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Comparison of MPs Contamination between Downstream and Upstream Sites: A Case Study of Lower Chao Phraya River, Thailand

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Abstract

Microplastics (MPs) were ubiquitously found and distributed globally in the environments especially marine environment. Majority of MPs were discharged from land to the sea. However, most of the studies focused on the marine environment and few reports were studied MPs in the freshwater environment especially from Asia continent which was reported to be main contributor for MPs pollution. Thailand as one of the top countries that was estimated to produce mismanaged plastic waste to the ocean is expected to discharge MPs to the river and the sea. This study investigated MPs pollution in Chao Phraya river, major river in Thailand, by focusing on the lower Chao Phraya river at two sites: upstream at Pathum Thani province and downstream at Bangkok Metropolis to identify concentration and characteristics of MPs in surface water and evaluate impact of urbanization by comparing MPs results from two different sites. MPs were sampled on surface water by manta trawl. Results of MPs concentration were 4.0 and 22.9 MPs particles/m^3 at upstream and downstream sites, respectively. FT-IR results reveal that majority of MPs were polyethylene and polypropylene which are common materials for single use plastics. In addition, the compared results showed that the downstream site had higher MPs concentration and component types which indicate higher MPs inputs from several sources which clearly showed effects of urbanization at Bangkok. More investigation about MPs sources and seasonal variation are recommended for future study. In addition, results of MPs size distributions at both sites showed a similar trend toward smaller size and 8 percent of MPs found at the downstream site were below 335 μm which is mesh site of manta net used in this study. Thus, investigation of smaller MPs is also recommended in the future.

Keywords : Microplastics; Freshwater environment; Thailand; the Chao Phraya River

Introduction

Plastics are man-made materials that are used worldwide due to their durability and resistance. Global production and consumption of plastics has been rapidly growth since their first production in 1950. Sixty percent of all plastics production (between 1950 to 2015) or 4,900 million metric tons of plastics were estimated to be discarded and accumulated in the environments [1]. Plastics are major marine litter in seas and oceans. Therefore, plastic pollution are long-term threat and challenge to be solved worldwide. Large amount of marine plastic pollution was derived from land-based sources which were estimated to be 4.8 to 12.7 million metric tons of plastic waste discharged from land to the sea, annually [2]. Aside from marine plastics pollution, in recent years, concerns over another plastic pollution or so called "microplastics" were arose. Microplastics referred to plastics particles that smaller than 5 millimeters which are classified by their sources into primary microplastics and secondary microplastics [3]. Primary microplastics typically refers to intentionally produced microplastics such as plastics pellets used for industrial feedstocks, microplastics used as exfoliating agent in personal care and cosmetics products, and synthetic fibers that could be released from domestic washing of synthetic clothes while secondary microplastics which were dominant group found in the environment was generally referred to small pieces of plastics unintentionally degraded by weathering processes such as oxidation, photodegradation and biodegradation [3]. Microplastics are emerging pollutants that pose environmental problems to organisms especially aquatic organisms as microplastics can absorb organic contaminants, heavy metals as well as pathogens from the environments into organisms [4].

As mentioned earlier, majority of plastic waste were inputted from land-based sources to marine environment with estimation of 1.15 to 2.41 million metric tons of plastic waste that were discharged from rivers to the oceans and Asia continent were estimated to be main contributor which account for 67 percent of global estimation [5]. While Thailand, one of Southeast Asia countries, was estimated as the sixth place for countries with mismanaged plastics waste with 0.15-0.41 million metric tons of plastic waste/year that were expected to be discharged to the ocean [6]. However, microplastics data in Thailand is still insufficient and more details are needed to understand MPs pollution and use for future prevention of MPs. In this study, investigation of MPs was focused on MPs pollution at the Chao Phraya river, major river in Thailand as Chao Phraya river basin covers 30 percent of land area in country and supplies water resources for irrigation, electricity generation, industrial use, domestic water use, navigation, and river integrity in Thailand [7]. In this study, we aim to investigate the MPs concentration in Chao Phraya river and to evaluate impact of urbanization by comparing MPs data from two sampling sites: downstream site at Bangkok Metropolis and upstream site at Pathum Thani province.

Methodology

Study area

The Chao Phraya river originated in middle part of Thailand. The river length is around 365 km. Chao Phraya river flows through the heart of Bangkok Metropolis and eventually flows southward to the Gulf of Thailand. The river plays important roles for people in Bangkok as water supply, drainage, transportation, and water recreation. However, due to urbanization in Bangkok Metropolis and increase of industrial sites, water quality in the Chao Phraya river became deteriorated which greatly affects social and economic aspects for people [7]. Bangkok Metropolis is the capital city of Thailand with population over 9 million and several industries include plastic industries also included [8]. In addition, over 0.6 million plastic bags were estimated to be used daily in Bangkok in 2010 [9].

