Abundance and characteristics of microplastics in major urban wetlands of Dhaka, Bangladesh

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Research Article

Keywords: Microplastic, Urban Lake, Sediment, Water, Fish, FTIR

Posted Date: April 12th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1455552/v1

Abstract

The study was performed to evaluate the abundance and characteristics of MPs in water, sediment, and fish samples of three major urban lakes, namely Dhanmondi Lake, Gulshan Lake, and Hatir Jheel Lake in Dhaka, Bangladesh. The abundance of microplastics varied from 0-9 items/L in surface water, 0-16 items/kg in sediment, and 0-17 items/individual; 0-4.88 items/g in the gastrointestinal tract (GIT) of test fish species, respectively. Highest abundance of microplastic in an individual fish was observed in *Oreochromis mossambicus* from Dhanmondi Lake. The samples were visually observed under a stereo microscope, which showed the dominant type of microplastics in both water and sediment samples were films followed by micro pellets, fragments, fibers, and in fish samples pellets and foams were dominant. According to the Fourier Transform Infrared analysis (FTIR) the dominant polymers in the analyzed samples were High density polyethylene (HDP), Ethylene Vinyl Acetate (EVA), Polyvinyl chloride (PVC), Polycarbonate (PC), Cellulose Acetate (CA), and Polypropylene (PP). In water and sediment samples of Gulshan Lake, MPs were relatively higher than in other lakes, and in fish samples of Dhanmondi Lake MPs were higher. The results of this study indicate that MPs were abundant in studied lakes and suggested a high level of microplastic contamination occurred not only in the water and sediment but also in the resident fishes. The implication of the finding suggests that the presence of MPs in urban lakes has raised concerns about the potential human health impact.

Highlights

- Presence of microplastics in the major urban lakes of Dhaka, Bangladesh, is evaluated as it is largely unknown.
- Microplastics were relatively higher in water and sediment samples of Gulshan Lake than other lakes.
- The highest microplastic abundance in an individual fish was observed in *Oreochromis mossambicus* from Dhanmondi Lake.
- Films were the most prevalent in water and sediment samples, whereas pellets and foams were dominant in fish samples.
- Prevailing polymers in examined samples were HDPE, PVC, PC, PP, CA and EVA.

1. Introduction

Plastic has brought boundless convenience in everyday life. It is used due to various outstanding properties, such as low cost, outstanding corrosion resistance, lightweight, longevity, fast deformation and manufacturing, and outstanding insulator properties (Geyer et al., 2017). Nevertheless, mass processing and long deterioration cycles of plastics have contributed to prevailing and mondial environmental concerns (Lebreton and Andrady, 2019). Up to 10% of the produced plastic finds its way into the aquatic ecosystem, where it persists and accumulates in the terrestrial environment (Thompson, 2005; Ogunola and Palanisami, 2016). This increased production raises concerns about the biological impact of ingested plastics and the possible health impacts (Faure et al., 2015; Peters and Bratton, 2016). Now they have covered almost all aquatic, terrestrial environments (Andrady, 2017; Gündoğdu and Çevik, 2017; Van C. et al., 2013). The high prevalence of micro-sized persistent plastic particles in aquatic ecosystems, known as microplastics, has become an emerging problem in the recent decade. Microplastics are inconspicuous microscopic plastic polymer particles with a diameter of less than 5 mm (Cole et al., 2011; Wright et al., 2013). In freshwater ecosystem, microplastic associated risks have raised severe environmental concerns (Li et al., 2020). Microplastics are ubiquitously present in all marine territories from beaches to the depth of the ocean, which is well documented (Thompson et al., 2004; Cozar et al., 2014; Law and Tompson, 2014; Van C. et al., 2013). However, due to the widespread usage of plastics, MPs have recently been discovered in freshwater habitats, particularly rivers and lakes (Eerkes et al., 2015; Castaneda et al., 2014; Fishcher et al., 2016).

Microplastics are introduced to the ecosystem from a range of sources; primary and secondary sources are known to be the key paths into the ecosystem for microplastics (Horton et al., 2017). Primary sources are the micro-sized plastic particles that originate from spillage after the manufacture or disposal of plastic and micro-cleansing particles of personal care products such as bath gel, scrub, face wash, hand wash and gel toothpaste (Duis and Coors, 2016; Karlsson et al., 2018). Moreover, they are considered the key sources of microplastic pollution as microbeads are the major primary sources in personal care products (Conkle et al., 2018). Secondary sources are microscopic plastic particles that are derived from broken fragments of larger plastic pieces due to physical, chemical, and biological causes (Cole et al., 2011), such as aquatic litter, debris from landfills, synthetic fibers from textile waste, fishing net and commercial or agricultural sources (Kole et al., 2017). They are derived from the fragmentation of larger plastic waste by mechanical forces, solar radiation, thermo-oxidation, photolysis, and bio-degradation processes (Cesa et al., 2017). Owing to the wide number of origins and routes, it is also difficult to distinguish secondary microplastics (Collignon et al., 2012; Stolte et al., 2015).

However, micro pellets are mostly used in plastic processing plants, which are eventually discharged into freshwater bodies. Through production, storage, handling and transportation it ends up in marine environment (Lebreton et al., 2017). The polymer density of plastic particles is lighter, which helps to transport by winds and currents and recirculates between sediments and water (Eubeler et al., 2010). Pellets may accumulate in sediment after sinking or be swallowed by aquatic organisms, especially fish (Ramirez et al., 2019; Karlsson et al., 2018). Additionally, plastic waste incidence increases from the leaked pellets, posing environmental threats to the local ecosystems (Rochman, 2018).

Microplastics is consumed by a diverse range of aquatic species, including fishes, which causes deleterious effects (Driedger, 2015; Qu, 2018). Fish may purposely or accidentally ingest microplastics when searching for a prey (e.g., plankton), where the microplastics may already be present within or attached to the prey. Since fish are one of the most vital food sources for humans, they are commonly included in experiments and analyses of microplastic pollution's abundance and distribution (Dehaut et al., 2019). Field experiments on microplastic accumulation in fish bodies has been documented on a range of fish species from various environments (Bessa et al., 2018; Calderon et al., 2019; Collard et al., 2019). Furthermore, comprehensive exposure studies have indicated that high microplastic concentrations may have harmful effects on fish (Choi et al., 2018; Pedà et al., 2016; Jabeen et al., 2018). Several varieties of MPs have been found in fish (Davison and Asch, 2011), with polyester, polyethylene terephthalate, polyethylene, polyacrylonitrile, polypropylene, and nylon being the most common (Akhbarizadeh et al., 2020; Neves et al., 2015; Yonkos et al., 2014).

