Extent and distribution of microplastic contamination in the benthic sediment of Turag river in Bangladesh

Tofa T.[1,2], Chowdhury V.[1,*], Nur S.[1], and Chowdhury M.[1]

[1] Department of Civil and Environmental Engineering (CEE), Islamic University of Technology (IUT), Boardbazar, Gazipur, Bangladesh.

[2] Department of Civil Engineering, Military Institute of Technology (MIST), Mirpur Cantonment, Dhaka-1216, Bangladesh.

*corresponding author e-mail: vubanchowdhury@iut-dhaka.edu

Abstract

Microplastics are ubiquitous in the aquatic environment. However, a limited number of studies have been conducted on the quantification of accumulated microplastics in benthic sediments of freshwater bodies, which pose threat to the health of benthic communities through food chain contamination. The research aims to quantify, categorize, and determine the distribution pattern of microplastic residues in the benthic sediment along the stretch of an alluvial river (adjacent to public and private establishments such as markets, mosques, universities etc.) on the northern part of Dhaka city. A two-step mechanism made up of size-fractionation and density separation was carried out for microplastic extraction. Extracted microplastics were classified based on size, type and density. The mean abundance was 559.03 ± 10.71 items per 500 g. ANOVA indicated a significant variability with respect to location, size and interaction between the two. Correlating size and microplastic number revealed the presence of a higher number of microplastic in smaller size fractions. Contamination was the highest in the sample beside a market (1311 items) and the lowest beside a university (236 items). Discoveries from this study help to reduce the scarcity of knowledge on microplastic contamination in the context of a freshwater body in the study area.

Keywords: Microplastics, River, Benthic sediment, Extraction, Categorization.

1. Introduction

Microplastics (MP) are solid synthetic materials of petrochemical origin smaller than 5 mm with poor water solubility and biodegradability (Verschoor et al., 2014). Under natural conditions, secondary MP are derived from environmental degradation of larger plastic objects but MP can also be manufactured for commercial purposes e.g.: MP are utilized as raw materials (resin pellets) (Wagner et al., 2014). Both direct ingestion by organisms and absorption from water can transfer MP across different trophic levels, posing a threat to an entire ecosystem (Sharma & Chatterjee, 2017). An investigation of the spatial extent of MP contamination across six continents on eighteen shores revealed that the abundance of MP per sample ranged from 2 (Australia) to 31 (U.K., Portugal) fibers per 250 mL of sediment with the prevalence of a higher quantity in densely populated areas (Browne et al., 2011). The last two decades saw a rise in the number of studies on MP contamination of marine systems but the shortage of similar studies on global freshwater systems has been noticed for a long time (Ivleva et al., 2016). Density separation is an effective step implemented in the extraction of MP from sediment samples. Semensatto and Dias-Brito (2007) compared the cost of the two most effective flotation media for density separation and stated that a working solution of SPT costs 30 times more than that of zinc chloride ($ZnCl_2$). The recovery rate of $ZnCl_2$ in separating MP has been analyzed in different studies and it lies within a range of 95.5% - 100% (Coppock et al., 2017; Imhof et al., 2012; Konechnaya et al., 2020). Using $ZnCl_2$ as the floatation medium, the Sediment Microplastic Isolation unit (SMI), a single-step separation mechanism used in Coppock et al. (2017), obtained a recovery rate of 92% - 98% which was similar to the more sophisticated Munich Plastic Sediment Separator (MPSS) used in Imhof et al. (2012). The SMI unit improves the recovery rate of the classic floatation method (Hidalgo-ruz et al., 2012) and eliminates the necessity of repeating the separation procedure 3-5 times (Claessens et al., 2013) as suggested by Coppock et al. (2017). In Bangladesh, a few recent studies such as Hossain et al. (2021) have confirmed the abundance of MP in marine sediments. But there exists a knowledge gap regarding the abundance of MP in the benthic sediment of alluvial rivers. The Benthic zone of a water body consists of the sediment surface that extends across its slope from the continental shelf to the abyssal zone. Freshwater and marine water bodies share a lot of similar sources of MP contamination. However, it can be hypothesized that the benthic zone of rivers is likely to possess a higher concentration of MP in comparison because of the lower volume of water.

