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Abundance and Distribution of Microplastics in Mixed Land Use: A Case Study of Bangpakong River Basin, Thailand

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Abstract

Microplastics (MPs) are an ongoing environmental issue caused by the rapid growth in plastic consumption and a lack of proper management. This study aimed to determine the abundance and distribution of MPs and to assess the health risk level of MPs in the Bang Pakong River Basin (BRB), the main river in the eastern part of Thailand. It was found that the abundance of microplastics in the BRB was 0.194 particles/m^3 (0.000194 particles/L) with an average size of 273.88 ± 140.04 μm. The most common particle type was secondary microplastics at 88%, and the most frequently found form was fragment at about 46%. The dominant color of these MPs was white, accounting for 16% of the total MPs. Polypropylene and polyethylene were the main polymers found, which together accounted for approximately 85%. Most of the MPs were discovered at the Wat Sothonwararam Worawihan station, where 78 MPs were discovered. The risk levels of MPs found at every sampling station were high; however, the pollution load index of MPs was low.

Keywords: Bang Pakong River Basin, Freshwater debris, Microplastics, μ-FTIR, Risk assessment

1. Introduction

Microplastic pollution is the most urgent global environmental problem due to the rapid growth of plastic consumption, from two million tonnes in 1950 to 348 million tonnes in 2018 (Plastic Europe, 2018). Approximately 79% of the plastic waste was not properly managed (UNEP, 2018). Large pieces of plastic waste were broken into small pieces by sunlight, microorganisms, water waves, and water turbulence (Cole *et al.,* 2011). Plastics with a diameter of less than 500μm are called microplastics (MPs) (Thompson *et al.,* 2004; Arthur *et al.,* 2009). The effects of microplastics on human health are less evident (Wu *et al.,* 2022). Nevertheless, microplastic pollution is still a concern regarding its adverse risks to human health.

Surface water is the reservoir of microplastic waste, especially in the ocean. Freshwater is a significant pathway of MPs for its connection to the sources of plastic or MPs on land and sea. Therefore, several studies have reported the contaminations of MPs in surface water around the world, including North America (Ericksen *et al.,* 2013; Shruti *et al.,* 2019), Europe (Faure *et al.,* 2012; Imhof *et al.,* 2013; Lechner *et al.,* 2014; Sadri and Thompson, 2014), Africa (Dahms *et al.,* 2020), and Asia (Free *et al.,* 2014; Kataoka *et al.,* 2019; Wong *et al.,* 2020; Zhang *et al.,* 2017). The results from these studies indicated that the abundance of MPs varied in each section of the river. Yuan *et al.,* (2022) found that the highest abundance of MPs was in downstream and community areas. Additionally, the municipal wastewater treatment plant and industry are significant sources of MPs (Ericksen *et al.,* 2013). Concerning environmental contamination, MPs can enter the food web through aquatic animals' ingestion, for example, shellfish (Feng *et al.,* 2018) and fish (McNeish *et al.,* 2018; Zhang *et al.,* 2017). MPs with a size of 1 - 2.79 mm can be mistaken for plankton

(Boerger *et al.* 2010), and white MPs are also consumed by fish due to being the same color as their favorite food. (de Sá *et al.,* 2018). Eventually, those MPs can pass into the human body via seafood consumption and cause human health risks from toxins in MPs, such as persistent organic pollutants (POPs) and polycyclic aromatic hydrocarbons (PAHs) (Rochman *et al.,* 2013). In addition, the MPs between 0.5 and 5µm cause metabolic disorders in children (Bhuyan, 2022). The cadmium pigment in MPs can also release Cd^{2+} into the river, especially for particles smaller than 0.85 mm (Liu *et al.,* 2020), which can harm human health.