Lakes are widely recognized for provide significant ecological services, including species habitat, food production, flood protection, water reservoir, climatic regulation and recreational purposes (Woodward and Wui, 2001; Eriksen et al., 2013). Sustainability of lake ecosystem is a major concern in environmental management (Pettigrove and Hoffmann, 2005). Some urban lakes are especially intended to manage urban runoff and receive rainwater compared to natural water bodies, making them more susceptible to anthropogenic pollution and environmental stress (Wong and Geiger, 1997 Increased anthropogenic activity indicates that microplastics will likely be more abundant in wetlands (Floehr et al., 2013; Ismail et al., 2014; Driedger et al., 2015). Microplastics can be found in natural wetland's water, sediment, and organisms based on some preliminary studies (Bessa et al., 2018; Biginagwa et al., 2015; Lourenço et al., 2017). On the other hand, plastic pollution monitoring in urban lakes and their inherent species is rare. Urban lakes are relatively small water bodies but receive a significant volume of surface runoff content, making it a crucial source of microplastic waste (Dehghani et al., 2017).

In this study, microplastics were investigated in the urban lakes of Dhaka, the capital city of Bangladesh. The study sites were Dhanmondi Lake, Gulshan Lake, and Hatir Jheel Lake, located in the most populous and rapidly developing residential areas of Dhaka metropolitan city, where pollution due to secondary microplastics may be very prevalent due to anthropogenic sources. In this study, the abundance and characteristics of microplastic pollution in the water, sediments, and fishes of Dhanmondi, Gulshan, and Hatir Jheel lakes were examined.

2. Materials And Methods

2.1. Studied Urban Lakes: Dhaka is the capital and the largest city of Bangladesh within a total area of 300 square kilometers. Estimation shows that around 7000 billion microbeads are released every month into the encompassing water bodies and wastelands in and around Dhaka city (ESDO, 2016). In this study, three major lakes were investigated and the sites were Dhanmondi Lake, Gulshan Lake, and Hatir Jheel Lake (Figure 1), located in the most populous and rapidly developing residential areas of Dhaka metropolitan city. These locations were chosen because of the intense anthropogenic activities surrounding that area.

2.2. Sample collection: Water, sediment and fish samples were collected from three lakes. Water sample was collected from each lake and the exact location of each site was recorded using a global positioning system (Garmin GPSMAP 78S) device. At each site, 5L water was collected using a steel bucket within 0-10 cm from the surface and 3 replicates per location were kept. From each location, physical (Turbidity, EC, Salinity, Temperature) and chemical (TDS, pH, BOD, DO,) parameters of collected water samples were measured using multi-parameter (HANNA HI 9829), and DO was observed using DO meter (YSI PRO 20i).

Sediment samples were collected from each lake with a stainless-steel spatula within 0-10 cm from the benthic layer. From each site approximately 1 kg of wet sediment was collected and 3 replicates per location were kept. Sediment samples were stored in a clean, labeled aluminum foil bag. Sediment samples were brought to the laboratory and stored at -20°C before analysis. Prior to sampling, all instruments and containers were washed with distilled water and sealed.

In September 2021, fish samples from the individual lakes were collected using a net within the depth of 1-10 meters. A total of 7 species (n=90) from above mentioned lakes were collected and used for the investigation. From Dhanmondi lake, *Channa marulius*, *Channa punctate, Chitala chitala, Oreochromis mossambicus and Catla catla* were collected. From Hatir Jheel Lake, *Pangasius pangasius, Catla catla* and *Channa striata* were collected. From Gulshan Lake, *Pangasius pangasius* was collected. After collection, species were identified and photographed. For further analysis collected fishes were wrapped with aluminum foil and kept at −20 °C in the refrigerator. All the procedures were reviewed, and ethical clearance was approved by the Ethical Committee of Bangladesh University of Professionals (BUP).

2.3. Isolation of Microplastics: The MPs were isolated from collected water samples (Figure S1) using the method of Su et al. (2016). At first water volume was recorded and filtered through a nylon membrane with a pore size of 20 μm and diameter of 47 mm (Ultrapor N66 Nylon, 6.6 membrane) and the speed was accelerated using a vacuum pump (L-79200, Cole Parmer). The substances on the membranes, including organic matters were then rinsed into a 250 mL glass flask with 100 mL of 30% H_2O_2 (v/v), and the flask was promptly covered with a glass dish. To digest organic matter, these flasks were transferred to an oven (Biolab BODR-305) and kept at 65 °C, not more than 72 hours. Afterwards, the resultant digestate were filtered through a nylon membrane with a pore size of 0.2 μm and diameter of 47 mm (Ultrapor N66 Nylon membrane), afterwards the filtrates were transferred into glass petri dishes. For further observation, the filter papers along with MP were air dried overnight.

As raw plastics were abundant, sediments were pre-sieved using 1 mm stainless steel mesh to isolate microplastic (Figure S2) from sediment samples (Li., et al, 2020). Samples were then placed in aluminum foils and oven (Biolab BODR-305) dried at 65°C for 3 days. Then 300 gm of sediment as weighed at a precision balance (Radwag PS 4500/C/1). A solution of NaCl was prepared (360g/L) and it was mixed to the 300g sediment in a ratio of 1:2(V/V). Then the mixture was stirred for 30 minutes in a magnetic stirrer (SciLogex MS-H-S) and after that allowed to settle overnight. Following that, the hydrogen peroxide treatment (H_2O_2) and microplastic isolation were performed as described above for the water sample processing procedure.

The method of Li et al. (2015) was used to isolate microplastics from fish species (Figure S3). In the laboratory, the preserved fish species were thawed in a metal tray and rinsed with double distilled water. Each specimen's total length and body weight were measured. To determine the occurrence of MP consumption in fish, 30 specimens per lake were selected for the analysis. The specimens were dissected individually in a metal tray using dissecting scissors, blades, scalpel, and forceps. The gastrointestinal tract (GIT) was removed and weighed in a petri-dish. Afterwards, each sample was then placed in a 500 ml glass beaker. Depending on the weight of the soft tissue in each beaker, 100-200 mL of 30% H_2O_2 (v/v) was added to digest the organic matter (Li et al., 2020; Su et al., 2016). The microplastic extractions were carried out in the same way as the water sample processing approach described above.

