OCCURRENCE AND QUANTIFICATION OF MICROPLASTICS IN THE SELECTED WATERBODIES OF DHAKA CITY

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ABSTRACT

Today a world without plastics is unimaginable. But their non-biodegradability poses serious threat to the ecosystem, especially to the aquatic environment. Probable adverse effects of microplastics include adsorption of persistent organic pollutants, bio-accumulation, and death of various aquatic organisms, which eventually leads to loss of biodiversity. Though freshwater environment is closely associated with the origin microplastics and their transfer to the seas and oceans, limited studies have been conducted on freshwater ecosystem compared to the marine environment. There is virtually no data on microplastics for the waterbodies in Bangladesh. This study was aimed at assessment of the occurrence of microplastics and determination of their quantity in five selected waterbodies of Dhaka city. Concentration of microplastics was determined by wet sieving where 4.75-mm and 0.3-mm sieves were used to isolate the solid material of appropriate size, then wet peroxide oxidation was done using hydrogen peroxide (H_2O_2) to digest labile organic matter while the plastic debris remained unchanged. Then density separation was done using sodium chloride (NaCl) solution to isolate the plastic debris through flotation. The floating solids was then separated from the denser undigested mineral components using a 0.3 mm filter, air dried and weighed. Finally, microplastics were detected using a magnifying glass. The quantity of microplastics in water samples from five water bodies of Dhaka City varied from 0.49% (in Dhanmondi Lake) to 9.48% (in Turag River) of total solids. Quantity of microplastics in inland water bodies (Dhanmondi Lake and Ramna Lake) have been found to be relatively low, compared to those found in the two peripheral rivers – Buriganga and Turag. Hatirjheel, which receives storm water mixed with domestic sewage, also contains relatively high concentration of microplastics. This study gives an idea about the degree of microplastics pollution in different water bodies of Dhaka city. It also provides insight into the possible sources of microplastics.

Keywords: *Microplastic, Water body, Eco-system, Organic Pollutants.*

1. INTRODUCTION

Plastics are synthetic organic polymers, which are formed from the polymerization of monomers extracted from oil or gas (Derraik et al, 2002; Rios et al., 2007; Thompson et al., 2009). The common forms of plastics used in modern days include polyethylene terephthalate (PETE or PET), polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), polylactic acid (PLA), polycarbonate (PC), acrylic (PMMA), etc. They can be molded into shape while soft, and then set into a stiff or slightly elastic form. They are lightweight, durable, inert and corrosion-resistant. About 260 million tons of plastics are produced each year globally, about 10 percent of these ends up in the Ocean, (Greenpeace, 2006). The possibility that microplastics pose a threat to biota, as they are increasingly found in marine organisms, is of increasing scientific concern (Barnes et al., 2009; Derraik et al, 2002; Fendall and Sewell, 2009; Lozano & Mouat, 2009; Ng & Obbard, 2006; Thompson et al., 2004). Exposure of freshwater organisms to microplastics has been found to cause mortality, neurotoxicity, oxidative stress and damage, decrease of individual and population fitness, and several other adverse effects (Au et al., 2015; Bhattacharya et al., 2014; Lagarde et al., 2016). Microplastics and nanoplastic have been found to cause a wide range of adverse effects, such as immobilization, mortality, feeding inhibition, decreased reproductive fitness, among others (Besseling et al., 2014; Jemec et al., 2016; Nasser and Lynch, 2015; Ogonowski et al., 2016; Rehse et al., 2016; Frydkjær et al., 2017).

Although presence of microplastics in the marine environment received most attention, in recent years, presence of microplastics in inland water bodies (e.g. lakes and rivers) is becoming a major concern. There is virtually no data on the occurrence and quantity of microplastics in water bodies in Bangladesh. It is therefore important to assess occurrence of microplastics in the waterbodies in Bangladesh, and quantify the concentration of microplastics, as the first step in understanding the adverse impacts of this pollutant on the aquatic ecosystem. The overall objective of this study is to quantify microplastics in five selected water bodies (Dhanmondi lake, Ramna lake, Hatirjheel, Buriganga and Turag Rivers) within and around Dhaka City.

2. METHODOLOGY

2.1 Sample Collection

In this study, five water bodies were selected for collection of samples for analysis of Microplastics. These included 3 water bodies (lakes) within Dhaka city and two peripheral rivers. The inland water bodies included: (a) Dhanmondi Lake, (b) Ramna Lake, and (c) Hatirjheel. The peripheral water bodies included: (a) Buriganga River, and (b) Turag River.

