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Abundance and Distribution of Suspended Microplastics in the Surface Water of Chao Phraya River Estuary

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Abstract

This study investigated the abundance and distribution of microplastics in the surface water of Chao Phraya River Estuary and estimated the possible emission sources. Three surface water samples were collected by Manta trawl and then sample pretreatment steps were performed, and analyzed using Fourier Transformed Infrared Spectroscopy (FTIR). The results indicated the prevalence of microplastics with the mean concentration of 2.3×10^5 particles/km^2 in the Chao Phraya river estuary, representing high microplastics pollution. The collected microplastics were categorized into different size ranges, shapes, colors and chemical structures. The smallest size range (335 to 515 microns) was the most abundant size approximately 70% of total collected microplastics. The abundance of larger size ranges of MPs significantly decreased with distance far from the land but the smallest size range remained nearly the same quantity. The dominant shapes of MPs were film and fragment with white and transparent colors indicated that these were derived from the fragmentation of mismanaged plastic waste from the land as the secondary MPs. The result of this study provides the overview of microplastics pollution in the study area to the government and environmental organizations to enforce to reduce the plastics usage and to improve the solid waste management to prevent plastic debris from entering the estuary.

Keywords : microplastics; plastic-debris; Manta Net; FTIR; river transport; Chao Phraya Estuary

Introduction

Microplastics (MPs) in the water bodies are considered as anthropogenic emerging pollutant and one of the pressing issues to the global environment nowadays. MPs in the aquatic environment are reported as hazardous waste because hydrophobic toxic pollutants in the water could be adsorbed and concentrated on the MPs while they transverse through the environment. In the aquatic environment, plastics provide substratum for adsorption of various contaminants including persistent organic pollutants (POPs), metals (e.g., Cu, Pb) and pathogenic species [1]. When a small piece of plastic waste in the water bodies degrades, it could produce small sizes, varied shapes, and particular colours of MPs that could be ingested by a variety of organisms. Meanwhile, aquatic organisms at the lower level of food chain ingest MPs, these contaminants threaten to ingesting organisms and the connected food chain [2]. MPs in the estuary are described as one of the sources of plastic debris entering into the sea [3]. Most studies about MPs are in the rivers and the marine environment so the information about the estuarine environment is very limited globally.

Studies of MPs conducted in Thailand have investigated in rivers, sediments, and biota in the respective area but abundance of MPs within the estuaries are sparsely investigated [4, 5]. Furthermore, estuaries are identified as MPs hotspots because of the discharge of mismanaged plastic waste transported by the river discharge. Chao Phraya River flows through the most heavily populated regions of Thailand, as a result, large quantities of domestic and industrial wastes are discharged to the Gulf of Thailand by the river. Unfortunately, there is no extensive information on the abundance of MPs in the Chao Phraya River Estuary. Therefore, the objectives of this study are 1) to investigate the abundance, composition, and distribution of MPs in the Chao Phraya River Estuary, and 2) to characterize the chemical structure of MPs and identify the possible emission sources. Results from this study may contribute to support the current status of MPs pollution in the study area for decision makers and environmental organizations to draw public awareness of wastewater and the solid waste management system.

Methodology

Study area

Chao Phraya River is the largest river in Thailand and flows south through Bangkok and several other large cities, the drainage area is about 177,000 km^2 [6]. As a result, its basin is one of the most heavily populated regions of Thailand, where agricultural and industrial activities are developed as a consequence, large amounts of domestic and industrial wastes are carried by the river to the Gulf of Thailand. The mean river discharge is 430 m^3/s and the high flow can reach about 3,000 m^3/s during the large flood conditions. The mean depth of the estuary is very shallow with an average depth of 15 meters (minimum 8 m to maximum 24 m) [7]. The Chao Phraya River Estuary is relatively close to Bangkok Metropolis and heavily affected by a variety of anthropogenic activities along its length. The surface water samples of Chao Phraya River Estuary were collected from three stations of the study area in August, 2019 (Figure 1). The sample collection route was selected in the navigation channel to obtain the representative discharge flow of river in the estuary. The coordinates of the sampling stations and distances from the nearest land are listed in Table 1.

