TYPE AND DISTRIBUTION OF MICROPLASTIC CONTAMINATION IN BEACH SEDIMENT ALONG THE COAST OF THE LOWER GULF OF THAILAND

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Abstract. The investigation of microplastic occurrence in 5 beaches along the lower Gulf Coast of Thailand including 1) Ban Bang Dee (BD), 2) Laem Son On (SO), 3) Laem Samila (SM), 4) Talo Kapo (TK) and 5) Thaksin Ratchaniwet Palace (TS) was conducted. The results showed TK with the most microplastics found at 1144 ± 346 pcs/m² followed by SO = 650 ± 500 pcs/m², SM = 484 ± 304 pcs/m², TS = 482 ± 509 pcs/m² and BD = 404 ± 88 pcs/m² which can be related to the different intensity levels of nearby human activities. In the rainy season, microplastics contamination was the most at TS = 974 ± 14.85 pcs/m² followed by TK = 377 ± 167 pcs/m², SO = 263 ± 18 pcs/m², BD =148 ± 209 pcs/m² and SM = 62 ± 79 pcs/m². The higher microplastic amount was observed in the dry season than that in the rainy season since there was not enough rainfall to dilute microplastic abundance. Surprisingly TS located near boundary line has no human activity but the highest amount of microplastic was found here during the rainy season. This is probably caused by counter-clockwise current in the Lower Gulf and the first evidence indicating the existence of transboundary contamination.
Keywords: *marine debris, polymer, shoreline, season, anthropogenic*

Introduction

At present, marine debris is a major pollution problem around the world. The data from the Department of Marine and Coastal Resources, Thailand (DMCR, 2017) showed that the sources of marine debris came mostly from human activities including fishing and tourism, etc. The marine waste from land-based sources made up 80 percent of the marine pollution of the world and most of which were plastic waste. They will be able to float on the sea surface since the densities of most plastic polymers synthesized and used in human activities are less than that of seawater. Plastic waste is a problem in Thailand, Asean and many countries in the world. Furthermore, Thailand is presently ranked as the sixth worst producer of marine fragments in the world and number four in Asean (Pradit et al., 2020a; Sornplang et al., 2021). The floating plastic garbage island has not been biodegradable in the short term as new plastic waste is continuously being added to the ocean and it breaks down and disintegrates into smaller sizes, known as microplastics. They are plastic waste smaller than 5 millimeters in length, caused by breakage and degradation of large plastic waste or generated by plastic that has been originally created to be small to suit the purpose of use such as small plastic beads in cosmetic products. They currently cause

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marine environmental problems such as fishery, coastal docks, coastal and maritime tourism activities. The plastic materials that are components of these industries, such as fishing nets, platic bags and bottles may be corroded or damaged and can be eventually contaminated into the sea. The occurrence of microplastics in the sediment beach obtained from 3 study sites along the coast at Phuket Province, Thailand varied in abundance from 1 to 35 pcs/m^2 (Akkajit et al., 2018). Microplastic abundance on sandy shorelines at seven locations in a northern Gulf of Mexico estuaries during the summer of 2014 was approximately 23.3 pcs/m^2 (Wessel et al., 2016). Microplastic pollution of Guanabara Bay, Southeast Brazil, microplastic concentration ranged from 12 to 1,300 pcs/m^2 (Carvalho and Neto, 2016). Furthermore, microplastic abundance on sandy beach and mudflat at Libong, a pristine island in Andaman Sea, Thailand investigated by Pradit et al. (2020b) was 25 and 4 pcs/m^2 respectively. These microplastics can be distributed in many parts of the environment, such as beaches, estuary sediments, coasts, and water bodies, where control or removal is difficult. This presently makes the microplastic debris be a global problem of marine and coastal pollution that tends to affect both marine and coastal ecosystems in cases of ingestion leading toxic substances into the food chain and the impact on the livelihood of organisms in the ecosystem. Microplastics have shown multiple damaging effects in the environment, including adsorption of toxic organic contaminants (Endo et al., 2005; Teuten et al., 2007; Rochman et al., 2013), ingestion by animals with implications for human consumption (Van Cauwenberghe and Janssen, 2014; Rochman et al., 2015).

Many studies have been conducted on the accumulation of microplastics in aqutic organisms (Phaksopha et al., 2023; Jitkaew et al., 2023), coastal environments, such as mangrove sediment (Chaisanguansuk et al., 2023), river (Chinfak et al., 2023), and sandy beach (Pradit et al., 2020b; Jualaong et al., 2021). Therefore, data on the spread of microplastics in the marine and coastal environments was studied to understand the situation of microplastic contamination in sediments in the lower Gulf of Thailand. This study investigated the distribution and amount of microplastic waste in sediment beach along coast of the lower Gulf of Thailand which is one of the significant fishing grounds of Thailand.

