MICROPLASTICS IN RIVERBANK SEDIMENT FROM A SEGMENT OF THE BHAIRAB RIVER IN BANGLADESH: OCCURRENCE, CHARACTERISTICS AND RISK ASSESSMENT

Md. Hasibul Hassan*[1] and Islam M. Rafizul[2]

[1] *Undergraduate Student, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: md.hasibulhassan7429@gmail.com*
[2] *Professor, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: imrafizul@ce.kuet.ac.bd*

***Corresponding Author**

ABSTRACT

Microplastic (MP) pollution is a significant concern for both aquatic ecosystems and human health due to its widespread distribution. Khulna City is in southwest Bangladesh, along the Rupsha and Bhairab rivers. The rivers in this area are susceptible to microplastic pollution due to the proximity of urban and industrial activities. This study assessed the occurrence, characteristics, ecological risks, and possible sources of microplastics in sediment along the bank of the Bhairab River. Along a selected segment of the Bhairab River, ten sediment samples were collected from the riverbank at five locations, considering the land use pattern and industrial activities. Microplastics (MPs) were extracted using the density separation method, followed by microscopic examination and FTIR analysis. The average MPs count in riverbank sediment samples was 13.9±3.9 MPs/Kg dry weights. The size range of all particles was between 1 mm and 4 mm. The identified microplastic particles had various shapes, including fragments, fibers, films, and filaments. Fragments were the most dominating shape in each sampling location. Principal component analysis (PCA) revealed a positive correlation between fibers and films. Most of the particles were colored, while some were transparent. FTIR analysis identified two polymer types: Polypropylene (PE) and Low-density polyethylene (LDPE). The ecological risk assessment using the pollution load index (PLI) indicated that the river segment fell in the risk category I, meaning slightly polluted. The potential sources of microplastic pollution are wastewater discharge to the river, launch ghats, ferry ghats, mills, and factories. This study alludes that microplastics result from anthropogenic activities near the rivers in this region.

Keywords: *Microplastics, Riverbank sediment, Microplastic identification, FTIR, Ecological risk*

1. INTRODUCTION

Plastic pollution poses a significant threat to the environment and is considered one of our most pressing environmental issues. Plastic particles have become smaller worldwide in recent decades, and microplastics have become more prevalent (Barnes et al., 2009). The pollution of microplastics in the environment is on the rise as they are being distributed more widely across the world (Nawar et al., 2023). Microplastics are plastic particles less than 5mm in length (Masura et al., 2015). The minimum size can be considered as 333µm (0.3mm) (Arthur et al., 2008). There are two sources of microplastics: primary and secondary. Primary microplastics are produced for commercial use in products such as facial cleansers, air-blasting media, cosmetics, and medicine (Cole et al., 2011). When large plastic particles degrade as a result of aging and weathering, secondary microplastics form (Guo et al., 2019). Aquatic organisms can ingest tiny microplastics (Cole et al., 2011), affecting their feeding, growth, reproduction, and survival (Issac et al., 2021). A complete understanding of the potential health risks to humans associated with microplastics has yet to be achieved (Yong et al., 2020). More accurate measurements of microplastics' abundance and distribution worldwide are necessary to draw meaningful conclusions. The abundance and characteristics of microplastics must be studied to create policies to prevent pollution (Wrinkor et al., 2019). Additionally, it is crucial to assess the ecological and environmental hazards that microplastics present. Recent studies have shown that microplastics are present in water bodies worldwide, and research is focusing on their occurrence and characteristics. Furthermore, there are methods to assess the ecological risks imposed by microplastics (Wang et al., 2021; Xu et al., 2018; Banik et al., 2022).

Bangladesh is a country dominated by rivers, with approximately 700 rivers (Chowdhury et al., 2021). The country's ecosystem, agriculture, transportation, and standard of living are significantly reliant on these waterways. In recent decades, various anthropogenic sources have polluted the rivers that flow through major cities, including plastic waste dumping. The plastic industry has expanded significantly over the past two decades, resulting in a surge in plastic production (Islam et al., 2022). Plastic consumption per person in Bangladesh increased from 2.07 kg to 3.5 kg between 2005 and 2014 (Hossain et al., 2021). A significant amount of plastic waste from urban areas, agriculture, industry, households, and sewage systems ends up in rivers and other freshwater bodies (Abdullah et al., 2022).

