Characterization of microplastics and its Pollution load index in freshwater Kumaraswamy Lake of Coimbatore, India

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Abstract

Mass production, consumption, and disposal of plastics pollute the freshwater environment. Microplastics are small plastic particles less than 5mm in diameter that enter the ecosystem as a result of the breakdown of large plastic particles or the direct release of small plastic particles by climate and human activities. This study focused on investigating the spatial, and seasonal dispersal of microplastics in the surface water of Kumaraswamy Lake, Coimbatore which is located at the Latitude of 110’00.52" N, Longitude of 76056’42” E. In different seasons, such as summer, pre-monsoon, monsoon, and post-monsoon samples were taken from the inlet, centre, and outlet. Microplastics made of linear low-density polyethylene, high-density polyethylene, and polypropylene were found in all sampling points. From the water samples, fibre, thin, fragments, and film shapes of microplastics were identified and most of them were black, pink, blue, white, transparent, and yellow in colour. The lake's microplastic pollution load index values were less than 10, which implies the risk I category. Microplastic concentration over four seasons was 8.77 ± 0.27 particles per liter and a high distribution was observed in the outlet area (10.70 ± 0.25 particles/L). Seasonally, the highest microplastic concentration was found in the monsoon season followed by pre-monsoon, post-monsoon, and the lowest in the summer season. These results emphasize that the distribution of microplastics spatially and seasonally wise may cause harmful effects on the fauna and flora that live in lake habitats.

1. Introduction

Microplastic pollution is a global issue that threatens marine and freshwater environments. The industrial plastics production and use of it led to waste disposal with poor waste management that affects the aquatic, and terrestrial environment where this phenomenon is strongly documented (Moore 2008;K Davis and Raja 2020). Polyethylene, polypropylene, polyethylene terephthalate, and polyvinyl chloride (Zimmermann et al. 2019) are types of microplastics, which are characterized as plastic particles smaller than 5mm with a large surface area and strong hydrophobicity (Thompson et al. 2009). The production of microplastics and the progressive breakdown of plastic pieces can be caused by environmental and human factors (Thompson et al. 2004). Microplastics usually enter the aquatic ecosystem from the terrestrial environments as a result of improper disposal, drainage, transport by wind, and direct dumping (Hansen 2016). The wide distribution of microplastic sources includes the fragmentation and degradation of plastic bags, plastic bottles, rope, pipes, and other waste plastics through surface water runoff (Vanapalli et al. 2021). Microplastics can accumulate over long periods in lakes, rivers, and the marine environment due to their high durability and floating nature.

Microplastic is considered to enter the ocean mostly via rivers and lakes (Blanco and Scatena 2006), and numerous studies have demonstrated how microplastics are dispersed around the world (Masura et al. 2015; Zheng et al. 2019; Athawuda et al. 2020; Xia et al. 2021). Freshwater systems are the most productive life support system, they are vital to humankind's social, ecological, and economic well-being, and they are surrounded by dense populations that can bring primary and secondary microplastics into the water. Only a few studies have been conducted on microplastics in freshwater lakes (Eriksen et al.

2013; Liu et al. 2019; Anderson et al. 2017). Microplastic distribution varies on a seasonal and spatial basis as well. Despite microplastics coming from a variety of terrestrial sources, land cover and proximity to anthropogenic activity are crucial factors in the pollution of freshwater (Grbić et al. 2020). Numerous studies, for instance, show higher microplastic concentrations during the rainy season (Wang et al. 2021; Gupta et al. 2021; Hurley et al. 2018) since land-based microplastics may enter waters through wind, and runoff water. Heavy rains and an excessive inflow of freshwater from rivers during the wet season convey more terrestrial plastic debris into the Mandovi Zuari estuarine system, Goa, increasing the average microplastic density on the surface water (Gupta et al. 2021). Heavy rain the day before the sampling day was linked to an increase in microplastic content (Schell et al. 2021). Increased the concentration of microplastic loads in sewage outflow and stormwater runoff in studies due to heavy rain and flood (Blettler et al. 2017; Kataoka et al. 2019). Another important element that transports or disperses the microplastics in coastal areas is the surface current (Kim et al. 2015). The concentration and distributions of microplastics in the *Carassius auratus*, surface water, and sediments of Poyang Lake (Yuan et al. 2019) are highly varied, and the lake contains other toxicants on the surface, resulting in a combined effect on aquatic and terrestrial organisms (Beckingham and Ghosh 2017).

In microplastic analysis, different water sampling methods, sample treatment, and separation methods were studied (Rezania et al. 2018; Liu et al. 2019). For the microplastic separations, samples were usually separated by using $ZnCl_2$, and the 30% H_2O_2 (Su et al. 2016; Athawuda et al. 2020) for the digestion of organic matter present in it. Standard techniques for identifying and characterizing microplastic polymers include Fourier transform infrared spectroscopy (FTIR) and Field Emission Scanning Electron Microscope (FESEM) (Tagg et al. 2015). Microplastic dispersal in water is determined by plastic size, type, shape, and surface area. Microplastic, due to its small size and low density, may travel long distances and reach almost all ecologies via wind, water flow, and ocean currents (Rochman 2018). The freshwater lake receives microplastics from urban, industrial, and direct dumping of wastes increasing the risk of pollution. Fishing is inseparable from polymer materials such as fishing nets, buoys, net cages, and ropes; by their shapes, size, and attractive colour it is mistaken as food by aquatic organisms such as fish (Baalkhuyur et al. 2018; Xiong et al. 2018), mussles (Digka et al. 2018), sessile invertebrates (Wright et al. 2013) and molluscs (Abidli et al. 2019). Microplastics found in fish can cause physical damage, intestinal blockage, histological alterations in the intestines, and behavioural changes (Jovanović 2017). They can also accumulate at a high level throughout the food chain, posing a concern to human health (Yuan et al. 2022).

Only a few studies on the microplastic pollution of lakes in Tamil Nadu State have been published. These lakes include Veeranam Lake in Cuddalore (K et al. 2021), Red Hill Lake in Thiruvalluvar (Gopinath et al. 2020), Puzhal Lake in Chennai (Silambarasan and Sheela 2020), Pulicat Lake in Chennai (Sathish et al. 2020), Ousudu Lake in Pondicherry (Varshini et al. 2021), and Periakulam Lake in Coimbatore (Jesudass et al. 2020). Our study area Kumaraswamy Lake is located in Coimbatore District in Tamil Nadu State and is an important source of water, fishing, and an important habitat for birds, fish, plankton, insects, amphibians, reptiles, and mammals. Due to its proximity to cities, the lake becomes a dumping site for plastic waste. No baseline data on microplastic pollutants were obtained from the proposed research location, and fewer people are aware of the dangers that microplastic pollution poses to their health. Therefore, it is important to realize the characterization, distribution, and quantify the level of microplastic contamination by combined field survey and laboratory analysis. Microplastic distribution depends on seasonal and spatial influences such as rainfall, wind, sewage influx, and anthropogenic activities. In Coimbatore, high rainfall and wind during the monsoon season cause microplastic to be distributed to lake water through Selvampathy lake, sewage inlets, and terrestrial environments. So the spatial and seasonal distribution of microplastic analysis is important for the Kumaraswamy Lake study.