This study focuses on Chao Phraya river at two different sites. The first site was located downstream at Bangkok Metropolis (Latitude 13.671648, Longitude 100.545654) to investigate MPs concentration at the capital city with high consumption of plastics and solid waste generation which might result in large amount of microplastics discharge to the Chao Phraya river. To evaluate impact of urbanization in Bangkok. The second site was located at the upstream location of Chao Phraya river, Pathum Thani province at Samlae water supply pumping station (Latitude 14.042385, Longitude 100.554446). This pumping station locates 41 kilometers away from Bangkok and supply raw water from the Chao Phraya river for water treatment plant in Bangkok with the capacity of 3.8 million m^3/day [10]. The locations of both sites are demonstrated in Figure 1.

MPs Sampling

MPs were sampled from two sites of lower Chao Phraya river in July 2019 by using Microplastics Manta net, Hydrobios company, Germany (opening of 30 cm high x 15 cm wide with the mesh size of 335 μm). Samples from both locations were collected by trawling Manta net on the surface of the river outside of wake zone beside a research boat for 15 minutes with trawling speed between 4.9-11.9 kph depend on wave and weather condition. Furthermore, Sampling were done against direction of river flow from downstream toward upstream and MPs sampling were operated during low tide time that river water flow to the sea to avoid tidal effects and intrusion of MPs from seawater. Filter water volume were calculated from Mechanical Flow Meter Model 438 110 (Hydrobios, Germany) that was installed at mouth of the manta net. Total filter water volumes were 45 and 51 m^3 at upstream and downstream site, respectively. Filtered samples were washed from manta net bag with DI water and kept in glass bottle before transfer to laboratory for further analysis.

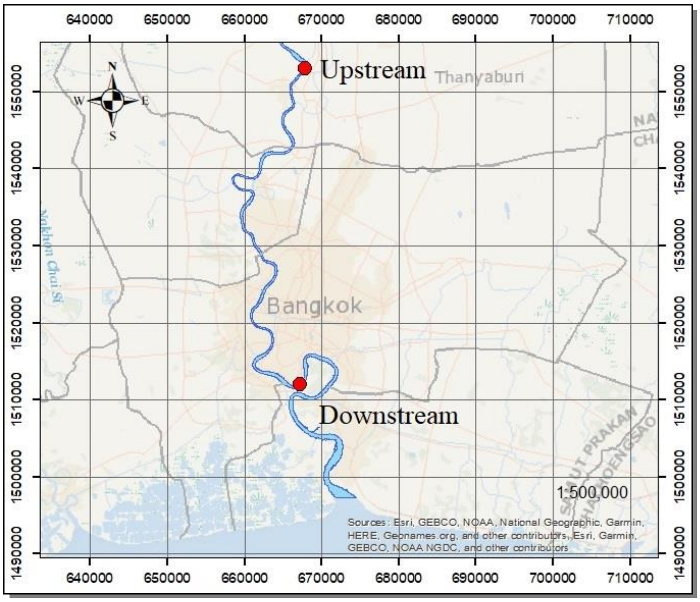

Figure 1 Sampling sites at upstream and downstream of the Chao Phraya River

MPs Purification

At the laboratory, the collected samples were washed with deionized water through stack of stainless sieves (mesh size 5 mm, 1 mm, 0.515 mm, and 0.108 mm). Particles that larger than 5 millimeters were discarded. Samples were then separated into three size ranges base on sieves' mesh sizes: 5-1mm, 1-0.515 mm, and 0.515-0.108 mm. After that, samples were purified with 200 mL 30% hydrogen peroxide and incubated at 55°C for 3 days to digest organic matter such as plankton that was also filtered and mixed with MPs samples. After that, MPs were separated from other inorganic substances by density separation method, using 5.3 M NaI (density 1.52 g/cm^3). All MPs and particles floated on the supernatant were recovered for further analysis. In addition, the MPs purification process had been tested before by using the standard Polypropylene pellets (average size = 4.3 mm) and Polyethylene pellets (average size = 440 µm) which were represented the highest and the smallest size of MPs in this study. The test results showed no physical observation and size changes after purification processes.