Table 1 GPS coordinates of sample collection stations

Sampling Station	Start Point		End Point		Distance from the nearest land (km)
	Latitude	Longitude	Latitude	Longitude	
ST1	13.51844°	100.62574°	13.50322°	100.63770°	0.6
ST2	13.50343°	100.63795°	13.48013°	100.64839°	1.7
ST3	13.47972°	100.64915°	13.45519°	100.66157°	4.0

Figure 1 Locations of sample collection stations in Chao Phraya River Estuary

Sample collection and preparation

The sample collections were conducted on the same day at high tide period to obtain the same metrological condition. Manta net with 335 microns mesh size, 30 × 15 cm rectangular metal mouth opening, and the depth from the centre of side wing to the bottom of the mouth opening is 10 cm (Hydro-Bios, Germany), was attached to the boat, "Samut Prakan 220" and trawled about 25 to 30 minutes. The distance between the boat and net was maintained about 1.4 m to reduce the disturbance of the bow wave (Figure 2). The boat speed was maintained at constant slow speed (approximately 3 knots) when sampling to avoid bouncing of the net on the wave crests. The trawl distance was recorded from the mechanical flow meter with pitch 0.3 m/rev (Hydro-Bios, Germany) installed in the lower frame of the mouth opening. The GPS positions of the start and end point of the sampling were recorded. The collected debris in the net were rinsed with the tap water (filtrated with 100 microns filter sheet) and transferred to the 1 L glass jar (Figure 3). The glass jars were kept in the cooler box and brought back to the Water Quality Engineering Lab (Mahidol University).

Figure 2 Sampling with Manta net in the study area

Sample from ST1 Sample from ST2 Sample from ST3

Figure 3 Samples collected from the study area

Large debris and aquatic organisms from the collected sample were separated and discarded by 5 mm stainless-steel sieve in the laboratory. The organic matter in the samples were digested with 30% hydrogen peroxide for 24 hours at room temperature. Density separation with 5 M NaCl solution (density 1.2 g/cm^{-3}) was performed to separate the remaining particles. The floated particles were collected and separated to four different size ranges (335 to 515 microns, 516 to 990 microns, 991 to 2100 microns and 2101 to 5000 microns) with the stainless-steel sieves. The separated particles from four size ranges were transferred to glass petri dishes and dried at 40°C in the oven and then weighted with the precision balance (5 decimal places, 0.00001 g).

Sample analysis

The collected particles were quantified and identified by the Stereomicroscope and Motic Plus3 program to classify physical features such as size, shape, and color. The particles from two large size ranges were analyzed all but for two small size ranges were picked quarter from the glass petri dish, approximate 25% by total weight to analyze. To identify the chemical composition of polymer, Fourier Transformed Infrared Spectroscopy (Thermo Fisher, USA) was used in Attenuated Total Reflectance (ATR) mode to collect the spectra of the collected MPs. FTIR was operated in the single reflection mode and analyzed 32 scans per particles to obtain the resolution of 4 cm^{-1} between the Infrared (IR) range of 600 to 4000 cm^{-1}. The collected spectrum was compared to the reference spectra of OMNIC polymer database provided by Thermo Fisher. Particles with higher than 70% similarity index were accepted as MPs and below 70% were assumed as non-plastic [8].