During the study, precautions were taken to minimize errors. To minimize contamination, 100% cotton laboratory coats were worn throughout the analysis. Prior to analysis, liquid solutions including tap water, saturated NaCl solution and H_2O_2 (30% v/v) were filtered. All instruments and containers rinsed with filtered tap water before and after use and stored covered until needed. All the samples along with the chemicals used for sample processing included procedural blanks. Cross contamination was eliminated during sample processing, transportation to the laboratory, storage, thawing and cleaning, dissection and removal of GIT, digestion, and microplastic detection. At the earliest convenience, the experimental procedures were completed.

2.4. Visual observation of microplastics: The presence of potential microplastics in the filtered samples were visually analyzed using a Stereo Microscope (Cobra Micro Zoom MZ1000, Micros Austria) at 40X and all photographs were captured using a microscopic camera (Olympus-DP22; model U-TV0.5XC- 3, SN-5M01493). First, visual assessments have been used to quantify probable microplastics based on their physical properties. Under the microscope, each sample was examined thrice. Microplastics have identical features such as burnished surfaces, potent colors, and sharp and geometrical shapes. Artificial fibers are described to have potent color and luster, which are quite rampant because of anthropogenic activities (Horton et al., 2017). The items were visually identified (Figure 2) and classified according to morphotypes of microplastics, which can be classified as: fragments, films, micro-pellets, fibers, and foam (Anderson et al., 2017). In all, 138 particles were visually identified, which includes 22 particles in water samples, 36 particles in sediment samples, and 80 particles in fish samples. And then, they were sorted according to their morphotypes. The microscopic camera helped to determine the extent and amount of microplastics that were present.

2.5. Characterization and chemical group identification: From each morphotype a representative number of microplastics were selected and identified using FTIR (IRAffinity-1, A213748-SHIMADZU) which is ideal for high-precision analysis. It is a cost-effective and easy approach for deciding the polymer form of microplastics (Browne et al., 2010). Spectra from 4000 cm^{-1} to 450 cm^{-1} were obtained using Attenuated Total Reflection (ATR). The spectral resolution was set at 8 cm^{-1}, data interval was set at 1 cm^{-1} and where resolution was 4 cm^{-1}. For each measurement the collection time was 10s and 40 co-scans. For detection of the structure and origin of microplastics, plastic polymers have extremely complex IR spectra of distinct band patterns (Van der Hal et al., 2017). The spectrums were compared with the reference spectrum to evaluate of polymer and chemical groups (Jung et al., 2018).

3. Results

3.1. Distribution of microplastic in water and sediment samples: According to the data based on (Table S1) the water quality of urban lakes is poor, but the condition of Gulshan Lake is worse than the other lakes. The Dissolve Oxygen (DO), Electrical conductivity (EC), Turbidity is higher than the permissible limit. As well, the presence of microplastic debris was identified in all the water and sediment samples (Table S2) of urban lakes. In water samples, microplastic abundance varied from 0-9 items/L. Highest abundance of microplastic was observed in Gulshan Lake (0-9 items/L), followed by Hatir Jheel Lake (0-8 items/L), and comparatively low abundance of microplastic was observed in Dhanmondi Lake (0-4 items/L). In sediment samples, abundance varied from (0-16 items/kg). The abundance of microplastic was highest in Gulshan Lake (0-16 items/kg), followed by Hatir Jheel Lake (0-11 items/kg), and comparatively low abundance of microplastic was observed in Dhanmondi Lake (0-9 items/kg).

The morphotypes of identified microplastic particles were: (a) Fiber (uniform plastic strands); (b) Fiber (fibrous); (c) Fragments (hard); (d) Fragments (jagged-edged); (e) Micro-pellets (hard, rounded particles); (f) Films (2-dimensional plastic films) (h) Foam (Styrofoam material).

The dominant morphotypes were identified for all environmental samples. In water samples, the prominent types of microplastic were film (40.91%), followed by micro pellets (36.36%), fragment (22.73%), and fiber (13.63%). In sediment samples, film was the most abundant type of microplastic, accounted for about 33.33%. There was also fiber (30.55%), fragment (27.77%), micro pellets (2.77%) and foam (2.77%). The most dominant polymer was film, found almost in every sample. Two types of fibers were found in the samples (fibrous and uniform plastic strand). Between them fibrous fibers were the prominent one.

In water samples, from 20 items a representative number of particles (n=5) were selected and confirmed as plastic particles with FTIR analysis. The detected polymer types were High-density polyethylene (HDPE), Polyvinyl chloride (PVC), Polycarbonate (PC). The dominant type was HDPE accounting for 60%, followed by PVC 20%, PC 20%.

In sediment samples, from 36 items a representative number of particles (n=7) were selected and confirmed as plastic particles with FTIR. The detected polymer types were High-density polyethylene (HDPE), Cellulose acetate (CA), Polycarbonate (PC), Polypropylene (PP). The most abundant polymer was HDPE, which accounted for 42.85%, followed by PC 28.57%, CA 14.28%, and PP 14.28%.

Table 1: Abundance of MPs in fish samples from each lake

Site	Species	Items/individual	Items/gm (GIT)	Dominent morphotype
Dhanmondi Lake	*Channa marulius*	0-7	0-0.31	Foam
	Channa punctate	0-1	0-0.60	Film
	Chitala chitala	0-11	0-2.30	Micro-pellet
	Oreochromis mossambicus	0-17	0-4.88	Micro-pellet
	Catla catla	0-2	0-0.11	Foam
Gulshan Lake	*Pangasius pangasius*	0-2	0-1.2	Fragment
Hatir Jheel lake	*Pangasius pangasius*	0-2	0-0.13	Micro-pellet
	Channa striata	0-7	0-1.23	Foam
	Catla catla	0-15	0-1.40	Micro-pellet

3.2. Distribution of microplastic in fish samples:

Microplastic abundance was observed in all the fish samples (Table S2) and microplastics were found in almost all the samples after digestion. Based on the data from (Table 1), the highest abundance of microplastic observed in an individual fish was in *Oreochromis mossambicus* from Dhanmondi Lake, showing the presence of 0-17 items/individual, 0-4.88 items/g in the GIT, followed by *Catla catla* from Hatir Jheel Lake containing 0-15 items/individual, 0-1.40 items/g in the GIT. A comparatively low abundance of microplastic was observed *Pangasius pangasius* in Gulshan Lake where 0-2 items/individual, 0-1.2 items/g in the GIT were present. The percentage of dominant type was identified for all the fish samples. A prominent type of microplastic in fish samples were micro pellets 29.28%, followed by foams 27.85%, film 24.28%, fragment 17.28%, and fiber 13.63%. However, plastic films were prevailing in water and sediment samples, whereas micro pellets were dominant in fish samples. In fish samples, from 81 items a representative number of particles (n=10) were selected and confirmed as plastic particles with FTIR. The polymer types were High-density polyethylene (HDPE), Polyvinyl chloride (PVC), Polycarbonate (PC), Polypropylene (PP), Ethylene vinyl acetate (EVA) and 1 remain unidentified. The dominant polymer was HDPE accounted for 40% followed by PVC 30%, PC 10%, EVA 10%, PP 10%.