MPs size measurement and Identification

Total particles remained in each size ranges after purification processes were weighted and 25% by weight of each size ranges were randomly taken as representatives of sample population for visualization and identification processes. Representative particles were then observed under Trinocular Zoom Stereomicroscope (Iris, model SZM45-B8L-T, Thailand). Image of each particles was taken with Moticam 5+ camera and used for particle size measurement using image processing program: Motic Image Plus 3.0 program. After that, all particles were identified their chemical components by using Nicolet 6700 FT-IR Spectrometer, diamond ATR mode to determine MPs and identify different types of MPs components.

Results and Discussions

MPs Concentration

83.7% and 97.6% of all particles from the upstream and downstream obtained from the purification processes were confirmed to be MPs by FT-IR results. MPs concentration at downstream site was calculated to be 22.9 particles/m^3 which was almost five times higher than MPs concentration founded at the upstream site: 4.0 particles/m^3. MPs concentration found in this study were also higher than the previous study at Bangkok area reprting MPs concentration at 7 particles/m^3 [11] and in the Greater Paris and the Danube river at 0.35 particles/m^3 [12] but the similar concentration was reported at the Saigon river, Vietnam (10-223 particles/m^3) [13]. Thus, MPs concentration were most likely higher in Asia countries as expected from the estimation in [5].

Shape of MPs

Observation of MPs under stereomicroscope revealed different shapes of MPs as shown in Figure 2. MPs were catagorized based on their appearances into 5 groups; fragment, sheet or film, foam, fiber and bead or pellet which were commonly classified in MPs researches [14].

While Figure 3 shows results of MPs in different shapes at both upstream and downstream sites. More than half of results were fragment types followed by sheet or film and foam types which to be expected as majority of MPs, which were resulted from degradation of larger plastics pieces. Thus, fragment, sheet or film, and foam were likely to degrade from plastic bag, plastic packaging other plastics materials in daily use while fiber might indicate MPs from primary source: domestic washing of synthetic cloths. Bead or pellet also indicated MPs from primary sources. Although beads and pellets have been referred interchangeably but beads usually refer to MPs

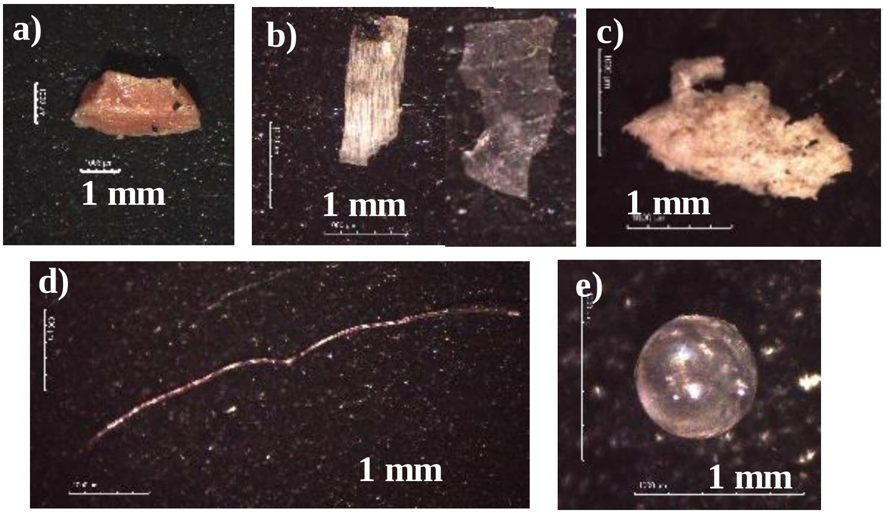

Figure 2 Examples of MPs in different shapes;
a) fragment b) sheet (left) and film (right) c) foam d) fiber and e) bead