Khulna is a city in the southwest of Bangladesh, with the Bhairab River to the north, the Rupsa River in the middle, and the Pasur River to the south (Roy et al., 2005). The Bhairab River in this region serves multiple purposes, such as irrigation, drinking, and industrial processes, as well as wastewater disposal (Khan et al., 2019). Microplastic pollution in this river is possible due to anthropogenic activities and land use patterns along the river. Across the globe, numerous studies on microplastics in river water, sediment, and various fish species have been carried out. Sediment is a major sink for microplastics in freshwater and can also serve as a source of pollution through sediment resuspension (Zhang et al., 2021). To date, no research has been carried out on microplastic pollution in the Bhairab River. This study was the first to investigate microplastics in Bhairab River bank sediment, including their characteristics and ecological risk.

2. METHODOLOGY

2.1 Sampling Site and Sampling

For this study, a segment of the Bhairab River consisting of five sampling sites was selected, taking into consideration the land use pattern. Two samples were collected from each sampling site between March to August 2023. Riverbank sediment samples of 1 kg were collected from a 0.3 m × 0.3 m quadrant using a stainless steel scoop from an upper 10 cm depth (S.K. et al., 2020). After collecting samples in polyethylene bags, they were immediately taken to the Waste Laboratory at KUET for further processing.

Table 1: Sampling Locations

Sampling Location	Latitude	Longitude	Location Name	No. of Samples
S1	22°55'3.84"N	89°30'55.86"E	Shiromoni Ghat	2
S2	22°54'33.16"N	89°31'4.94"E	Cable Terminal	2
S3	22°53'55.73"N	89°31'6.80"E	Fulbari Gate Ghat	2
S4	22°52'58.57"N	89°31'21.21"E	Religate Ferry Terminal	2
S5	22°52'12.70"N	89°31'37.80"E	Daulatpur Launch Terminal	2