2. Materials and methods

2.1 Study area

The Kumaraswamy Lake (110’00.52” N, Longitude of 76056’42” E) is located in Coimbatore, Tamil Nadu with a total area of 93.67 acres with a catchment area of 16 sq. km (Priya et al. 2011). The map of Kumaraswamy Lake is generated by using ArcGIS 10.6 as shown in Fig. 1. The lake is located on Thondamuthur Road in Coimbatore, and it receives water from the Noyyal River via the Chithravadi channel, and also excess water from Selvampathy Lake. Thadagam road on the eastern side and Narisipuram road on the northern side of the lake. The outlet of the lake is connected to Selvachintamani Lake. Lake provides essential habitat for many species of plants, fish, birds, and frogs. Lake provides a prime diverse habitat for avifauna including *Tachybaptus ruficollis*, *Phalacrocorax niger*, *Phalacrocorax fuscicollis*, and *Egretta garzetta*. *Catla catla*, *Labeo rohita*, *Channa punctata*, *Channa striata*, *and Oreochromis mossambica* are among the variety of fish found in lakes, and flora diversity includes *Eichhornia crassipes* (Mart.) Solms., *Typha* sp., *Celosia argentea* L., *Gomphrena globosa* L., *Parthenium Hysterophorus* L (Quadros et al. 2014). Amphibians and reptiles are a much-neglected group of fauna from the lake. Sediments and plastics enter lakes primarily by way of runoff (rain and stormwater) water that comes from land surfaces. The lake has received building debris, domestic solid waste, and untreated sewage water through the various pathways that will be considered dumping grounds.

2.2 Sample collections

The surface water was collected in different seasons like summer, pre-monsoon, monsoon, and post-monsoon (James et al. 2021) in 2019 at different sampling points of the inlet, centre, and outlet of the lake. Glass bottles were used to collect one litre of surface water samples (Sathish et al. 2020), with twelve replicates taken separately at each sampling point and transported into the laboratory without airborne microplastic contamination. All sampling containers and tools were cleaned with filtered deionized water prior to sampling.

2.3 Isolation of microplastics

Samples were filtered in a vacuum filtration system using 0.45 μm pore size filter paper in a clean laminar airflow to eliminate large debris and retain smaller than 5 mm particles (Su et al. 2016). The filtrate samples were washed into a glass beaker and it was immediately covered by aluminium foil. Further, the samples were subjected to wet peroxide oxidation (30% H_2O_2) in the presence of 0.05M Fe (II) solution (Masura et al. 2015) as a catalyst to digest organic matter. In a vacuum filtration system, the digests were filtered through 0.45 μm pore size filter paper. The filtrate samples were placed into petridish and dried in the oven at 45 ^{0}C. Similarly, the blank groups were analyzed simultaneously for the estimation of cross contamination.

2.4 Identification of microplastics

The filtrate samples were characterized and isolated based on size, colour, and shapes by an inverted trinocular microscope (Olympus). Further, examined by Field Emission Scanning Electron Microscope (FESEM- TESCAN- MIRA3 XMU) was used to obtain the physical structure. Particles observed on the filtrate were classified as film, thin, fragment, and fiber shaped. The size fraction of microplastics is classified as 5 – 3 mm, 3 – 1 mm, 1-0.5 mm, and 0.5 mm-1μm, and characterized the plastic particles based on their colours. Microplastic types were identified using attenuated total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR SHIMADZU (Miracle 10)) at the mid- IR range of 400 and 4000 cm^{-1} (Tagg et al. 2015).

2.5 Quality assurance and controls

Blank controls were conducted at each field sample location to prevent samples from being contaminated by artifacts and airborne particles. Before and after use, all tools and containers were washed with filtered deionized water and covered in aluminium foil. Cotton lab coats, gloves, and cotton masks were worn throughout the experiments. Through 0.45 μm filters, all of the liquids used in the experiment were filtered. Pre-treatment steps were performed in a laminar flow chamber to reduce airborne contamination from the lab environment. No microplastics were detected in any procedural blank samples. Therefore, contamination during the analysis process was negligible.

2.6 Assessment of Microplastic Pollution load index

The extent of the pollution load of surface water by microplastics can be estimated using the pollution load index (PLI). The PLI method was proposed by Tomlinson et al.(1980) to evaluate the status of overall metal pollution. PLI is an effective index to assess the risk level of microplastics in different sampling points during different seasons. The formula for calculating the pollution load index was followed:

$$CF_i = \frac{C_1}{C_0}$$

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \ldots\ldots CF_n}$$

CF_i of the microplastic is the quotient of the microplastic concentration at each sampling points (C_1) and C_0 is the background value, which was selected as the lowest microplastics concentration in the sampling points. The PLI is calculated by n-root from CF_i of all studied microplastics concentration. Our study utilized the hazard scores of plastic polymers from Lithner et al. (2011) (Table 2).

2.7 Statistical analysis

The abundance of microplastics in water was expressed in particles/L and the data were expressed as mean ± SE. After checking the homogeneity of variances, the differences among sampling sites were compared using one-way ANOVA following the Duncan test and statistical significance was set at a p-value of 0.05. The data analysis was performed using SPSS software (IBM SPSS Statistics Version 20) and graphics were created using Origin 8.5, Graph pad prism (Version 5.01), and excel (Version 2109).

3 Results

3.1 Abundance and distribution of microplastics

Microplastics were detected in all of the selected sites in all seasons, with a concentration of 368 particles/L, demonstrating that they are widely dispersed in the lake's surface water. The map of Kumaraswamy lake is generated by using ArcGIS 10.6 as shown in Fig. 1. The abundance of microplastics increases over the monsoon season and decreases during the summer seasons. In monsoon (12.41 ± 0.41particles/L), and pre-monsoon (11.16 ± 0.47 particles/L) seasons have a high microplastic concentration in the outlet of the lake. The minimum abundance of microplastics was observed at the inlet (3.33 ± 0.54 particles/L) during the summer season as shown in Fig. 2. Since there were no microplastics on the blank controls, no blank correction was made.

3.2 Microplastic morphology

Microplastics can be evaluated based on their specific morphology, as well as the sorts of plastics that are of great concern. Surface water was found to include microplastics of various colours (Fig. 3a), which were divided into five categories: white, transparent, black, yellow, blue, and pink, with a higher concentration of white coloured microplastics identified in the outlet area (5–39%). The film, fragment, thin, and fiber were identified as the most common microplastic shapes throughout seasons (Fig. 3b; Fig. 5), with the film being the most prominent microplastic in all studied sampling points. FESEM was used to determine the microplastic particle size range of less than 1mm which was initially identified as microplastic by visual observation and an Inverted trinocular microscope (Fig. 6). Microplastics in the size range of 5 mm to 1 μm were detected in this study and were mainly divided into 5 – 3 mm, 3 – 1 mm, 1-0.5 mm, and 0.5-1 μm (Fig. 3c). During the monsoon season in the outlet area, microplastics measuring 5 – 3 mm (34 percent) and 3 – 1 mm (30.20 percent) were found in greater abundance than other particle sizes in surface water.