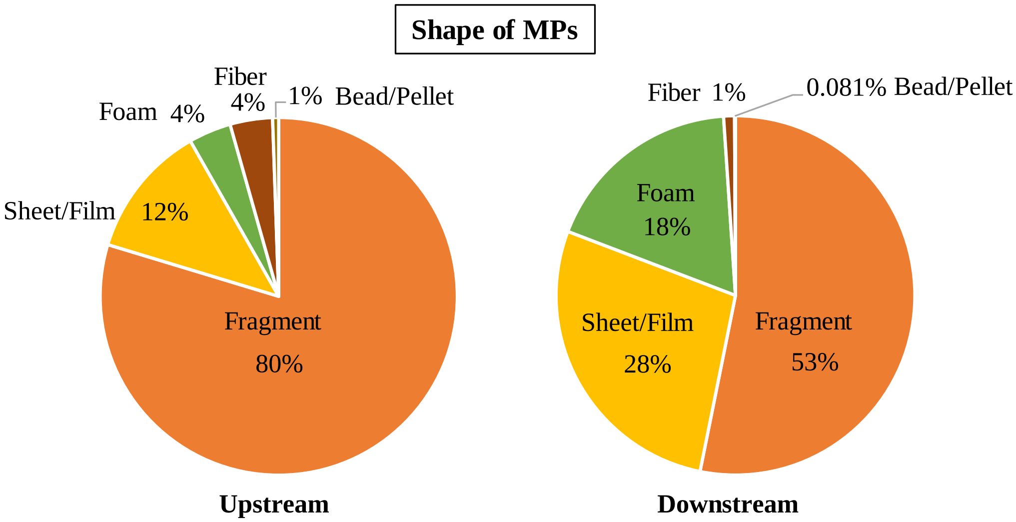

Figure 3 Distributions of shape of MPs at upstream and downstream sites

used for exfoliating purpose in personal care and cosmetics products where as pellets refer to pre-production or feed stock pellets used for manufacture of plastic products [14]. Comparison shows difference of MPs shape distribution between upstream and downstream sites. Although fragment types are dominant in both sites. Sheet/film type and foam type are significantly increase at the downstream. Sheet/film type indicates consumer uses such as plastic bags and wrappers while foam type indicates food containers and protective packaging [14]. Thus, increase in different shapes of MPs at the downstream site demonstrates more input of plastic waste from the use of several types of plastics by human activities, corresponding to high population and high consumption of plastics especially single-use plastics in Bangkok due to urbanization.

Difference in MPs composition

FT-IR results revealed chemical components of each MPs particle. Results from the upstream and downstream sites were used for calculation of MPs concentration with different polymer types in particles/10 m^3 of surface water at the upstream and downstream sites as shown in Figure 4.

Majority of composition were Polyethylene (PE) and Polypropylene (PP) follow by PP/PE blend. They are the main materials for plastic packaging and single-use plastics while Polystyrene (PS) indicated foam types MPs which are commonly used for food and protective packaging. Overall, the higher concentration of MPs were found in all polymer types at the downstream location compared to the upstream location. The results demonstrated the higher MPs pollution from different sources discharged to the Chao Phraya river at downstream location. Furthermore, Polyurethane (PU) and Paraffin wax were detected only at the downstream site. Polyurethane in the form of flexible foam, which is used as material for home furnishings indicating that MPs pollution from furniture waste discharged to the river at downstream point. It shows contamination of large or bulky solid waste to the Chao Phraya river in Bangkok. Paraffin wax, which is one of petroleum waxes, is also commonly used for coatings of several products such as food products, packaging, personal care and home care products [15]. In consequence, MPs at the downstream location not only vary widely in shapes but also in components of MPs which probably results from the higher consumption and disposal of plastics products in Bangkok.

Size distributions of MPs at upstream and downstream sites

Size distributions of MPs at both downstream and upstream sites are demonstrated in frequency percentage as shown in Figure 5. Comparing to the upstream site, MPs in downstream site were broader in their size ranges from large particles at 5,000 μm to very smaller size of 200 μm while MPs in the upstream were ranged between 4,400 to 400 μm. While gray lines show cumulative frequency of MPs size distribution, almost 50% cumulative frequency of MPs in both upstream and downstream locations were in size range below 1,200 μm which indicate high abundance of MPs toward smaller sizes. MPs that smaller than 400 μm were detected only at downstream site. Overall, size distributions of both downstream and upstream location were increased toward the smaller size range and 50% cumulative frequency of MPs in both sites were smaller than 1,200 μm. Thus, in term of quantity, majority of MPs found in the lower Chao Phraya river were ranged in mini-microplastics range (<1mm). Moreover, mesh size of manta net used for MPs survey in this study is 335 μm but eight percent of MPs resulted in smaller size than survey mesh size with minimum size of 164 μm.