A sampling net prepared using a piece of cotton cloth (similar to Manta net) was used for collection of water samples from the water bodies. Sample from Dhanmondi Lake was collected from the area surrounding the Number 8 Bridge. From Ramna Lake, water samples were collected from a location near a sewage outlet. Sample from Hatirjheel was collected from a stagnant area. Water samples from Buriganga River and Turag River were collected using a boat. All water samples were collected during November-December, 2018.

2.2 Analysis for Microplastics

The standard method for analysis of Microplastics involves filtration of the collected solids through 5.6-mm and/or 0.3-mm sieves to separate the solid material of the appropriate size. But due to unavailability of sieves with this particular opening, the collected samples were sieved through #4 (4.75-mm) and #50 (0.3-mm) sieves. First the sample was poured through a stacked arrangement of 4.75-mm (No. 4) and 0.3-mm (No. 50) stainless steel mesh sieves and rinsed with a squirt bottle filled with distilled water to transfer all residual solids to the sieves. Sieves were rinsed thoroughly using distilled water ensuring all material been well washed, drained, and sorted. Then materials retained on 4.75-mm sieve was discarded.

A clean and dry 500-mL beaker was weighted to the nearest 0.1 mg. The solids collected in the 0.3-mm sieve was then transferred to the tared beaker using a spatula and minimal rinsing with a squirt bottle containing distilled water ensuring all solids are transferred into the beaker. The beaker was then placed in 90° C drying oven for 24 hours or longer to sample dryness. The mass of the beaker with dried solids was determined using an analytical balance to the nearest 0.1 mg. The mass of the tared beaker was subtracted to provide the mass of total solids collected in the sieve. This was the mass of all Microplastics and natural materials.

For wet peroxide oxidation, 20 ml of aqueous 0.05 M Fe (II) solution was added to the beaker containing the 0.3 mm size fraction of the collected solids. Then 20 ml of 30% hydrogen peroxide was added. Then the mixture was allowed to stand on a lab bench at room temperature for five minutes prior to proceeding to the next step. A stir bar was added to the beaker and covered with aluminum foil. Thereafter, it was heated to 75°C on a hotplate. As soon as gas foams/bubbles were observed at the surface, the beaker was removed from the hotplate. If reaction appeared to have the potential to overflow the beaker, distilled water was added to slow the reaction, then continued to heat to 75° C for an additional 30 minutes. The process was repeated until no natural organic material was visible. The WPO mixture was then subjected to density separation in NaCl (aq) to isolate the plastic debris through flotation. About 6 g of salt (NaCl) per 20 ml of sample was added to increase the density of the aqueous solution (~5 M NaCl) and again the mixture was heated to 75° C until the salt dissolved. This mixture is highly reactive and can boil violently if heated >75°C. So proper laboratory safety practices were followed for handling this mixture before completing this analysis.

The WPO solution was transferred for density separation. The WPO beaker was rinsed with distilled water to transfer all remaining solids to the beaker and covered loosely with aluminum foil. The solids were then allowed to settle overnight. The settled solids were inspected visually for any Microplastics. If any were present, then the Microplastics were removed using forceps and the residuals was discarded. Floating solids were collected in a clean 0.3-mm custom sieve. The beaker was rinsed several times with distilled water to transfer all solids to the 0.3-mm sieve and the sieve was allowed to air dry while loosely covered with aluminum foil for 24 hours. A clean and dry 4-mL vial was weighed. Under a magnifying glass, identifiable Microplastics were collected from the 0.3-mm sieve and were transferred to the tared vial. The mass of the vial and Microplastics were weighted to the nearest 0.1 mg. The mass of the tared vial was subtracted to provide the mass of Microplastics collected in the sieve.

3. RESULTS AND DISCUSSION

Microplastics were identified in varying quantities in the water samples collected from the 5 water bodies in and around Dhaka City. Figure 1 shows the photographs of microplastics collected from the 5 water bodies. Figure 2 shows the quantity of microplastics (expressed as % of total solids) found in different water bodies. It clearly shows that the quantities of microplastics in inland water bodies (Dhanmondi Lake and Ramna Lake) are relatively low. On the other hand, much higher quantity of microplastics was detected in the two peripheral rivers – Buriganga River and Turag River. Hatirjheel, which receive storm water mixed with domestic sewage, also contains relatively high concentration of microplastics.