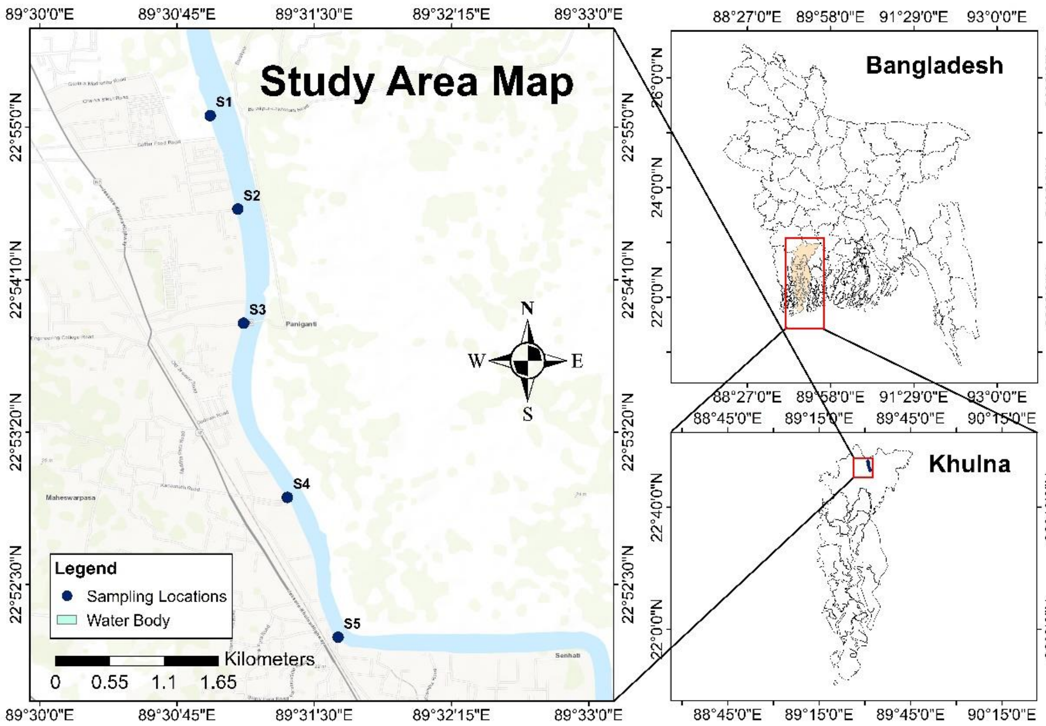


Figure 1: Sampling locations at Bhairab Riverbank

2.2 Microplastic Extraction

The laboratory procedure was conducted in the Waste Laboratory and Environmental Engineering Laboratory, Department of Civil Engineering, KUET. The procedure mostly followed the "National Oceanic and Atmospheric Administration" method (Masura et al., 2015). Several modifications were made following other literature (Parvin et al.,2022; Yang et al.,2021). The wet sediment sample weighing 400 grams was dried for 24 hours in an oven at 60 °C. The dried sample was crushed and ground into powder to facilitate sieving. Then, the ground sample was sieved through No.4 (4.75 mm) and No.50 (0.3 mm) sieves. The sample retained on the No.4 sieve was discarded. A concentrated NaCl solution was prepared by adding 6g NaCl per 20 mL of distilled water (5M NaCl). The sample retained on the No.50 sieve was placed in a 600 mL beaker, and then 400 mL of concentrated NaCl solution was added. The mixture was stirred thoroughly. The beaker was covered with aluminium foil paper and left for 48 hours for density separation. Then, the supernatant was sieved through a No.50 sieve, and the retained sample was taken to a 100 mL beaker. The beaker was placed in an oven at 60°C for 24 hours. Afterward, 20mL of a 30% H_2O_2 solution was added to degrade the organic matter in the sample. The beaker was then left to sit at room temperature for 48 hours while covered with aluminium foil. Next, 60mL of concentrated NaCl solution was added and left for 24 hours to undergo second-density separation. Then, filtration was carried out using a 0.45µm Cellulose Nitrate filter paper. A glass petri dish was used to hold the filter paper, which was then placed in an oven at 60°C for 24 hours. Finally, the filter paper was examined under a microscope.

2.3 Microscopic Examination

Microscopic examination was conducted using a Leica ICC50 W microscope equipped with a camera from the Department of Biomedical Engineering, KUET. The number of extracted microplastics on the filter paper was determined under 40x zoom. Suspicious particles underwent a hot needle test (Banik et al., 2022). The microplastic particles were imaged using the LAS EZ software (Version 3.4.0). The sizes of the microplastic particles were determined using the ImageJ software (Version 2.0.0). In order to classify microplastics, their sizes, shapes, and colors were taken into consideration.

2.4 FTIR Analysis

Fourier Transformed Infrared (FTIR) spectroscopy was carried out in the postgraduate laboratory of the Department of Chemistry, KUET, to determine the types of polymers. Representative microplastics were chosen for the KBr-FTIR test. From the test data, peaks in the wavenumber 400-4000 cm^{-1} range were observed. The types of polymers were identified by comparing them with other literature (Jung et al., 2018; Noda et al., 2007).

2.5 Risk Assessment

The Pollution Load Index (PLI) is commonly utilized to assess environmental risk in both land and water-based ecosystems (Tomlinson et al.,1980). MP concentration was regarded as the contaminant in this investigation to assess the ecological risk. To evaluate the PLI, the equations below were utilized (Xu et al., 2018; Wang et al., 2021; Banik et al., 2022).

$$CF_i = \frac{C_i}{C_{oi}} \quad (1)$$

$$PLI = \sqrt{CF_i} \quad (2)$$

$$PLI_{Zone} = \sqrt[n]{PLI_1\, PLI_2 PLI_3 \dots PLI_n} \quad (3)$$

Where CF_i is the contamination factor for microplastic pollution in each sampling location. C_i is the microplastics' concentration in each sampling location, and Co_i refers to the concentration of MPs in sediment before the plastics industry's expansion (Banik et al.,2022). Since there was no study regarding microplastics in the sediment of the Bhairab River, Co_i was taken as the minimum concentration among all sampling locations (Banik et al., 2022; Xu et al., 2018; Wang et al., 2021). The PLI value was categorized following the criteria proposed by (Xu et al., 2018) to understand the risk level.

2.6 Data Analysis

MS EXCEL 2016 was used to analyze Microplastic particles' abundance and characteristics. The FTIR data was plotted in Origin 2023b software. PCA (Principal Component Analysis) was performed using XLSTAT 2023 to understand the correlations between the various shapes of microplastics.