3.3 Polymer identification by ATR-FTIR

Different microplastic types were successfully imaged and identified using FTIR imaging. Linear low-density polyethylene, high-density polyethylene, Polyethylene terephthalate, and polypropylene were the frequent types of microplastics identified in the lake (Fig. 3d). The characteristic linear low-density polyethylene bands (Fig. 4a) appear at 2917.04 cm^{-1} corresponds to CH_2 asymmetrical stretching, 2845.05 cm^{-1} corresponds to CH_2 symmetrical stretching, and 1465.90 cm^{-1} corresponds to bending deformation, 717.52 cm^{-1} corresponds to rocking deformation, 1299 cm^{-1} CH_3 bending. High-Density polyethylene bands (Fig. 4b) appear at 2916.37 cm^{-1} corresponding to CH_2 asymmetrical stretching, 2846.93 cm^{-1} corresponds to CH_2 symmetrical stretching, weak wagging deformation (1365.60 cm^{-1}), weak twisting deformation (1306 cm^{-1}), 1465.90 cm^{-1} corresponds to bending deformation, and 717 cm^{-1} corresponds to rocking deformation. Polyethylene terephthalate plastic bands appears 2970.38 cm^{-1} (CH symmetrical stretching vibration), 2360.87 cm^{-1}(axial symmetrical deformation of CO_2, 1712.79 cm^{-1} (C = O stretching), 1404.18 cm^{-1} (aromatic skeletal stretching band and ring in plane of deformation), 1338.99 cm^{-1} (CH_2 wagging of glycol), 1242.16 cm^{-1} (ester C = O stretching), 1095.57 cm^{-1} (ester C = O stretching), 1018.41 cm^{-1} (Methylene group and vibrations of the ester C-O bond), 871.82 cm^{-1}(aromatic rings 1,2,4,5), 725.23 cm^{-1} (CH_2 rocking), 547.78 cm^{-1}. Polypropylene spectra (Fig. 4c) produced the characteristic peaks with wave numbers 2950 cm^{-1}, 2916 cm^{-1}, 2850 cm^{-1} (CH stretching), and 1458 cm^{-1} (CH_2 bending), and 1373 cm^{-1} (CH_3 bending).

3.4 Pollution load index of microplastics in surface water

Microplastic risk assessment at three sampling points was assessed using the Pollution load index. The status of microplastic contamination in surface water was shown in the Table 3. According to PLI values, all the sampling points showed minor contamination with microplastics (Linear low-density polyethylene, High-density polyethylene, and Polypropylene) (ie., PLI < 10) as shown in Fig. 7. The lake falls in the risk I category. During monsoon seasons, the PLI value was higher at the inlet sampling point (1.68), whereas it was lower in the summer season (Fig. 7).

4 Discussion

Microplastics were detected in all of the selected sites in all seasons, with a average concentration of 8.77 ± 0.27 particles/L, demonstrating that they are widely dispersed in the lake's surface water. The surface water Guaiba lake in Brazil (11.9–61.2 items/m^3) (Bertoldi et al. 2021) has a higher abundance of microplastic due to their large surface area of lakes and it still receives residential wastewater through various inlets (Andrade et al. 2019). Kumaraswamy Lake surface water shows 1263 microplastic than other studies (Table 1). The main contributors of contamination to the lake have been recognized as rivers from across the world (Li et al. 2013), and the nearby location with extensive anthropogenic activities is also suspected of being a source of plastic contamination (Eriksen et al. 2013).

The abundance of microplastics in the outlet (10.70 ± 0.25 particles/L) of the Lake was substantially higher than in the centre (9.12 ± 0.42 particles/L) and inlet (6.47 ± 0.46 particles/L) point ($p < 0.05$) (Fig. 2), which might be due to the outlet area of the Lake is dumping ground for waste from terrestrial environment as a result of improper disposal, through drainage, transport by wind, and direct dumping.

For instance, much higher microplastics concentrations were spotted in the outlet channel between Yangtze River and Dongting Lake (Wang et al. 2018), this region is noticeable for its busy shipping, narrowing of the water surface may escalate the concentration of floating plastics, which is supposed to be a potential source of microplastics contamination in aquatic environments (Eerkes-medrano et al. 2015). Jian et al. (2020) also reported that the high abundance of microplastics at the outlet sites of Poyang Lake into the Yangtze River could be associated with the high provincial human population, and vigorous anthropogenic activities at the outlet region, such as agricultural, aquaculture, shipping, fishing, ferries, and industrial manufacturing. South Bay has high microplastic abundance than the Central region and North Bay due to the high level of urbanization and the presence of industry and urban-use zones in addition to mariculture and fishery zones (Wang et al. 2020). Microplastic distribution varies with the seasons, which indicated that microplastics remain in the water for a long time and their distribution was high during monsoon seasons. Relatively, the monsoon season in Kumaraswamy Lake had a higher abundance of microplastics in the outlet (4.50 ± 0.57 particles/L), center (3.60 ± 0.46 particles/L), and inlet (2.33 ± 0.33 particles/L) than the pre-monsoon, post-monsoon, and summer seasons (Fig. 2) due to heavy rain, anthropogenic activities, and wind. During the outlet of water in the monsoon season, the land-based microplastics are likely carried into and accumulated in the Lake. Due to excessive rainfall and subsequent sewage influx, an increased quantity of microplastics was reported in the surface water of the Vellar Estuary, India, during the northwest monsoon of 2018 (Nithin et al. 2022). Lake Erie's water current patterns are more intricate than those of Lake Huron and Lake St. Clair, making a causal link between water circulation and plastics distribution problematic (Zbyszewski et al. 2014). Wang et al. (2020) conducted a microplastic study during the rainy time when the outflow of the Yangtze and Qiantang rivers into Hangzhou Bay altered microplastic distribution. The dispersion of microplastics in the Indian aquatic environment is influenced by microplastics from the terrestrial environment, inadvertent leakages during shipping, marine trash, and hydrodynamic conditions during the northwest and southwest monsoons affect the concentration of microplastics in the Indian aquatic environment (Jeyasanta et al. 2020; Davis and Raja 2020; Vanapalli et al. 2021).

Microplastic deterioration and erosion are caused by photodegradation, oxidative weathering, biodegradation, mechanochemical activity, and catalytic action (Shah et al. 2008; Singh and Sharma 2008). The size and shape of the microplastic were mainly due to local climatic conditions, transportation process, thermal degradation, distance from the origin, and residence time of the microplastics in the aquatic environment. The film, thin, fragment, and fiber were the most forms of microplastic identified from Kumaraswamy Lake (Fig. 3b: Fig. 5) that originated from sewage inlet, surface runoff, and the breakdown of fishing gears such as plastic bags, nets, and ropes. The film, thin, fragment, and fiber were the forms of microplastic originating from commercial fishing nets, washing, residential wastewater, and the natural aging of textiles (Patterson et al. 2019; Browne et al. 2011). The breaking of larger polymer products due to weathering and abrasion could well be the origin of fragments (Vidyasakar et al. 2018) Fiber, film, and fragment microplastics were detected in Lake Ulansuhaii, Yellow River Basin, China (Wang et al. 2019). The outlet of the Kumaraswamy Lake during the monsoon season shows high concentration of film (37.58%), and fragments (20.13%). Moreover, the proportion of film-shaped microplastics in the outlet area during pre-monsoon was relatively high (37.31%) (Fig. 3b). For Dongting Lake and Hong Lake, the average proportion of films was 13.5% and 16.0%, respectively (Wang et al. 2018). Microplastic particles were fragments and fibers which accounted for 35% and 12% respectively in the Bohai Sea, China (Zhang et al. 2020). Fragments, foams, flakes, and fibers were also found in Italian subalpine lakes, and fragments were the most widespread fraction in surface waters, representing 73.7 percent of the total (Sighicelli et al. 2018). Similarly, Campanale et al. (2019) analyzed the Ofanto River and discovered that microplastic fragments predominated (56 percent) during all sessions.