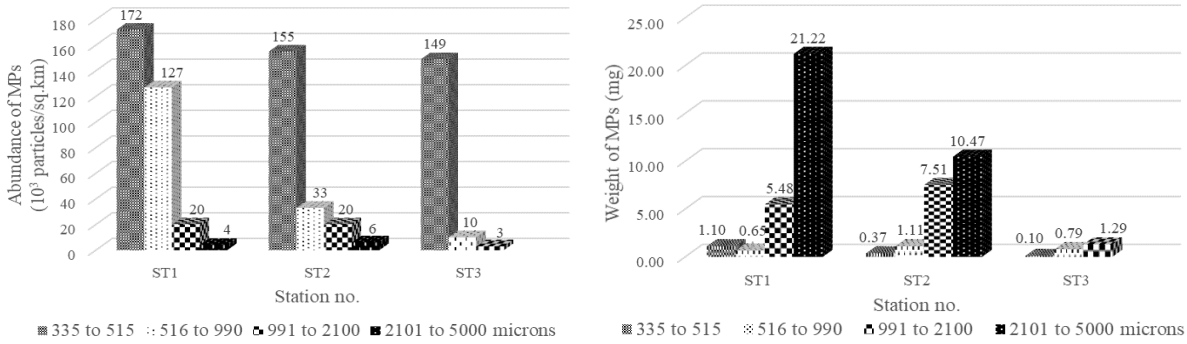
Results and Discussion

Abundance and distribution of microplastics

MPs were found in all stations of the study area with the mean concentration of 2.33×10^5 particles/km^2 (2.33 particles/m^3) which is lower than the concentration in Japan Sea (1.7×10^6 particles/km^2) but much higher than the concentration in East China Sea (0.167 ± 0.138 particles/m^3) [9, 10]. Globally accepted standard procedures are not yet set for sampling and identifying of MPs so the inconsistent methodologies are the main challenge for comparing with other findings from different regions of the globe. Moreover, there is no universal unit for presenting MPs concentration which is expressed as particles per unit area or volume of water. However, the comparison provides the qualitative information on the severe threat of MPs to the organisms in the study area. The standardization of methodology as well as harmonization of unit are required for comparing and reporting of MPs concentration globally.

All collected MPs were classified according to the size ranges, shapes and colors. MPs concentration of 3.23×10^5 particles/km^2 was observed from ST1 which located 0.6 km from the nearest land. The concentration of ST2 (1.7 km) and the last, ST3 (4.0 km), were 2.14×10^5 particles/km^2, and 1.62×10^5 particles/km^2, respectively. The results showed that the highest concentration point was the nearest to the land and the lowest one was the farthest from the land. According to the results, the abundance of MPs decreased with the distance far from the land and it indicated that collected MPs were derived from the land-based sources.

Figure 4 shows the abundance and weight of the collected MPs which were sorted into four different size ranges (335 to 515 microns, 516 to 990 microns, 991 to 2100 microns and 2101 to 5000 microns) to know more clear distribution pattern of MPs in the study area. The abundance of smallest size range MPs (335 to 515 microns) collected from ST1 was 172×10^3 particles/km^2 (1.10 mg in weight), the second smallest range was 127×10^3 particles/km^2 (0.65 mg), the third range was 20×10^3 particles/km^2 (5.48 mg), and the largest range was 4×10^3 particles/km^2 (21.22 mg), respectively. For ST2, the smallest size range was 155×10^3 particles/km^2 (0.37 mg), the second smallest range was 33×10^3 particles/km^2 (1.11 mg), the third range was 20×10^3 particles/km^2 (7.51 mg), and the largest range was 6×10^3 particles/km^2 (10.47 mg). For the last station (ST3), the smallest size range was 149×10^3 particles/km^2 (0.10 mg), the second smallest range was 10×10^3 particles/km^2 (0.79 mg), the third range was 3×10^3 particles/km^2 (1.29 mg), and the largest range was not found in that station.



(a) (b)

Figure 4 Abundance of microplastics (a); weight of microplastics (b) in each station of the study area

According to the results, the abundance of MPs in the study area was inversely proportional to its weight except second smallest size range at ST.1 that indicated large size ranges MPs (especially largest size range) with high weight could generate numerous smallest size MPs in the study area by fragmentation. Furthermore, the abundance of larger size ranges significantly decreased by the distance far from land but the smallest size range remained nearly the same quantity.

The results indicated that the average abundance size was the smallest range with 68% of the total collected MPs. The second, third and last size ranges accounted for 24%, 6%, and 1% respectively. The concentration of MPs with the smallest size range was significantly higher than the other sizes. The smallest size range of MPs are similar size with zooplankton and the high threat to the other aquatic organisms because of the high probability of mistaken ingestion as their food [11]. The result indicated that the possibility of ingestion increased to the aquatic organisms in the study area that may not only stress to their organ systems and affect to their bioavailability but also threaten to the connected food chain.