3.3. Factors influencing MPs uptake by fish sample: There is a significant possibility of MPs ingestion among large fishes as they need high energy resulting in high food intake. Several studies investigated and observed MPs accumulation have significant positive correlations with length/body weight of fish (Horton et al., 2018; Hossain et al., 2019). The goal of this study was to observe if MP intake differs as body weight and length of a fish species varies. Though, no significant correlations between microplastic abundance and fish body weight/length (R^2= 0.0156-0.0340, $p>0.4$) were found (Figure 4).

As a result of the above observation, it can be assumed that the abundance of MPs in fish is not proportional to body length or weight, rather it is dependent to the intensity of plastic pollution in the surrounding environment. It was also observed by Carbery et al. (2018) that environmental plastic abundance affects MPs intake by fish. However, due to the small sample size significant correlations between MPs abundance and fish body weight/length may be obscured.

3.4. Identification of potential MPs using FTIR technique:

From each morphotype a representative number of microplastics were selected for FTIR verifications out of 138 particles. Particles were carefully cleaned and dried before being analyzed to remove organic debris. A total 17 particles were selected for verification and failed to verify particles were considered as non-plastic material to ensure validity of result. From 17 particles 16 were confirmed as plastic while 1 considered non-plastic material. The primary polymer types detected based on characteristic peak from FTIR analysis (Figure S3) are High density polyethylene (HDPE), Polyvinyl chloride (PVC), Polycarbonate (PC), Ethylene Vinyl Acetate (EVA), Cellulose Acetate (CA), and Polypropylene (PP) (Noda et al., 2007; Krehula et al., 2014; Jung et al., 2018). The composition of these polymers are as follows: HDPE (5 particles), EVA (3 particles), PVC (3 particles), PC (2 particles), PP (2 particles), CA (1 particle).

The IR spectrum based on adsorption band (cm^{-1}) of the corresponding particles are shown in Figure 5. In contrast to the reference polymer spectra, spectrum (a) shows the characteristic peak for HDPE assigned to CH_2 Asymmetric C-H stretching at peak 2916.37 cm^{-1} and CH_2 Symmetric C-H stretching at peak 2848.86 cm^{-1}; CH_2 bend stretching at peak 1739.79 cm^{-1}, 1469.76 cm-1, 1456.26 cm^{-1}; CH2 rock stretching at 719.24 cm^{-1} and C(=O)O stretching at peak 667.37 cm^{-1} (Jung et al., 2018).

In contrast to the reference polymer spectra, spectrum (b) shows the characteristic peaks for PVC are assigned to Aromatic CH in plane bending at peak 1170.79 cm^{-1}; C=C stretching at peak 1099.43 cm^{-1} and 1033.85 cm^{-1}; C-Cl stretching at peak 601.79 cm^{-1} and 557.43 cm^{-1} (Jung et al., 2018).

Spectrum (c) exhibits the distinctive peaks for EVA are assigned to CH_2 Asymmetric C-H stretching at peak 2950.83 cm^{-1} and CH_2 Symmetric C-H stretching at peak 2895.70 cm^{-1}; C=O stretching peak at 1741.72 cm^{-1}; CH_2 bending at peak 1535.97 cm^{-1} and 1460.784 cm^{-1}; C(=O)O stretching at peak 1166.581 cm^{-1}; C-O stretching at peak 1097.953 cm^{-1}; CH_2 rocking at peak 721.639 cm^{-1} (Jung et al., 2018).

Spectrum (d) shows the characteristic peak for PC were found at absorption band 2923.35 cm^{-1},1740.34 cm^{-1}, 1433.3401 cm^{-1}, 1409.58 cm^{-1}, 972.65 cm^{-1}, 838.59 cm^{-1}. The absorption bands indicate the presence of CH stretching at peak 2923.35 cm^{-1}; C=O stretching at peak 1740.34 cm^{-1} and 1409.58 cm^{-1}; Aromatic ring stretching at peak 1433.3401 cm^{-1}; Aromatic CH in plane bending at 972.65 cm^{-1}, 838.59 cm^{-1} (Jung et al., 2018).

Spectrum (e) shows the distinctive peaks for CA are ascribed to C=O stretching at peak 1716.010 cm^{-1}; CH_3 bending at peak 1247.672 cm^{-1}; CH bending at peak 1015.652 cm^{-1}; O-H bending at peak 724.092 cm^{-1} (Jung et al., 2018).

Spectrum (f) shows the characteristic peak for PP were found at absorption band 2850.639 cm^{-1},1741.316 cm^{-1}, 1462.246 cm^{-1}, 1166.54 cm^{-1}, 1029.226 cm^{-1}, 878.94 cm^{-1} and 769.18 cm^{-1}. The absorption bands indicate the presence of C-H stretching at peak 2850.639 cm^{-1}; CH_2 bending at peak 1741.316 cm^{-1}; CH_3 bending at peak 1462.246 cm^{-1}; CH bending at peak 1166.54 cm^{-1} and 1029.226 cm^{-1}; CH_2 rocking at peak 878.94 cm^{-1} and 769.18 cm^{-1} (Jung et al., 2018).

4. Discussion

4.1. Assessment of MPs in water, sediment, and fish samples: In this study, the surface water, sediment, and fishes from three major lakes of Dhaka- Dhanmondi Lake, Gulshan Lake, and Hatir Jheel Lake were analyzed for the presence of microplastic and comparatively a high amount of microplastic pollution with distinct characteristics was discovered. These lakes are located across the most developed regions in Dhaka city and confront heavy loads of pollution from drainage, dumping of solid wastes, disposal of untreated domestic and commercial wastewater. It is reasonable to observe a greater amount of microplastics in the urban lakes with intensive anthropogenic activities (Eriksen et al., 2013; Free et al., 2014).

