquisition and writing – review & editing; Nirupam Aich: conceptualization and writing – review & editing.

Conflicts of interest

The authors declare no competing interest.

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Data availability

Raw data and images of individual samples are included in the supplementary information. See DOI: **https://doi.org/10.1039/d4va00370e**.

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