Physical identification of microplastics

The results from physical identification shown that the shapes of MPs in ST1 were 215×10^3 fragments, 53×10^3 pellets, 38×10^3 films, and 18×10^3 fibers. For ST2, the shapes were 125×10^3 fragments, 59×10^3 pellets, 31×10^3 films and no fibers were found. The shapes in the last station (ST3) were 109×10^3 fragments, 26×10^3 pellets, 14×10^3 films, and 13×10^3 fibers. The shape of MPs represents their origin (primary or secondary MPs). Fragments and films were the product of photo-chemical degradation and mechanically break down of the larger pieces of plastic waste therefore they were secondary microplastics. Pellets were likely to be considered as primary microplastics which mostly used as the industry feedstock for plastic material productions. Fibers were considered as the secondary microplastics from the wastewater of washing machine and degradation of the fishing net. According to the results, the predominant shape in the study area was the fragment with 64% of total collected MPs which follow by pellet (20%), film (12%), and fiber (4%), respectively (Figure 5). This result indicated that combination of fragment, film and fiber accounted 80% of total collected

MPs were secondary MPs derived from the fragmentation of larger plastics pieces and the rest 20% were primary plastic probably generated from the industrial sector.

Physical identification showed that the number of MPs in colors followed as a decreasing order: white > transparent > blue > red > brown > black. Among these, white and transparent were dominant colors with 84% of total collected MPs. 10% of total MPs were blue and the rest were 2% of each black, red and brown colors, respectively (Table 2). White and transparent MPs were mostly in film and fragment shape and these colors were widely used in the packaging industry that indicated such MPs were derived from the fragmentation of plastic waste from the land as the secondary MPs. White and blue were dominant in the form of fiber which could be derived from the degradation of the fishing lines and nets. Predominant of the blue color fibers in the gut of fish in Goiana Estuary, Brazil has been reported [12]. The rest colored MPs were also very harmful to the aquatic organisms for the reason that the color of MPs attracts the predators to increase misidentification as their food [13].

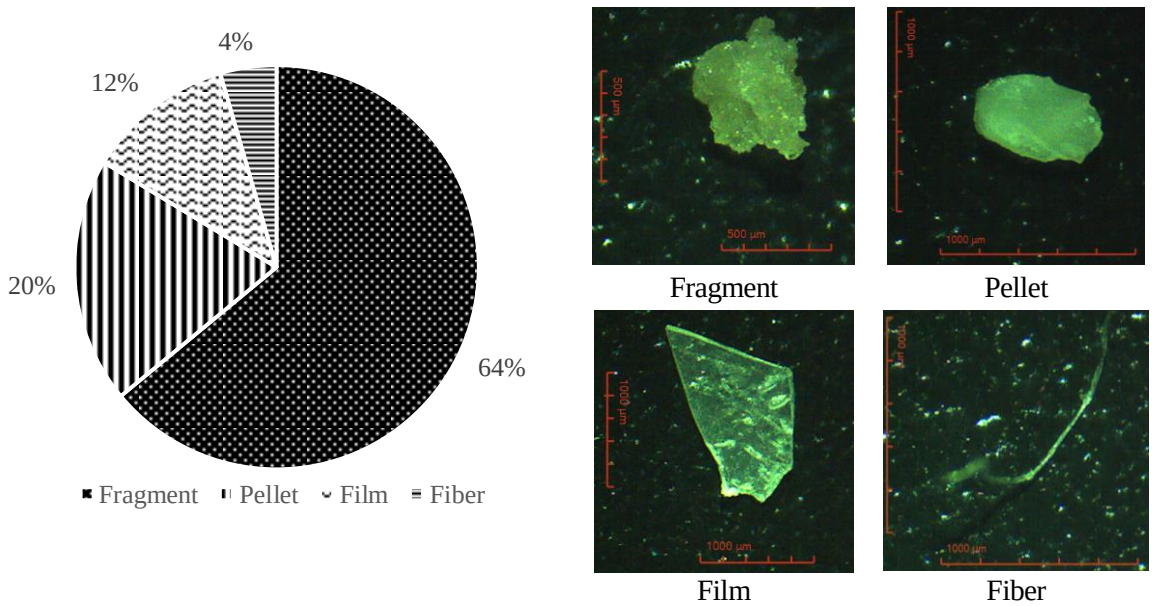


Figure 5 Shapes of microplastics found in the study area and proportions of the shapes