As previously stated, MPs are classified as a nonpoint source because they are transported from land to river terrestrials before ending up in the sea (Cole *et al.,* 2011). Therefore, the MPs found at each freshwater sampling station led to contrasting conclusions in terms of numbers, shapes, and polymer types (Tibbetts *et al.,* 2018). In Thailand, several studies attempted to determine the abundance of MPs in biota, sediments, rivers, and estuaries (Thushari *et al.,* 2017; Boontanon *et al.,* 2020; Wang *et al.,* 2020). However, river examination remains inadequate since MPs can be in tributaries, which have numerous branches running through lands with specific uses before being transported from isolated lands to estuaries. Furthermore, most of the previous data on MPs was reported in surveillance terms, with only a few reports focusing on the public health approach. The Bang Pakong River Basin (BRB) is the most crucial watershed in the eastern region of Thailand and an extensive water supply source for heavy and light industries, agriculture, animal cultivation, municipal water supply, and wastewater dilution (Department of Water Resources, 2016). A study of MPs in the river basin using the public health approach will not only shed more light on the abundance and distribution of microplastic waste from mixed land use but also help evaluate the health risk level of the MPs.

The objectives of this study were 1) to determine the abundance and distribution of MPs in the Bang Pakong River Basin (BRB) 2) to examine the chemical structures of MPs, and 3) to assess the public health risk level of MPs. The results from this study can support the current situation of microplastic pollution in the study area for environmental organizations or policymakers to increase community awareness of plastic use and waste management.

2. Materials and methods

2.1 Study area

The BRB, Thailand's most important watershed in the eastern region, flows south to the Gulf of Thailand through the provinces of Nakhonnayok, Chachoengsao, and Chonburi. It consists of three significant sub-basins: the Nakhonnayok River, the Klong Thalad branch, and the Klong Luang branch. The BRB has a drainage area of approximately 10,707 km^2. The sampling sites were determined according to the land use types, including industrial parks, municipalities, forests, and agriculture. The water samples were collected from the catchment areas where the river and its tributaries assembled between August and October 2020 (wet period) because the highest MPs concentration presented during wet season (Zhao *et al.,* 2020). There were six sampling stations around the BRB. The estuary station (ST1) was for the MPs released from the Bang Pakong River to the ocean. The downstream station (ST2) represented the urban area. Another three sampling stations were at the tributaries of the BRB (ST3, ST4, ST5), whereas the upstream station (ST6) was a forested area with almost no human footprint (Figure 1). The distances from these stations (ST2, ST3, ST4, ST5, and ST6) to the estuary (ST1) were around 16.24, 51.92, 97.79, 49.04, and 185.31 km, respectively.

2.2 Sample collection and preparation

The Neuston net, with 333 microns of mesh, a 75 x 75 cm rectangular opening mouth, and a depth of 37.5 cm from the center of the side frame to the bottom of the net mouth, was used for microplastic sampling. The net was attached to the boat (Figures 2a and 2b) and trawled for 15 minutes during sample collection. To steer clear of water turbulence, approximately one meter of space was added