4.2. Abundance and types of MPs in water samples: A total of 22 particles were observed in water samples of the lakes. This total abundance of microplastic in Gulshan Lake (0-9 items/L) and Hatir Jheel Lake (0-8 items/L) is regarded as a significant source of microplastic contamination in these water bodies (Murphy et al., 2016). The low abundance of microplastics in Dhanmondi Lake's surface water (0-4 items/L) reflects a low discharge of microplastics into the receiving water over a brief period of time. It can be assumed that a higher quantity of microplastic in this area could be the contribution of human activities near Gulshan area.

In Gulshan Lake and Hatir Jheel Lake comparatively high percentage of micro-pellets and films were noticed. Firstly, plastic films are primarily made of polyethylene, the most used type of plastic in urban areas. Secondly, micro pellets are highly used in cosmetics and industries, and they can be scattered on the ground or directly discharged into the water body. Natural factors like excessive rainfall and surface runoff can play a vital factor transporting plastic pellets on the ground to the aquatic environment (Wagner et al., 2014; Duis and Coors, 2016; Zhou et al., 2020). In this study, foam was not found in water bodies as fiber and pellets are used as raw materials by the local plastics processing factories instead of foams (Li et al., 2020). Similarly, in studies like (Hu et al., 2018; Su et al., 2016) it was extrapolated that micro pellets are one of the dominant types of microplastic in water.

4.3. Abundance and types of microplastic in sediment samples: This study also observed a high abundance of microplastic in sediment samples. The abundance of microplastic in Gulshan Lake (0-16 items/kg) and Hatir Jheel Lake (0-11 items/kg) was comparatively higher than the amount of plastic in Dhanmondi Lake (0-9 items/kg). The microplastic amount in sediment samples of Gulshan Lake (0-16 items/kg) was much higher than (0-9 items/L) that in the surface water of the sampling sites. The reason behind the high abundance of microplastics in sediment samples than water samples could indicate a higher level of microplastics input over a longer duration of time.

The prevailing microplastic in sediment samples were films, fiber, and fragments. Films are prevalent in sediments as they are created by the fragmentation of plastic carry bags (Nor and Obbard, 2014), and plastic fibers are generally created from synthetic particles of clothing that can fall off during washing or when clothes are thrown. Likewise, fragments possibly originated from fragmented pieces of plastic waste products, which resulted from the direct dumping of solid waste. Fragments are the most ubiquitous type of microplastic among others because there is a large variety of possible sources. Fragments are likely to reach the sediments as they are weathered from other plastics and tend to be heavier. Plastics are generally transferred to nearby aquatic bodies and the ultimate destination of microplastics in the aqueous system is the sediments, where it is difficult to degrade (Mathalon et al., 2014).

4.4. Abundance and types of microplastic in fish samples: In total 86 microplastics were identified in 90 test fish species (Table S2). In Dhanmondi Lake, there was an abundance of microplastic and altogether 38 items were identified where 0-17 items/individual; 0-4.88 items/g in GIT was observed in the fish *Oreochromis mossambicus,* which has the highest number of ingested microplastic. In Hatir Jheel Lake, 31 items were identified which was also higher in amount. *Catla catla* from Hatir Jheel Lake had 0-15 items/individual and 0-1.40 items/g in GIT, indicating a great amount of microplastic pollution in the lake.

Microscopic observation of the samples showed a prevalence of pellet (30 MPs), fibers (24 MPs), film (15 MPs), fragments (7 MPs), and foam (2 MPs) which could have come from industrial and domestic sewage. Even though fibers and films were the most common type of MPs in water and sediment, fish mostly ingested micro pellet. Pellets are commonly made of low-density polymers like polystyrene, which tends to float in surface waters and are therefore accessible to fish. Fibers were also prominent and showed signs of physical degradation, which can result from the gill movement, and digestion processes of fish.

4.5. Composition of Microplastics: Several studies (Song et al., 2015; Shim et al., 2017) have been published comparing various approaches for MP recognition, but no current standard method exists. The FTIR- ATR (Attenuated Total Reflection) mode of analysis was used by Jung et al. (2018) to classify microplastic, which included ingested MPs by aquatic organisms. A group of FTIR spectra was elaborately described in their published work which acted as a standard for the analysis of the collected FTIR spectra in this research. Since there was no database to compare FTIR spectrum, it is presumed that the microplastics isolated were any of the 16 most common synthetic polymers. Moreover, previous research also implies High-density Polyethylene, Low-density Polyethylene, Polycarbonate, Polypropylene, Polyvinyl chloride, Polystyrene, Cellulose Acetate, Ethylene vinyl acetate, and Polyethylene terephthalate as the most commonly found polymers in aquatic bodies (Hidalgo-Ruz et al., 2012).

The samples had HDPE, PP, and EVA which exhibit significant bands in the C-H stretching area and have almost similar band profiles in terms of appearance. PP was also present and it shows several bands compared with the double stretching peak produced by the 2951 and 2848 cm^{-1} band. Sediment samples appear to cellulose acetate components. Almost all samples exhibited the C-H vibrational modes of polyethylene-based polymers, with an extra characteristic peak of around 1720–1750 cm^{-1} attributed to the carbonyl bond stretching vibration where the spectra resemble those of ethylene vinyl acetate (EVA).

In summary, the presence of HDPE, PVC, PP, PC, EVA, and CA were identified in examined samples. According to FTIR data, majority of the microplastic isolated from the water, sediment, and fish samples in the analysis were mainly PE-based. This is not surprising considering the extensive use of PE-based plastic bags, which often end up in aquatic environments (Yurtsever et al., 2018).

5. Conclusions

The study provides valuable insight into the prospect of urban lakes becoming a significant source of microplastics. This research is one of the first to deal with microplastic pollution in the urban lakes of Dhaka, Bangladesh. Microplastics were identified in significant concentrations not only in the water and sediment but also in the fish of the lakes. Microplastic pollution is prevalent in water and sediment, especially in the form of films, fibers, and fragments, which are likely the result of surrounding anthropogenic activity. The findings of the collected samples from urban lakes represent that these lakes might become a potential source of microplastics in the future. Microplastic abundances in resident fishes suggest that microplastics may go up the food chain to higher aquatic or terrestrial trophic levels. Such evidence can also be used as environmental indicators of anthropogenic impacts, which may help to resolve problems impacting human and environmental health, such as the possibility of bioaccumulation in humans and other species.