Different sized microplastics were fragmented from large plastic or released directly into Kumaraswamy Lake with less than 5mm in size were mainly divided into 5 – 3 mm, 3 – 1 mm, 1-0.5 mm, and 0.5-1 μm (Fig. 3c), and the small-sized coloured microplastics can easily get into the body of aquatic species. The most of microplastics in our sample were 3-1mm in size, implying that large plastics in the lake and nearby sources (household and industrial effluents) are breaking down into small particles, perhaps contributing to a rise in microplastic contamination in the lake. Large microplastic (5 – 3 mm, 3 – 1 mm) were more abundant in the monsoon season (34.89% and 30.20%, respectively) in the outlet area indicating that the distribution of microplastic will increase during rainy time. If there are large microplastics were increasing, the production of smaller microplastics will rise as well. The microplastic formed from large plastic is called secondary microplastics (Ling et al. 2017) Small-sized (0.5 mm-1 μm) microplastics were more abundant in the outlet area (13.95%) during pre-monsoon seasons (Fig. 3c) Microplastics of the size classes 5 – 1 mm and less than1mm were discovered on the Negombo coast of Sri Lanka (Karunarathna and Ranatunga, 2017). Surface water samples from Qinghai Lake were dominated by microplastics with a diameter smaller than 0.5 mm, but river water samples were dominated by microplastics with a diameter of 1–5 mm (Xiong et al., 2018). Microplastic samples from Dongting Lake and Hong Lake exhibited a clear tilt towards smaller sizes (< 2 mm), with over 65 percent of all microplastics collected in the two lakes falling into this category (Wang et al. 2018).

Black, Transparent, white, blue, pink, and yellow in colour microplastics were identified in Kumaraswamy Lake (Fig. 3a). The majority of the microplastic that was found in the outlet area during the post-monsoon season was transparent (11.76%), white (24.36%), black (31.09%), blue (17.64%), pink (8.40%), and yellow (6.72%). The everyday consumption of coloured (black and white) plastic items (such as food packaging, food wrappers, carry bags, and containers) would enhance the spread of plastic waste in the lake, which could be a key contributor to these prevalent white and black coloured microplastics. During monsoon season, a significant amount of white (30.80%) coloured microplastics were found in the outlet area (Fig. 3a). In Taihu Lake (Su et al. 2016) and Qinghai Lake (Xiong et al. 2018), microplastic in the colours translucent, white, black, red, green, and blue was discovered. In April and July, the most dominant colours collected were white (52.50% and 59.47%) and black (25.59% and 21.24%) (Wang et al. 2021). Some marine species' ingestion of microplastics was influenced by the colour of the microplastics (Katsanevakis 2008). When the colour of microplastics is nearly identical to that of prey, accessible marine predators may mistakenly consume the plastic (Peters et al. 2017). Gove et al. (2019) discovered that microplastics in larval fish were mostly blue or translucent in colour, which they believe is due to the microplastic thread-like seawater colour that is similar to copepod antennae. In all sampling points in different seasons, a total of 1263 particle/L were collected and the most polymers found in the study area were linear low-density polyethylene, high-density polyethylene, and polypropylene. The main contributions of microplastics are sewage inlets, fishing activities, and the dumping of waste. In Kumaraswamy Lake's surface water, polyethylene is identified as the most common microplastic form. The Linear low-density polyethylene microplastic were more abundant in the outlet area during the monsoon season (31.50%) (Fig. 3d). According to (Wang et al. 2018), the most abundant microplastic forms in Hong Lake and Dongting Lake were polyethylene and polypropylene. Gopinath et al. (2020) identified high-density polyethylene and polypropylene microplastics in Chennai's Red Hills Lake, and their spectra show similar characteristic peaks 2919 and 2847 cm^{-1} (-CH), 1470 cm^{-1} (-CH), and 716 cm^{-1} (-CH) of polyethylene and polypropylene spectra shows wavenumbers of 2866 cm^{-1}, 2836 cm^{-1}, 2950 cm^{-1} as well as linear low-density polyethylene microplastic were also reported in (Jahanmardi and Assempour 2008) studies. These polymer types are widespread in lakes and may float and move long distances in wind and water due to their low density (High-density polyethylene:0.93 to 0.97 g/cm^3, Linear low-density polyethylene: 0.915–0.925 g/cm^3, and Polypropylene:0.85 g/cm^3) (Ashraf 2015). Polyethylene and polypropylene pellets found along the Lake Huron shoreline are similar to those manufactured by petrochemical industries near Sarnia, Ontario, along the St. Clair River (Zbyszewski et al. 2014). The overwhelming use of polyethylene and polypropylene in modern life, such as plastic bags, bottles, and containers, is consistent with their massive global production and wise use (Plastics Europe 2018).

During the monsoon season, the PLI values for microplastic contamination in Kumaraswamy Lake's outlet (1.15) and centre (1.36) areas were higher than those in the inlet (1.68) sample point area (Fig. 7). The concentration of microplastic varies daily, and it accumulates in fish bodies and poses health risks. So risk level I is crucial to the lake ecosystem. Due to the increased influx of microplastic from sources including sewage inlets, direct disposal, and terrestrial environments during the monsoon season, the spread of microplastic is higher. (Ranjani et al. (2022) report that microplastic was higher in the Adyar region during both southwest and northeast monsoon seasons with minor contamination (PLI < 10). According to data from the Pollution Load Index, microplastic pollution in Lake Manipal is of Level I risk (Warrier et al. 2022). Due to an increased flux of microplastic particles from the surrounding area, the PLI was higher during the monsoon season. The PLI values decreased during the post-monsoon period, indicating that MPs in the water column may have sunk and blended with the sediments. Plastics are versatile and beneficial, but their effects are mixed; when incorrectly disposed of in natural habitats after usage, their durability and stability cause difficulties for the environment, human health, and food (Picó and Barceló 2019). Anthropogenic activity and land use are important controls on the spatial and seasonal distribution, release, and aggregation of microplastic pollution in Kumaraswamy Lake which could have an impact on the flora, fauna, and humans in the food chain.

5 Conclusion

Surface water was sampled in this investigation to quantify the number and dispersion of microplastics in freshwater. Our research found that the average microplastic abundance was 8.77 ± 0.27 particles/L in Kumaraswamy Lake, which is located near a densely populated urban part of the city, and that the lake fish has been used for human consumption. Heavy rain, and wind during the monsoon season influence high distributions of microplastics. The colour, shape, polymer types, and size profiles of microplastics were different in surface water. The major polymer components film, fragment, thin, and fiber microplastics are less than 5mm were linear low-density polyethylene, high-density polyethylene, and polypropylene. Film shapes of microplastics were predominantly present in surface water like white, transparent, blue, yellow, pink, and black in colour. Microplastics were preferred by aquatic species due to their appealing colour, smell, and taste. Pollution load index values of all the sampling points showed minor contamination with microplastics in the risk I category. The distribution of microplastics may increase or decrease according to day to day activities even the minute quantity of pollutants might affect directly or indirectly the freshwater Ichthyofauna. It provides a hindrance to aquatic organisms and reveals the presence of microplastic particles in fishes obtained from an urban lake. The surface water represents the distribution of microplastics that were associated with nearby human activities that may result in chronic toxicity to the Lake ecosystem and its associated people.