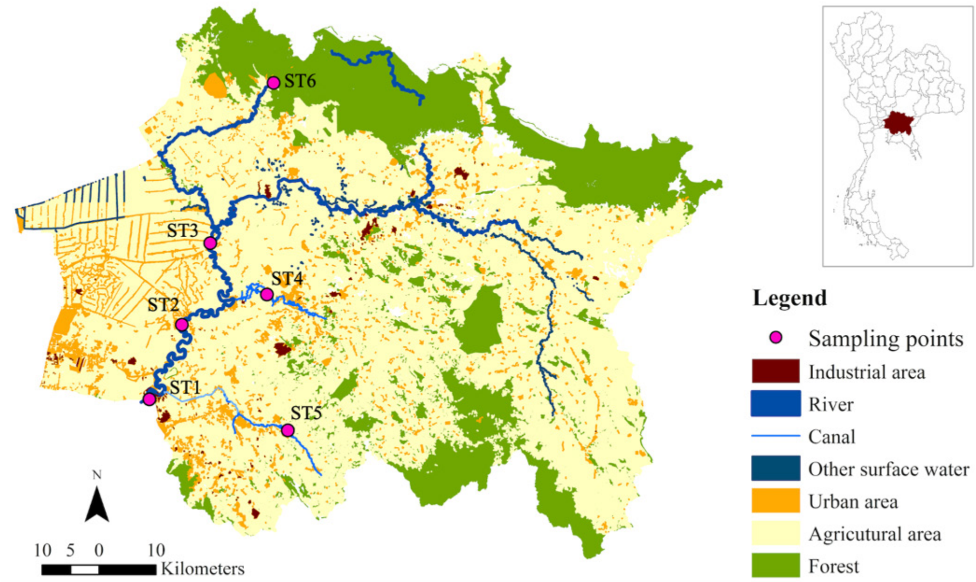

Figure 1. Locations and coordinates of sampling stations in the Bang Pakong River Basin

between the vessel and the net. The boat speed was kept constant at a relatively slow (1.6 knots) rate during sampling to avoid the net bouncing on ridge waves. A flow meter with a pitch of 0.16 m/rev was installed at the lower frame of the net mouth. The revolutions of flow rate were recorded, and the water volumes were calculated as shown in equation (1). GPS coordinates were recorded from the beginning to the end of the sampling. Each piece of garbage collected in the net was rinsed with reverse osmosis (RO) water and transferred to a one-liter glass. The glass bottles were then placed in a cooler box and transported back to the chemistry laboratory of the Faculty of Public Health at Thammasat University.

$$\text{Volume } (m^3) = A * L * F \qquad (1)$$

Where A is the area of Neuston net opening (m^2), L represents the revolutions of flow meter (rev), and F denotes the calibration of flow meter (0.16 m/rev).

The laboratory methods for MP analysis by Matura *et al.* (2015) were adopted in this study. The large liters and aquatic organisms from the collected samples were separated and discarded with a five-mm stainless-steel sieve. The organic matters in the collected samples were then digested with 50 ml of 30% H_2O_2 at 75 °C for four hours, or until completely digested. The remaining particles were then divided using 5M NaCl solution (Figure 2c). After that, the floating particles were collected and separated with a 300-nm stainless-steel sieve. Finally, all particles were transferred to the filter paper in petri dishes and sealed with parafilm.

2.3 Sample analysis

The collected particles were quantified and identified with the Stereo Zoom Microscope (OM-02) and OPTIKA Vision Pro PLUS software to assign physical characteristics such as size, shape, and color. After that, the Fourier transform infrared microscope (FTIR) (Thermo Scientific, USA) was used to identify the types of MP polymers based on their chemical composition with an Attenuated Total Reflectance (ATR) mode that gathered the spectra of the collected MPs. FTIR was operated in the single reflection mode and analyzed 64 scans per particle to obtain a resolution of 4 cm^{-1} within the infrared (IR) range of 600 to 4000 cm^{-1}. The collected spectra were matched with the reference spectra in the OMNIC polymer database provided by Thermo Fisher. Particles with a similarity index of more than 70% were accepted as MPs, and those below 70% were suspected as non-plastic (Frias *et al.,* 2016).

a) b) c) d)

Figure 2. Neuston net attached to a) small boat b) big boat, c) organic matter digestion process, and d) MPs separation process

2.4 Microplastic risk assessment

The risk assessment of MPs was evaluated by their two attributes, polymer type and quantity. MPs are considered ecologically harmful because of the toxins related to their chemical composition. As shown in Table 1, the polymers were categorized and given hazard scores by Lithner *et al.* (2011). According to Xu *et al.* (2018), the risk index of polymers was calculated based on the monomers of MPs as follows:

$$H = \sum P_n \, x \, S_n \tag{2}$$

Where H is the calculated polymer risk index, P_n denotes the percent of polymer type in MPs collected at a sampling station, and S_n represents the score of the polymer compounds that compose the particle of MPs.