Declarations

Author Contributions

Fariha Tahsin Mercy: Conceptualization, Methodology, Data collection, Material preparation, Formal analysis, Writing- Original draft preparation. **A.K.M. Rashidul Alam**: Conceptualization, Visualization, Draft Preparation, Reviewing and Editing, Supervision. **Md. Ahedul Akbor:** Resources, Supervision.

Conflict of interest

The authors state no financial or other conflicts of interest that may have impacted the work presented in this study.

Acknowledgments

The authors are sincerely thankful to the Institute of National Analytical Research and Service (INARS), Bangladesh Council of Scientific and Industrial Research (BCSIR) for helping to perform required

analytical techniques and to the Wazed Miah Science Research Centre, Jahangirnagar University for instrumental supports.

Consent to Participate

Not applicable.

Availability of data and materials

All relevant data are available from the corresponding author on request.

Ethical Approval

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Figures

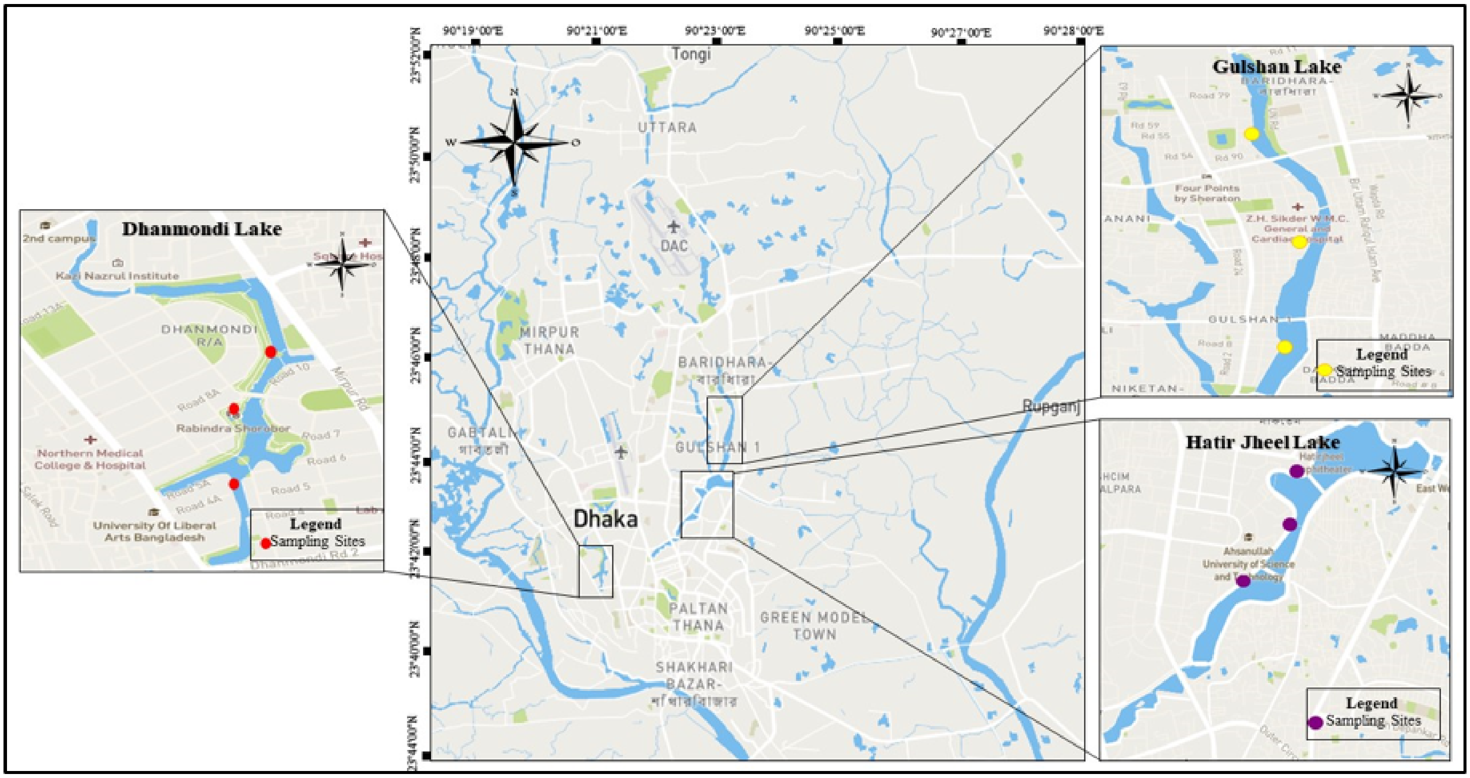

Figure 1

Location of sampling areas (Dhanmondi Lake, Gulshan Lake, Hatir Jheel Lake) and different color dots represent sampling sites of each lake.