The percentage of microplastics in Dhanmondi Lake has been found to be only 0.49% of total solids, which is not a very significant amount. Since Dhanmondi Lake is located in a residential area, the probable sources of microplastics pollution are degradation and abrasion of larger plastic products. Uncontrolled dumping of plastic products into the lake which includes ice cream packets, chips packets, and polythene could be a major reason for the formation of microplastics. Primary Microplastics resulting from micro beads intentionally incorporated into the personal care products could be another reason for the microplastic pollution in Dhanmondi Lake. The microplastics in this Lake were primarily low density plastics since most of them were obtained from the floating material during the laboratory work. Low density plastic is a thermoplastic made from the monomer ethylene. Low density plastic is very flexible, translucent with high impact strength and has a density value of 0.91gm/cm^3. It should be noted that after the renovation work in the recent past, Dhanmondi Lake does not receive any domestic sewage directly through sewer outfall. Therefore, the source of microplastics is most likely direct disposal of plastic materials (e.g., by people visiting the Lake area) and from storm runoff.

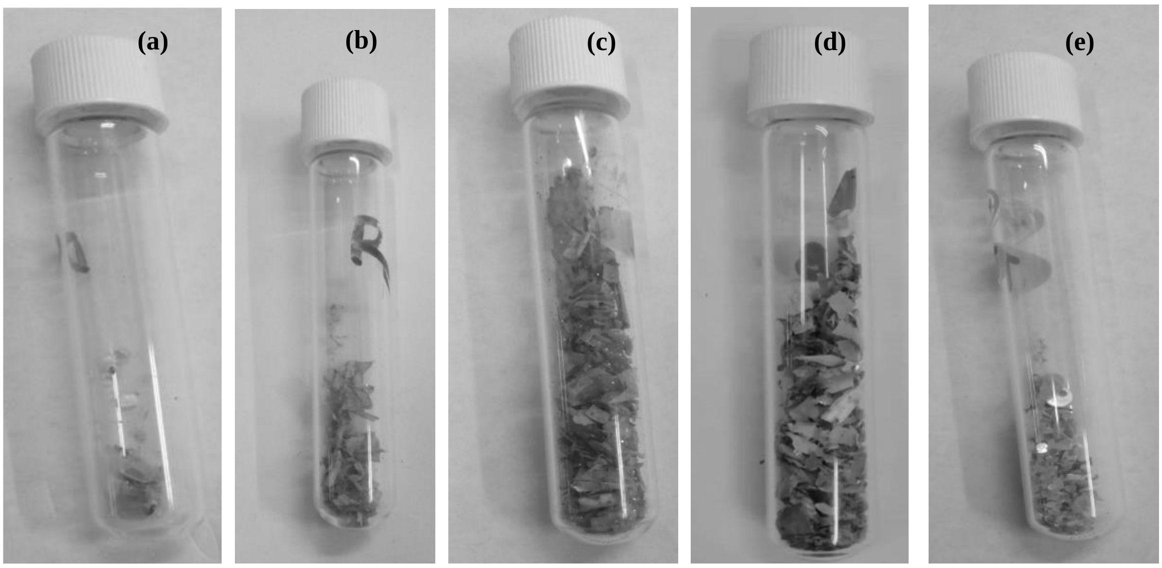

Figure 1: Microplastics extracted from water samples collected from 5 water bodies in and around Dhaka City: (a) Dhanmondi lake; (b) Rahman lake; (c) Hatirjheel; (d) Buriganga River; (e) Turag River.

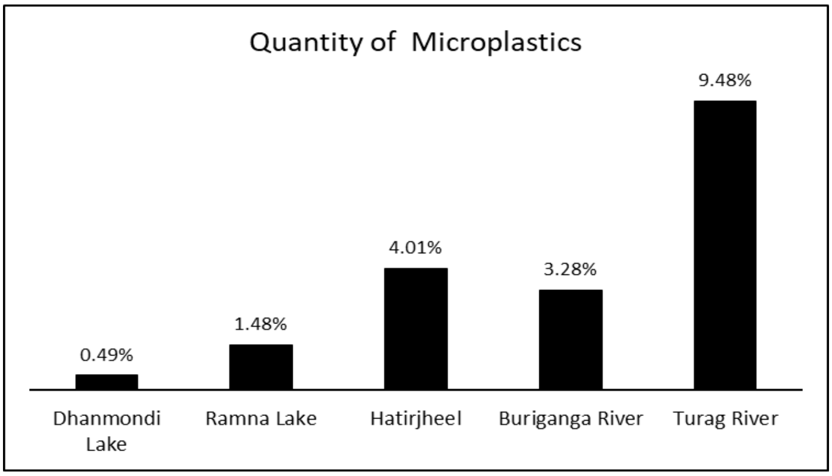

Figure 2: Quantity of microplastics in different water bodies in and surrounding Dhaka city