The pollution load index (PLI) was applied to assess the pollution level in a sampling station since this method is regarded as a standardized procedure for monitoring degrees of pollution in diverse areas. According to Tomlinson *et al.* (1980) and Xu *et al.* (2018), the PLI was calculated as follows:

$$CF_i = C_i / C_{oi} \tag{3}$$

$$PLI = \sqrt{C}F_i \tag{4}$$

Where PLI is the pollution load index of MPs in a sampling station, CF_i denotes the quotient from the MPs abundance at a station (C_i) and the observed lowest abundance of MPs (C_{oi}).

In Table 2, Xu *et al.* (2018) divided the risk levels of MP pollution into four groups.

3. Results and discussion

3.1 Abundance and distribution of microplastics

The discovered MPs from all stations had an average abundance of 1.94×10^{-4} particles/L (0.000194 particles/L or 0.194 particles/m^3), which was significantly lower than the abundance in the Chaophraya river estuary (2,330 particles/L), but higher than the abundance in Taihu lake (0.0034 - 0.0258 particles/m^3) (Boontanon *et al.,* 2020; Hamid *et al.,* 2018). However, the previous studies of MPs did not show the standards of sample collection, organic matter digestion, separation process, and international units for the reported values; therefore, it was impossible to compare more aspects of MPs from those studies. When focusing only on the abundance of MPs from the sampling stations (Figure 3a and 3b), ST2 had the highest abundance with 0.307 particles/m^3, while ST6 had the lowest abundance with 0.004 particles/m^3.

Table 1. The hazard scores of MPs found in Bang Pakong River Basin

Polymer	Abbreviation	Monomer	Hazard score[a]
Polypropylene	PP	Propylene	1
Polyethylene	PE	Ethylene	11
Polystyrene	PS	Styrene	30
Polyvinylchloride	PVC	Vinyl chloride	10,551
Polyamide	PA	Adipic acid	10
Polyurethane	PU	Propylene oxide	7384
Polyethylene terephthalate	PET	Ethylene glycol	4
Polyester		Terephthalic acid	4

[a] The hazard scores were taken from Lithner *et al*. (2011)

Table 2. Risk level criteria for microplastics pollution

Value of the polymer index	< 10	10 - 100	100 - 1000	> 1000
Value of the pollution load index	< 10	10 - 20	20 - 30	> 30
Risk category	I	II	III	IV

The results also showed that ST2 and ST5 had a greater abundance of MPs than ST1. It could indicate that the drainage from community wastewater and treated water from the wastewater treatment plant (ST2), as well as the reservoir for agriculture and fishery (ST5), released more MPs than the area with fisheries and industrial transportation ports. The results were consistent with the study of MPs in the Pearl River by Yan *et al.* (2019), which concluded that the abundance of MPs in urban rivers was three times greater than in estuaries. The station with the lowest abundance of MPs was ST6 because the area is a national park with little human activity. This study supported the River Tame survey of Tibbetts *et al.* (2018), which reported that the abundance of MPs was low in the upstream area and would increase as the river flowed downstream through urban areas.

This study investigated the MPs with diameters of 20 – 500 µm. Referring to the definition by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) and the National Oceanic and Atmospheric Administration (NOAA), the MPs found were divided into two categories: small MPs with a diameter of 20 - 100 µm, and large MPs with a diameter of 101 – 500 µm. The MPs had an average length of 273.88 ± 140.04 µm, with 36.94% being small MPs and 63.06% being large MPs. The proportion of large MPs was higher than that of small MPs, which contradicted previous studies by Tibbetts *et al.* (2018) and Yan *et al.* (2019). The large MPs were primarily involved in accidental ingestion of plastic by aquatic creatures (Boerger *et al.,* 2010), while small MPs simply released some additive chemicals such as Cd^{2+} into the aqueous phase (Liu *et al.,* 2020). The different methods of organic matter digestion may influence the differences in results. In this study, organic matters were digested using 30% H_2O_2 at 75 °C for four hours. However, the most effective digestion was achieved by oxidation with 15% H_2O_2 at 15 °C for at least eight hours (Avio *et al.,* 2015). As a result, the small MPs may have aggregated with organic matters and been lost during the separation process.