3. RESULT AND DISCUSSION

3.1 Abundance of Microplastics

Microplastics in each sample were expressed in items/kg of dry weight (Parvin et al., 2022). The mean abundance in two samples from each sampling location was reported as Mean ± Standard Deviation. All the particles of size less than 4.75 mm were considered, and the larger particles were discarded. The highest mean abundance was found in sampling location S3, which was 18.7±6.6 items/Kg of dry weight followed by 16.3±7.7 items/Kg of dry weight,13.8±4.7 items/Kg of dry weight, 12±2.1 items/Kg of dry weight in sampling location S1, S2, and S5 respectively. The lowest mean abundance was found in sampling location S4, viz. 8.6±2.4 items/Kg of dry weight (Figure 2).

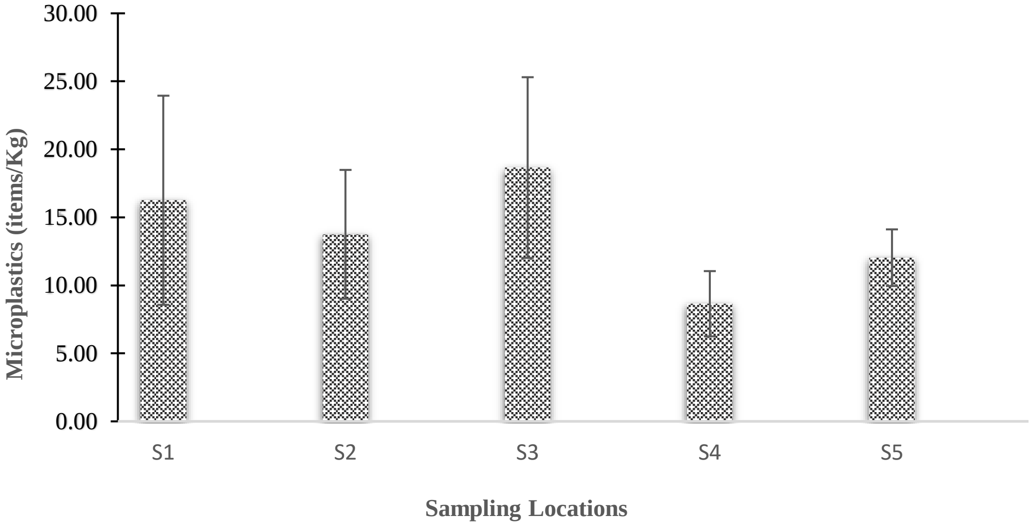


Figure 2: Abundance of microplastics in all sampling locations

3.2 Characteristics of Microplastics

The size range of the extracted microplastic particles was 1 mm to 4 mm. No particles larger than 4 mm were found; hence, the size range of 4 mm to less than 5 mm (4.75 mm) was omitted. The particles were categorized into three groups within the 1 mm to 4 mm range for each sampling location (Figure 3). The dominant size range was 2 mm to 3 mm, consisting of 55% of the total extracted particles (7.7±4.7 items/Kg of dry weight on average), followed by 3-4 mm (25%) and 1-2 mm (20%).

The microplastics were classified according to their shapes as fragments, fibers, films, and filaments (Figure 6). Fragments were the most dominant shape, consisting of 57% of the total extracted particles (7.9±5 items/Kg of dry weight on average), followed by films (22%), filaments (14%), and fibers (7%). The highest percentage of fragments was found in sampling location S5, comprising 85.71% (Figure 4).

Most of the particles were colored (82%), while some particles were transparent (18%). The percentages of different colored particles in all sampling locations are shown in Figure 5. Among colored particles, red was the dominant color, consisting of 40% of the total extracted particles (5.5±4.3 items/Kg of dry weight on average), followed by green (15%), black (14%), and other colors (13%).