Declarations

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Ethical Approval

Not applicable

Consent to Participate

All the authors consent to the publication.

Consent to Publish

All the authors agree for consent for publication.

Authors Contributions

Davis Ephsy: Conceptualization, Methodology, Formal analysis, Investigation, Validation, Visualization, Resources, Original manuscript writing, Review and Editing.

Selvaraju Raja: Supervision, Conceptualization, Methodology, Formal analysis, Validation, Review and editing.

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the first author and corresponding author on reasonable request.

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Tables

Table 1 Microplastic concentration in Lake surface waters across the world.

SI No	Location	Microplastic concentration (Range/Average)	References
1	USA Lakes	0.05 to 32 particles/m ^{3}	(Baldwin et al.2016)
2	Nine lakes across Patagonia, South America	0.3-1.9 items/m^3	(Alfonso et al. 2020)
3	Wuliangsuhai Lake, China	3.12- 11.25n/L	(Mao et al. 2020)
4	West Dongting Lake, China South Dongting Lake, China	616.67-2216.67 items/m^3 716.67- 2316.67 items/m^3	(Jiang et al. 2018)
5	Taihu Lake, China	3.4–25.8 items/L	(Su et al. 2016)
6	Dongting Lake, China Hong Lake, China	900-2800 n/m^3 1250-4650 n/m^3	(Wang et al. 2018)
7	Wuhan Lake, China	1660.0±639.1 to 8925±1591n/m^3	(Wang et al. 2017)
8	Qinghai Lake, China	$0.05×10^5$-$7.58×10^5$ items km^2	(Xiong et al. 2018)
9	Gehu Lake, China	6.33±2.67 n/L	(Xu et al. 2021)
10	Poyang Lake, China	5–34 items/L	(Yuan et al. 2019)
11	Guaiba Lake, Brazil	11.9±0.6 to 61.2±6.1 items m^{-3}	(Bertoldi et al. 2020)
12	Kallavesi Lake, Finland	Manta trawled samples- 0.27 ± 0.18 items m^{-3} Pump filtered samples- 1.8 ± 2.3, 12 ± 17, and 155 ± 73 items m^{-3}	(Uurasjärvi et al. 2019)
13	Bolsena Lake, Italy Chiusi Lake, Italy	0.82 to 4.42 particles/m^3 2.68 to 3.36 particles/m^3	(Fischer et al. 2016)
14	Red Hills Lake, India	5.9 particles/L	(Gopinath et al. 2020)
15	Kumaraswamy Lake, India	8.77±0.27 particles/L	Present study

Table 2 Risk level criteria for MP pollution.

PLI	Hazard category	Risk category
<10	I	Minor
10–20	II	High
20–30	III	Danger
>30	IV	Extreme danger

Table 3 Hazard level of microplastic in surface water of Kumaraswamy lake.

SI No	Sampling points	Microplastic risk category	Microplastic risk category	Microplastic risk category	Microplastic risk category
		Pre monsoon	Monsoon	Post monsoon	Summer
1	Inlet	I	I	I	I
2	Center	I	I	I	I
3	Outlet	I	I	I	I