Materials and Methods

Study Area

Samples were collected for the study of microplastic contamination and distribution in sediment in the lower Gulf of Thailand at 5 stations, namely Ban Bang Dee Beach (BD) Nakhon Si Thammarat Province, Laem Son On Beach (SO) Songkhla Province, Laem Samila Beach (SM) Songkhla Province, Talo Kapo Beach (TK) Pattani Province and Thaksin Ratchaniwet Palace Beach (TS) Narathiwat Province (*Fig. 1*).

Methods for Collecting and Preserving Samples

Collecting sediment samples from the beach area (the highest tide area) and the beach area that is constantly flooded, approximately 1 m below the low tide zone (the middle tide area) with each random line, 4 quadrants (50 x 50 cm) with the depth of 5 cm was conducted. The samples were placed in zip-lock bags and placed in a refrigerated container – 20 °C for storing and reserving samples before microplastics were extracted.

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The total of 8 samples (4 samples for high tide and 4 samples for middle tide) with 3 replicates were collected twice a year for the total of 5 stations.

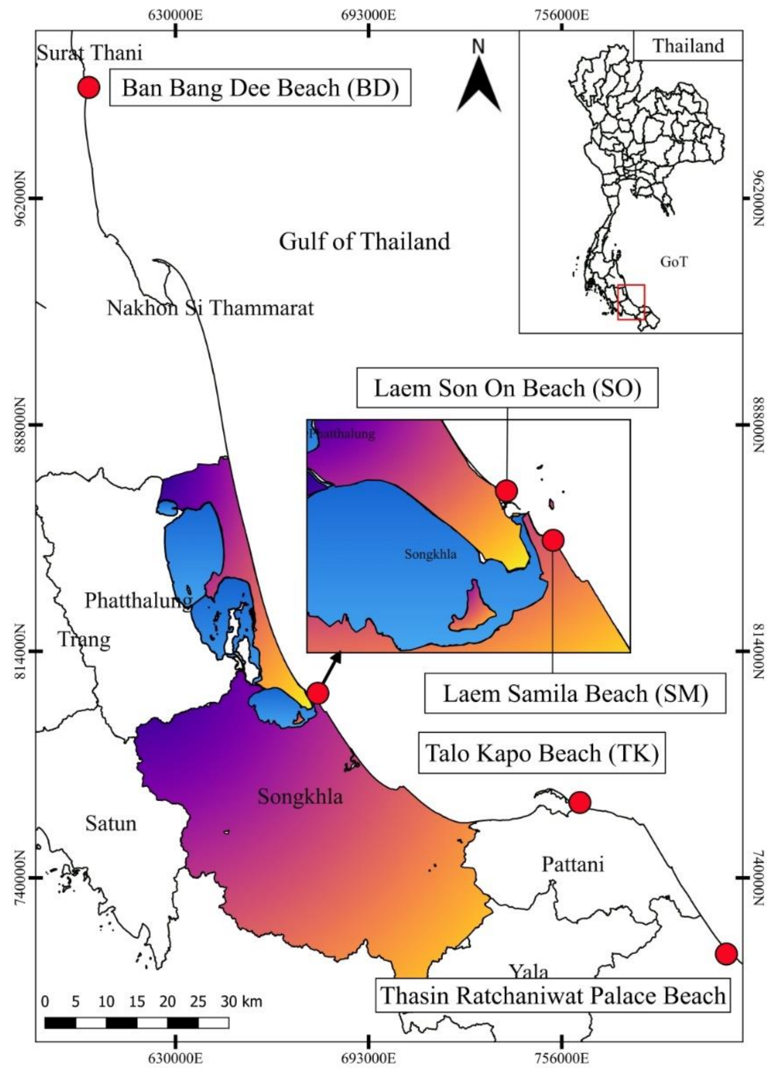

***Figure 1.** Map and location of sediment sampling stations in the Lower Gulf of Thailand, March (dry season) and July (rainy season) 2021*

Extraction and Classification of Microplastics in Sediment Samples

Microplastics were extracted from sediment samples using modified methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments (NOAA, 2015.). The sediment sample was divided into three sizes including: the first size: the sediment sifted with a sieve of size 1 and 5 mm (1 –<5 mm), the second size from the 300 μm cloth filtered (300 μm – <1 mm), and the third size from the water that filtered with GF/C filter paper (20 μm – < 300 μm). The filtered remnant obtaining from the filtration was oven dried and weighed. Then it was digested by H_2O_2 to remove contaminated organic matter and saturated saline was used to separate the microplastic samples. The microplastics were then identified by Fourier Transform Infrared Spectrometer (FTIR).