The study aims to acquire an overview of the extent of MP contamination, assess its variability based on different factors and distribution based on different categories in the context of an alluvial river of Bangladesh. A cost-effective and efficient two-step mechanism consisting of size fractionation and density separation was implemented for extraction and simple categorization.

2. Methodology

2.1. Sample collection & preparation

A total of 30 soil samples (600 gm.) consisting of the benthic sediments of Turag river (situated on the north of Dhaka city) were collected from 10 sampling stations from August 2020 to December 2020. 3 samples were collected at each station using a stainless steel spoon from varying depths. The edge of the Turag River is used as a dumping site for municipal and industrial solid wastes (Islam et al., 2013). This makes the benthic sediment of this river ideal for analyzing the extent of plastic pollution. The geographic coordinates of the sampling stations were recorded during sample collection and Figure 1 shows their locations. The locations were selected based on the presence of plastic contamination sources in the surrounding region. The collected soil samples were air-dried for 24 hours as shown in Figure 2. The soil samples comprised of clusters were disintegrated using mortar and pestle into smaller fragments to allow trapped MP to break free.

Figure 1. Location & surroundings of sampling stations

2.2. Grain size fractionation

After air-drying, the dry weight of the soil samples varied due to the difference in their initial moisture content. Hence, in the first step, an equal weight (500 gm.) of soil was separated from each of the air-dried samples and passed through a stack of sieves. The sieves were placed in a mechanical sieve shaker for 10 minutes and the soil sample retained on each sieve was weighed. This prepared the soil samples for extraction, identification & quantification of MP within 6 size fractions- 5 - 4.75 mm, 4.75 - 2.36 mm, 2.36 - 1.18 mm, 1.18 - 0.6 mm, 0.6 - 0.3 mm, 0.3 - 0.15 mm in the second step.

Figure 2. Air drying of two soil samples from sampling stations 7 (Recreational zone) and 8 (Factory)

2.3. Floatation medium

$ZnCl_2$ was chosen as the floatation medium considering its cost efficiency and effectiveness. 1.5 g/ml $ZnCl_2$ solution was prepared by adding $ZnCl_2$ to distilled water because of its effectiveness on different sediment types (Coppock et al., 2017).

2.4. Density separation

Considering the simplicity and the high recovery of the SMI unit used by Coppock et al. (2017) a similar density separator was developed as the second step in MP extraction. The density separator consisted of a sedimentation zone & a floatation zone made up of transparent polypropylene pipes (0.5 cm thick) which were connected by a ball valve (Figure 3). Closing the ball valve separates the two zones and blocks the re-suspension of sediments within the floatation zone.

All the individual components of the separator were washed using distilled water and dried prior to assembly to get rid of any pre-existing contaminants. The $ZnCl_2$ solution was poured into the separator, and the inside of the open valve was submerged to allow any externally driven contaminants to float up after assembly (Coppock et al., 2017). The decontaminated density separator was filled with 700 mL $ZnCl_2$ solution (1.5 g/ml) and soil grains from a sample within the size fraction 4.75 – 2.36 mm were added. The solution was stirred for 30 seconds while the valve was open, followed by a 15 minutes sedimentation period. Then the valve was carefully closed without agitating the solution and the solution from the floatation zone was passed through filter paper placed over a büchner funnel. The filtered subsamples were treated with 35% H_2O_2 at 60 ºC for 12 hours to eliminate the presence of organic matter (Konechnaya et al., 2020). Finally, the treated sub-samples were transferred to a petri dish for identification & quantification of MP as shown in Figure 4. The process was repeated for all the remaining grain sizes and samples. However, it was ensured that in every 700 mL of floatation medium, not more than 50 mL of sediment is present as an excess amount of sediment could lead to potential losses of MP being sunk by the weight of the soil grains (Coppock et al., 2020). The $ZnCl_2$ solution was recycled by vacuum filtration (Rodrigues et al., 2020) up to 2 times after the sediment filled a volume of 50 ml.