3.2 Physical identification of microplastics

The results of the physical identification revealed the five MP forms, including fragment, fiber, pellet, film, and foam, with fragment being the most found form. Foam and pellets were identified as primary MPs because they were used as raw materials in the plastic industry. Fragments, films, and fibers, on the other hand, were identified as secondary MPs since they were tiny pieces broken down from the larger ones. From most to least, the numbers of MP particles found in each form were as follows: fragments (128), fibers (78), pellets (32), films (28), and foams (7). The total number of primary MPs was 39 (14.55%), while the total number of secondary MPs was 234 (85.45%).

The MP forms discovered in this study were consistent with the survey of the River Tame by Tibbetts *et al.* (2018), which found fragments more frequently than fibers. It is worth nothing that the contamination of MP fragments plays a key role in microbial transportation and cultivation that can cause infections in humans and animals (Deocaris *et al.,* 2019). Besides, fibers accounted for approximately 41.03% of the total MPs found in ST3. Given that the ST3 area has been popular for freshwater aquaculture such as river prawns, freshwater fish, and artisanal fisheries (Department of Water Resources, 2016), most of the fibers were likely to have come from broken fishing nets.

The color identification showed that the colors of MPs found in the BRB consisted of white, transparent, blue, black, green, red, brown, and gray, with the numbers of particles being 72, 66, 63, 24, 19, 11, 11, and 2, respectively. The results correlated with the study of MPs in the Chao Phraya River estuary, which reported that most MPs discovered in that area were white and transparent, accounting for 84% of the total MPs. The color identification of MPs and polymer types can determine the source of waste. Plastic packaging, responsible for 36% of plastic consumption in Thailand, was mostly in white and transparent (Khanunthong, 2021). Therefore, the white, transparent, and blue MPs that were mostly found in this study could have been packaging such as plastic bags and food containers. In addition, the color of MPs also influenced food selection in aquatic animals; for example, *Pomatoschistus microps* prefer to ingest white MPs over black and red ones (de Sá *et al.,* 2018). Furthermore, toxins in the ingredients used to create colors in MPs could be released into the environment, such as Cd^{2+} from red, orange and yellow MPs (Liu *et al.,* 2020).

3.3 Microplastic chemical composition identification

The chemical composition was examined using μ-FTIR. The polymer types identified were displayed in the chromatogram (Figure 5). The μ-FTIR analysis showed that the balance of non-plastic particles in this study was about 9.78%. The chemical identification, excluding non-plastic particles, found that

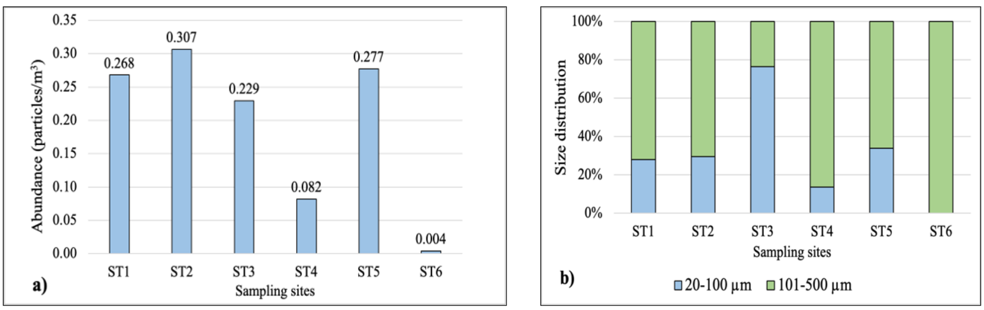

Figure 3. a) The average abundance of MPs per m³ in six sampling stations, b) The size distribution percentage of MPs in six sampling stations