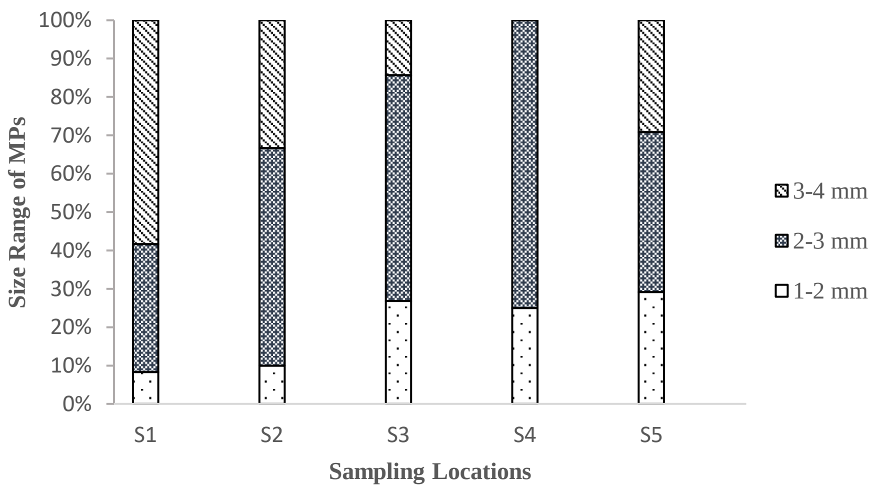


Figure 3: Size range of microplastics in all sampling locations

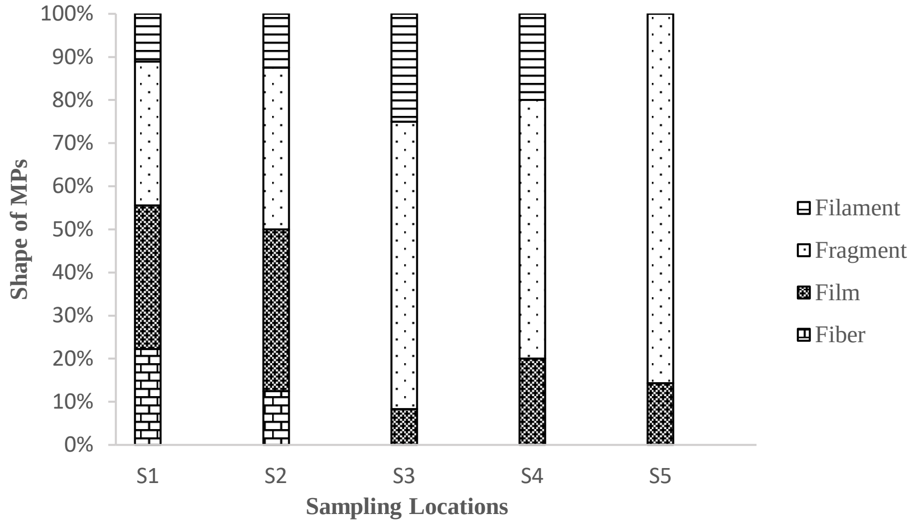


Figure 4: Shape classification of microplastics in all sampling locations

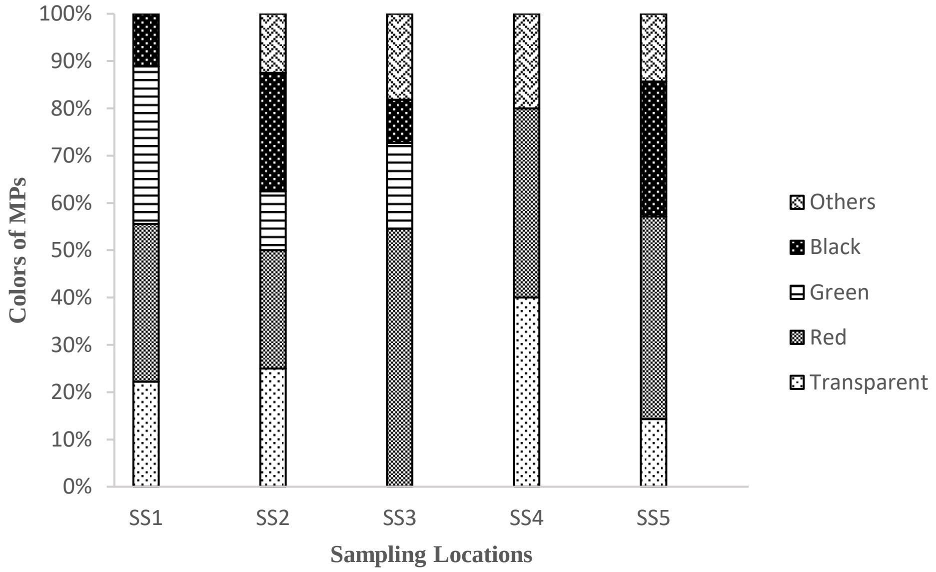


Figure 5: Colors of microplastics in all sampling locations

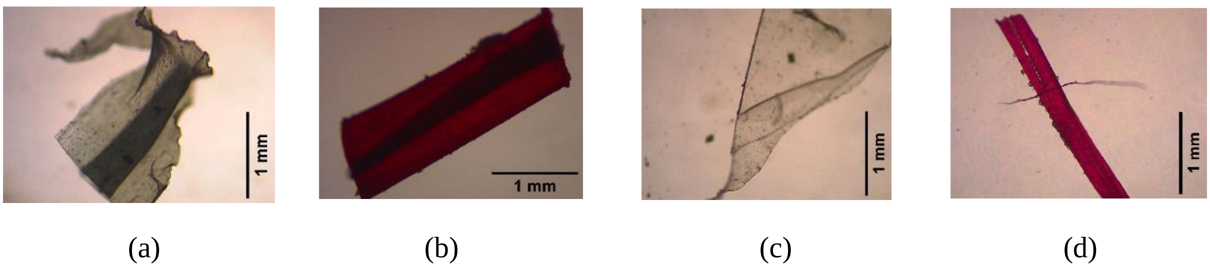


Figure 6: Shapes of extracted microplastics (a) Fragment, (b) Filament, (c) Film, and (d) Fiber

3.3 Principal Component Analysis

After analyzing the four shape variables - fragment, filament, fiber, and film - with Principal Component Analysis (PCA), it was discovered that 95.88% of the total variance could be described by two factors: PC1 and PC2. PC1 explained 69.74% of the variation in film, fragment, and fiber, while PC2 