2.5. Microplastic categorization, quantification and statistical analyses

MP were categorized and quantified based on size, type (fragments, fibers and others) (Figure 4) and density. Analysis of variance (ANOVA) was performed to determine the statistical significance of the variability of MP quantity based on location and size. A stereo-microscope was used for observation of form, structure based on which type was determined and decision regarding density was based on colour, transparency and elastic consistency of particles determined by applying tweezers similar to Fries et al., 2013.

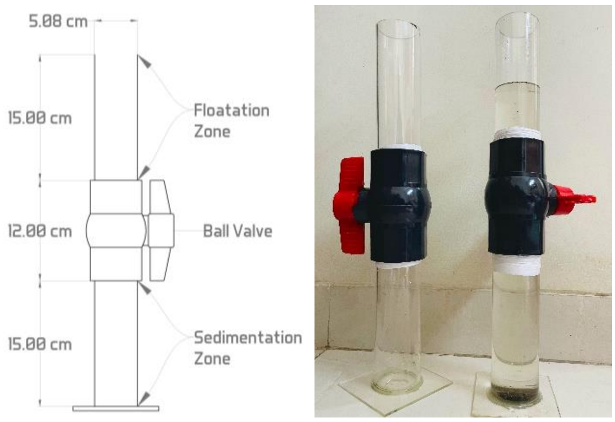

Figure 3. Schematic diagram (left) and photograph (right) of density separator

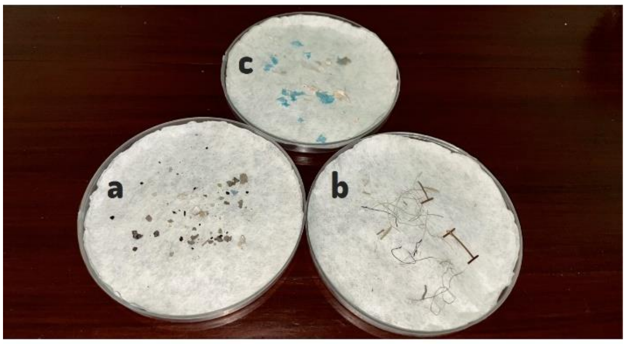

Figure 4. Samples of three types of extracted microplastic on petri dishes. (a) Fragments (b) Fibers and (c) Other (films, foams, pellets and beads)

3. Results and Discussion

The number of MPs varied from 236 to 1311 items per 500 g of sample with a mean abundance of 559.03 ± 10.71 items per 500 g. In comparison, Hossain et al. (2021) recorded a mean abundance of 368.68 ± 10.65 items per Kg in the intertidal zone at the beach of the Bay of Bengal. The comparison suggests that the concentration of MP in the benthic sediment of the Turag river is higher than that of the aforementioned marine sediment. The lower volume of water for dilution in the river can be a cause of the higher concentration of MP (McCormick et al., 2014). From one-way ANOVA, significant variability of quantity with respect to location ($p=0.0265$) was observed. The quantity of MP varied significantly based on size ($p<0.01$) as well. The two-way ANOVA showed significant variability of the quantity of MP based on location ($p<0.01$), size ($p<0.01$) and the interaction between the two ($p<0.01$). The difference in land use, people's tendency to dispose plastic and the population between regions can contribute to the variability based on location. The highest number (1311 items) of MP was collected from a sample beside the market (sampling station 4) which is prone to a large gathering of people. The abundance of MP can be traced back to the lack of improper plastic disposal which was observed in this region. The minimum number of MP (236 items) was observed in a sample collected from a location adjacent to a university (sampling station 5) which has a proper disposal system and an educated population. Significant variability in the quantity of MP based on size implies that plastics fragmented into various sizes deposits at the benthic zone of the river. This poses a great risk to the benthic population. A correlation analysis implied that there exists a higher number of MP in the smaller size fractions as the data from all the samples yielded a negative Pearson correlation coefficient between size and quantity (Table 2).