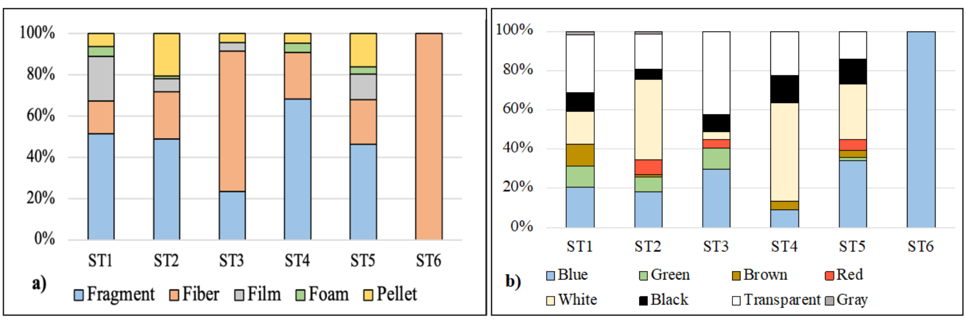

Figure 4. a) The percentage of MP form distribution in six sampling stations, b) The percentage of MP color distribution in six sampling stations

polypropylene (PP) covered 47.56% of the proportion, followed by polyethylene (PE) at 37.80%, polystyrene (PS) and polyurethane (PU) at 3.66%, polyvinyl chloride (PVC) and polyester at 2.44%, and polyamide (PA) and polyethylene terephthalates (PET) at around 1.22%. The distribution of chemical composition at each sampling station is shown in Figure 6.

The main types of polymers in BRB were PE and PP, taking up 85.36% of all polymers. The reason was that most of the plastic used in Thailand included single-use plastic bags and food containers made from PE and PP (Sedtha, 2023). The result of this study supported other studies in Asia, Europe, and Africa, which reported that the most found polymers in MPs were PE and PP, but contrasted with the investigation in America, where the majority was PET, and in Australia, where a large number of PS and cellophane were found (Shahul *et al.,* 2018).

Moreover, several types of polymers were found in ST1 because it is an estuary where water from various areas terminates before flowing to the sea. Several types of MPs were also identified in ST4 and ST5 because ST4 was located near the community market while ST5 was an agricultural, fishery, and community area. Contrarily, in ST6, only PVC was found due to the presence of a dam in the area and absence of community activities that contribute to MP pollution. However, artisanal fishing was permitted, hence, the PVC found in this area came primarily from fishing nets.

3.4 Microplastic risk assessment

As shown in Table 3, based on abundance of MPs and polymers, every sampling station was classified as high risk for human health (levels III and IV) and low risk for ecological harm (level I), meaning that the discovered MPs could negatively affect human health. The results were similar to the risk assessment of MPs in the Changjiang estuary, where most of the sampling stations were at high-risk levels (Xu *et al.,* 2018). Table 3 showed that the polymer index in ST6 was higher than in other sampling stations by about 7 – 2,200 times despite only polyvinyl chloride polymer being found. However, the PLI in ST6 was only 0.02, lower than other stations by about 23 – 79 times. The inconsistency between the numbers of polymer index and PLI, as seen in Table 3, was the obstacle to evaluating the ecological and public health risk. Nevertheless, the fact that the discovered MPs were at high-risk levels is enough to raise environmental and social concerns about the MPs hazard.

The Bangpakong River, the main river in the eastern region of Thailand, has been used for several objectives such as aquaculture, agriculture, and water supply for the community and industry. Since the discovered MPs indicated a high health risk, surveillance of MPs in the water should be implemented. For example, the area between ST2 and ST3 is the raw water intake station for water supply; therefore, the contamination of MPs should be monitored during the hydrological events, particularly in the rainy season, when rain may transfer MPs from land to water.