explained 26.14% of the variation in filament (as shown in Figure 7). The angle between film and fiber variables was less than 90°, indicating a positive correlation between these two types of microplastics. On the other hand, the angle between the fragment and filament was 90°, implying no correlation. Fiber and film were negatively correlated with fragments and filaments. Additionally, the results revealed that films and fibers were mainly distributed in S1 and S2, while S5 had the highest concentration of fragments. Filaments were mainly distributed in S3 and S4. The biplot also showed that S1 and S2 had similar types of shape distribution as they were closely located, which was also valid for S3 and S4.

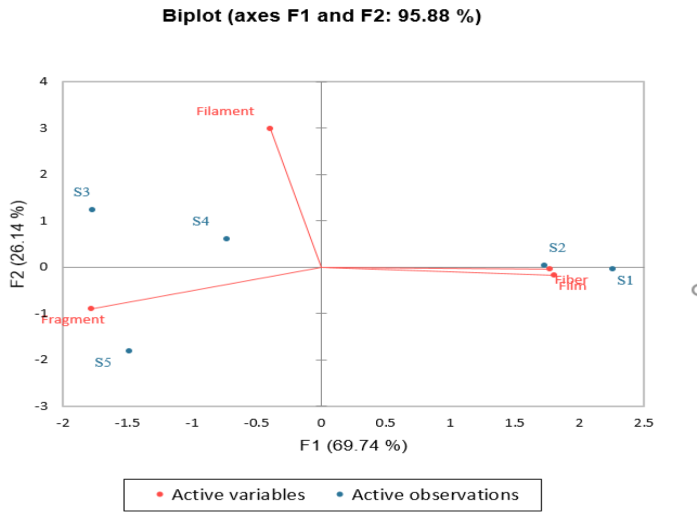
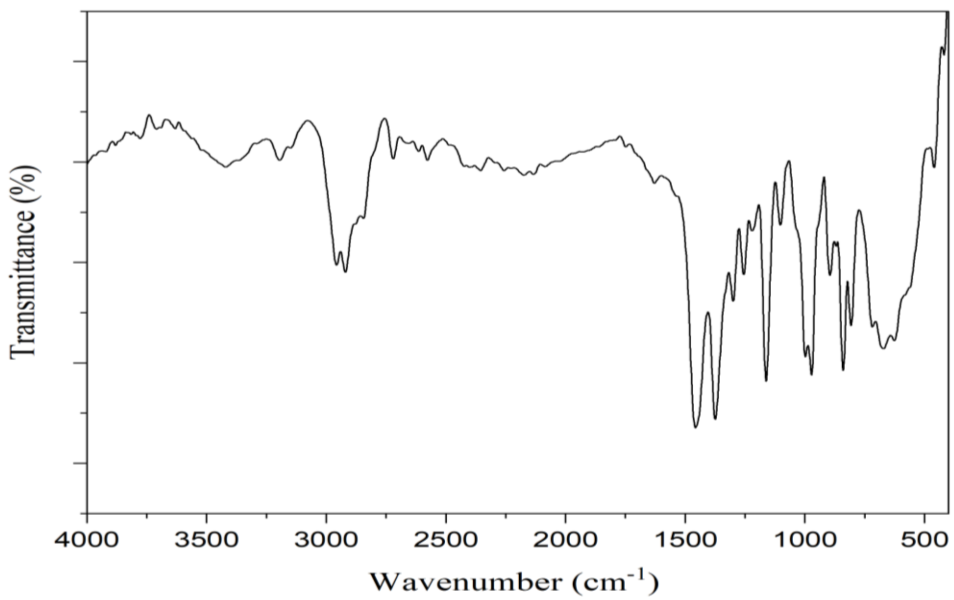