The percentage of microplastics in the Ramna Lake has been found to be about 1.48% of total solids. The microplastics found here were not colourful (see Fig. 1). The sample was collected from a location close to a sewage outlet. Like in Dhanmondi Lake, the fragmentation of larger plastic products such as chips packets, polythene bags, toys, tapes and ice-cream packets might have resulted in the formation of Microplastics. The microplastics were mostly high-density plastic since most of the Microplastics were obtained from the sediment during the laboratory work. High density plastics are thermoplastic polymer produced from the monomer ethylene.

The percentage of microplastics obtained from Hatirjheel is 4.01% of total solids. The amount is quite significant when compared to the percentage of microplastics found in the other two Lakes. The microplastics were not very colourful (see Fig. 1). It should be noted that Hatirjheel receives huge amount of storm water mixed with domestic sewage (especially during the wet season). This is a potential source of microplastics in Hatirjheel. Besides, since Geobags have been placed to protect banks from soil erosion, plastic fibers found in the sample could have resulted from these Geobags. Hatirjheel is a recreational place where many visitors come to the place every day to view the scenic landscape. Unfortunately, most of the visitors do not apply civic sense when they go to the area. They carry with them plastic bottles, chips packets, polythene filled with ground nut, biscuits and newspapers and leave there those after use. These could eventually contribute to the pollution of the water body with plastic products. These larger plastics then fragment to form the smaller pieces of Microplastics which pose serious hazard to the aquatic lives present in the water body. Most of the Microplastics were found from the floating materials so this indicates that the Microplastics were mostly low-density plastics.

Buriganga River is one of the most polluted rivers in Bangladesh. The microplastics obtained from Buriganga River is 3.28% of total solids. From visual inspection it was seen that the microplastics of Buriganga River is very colourful (see Fig. 1). This indicates microplastics in this river have resulted from a wide variety of sources. Household plastic products such as plastic buckets, plastic bottles, and polythene might have degraded to form the smaller pieces of microplastics. Since the Dhaka City dwellers have been dumping domestic waste into the Buriganga River, amount of plastic waste found here is significantly high. A lot of sewer outlets dump domestic and industrial wastewater in the river resulting in presence of a huge amount of primary microplastics. It is also suspected that the dumping of plastic waste by the nearby slum people such as ice cream packets, chips packets, and plastic bottle caps could be a major reason for the formation of microplastics. The amount of microplastics obtained is comparatively lower than from some of the water bodies even though visually it seems to be quite a significant. The possible reason is that the plastics are LDP (low density plastic).

The microplastics found from Turag River is 9.48% of total solids, which is highest amongst all the values. Even though from visual appearance it might not seem a very significant amount (see Fig. 1), but the weight of the microplastics is higher because the microplastics might be originated from the degradation of hard plastics which may include feeders, plastic containers for milk, shampoos and conditioners, detergents and bleaches. Glitters were found profoundly in this sample. One of the reasons could be that glitters, plastic embroidery works from the clothing might have drained into the river. At some point sewage outlet connected to domestic sources is seen and slum dwellers without proper drainage facilities discharge their sewage water into the river; so primary plastics used in personal care products might be present in our sample. Since many industries including pharmaceutical industries, dyeing industry, textile industry, etc. are located in the vicinity of the river, there are variety of sources which might have resulted in microplastics in the river.

4. CONCLUSIONS

Microplastics have been detected in all 5 water bodies from which samples were collected and analyzed in this study. The quantities of microplastics in inland water bodies (Dhanmondi Lake and Ramna Lake, Hatirjheel) are relatively low. Hatirjheel, which receives storm water mixed with domestic sewage also contains relatively high concentration of microplastics. Relatively higher quantity of microplastics was detected in the two peripheral rivers – Buriganga River and Turag River. Turag is most polluted with microplastics especially high density microplastics. The quantities of microplastics (as percentage of total solids) also depend on composition of microplastics (e.g., density of materials). This study gives an idea about the degree of microplastics pollution in the different water bodies of Dhaka city. This study also gives insight into the possible sources of microplastics. More studies are needed for identification and characterization of microplastics in freshwater environmnet and their possible impact on the environment and ecosystem.