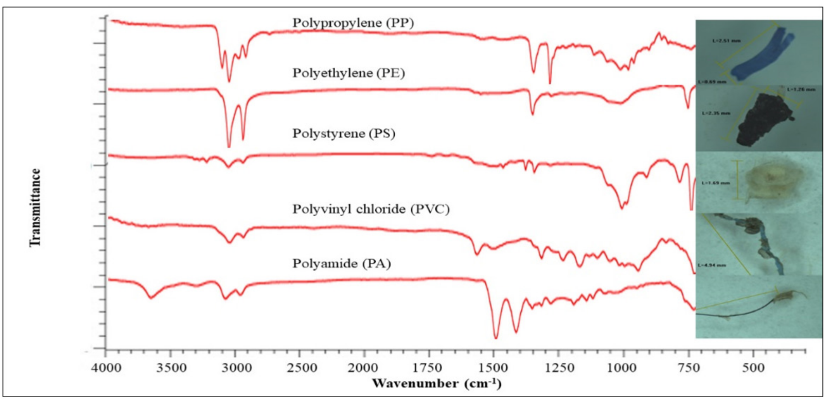

Figure 5. The polymer types found in the MPs in waveforms with their corresponding microscope images

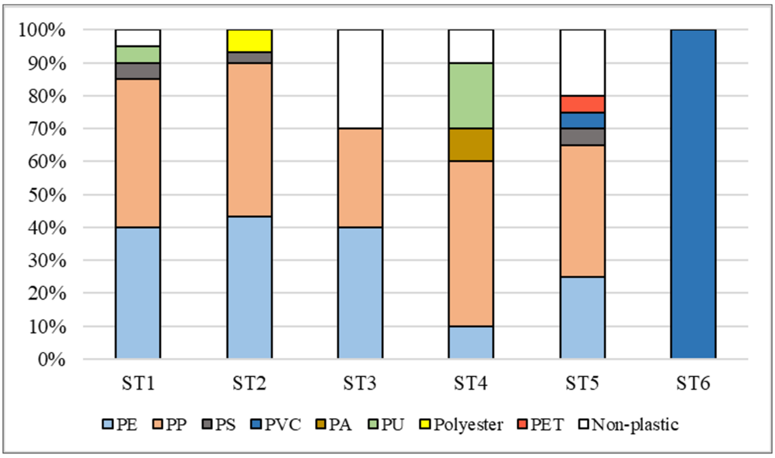

Figure 6. Proportions of polymer types in the six sampling stations

Table 3. The risk level assessment of the MPs from each station based on the abundance and polymers

Station	Human health risk		Ecological risk	
	Polymer index	Risk level	PLI	Risk level
ST1	37,555	IV	8.22	I
ST2	649.88	III	8.80	I
ST3	470	III	7.61	I
ST4	147,940	IV	4.54	I
ST5	53,240	IV	8.37	I
ST6	1,055,100	IV	1	I

4. Conclusion

The abundance of MPs from all the sampling stations in the BRB was 0.000194 particles/L (0.194 particles/m^3). Lower in the upstream areas, the abundance of MPs increased toward the downstream areas. The urban area had the highest number of MPs, while the forest zone had the lowest. Since the most abundant MPs were fragments, the secondary MPs were considered extensive contaminants in the BRB. The colors of the discovered MPs were mainly white and transparent, which are the usual colors of single-use plastic bags and food containers in Thailand. The polymer analysis also showed that PP and PE, known for being packaging materials, were the dominant plastics in the study area. According to the polymer index, the health risk levels of the MPs in every station were high, similar to the previous studies in Asia, Europe, and Africa. The results of this study highlight concerns about the risks and management of MP waste, particularly the use of single-use plastic bags and containers.

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