Figure 7: PCA Biplot for shapes of microplastics in all sampling locations

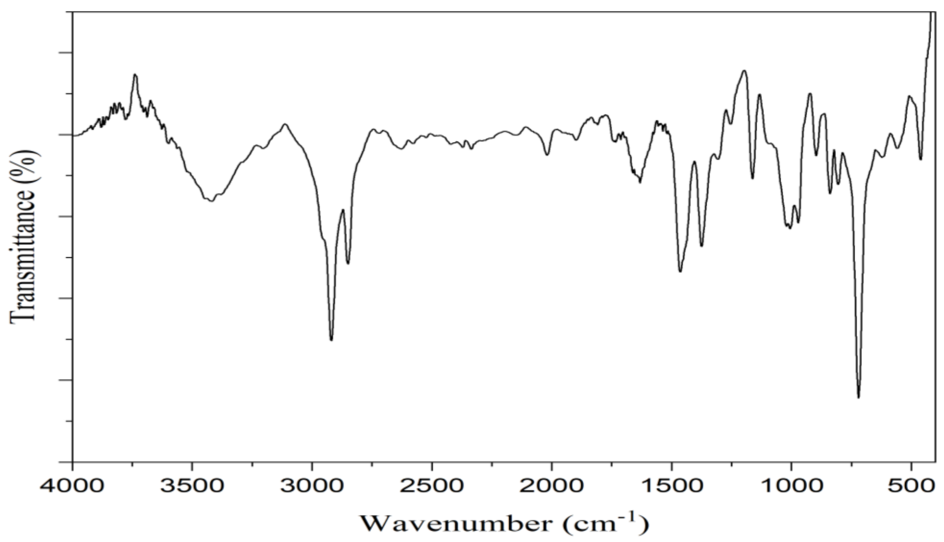
3.4 Polymer Types of Microplastics

Three representative microplastic particles were analyzed with FTIR spectroscopy. The KBr-FTIR test was adopted. The analysis showed that two of the three analyzed particles were Polypropylene(PP), and one was Low-Density Polyethylene (LDPE). Both of these polymers' FTIR spectra are displayed in Figure 8. The peaks at wavenumber 400-4000 cm^{-1} were observed. The transmittance bands pertaining to each kind of polymer have been sourced from extant literature (Jung et al., 2018; Noda et al., 2007). A representative particle from the sampling location S3 showed peaks at wavenumbers 2958 cm^{-1}, 2916 cm^{-1}, and 2845 cm^{-1}, representing the C-H stretch. Similarly, peaks at other wavenumbers such as 1462 cm^{-1} (CH_2 bend), 1379 cm^{-1} (CH_3 bend), 1166 cm^{-1} (CH bend, CH_3 rock, C-C stretch), 997 cm^{-1} (CH_3 rock, CH_3 bend, CH bend), 974 cm^{-1} (CH_3 rock, C-C stretch), 842 cm^{-1} (CH_2 rock, C-CH_3 stretch), and 804 cm^{-1} (CH_2 rock, C-C stretch, C-CH stretch) confirmed that the particle was more likely to be polypropylene(PP). Similarly, LDPE was also identified by carefully observing the various peak assignments and comparing them with the existing literature (Jung et al., 2018). Due to weathering, aging, and fragmentation of MPs, the peaks were not identical to the reference spectrum but slightly varied. As the variations were very slight, they were neglected.