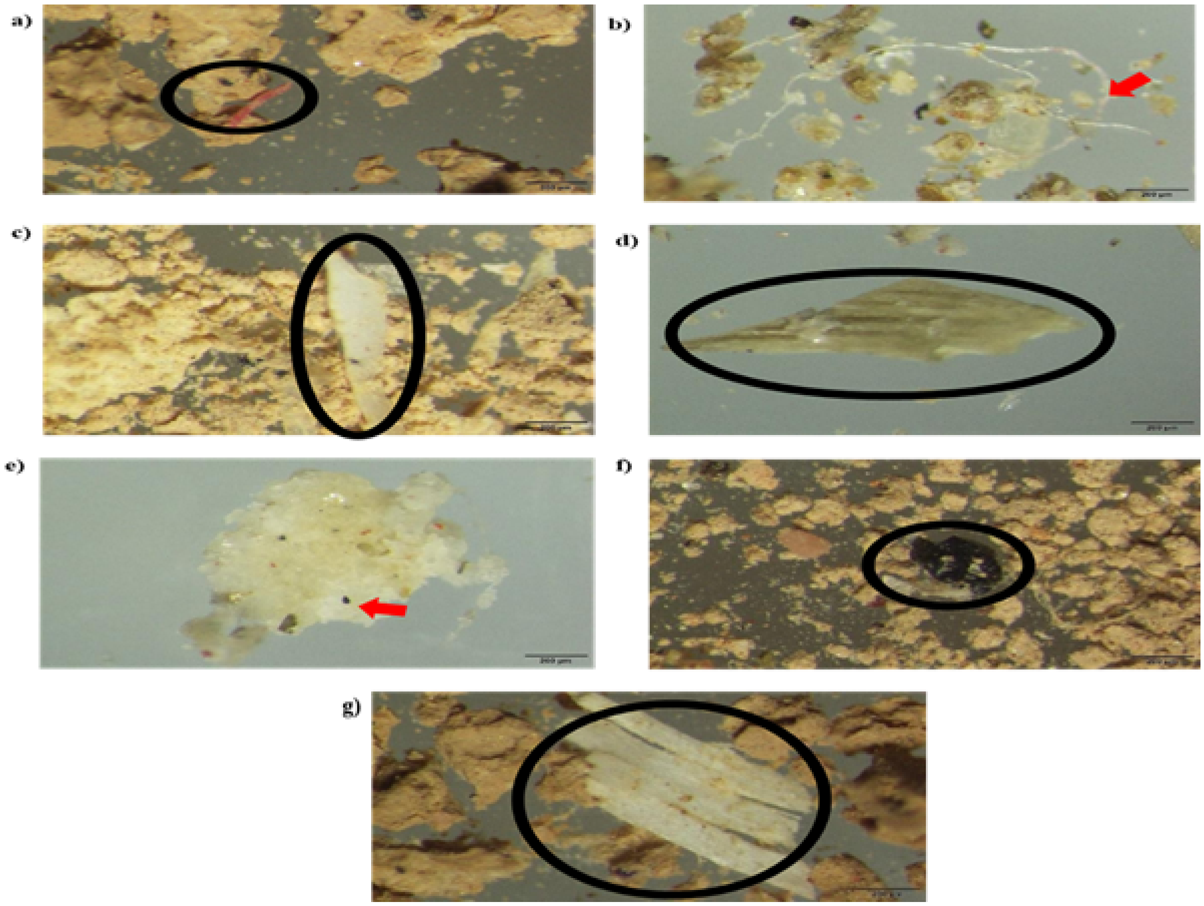

Figure 2

Visual identification of microplastic particles under Stereo Microscope (40X); grouped into five categories: (a) Fiber (uniform plastic strands); (b) Fiber (fibrous); (c) Fragments (hard); (d) Fragments (jagged-edged); (e) Micro-pellets (hard, rounded particles); (f) Films (2-dimensional plastic films) (g) Foam (Styrofoam material). The black bar below each picture indicates 200 μm size.

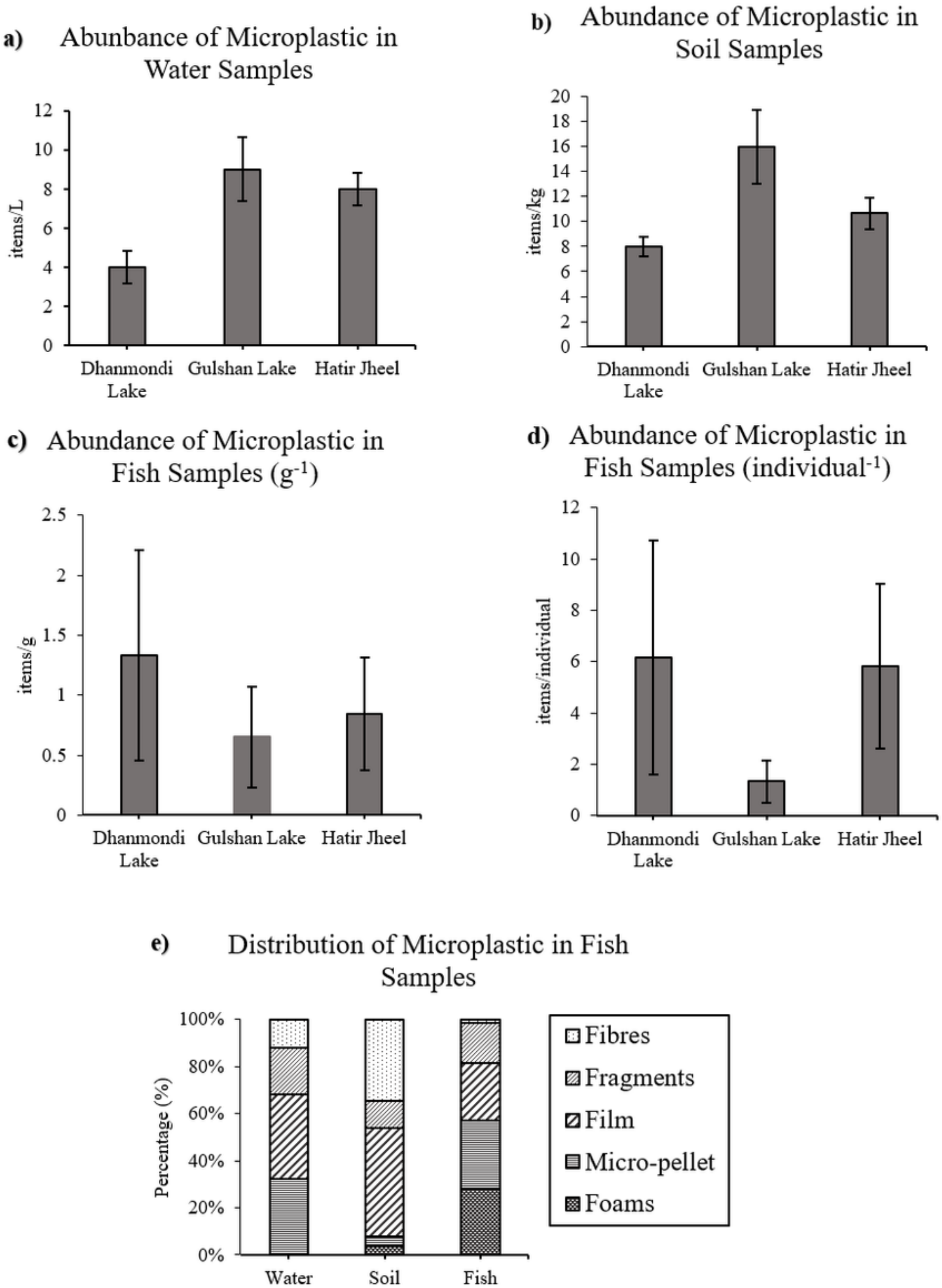

Figure 3

Abundance of microplastics detected in (a) surface water, (b) sediment, (c) fish gut, (d) individual fish samples, (e) along with distribution by the percentage of microplastics in samples from all sites.