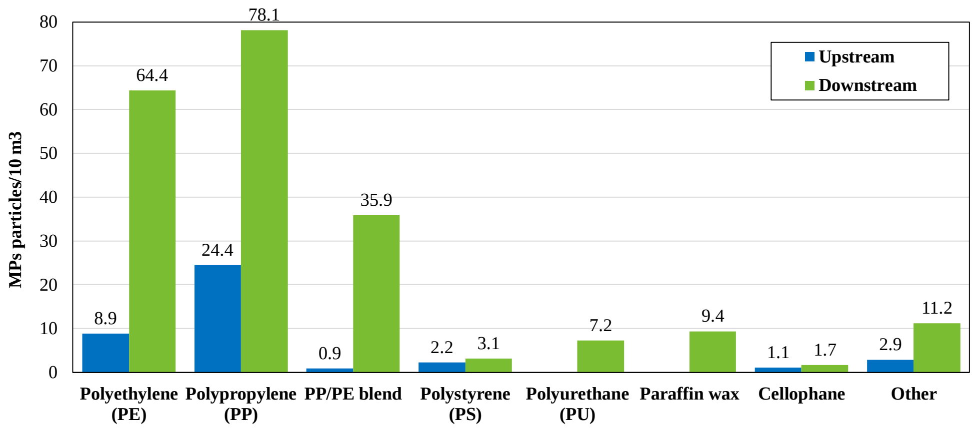

Figure 4 Concentration of MPs with different polymer types at upstream and downstream locations

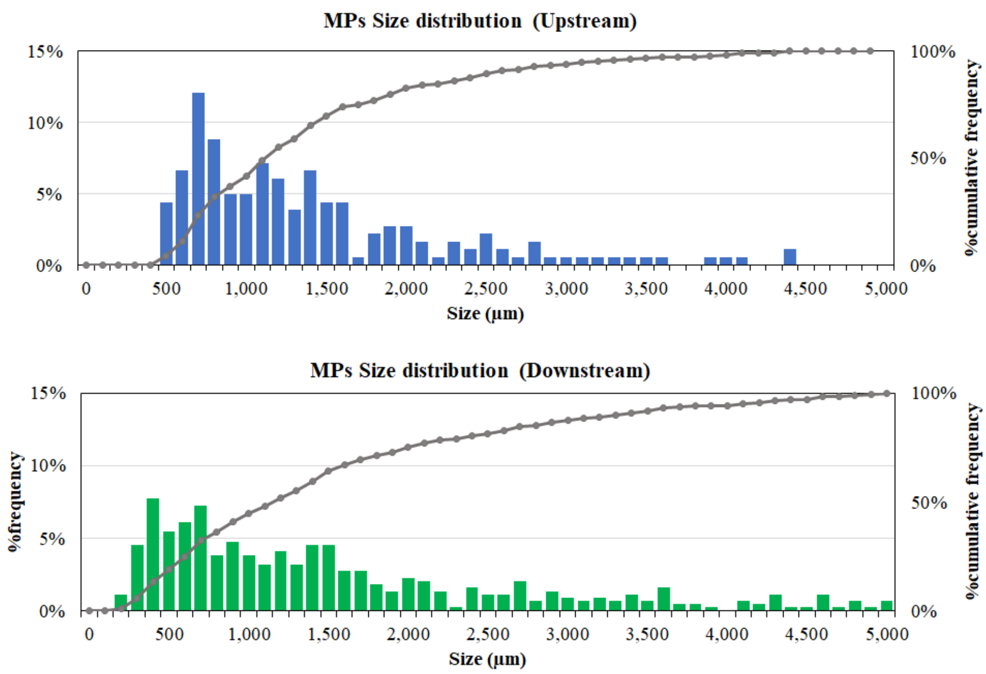

Figure 5 Size distributions of MPs at upstream and downstream locations

Corresponding to the study reported by Conkle et. al. which reported that almost 80% of current MPs survey focus for MPs with size range ≥300 µm (indicated by mesh size of manta net or plankton net used for MPs survey) and the author also surveyed MPs used for personal care and cosmetics. Results revealed almost 95% of MPs in these products were less than 300 µm [16]. Thus, depending on the focused size of sampling, current MPs studies might underestimate the signifcant amount of MPs in the environment and smaller size investigation is recommended for future survey.

Conclusion

At the downstream point of the lower Chao Phraya river, located in Bangkok city representing the urban area, the results reveal average MPs contamination at 22.9 particles/m^3 which was five times higher than concentration at the upstream point in Pathum Thani province, where the water supply pumping station is located. Comparison between downstream and upstream sites, the results showed higher polymer types of MPs at the downstream which indicated more input of plastic wastes from different sources at the downstream location. While size distributions of both sites showed similar trend of MPs increase toward smaller size range but distribution at the downstream was broader and smaller detected MPs compared to the upstream site. In conclusion, urbanization was affected the difference in MPs contamination between upstream and downstream location in several aspects; concentration, polymer types, and size distribution. Thus, we recommended future study to focus on MPs contamination data regarding location and season to provide source tracking data and seasonal variation. Moreover, investigation for the abundance of smaller size MPs in the future is also strongly recommended.

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