Polypropylene (PP) is used in plastic bottles, packaging textiles, plastic parts for machinery, etc. (Rabari et al., 2023). LDPE is mostly used in plastic packaging films and medical/healthcare items. The polymer types that were identified did not yield sufficient information to determine the actual sources of microplastics. However, the potential sources could be predicted. Several drains are located in the Khulna City Corporation, through which the wastewater containing plastic is directly dumped into the river. Various mills and factories could be a source of plastic waste entering the river. Due to the presence of launch ghats and ferry ghats, various plastic wastes are directly dumped into the river. The large plastics may have been degraded by weathering action and turned into microplastics. The river water carries these microplastics. The density and mobility of microplastics change in combination with suspended solids and algae, which causes the microplastics to settle (Zhang et al., 2021). As a result, during flood tides, the particles may have accumulated in the bank sediments.



(a)



(b)

Figure 8: FTIR spectrum of extracted microplastics (a) Polypropylene (PP) and (b) LDPE (Low-Density Polyethylene)

3.5 Risk Assessment of Microplastics

The PLI value was calculated for each sampling location, and the results are displayed in Figure 9. The minimum microplastic concentration (6.86 items/kg of dry weight) at the cumulative probability of 5% was used as the background value (Banik et al.,2022). The sampling location S3 had the highest PLI value (1.64 ± 0.29), followed by S1 (1.52 ± 0.37), S2 (1.41 ± 0.25), S5 (1.32 ± 0.11) and S4 (1.12 ± 0.16). The sediment of the Bhairab River was classified as slightly polluted by MPs, falling under risk category I according to the PLI, with all values above one and below 10 (Xu et al., 2018).

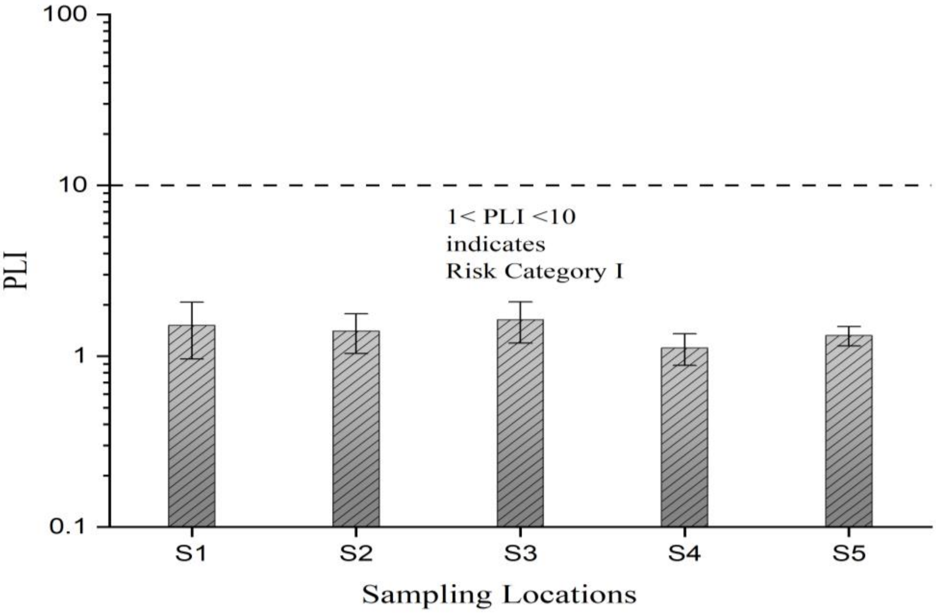


Figure 9: PLI value at each sampling location

4. CONCLUSION

This study was the first to assess the occurrence, characteristics, and risk of microplastics in the bank sediments of the Bhairab River. From the investigation, the presence of various shapes (fragments, filaments, fibers, and films), sizes, and colors of microplastics was confirmed in the sediments. FTIR analysis identified two types of polymers: PP and LDPE. These polymer types indicated that the microplastic particles came from various anthropogenic activities near and on the river. The potential sources are wastewater discharge to the river, launch ghats, ferry ghats, mills, and factories. The PLI values showed that the sediments in The Bhairab River's bank fell under risk category I, indicating slight pollution. This investigation can help make policies to inhibit microplastic pollution by properly managing plastic waste. To find out how microplastics affect aquatic life and human health, further research in this area is recommended.

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