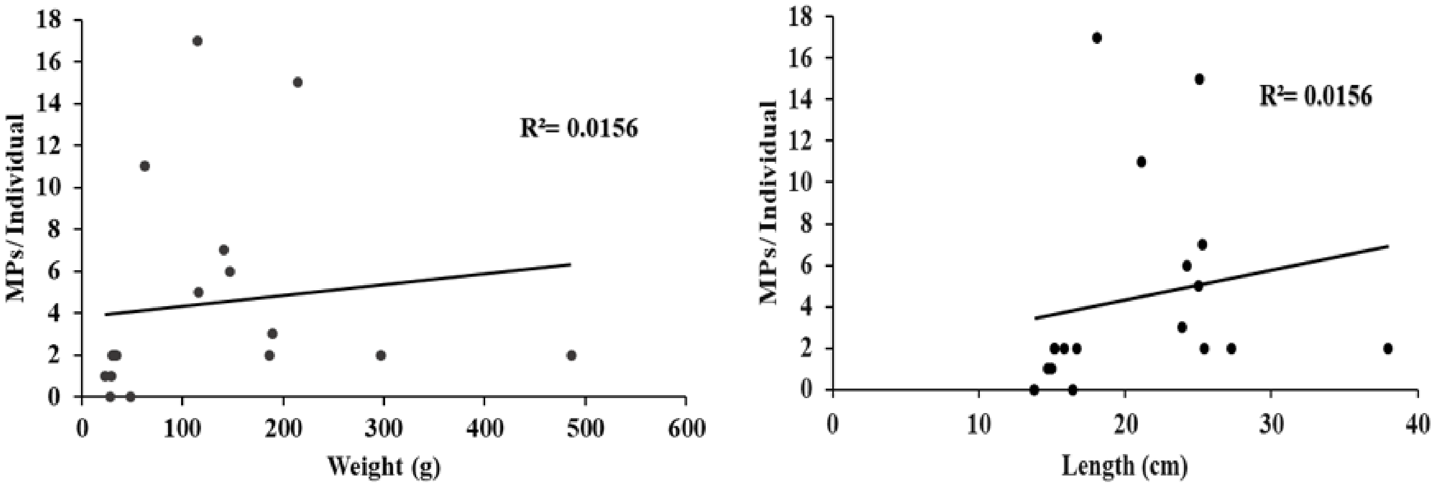

Figure 4

Correlation of MPs abundance with weight and length of fish species.

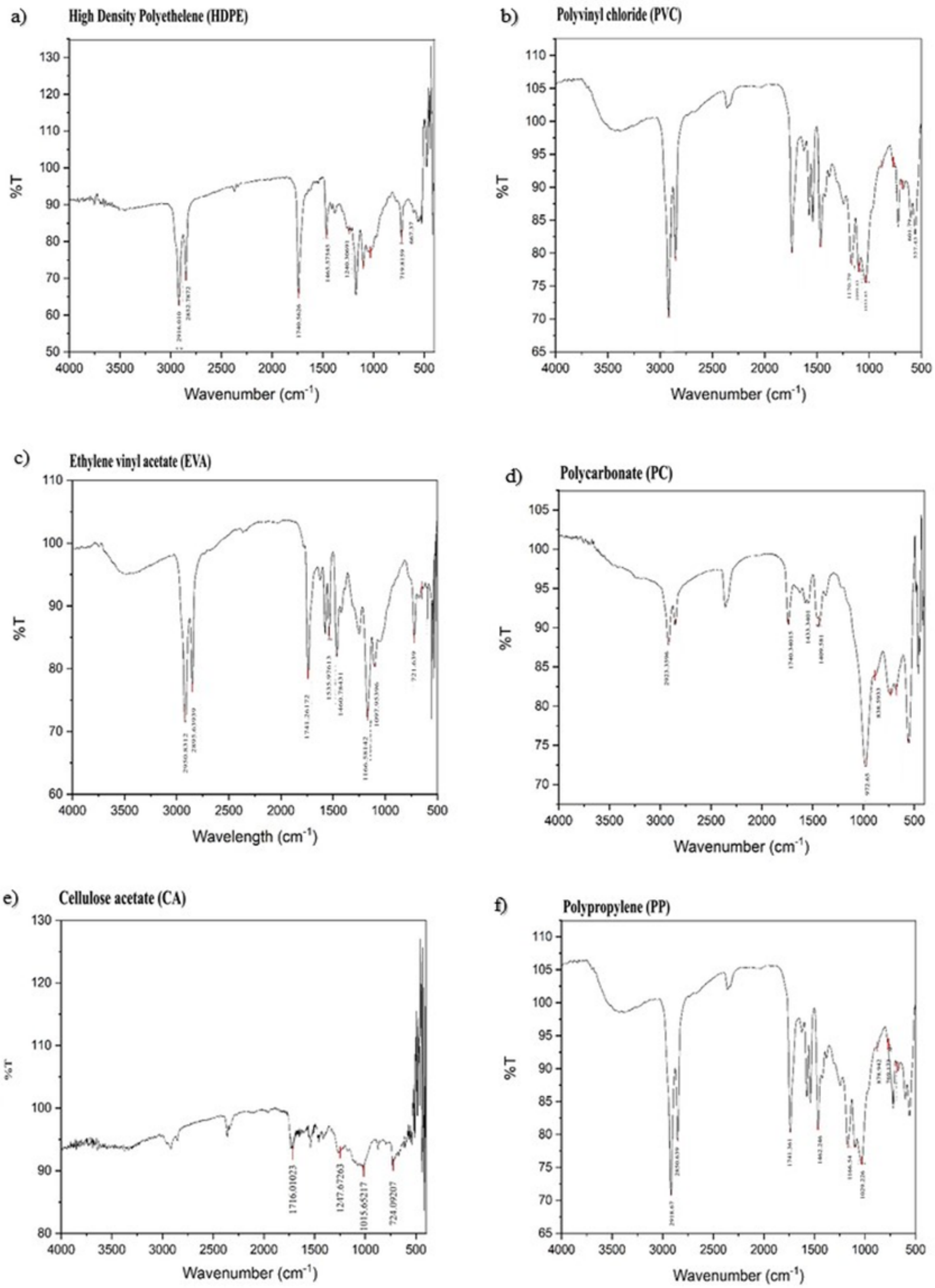

Figure 5

IR spectrum of the most prevalent type of MPs found in Urban Lakes. The representative particles showing significant adsorption bands of a) HDPE, b) PVC c) EVA, d) PC, e) CA, and f) PP.

Supplementary Files

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