Table 2. The average number of microplastic of different sizes and Pearson correlation coefficient (r) between size and quantity of microplastic at each sampling station (S.S.)

	Size (mm)						
S.S.	**<4.8**	**<2.4**	**<1.2**	**<0.6**	**<0.3**	**<0.2**	**r**
1	28	52	44	47	134	118	-0.68
2	24	67	59	32	125	165	-0.64
3	0	54	73	34	53	46	-0.69
4	95	177	176	280	292	290	-0.93
5	10	51	52	51	44	37	-0.73
6	19	53	58	15	74	77	-0.57
7	0	10	14	54	143	223	-0.69
8	0	0	9	96	157	190	-0.75
9	3	9	36	246	144	416	-0.69
10	0	0	57	91	356	327	-0.72

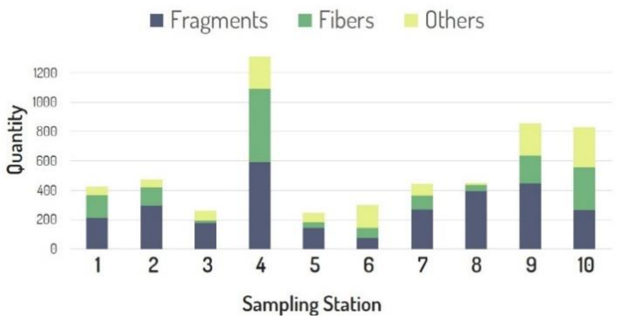

Figure 5. Quantity of fragments, fibers and other types of microplastic at different sampling stations

Categorization of MP based on type (figure 5) (fragments, fibers & others) revealed that sediment in sampling station 4 (market) had a relatively similar percentage of fragments (45%) and fibers (38%) which are secondary MP. A wide variety of MP contaminants is indicated by the similar percentage of all the types of MP (32% fragments, 36% fibers & 34% others) beside the Cafeteria (sampling station 10). A high percentage of fragments were found adjacent to the beverage factory (sampling station 8) (87%), the landfill (sampling station 2) (63%), the recreational Zone (sampling station 7) (60%) owing to the production or disposal of single-use plastic in such locations. The percentage of other types of MP was the most adjacent to the motor factory (sampling station 6) (52%).

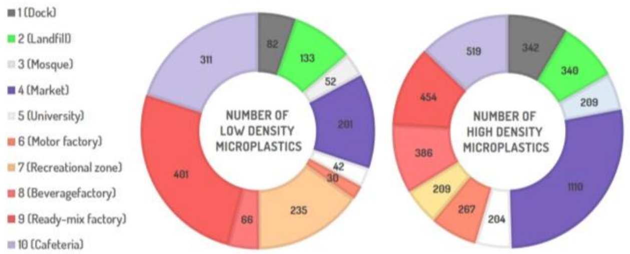

Figure 6. Distribution of low-density and high-density MP

Density-based categorization (Figure 6), indicates that high-density MP was most abundant beside the market, the cafeteria, the ready-mix and motor factory. The locations with a higher number of plastics in general also had a higher qunatity of low-density MP the market, the cafeteria and ready-mix factory.

The two-step mechanism was able to extract MP from a variety of sediments but it was followed by visual identification, manual sorting and quantification which creates a possibility of overestimation (Coppock et al., 2017). This mechanism coupled with chemical identification (micro-FTIR spectroscopy) (Ivleva et al., 2016) would result in more precise quantification and allow us to recognize the source of the individual pollutants without any bias. Time constraints amidst the covid-19 pandemic hindered the implementation of such methods.