Figures

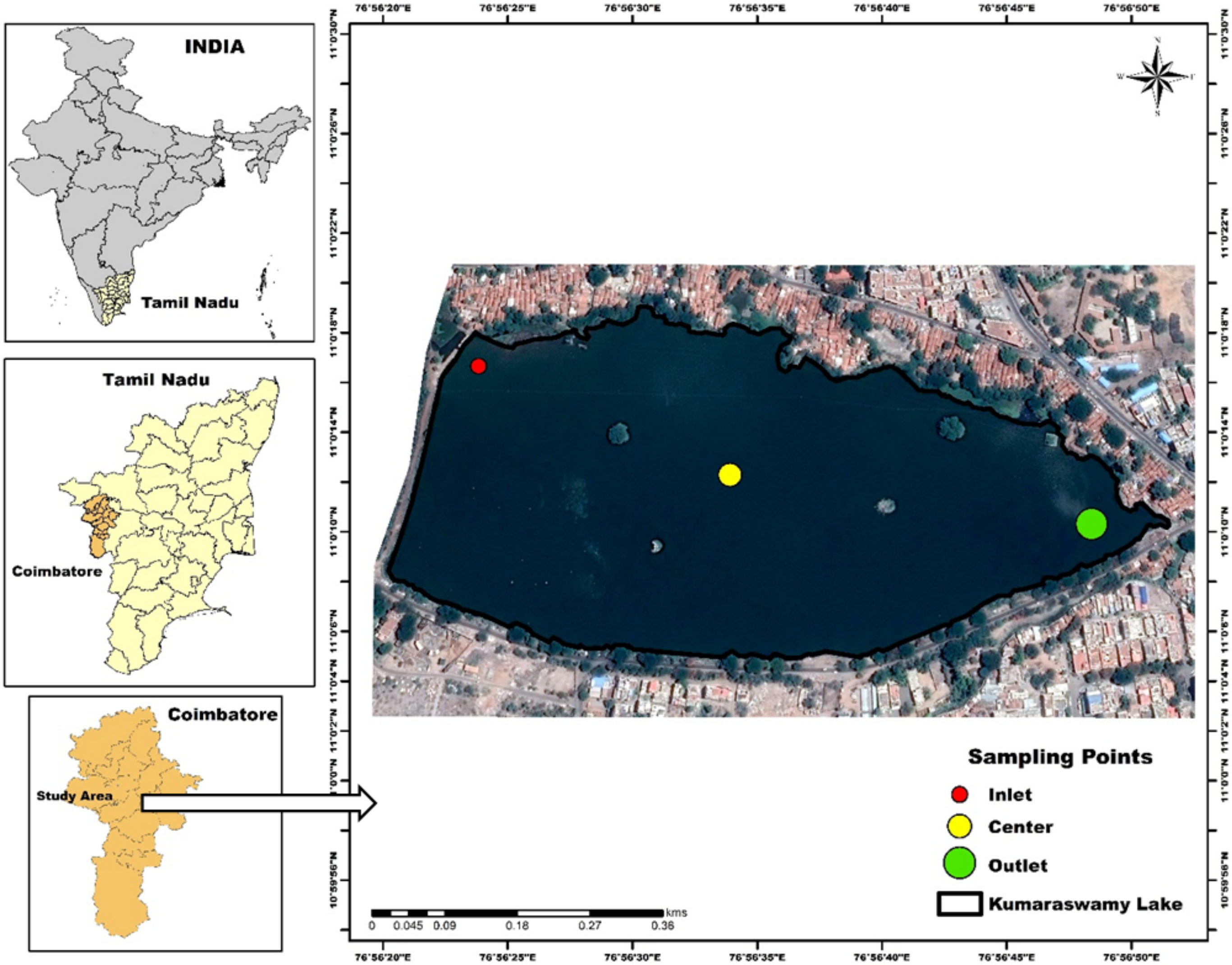

Figure 1

Geographic location of Kumaraswamy Lake

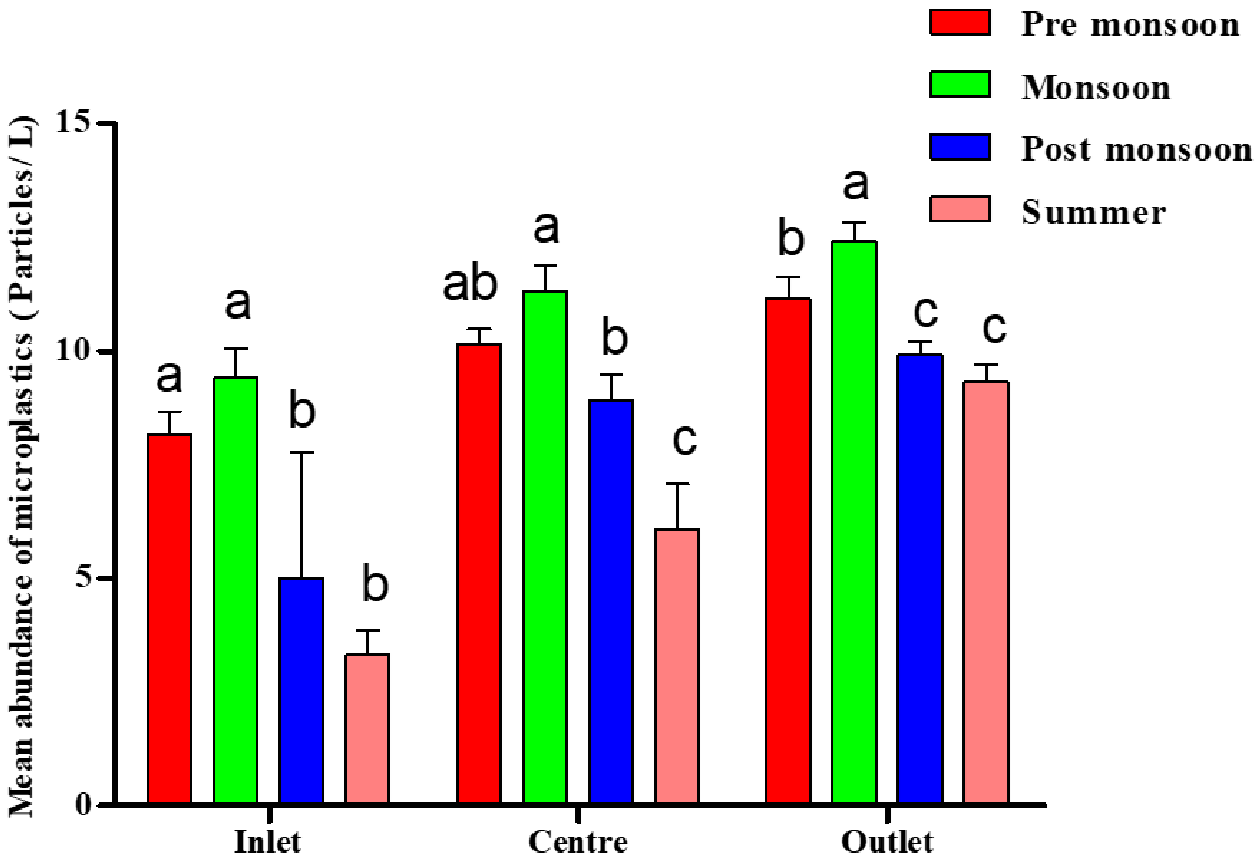

Figure 2

Mean abundance of microplastics (Mean ± Standard error) in Inlet, center, and outlet of the lake.

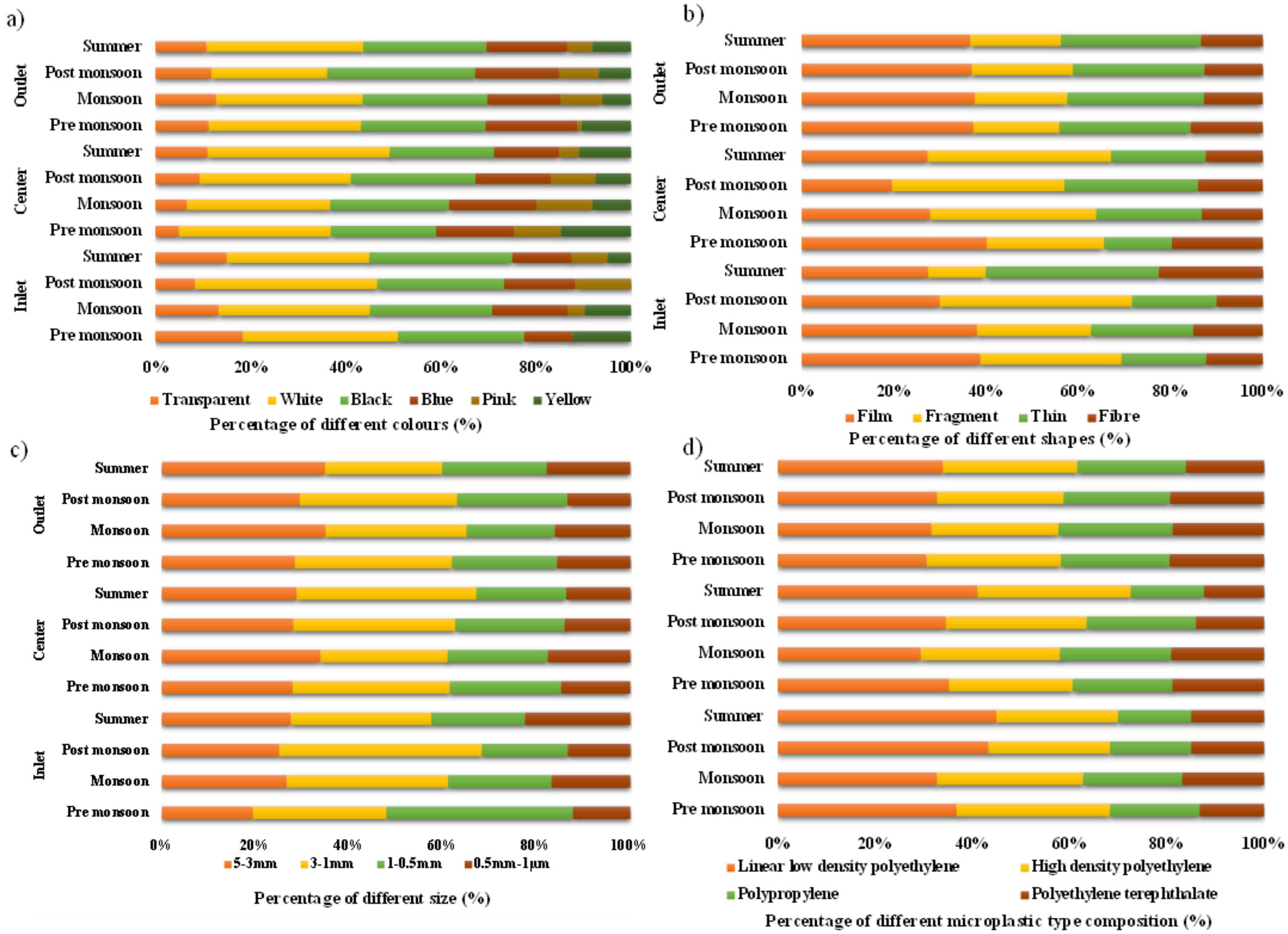

Figure 3

Microplastic size(a), shapes(b), size(c), and types(d) collected from surface water of the lake.