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REFERENCES

Au, S.Y., Bruce, T.F., Bridges, W.C., Klaine, S.J. (2015). Responses of Hyalella azteca to acute and chronic microplastic exposures. Environmental Toxicology and Chemistry, 34(11), 2564-2572.

Bajracharya, R.M., Manalo, A.C., Karunasena, W., Lau, K-T., (2014). An overview of mechanical properties and durability of glass-fibre reinforced recycled mixed plastic waste composites. Materials & Design, 62, 98-112. doi:10.1016/j.matdes.2014.04.081.

Barnes, D.K., Galgani, F., Thompson, R.C., (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences, 364, 1985–1998.

Besseling, E., Wang, B., Lurling, M., Koelmans, A.A. (2014). Nanoplastic Affects Growth of S. obliquus and Reproduction of D. magna. Environmental Science & Technology, 48(20), 12336-43. doi: 10.1021/es503001d.

Derraik, J.G.B., (2002). The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, 44, 842–852. doi: 10.1016/S0025-326X(02)00220-5.

Fendall, L.S., Sewell, M.A., (2009). Contributing to marine pollution by washing your face: microplastics in facial cleansers. Marine Pollution Bulletin, 58, 1225–1228. doi:10.1016/j.marpolbul.2009.04.025.

Frydkjær, C., Iversen, N., Roslev, P., (2017). Ingestion and Egestion of Microplastics by the Cladoceran Daphnia magna: Effects of Regular and Irregular Shaped Plastic and Sorbed Phenanthrene. Bulletin of Environmental Contamination and Toxicology, 99. 655-661. doi: 10.1007/s00128-017-2186-3.

Greenpeace (2006), Plastic Debris in the World's Oceans, Greenpeace International, Ottho Heldringstraat 5, 1066 AZ Amsterdam, Netherlands

Jemec, A., Horvat, P., Kunej, U., Bele, M., Kržan, A., (2016). Uptake and effects of microplastic textile fibers on freshwater crustacean Daphnia magna. Environmental Pollution, 219. 201-209. doi: 10.1016/j.envpol.2016.10.037.

Lagarde, F., Olivier, O., Zanella, M., Daniel, P., Hiard, S., Caruso, A., (2016). Microplastic interactions with freshwater microalgae: Hetero-aggregation and changes in plastic density appear strongly dependent on polymer type. Environmental Pollution, 215, 331-339. doi: 10.1016/j.envpol.2016.05.006.

Lozano, R.L., Mouat, J., (2009). Marine Litter in the North-East Atlantic Region: Assessment and Priorities for Response. KIMO International, 127.

Nasser, F., Lynch, I., (2015). Secreted protein eco-corona mediates uptake and impacts of polystyrene nanoparticles on Daphnia magna. Journal of Proteomics, 137, 45-51. doi: 10.1016/j.jprot.2015.09.005.

Ng, K & Obbard, Jeff. (2006). Prevalence of microplastics in Singapore's coastal marine environment. Marine pollution bulletin, 52(7), 761-767. doi: 10.1016/j.marpolbul.2005.11.017.

Ogonowski, M., & Schur, C., Jarsen, A., Gorokhova, E., (2016). The Effects of Natural and Anthropogenic Microparticles on Individual Fitness in Daphnia magna. PloS One, 11(5), e0155063. doi: 10.1371/journal.pone.0155063.

Rehse, S., Kloas, W., Zarfl, C., (2016). Short-term exposure with high concentrations of pristine microplastic particles leads to immobilisation of Daphnia magna. Chemosphere. 153. 91-99. doi: 10.1016/j.chemosphere.2016.02.133.

Rios, L.M., Moore, C., Jones, P.R., (2007). Persistent organic pollutants carried by synthetic polymers in the ocean environment. Marine Pollution Bulletin, 54(8), 1230–1237. doi:10.1016/j.marpolbul.2007.03.022.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D.,Russell, A.E., (2004). Lost at sea: where is all the plastic? Science, 304(5672), 838–838. doi:10.1126/science.1094559.

Thompson, R.C., Moore, C.J., Vom Saal, F.S., Swan, S.H., (2009). Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2153–2166. doi: 10.1098/rstb.2009.0053.