Table 2 Proportion of the observed colors of microplastics from the study area

Color	Total percent of each color (%)
White	56
Transparent	28
Blue	10
Red	2
Brown	2
Black	2
Total	100

Chemical identification of microplastics

The results from FTIR analysis showed that the proportions of chemical composition in ST1 were 68% of polypropylene (PP), 17% of low-density polyethylene (LDPE), and 15% of polyethylene (PE) respectively. For ST2, the proportions were 55% of PP, 15% of LDPE, 29% of PE, and 1% of polystyrene (PS) respectively. The proportions of last station (ST3) were 59% of PP, 27% of PE, 7% of PS, and 7% of nylon respectively. Among these compositions, the highest abundance of average proportion in the study area was PP with 62% of total collected MPs which follow by 22% of PE, 12% of LDPE, 2% of PS and 2% of nylon respectively (Figure 6). Polypropylene (PP) was significantly higher compared to other types in the study area as it is most widely produced plastic type in the world. Moreover, it is used in a wide variety of applications, especially in the packaging and labelling industries [14]. The high proportion of PE and LDPE was also not very surprising due to their wide application in our daily life and industrial sectors. The low specific density and high buoyant properties of PS allows to float and widespread distribution in the aquatic environment and it is widely use in the food packaging container and protective material for packaging. Nylon is commonly used in the textile and fishing net. The results indicated that MPs collected from the study area were mostly derived from the land based mismanaged plastic waste.

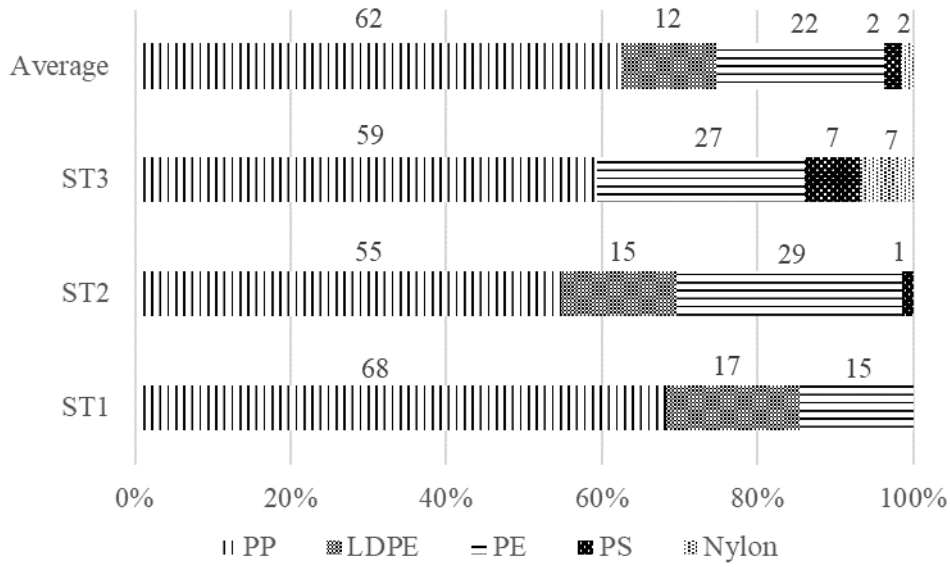


Figure 6 Proportion of chemical composition of collected microplastics from study area

Conclusions

MPs were found in all sample collection stations of the Chao Phraya River Estuary with the mean concentration of 2.3×10^5 particles/km^2. The abundance of larger size ranges of MPs significantly decreased with the distance far from land but the smallest size range remained nearly the same quantity. The dominant shapes of MPs were film and fragment with white and transparent colors indicated that these were derived from the fragmentation of mismanaged plastic waste from the land as secondary MPs. Polypropylene (PP) was the most abundance in the study area and other abundance plastics (PE, LDPE, PS, and nylon) are mostly derived from the degradation of packaging, labelling, daily use materials and industrial application as secondary MPs. Chao Phraya River is the main river system of Thailand and flows to the Gulf of Thailand therefore its estuary is a large habitat for many aquatic organisms. Therefore, the government and environmental organizations need to enforce to reduce the plastics usage and to improve the solid waste management to prevent the plastic debris from entering the estuary.

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