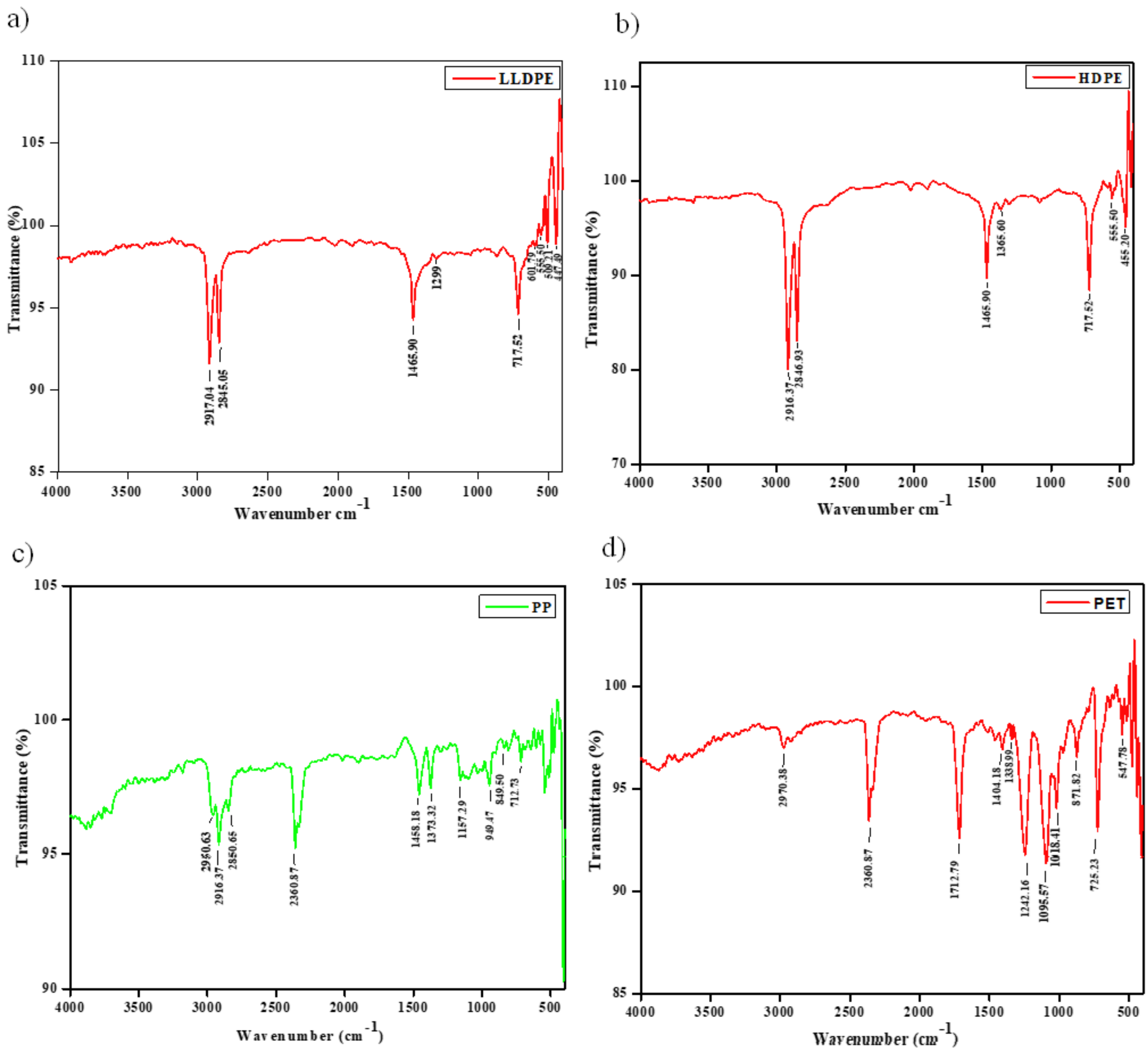

Figure 4

Representative polymer infrared spectra. (a) Linear low-density Polyethylene, (b) High density Polypethylene, (c) Polypropylene, (d) Polyethylene terephthalate.

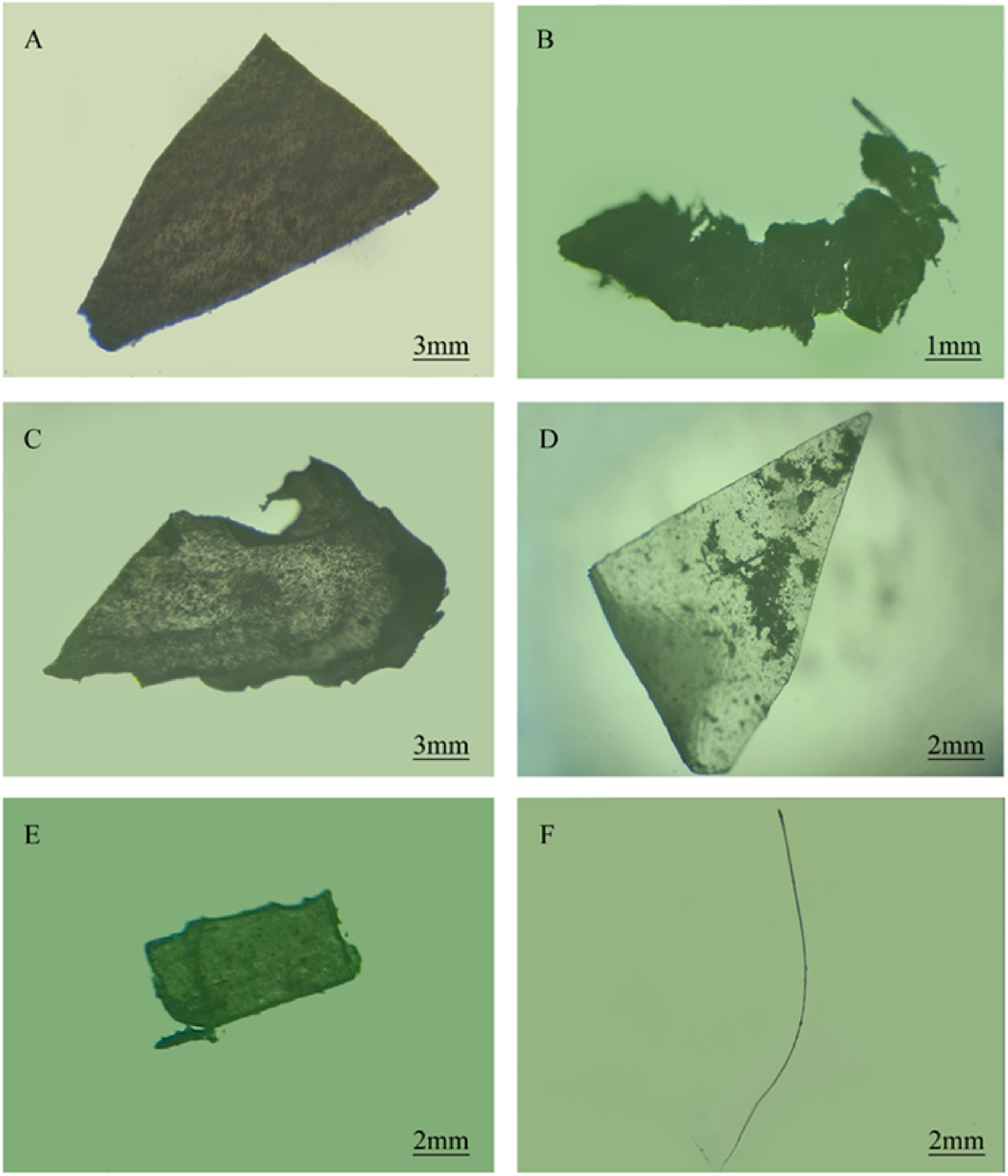

Figure 5

Different shapes of microplastics: film (A), fragment (B, C), thin (D), and fiber (E,F).