4. Conclusion

The study assessed the extent of MP contamination in the benthic sediment of Turag river implementing a two-step MP extraction mechanism. A large extent of MP contamination was confirmed with an average abundance of 559.03 ± 10.71 items per 500 g of sediment. The number of MP was categorized based on size, type and density. The maximum number of MP was recorded beside a market. The regions which had a high population also had a high extent of MP contamination pointing towards an underlying relationship between the two. Data on population distribution and land use of these regions would allow scope for us to better understand this relationship.

References

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastic on shorelines woldwide: sources and sinks. *Environmental science & technology*, *45*(21), 9175-9179.

Claessens, M., Van Cauwenberghe, L., Vandegehuchte, M. B., & Janssen, C. R. (2013). New techniques for the detection of microplastics in sediments and field collected organisms. *Marine pollution bulletin*, *70*(1-2), 227-233.

Coppock, R. L., Cole, M., Lindeque, P. K., Queirós, A. M., & Galloway, T. S. (2017). A small-scale, portable method for extracting microplastics from marine sediments. *Environmental Pollution*, *230*, 829-837.

Fries, E., Dekiff, J. H., Willmeyer, J., Nuelle, M. T., Ebert, M., & Remy, D. (2013). Identification of polymer types and additives in marine microplastic particles using pyrolysis-GC/MS and scanning electron microscopy. *Environmental science: processes & impacts*, *15*(10), 1949-1956.

Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environmental science & technology*, *46*(6), 3060-3075.

Hossain, M. B., Banik, P., Nur, A. A. U., & Rahman, T. (2021). Abundance and characteristics of microplastics in sediments from the world's longest natural beach, Cox's Bazar, Bangladesh. *Marine Pollution Bulletin*, *163*, 111956.

Imhof, H. K., Schmid, J., Niessner, R., Ivleva, N. P., & Laforsch, C. (2012). A novel, highly efficient method for the separation and quantification of plastic particles in sediments of aquatic environments. *Limnology and oceanography: methods*, *10*(7), 524-537.

Ivleva, N. P., Wiesheu, A. C., & Niessner, R. (2016). Microplastic in aquatic ecosystems. *Angewandte Chemie International Edition*, *56*(7), 1720-1739.

Islam, M., Tusher, T., Mustafa, M., & Mahmud, S. (2013). Effects of Solid Waste and Industrial Effluents on Water Quality of Turag River at Konabari Industrial Area, Gazipur, Bangladesh. *Journal of Environmental Science and Natural Resources*, *5*(2), 213-218. https://doi.org/10.3329/jesnr.v5i2.14817

Konechnaya, O., Lüchtrath, S., Dsikowitzky, L., & Schwarzbauer, J. (2020). Optimized microplastic analysis based on size fractionation, density separation and μ-FTIR. *Water Science and Technology*, *81*(4), 834-844.

McCormick, A., Hoellein, T. J., Mason, S. A., Schluep, J., & Kelly, J. J. (2014). Microplastic is an abundant and distinct microbial habitat in an urban river. *Environmental science & technology*, *48*(20), 11863-11871.

Rodrigues, M. O., Gonçalves, A. M. M., Gonçalves, F. J. M., & Abrantes, N. (2020). Improving cost-efficiency for MPs density separation by zinc chloride reuse. *MethodsX*, *7*, 100785.

Semensatto Jr, D. L., & Dias-Brito, D. (2007). Alternative saline solutions to float foraminiferal tests. *The Journal of Foraminiferal Research*, *37*(3), 265-269.

Sharma, S., & Chatterjee, S. (2017). Microplastic pollution, a threat to marine ecosystem and human health: a short review. *Environmental Science and Pollution Research*, *24*(27), 21530-21547.

Verschoor, A., De Poorter, L., Roex, E., & Bellert, B. (2014). Quick scan and prioritization of microplastic sources and emissions. *RIVM Letter report*, *156*, 1-41.

Wagner, M., Scherer, C., Alvarez-Muñoz, D., Brennholt, N., Bourrain, X., Buchinger, S., ... & Reifferscheid, G. (2014). Microplastics in freshwater ecosystems: what we know and what we need to know. *Environmental Sciences Europe*, *26*(1), 1-9.