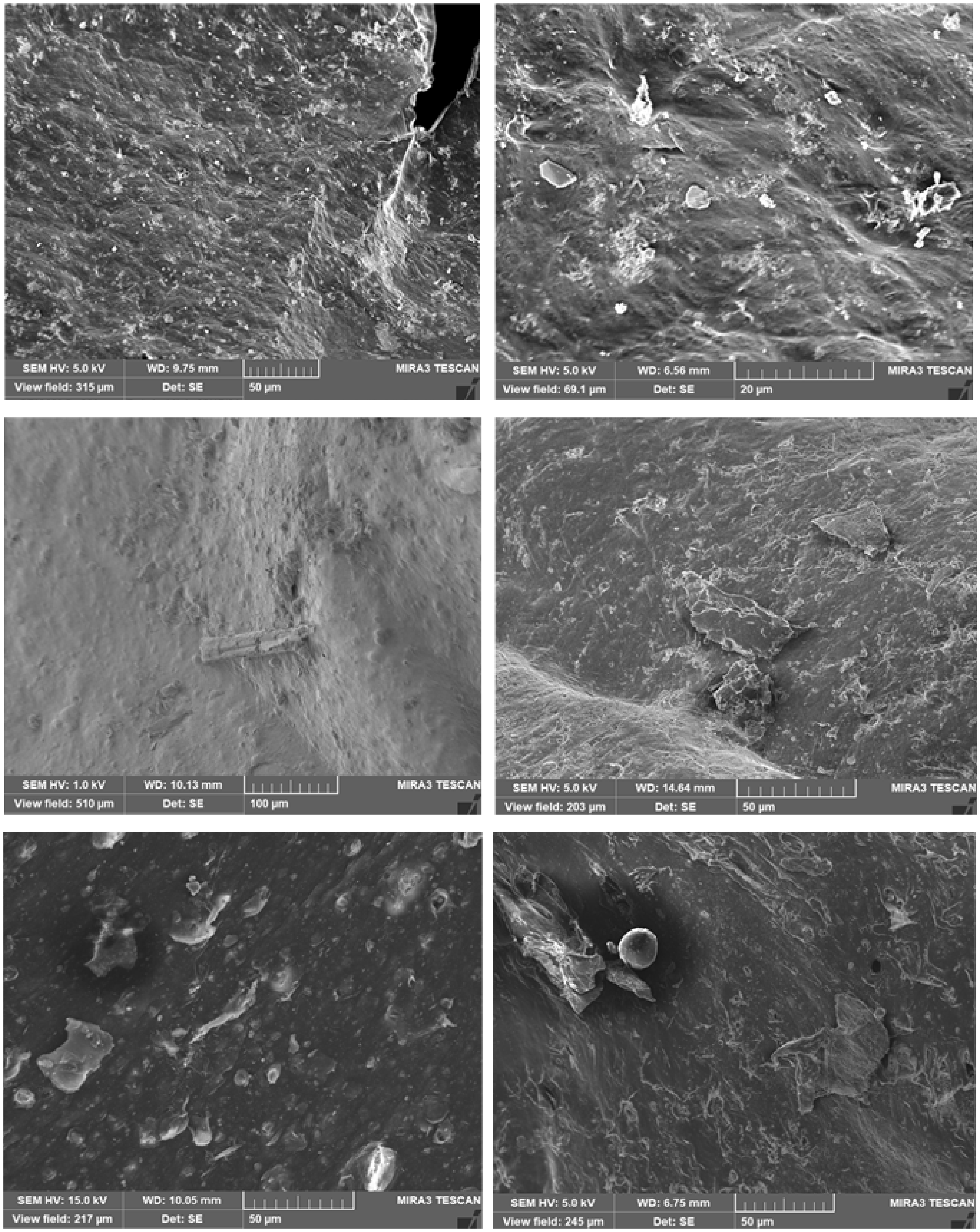

Figure 6

FESEM images of microplastic.

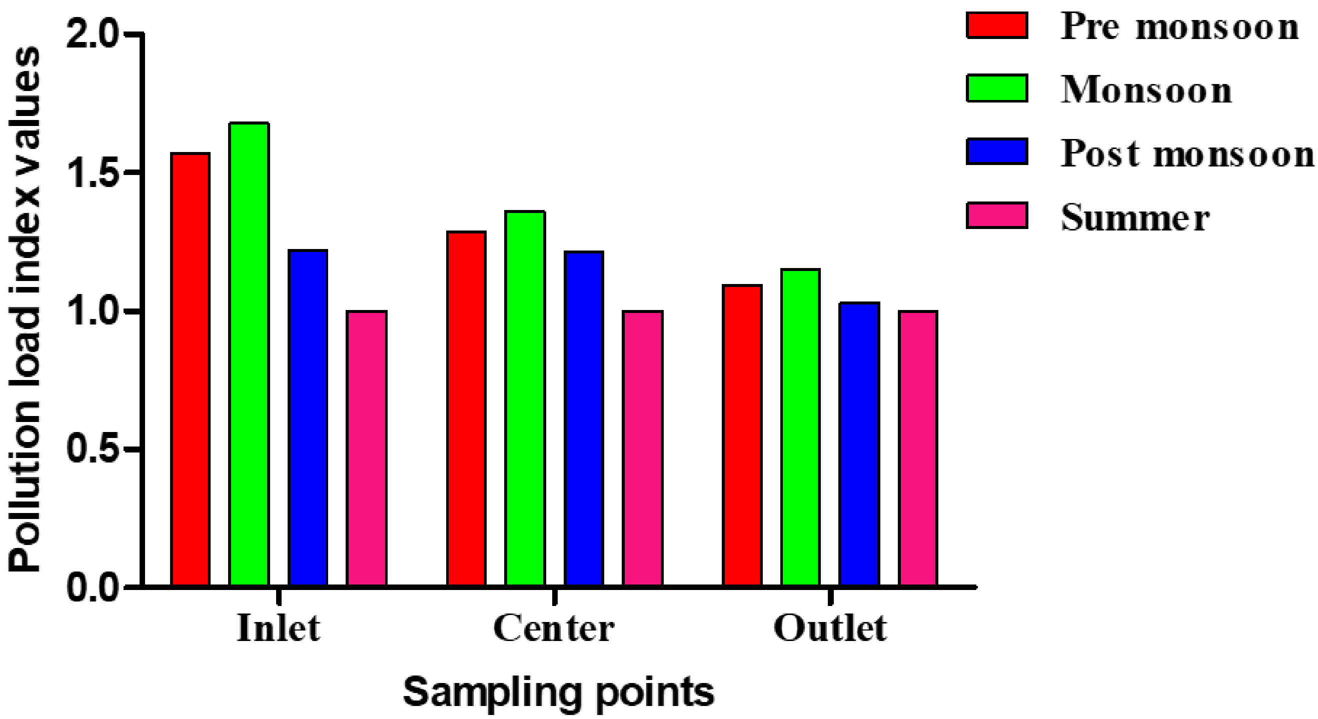

Figure 7

Pollution load index value of microplastics in surface water.