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Microplastic Identification

Approximately 20% of sorted microplastics from all the stations were selected from size classes and analyzed to identify the polymer types using a micro–Fourier Transform Infrared (μFTIR) Spectrometer (IRT-5200 FTIR Microscope from JASCO). The particle was transferred to potassium bromide (KBr) glass slide size 3 mm with forceps and covered with another KBr plate to make the sample ready for μFTIR analysis. To minimize the error from the background during the identification process, the background value at the empty space was measured and then the target item was measured. The wavelength used was 4000–600 cm^{-1} with transmission mode and scanned eight times per one target plastic. The obtained polymer type was compared with the library called Bio-Rad Laboratories, and 70% matching was accepted.

Preventive Measures

To avoid cross-contamination of air or clothing. All tools and glasses were cleaned and risen. To look for any airborne pollution. We poured distilled water into a petri dish and left it in the laboratory; at the end of the experiment, we detected no microplastic in the Petri dish.

Statistical Analysis

We tested the normal distribution of data and discovered that the amount of microplastic was not normal. We used a nonparametric test, compared fragment counts between sites using the Kruskal-Wallis test, and compared fragments and seasons using the Mann-Whitney U test at a p level of 0.05.

Result and Discussion

Microplastic Quantity

The amount of microplastics in sediment samples from the beaches in the lower Gulf of Thailand at 5 stations ranged from 0–1,144 pcs/m^2 as shown in *Table 1*. In comparison, abundance of microplastics of this study was higher than those of Phuket (1 to 35 pcs/m^2) and Libong Islands (4 -25 pcs/m^2) in Andaman sea as well as the northern Gulf of Mexico estuaries (23.3 pcs/m^2) as early mentioned in the introduction section. However, it is approximately as same order of abundance as Guanabara Bay (12 to 1,300 pcs/m^2), Southeast Brazil.

The results showed that microplastics were contaminated at all the 5 stations. In the dry season, TK was found microplastics the most at 1,144 ± 346 pcs/m^2 followed by SO with the amount of 650 ±500 pcs/m^2, SM = 484 ± 304 pcs/m^2, TS = 482 ± 509 pcs/m^2 and BD = 404 ± 88 pcs/m^2. The distribution characteristic of microplastics could be explained by human activities (anthropogenic factor) along the coast. The anthropogenic factor definitely controls the amount and type of microplastic debris present in beach sediment of the study area. The age of anthropogenic sediment normally increases with depth. The samples of this study were collected from the beach surface (0-5 cm depth). Thus, the microplastic debris present in the study area is likely to be microplastic debris resulting from current human activities rather than the past ones.

However, it is well known that our study areas, the coast of the lower Gulf of Thailand is an area mainly experiencing moderate coastal erosion (1-5 cm/year). Therefore, coastal sediments with microplastic fragments in the study sites have certainly short residence

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time in the coastal area before being eroded away by the strong wave and current during monsoon season. The cycle of microplastics present in beach sediment in our study area is proposed as follows: The human activities certainly generate the amount and type of microplastic debris depositing on the coastal area and provide the different physical signatures among the beaches that are related to intensity degree of human activities during the dry season. Then, the rainy season, monsoon storms cause coastal erosion, flash flood, homogenization of the presence of microplastic signatures generated by human activities along the coastal area and eventually deletes the different physical signatures of microplastic among the study sites. This is concordant with no significant difference of the amount of microplastics found among the different study areas during the rainy season, whereas the reverse is true for the dry season (*Table 1*). Hence, the distribution characteristic of microplastics of this study could be explained by human activities and the amount of rainwater flowing from rivers into the sea would both wash away and carry microplastics produced by human activities on land and coastal areas to the sea and simultaneously dilute the amount of microplastic deposit in coastal areas. TK, SM and SO have considerable tourism activities whereas BD possesses small fisherman villages with marine resources conservation activity. Thus, all the coastal study stations with human activity (TK, SM, and SO) had higher levels of microplastics in coastal sediment samples than those of the stations with little or no human activity (BD and TS), since human activities certainly provided a significant source of microplastics released into coastal sediments. Furthermore, the amounts of microplastics in the sediment samples at sampling sites with human activities (TK, SM, SO and BD) were higher in the dry season than those in the rainy season except TS since in the dry season there was no rainfall to dilute the amounts of microplastics deposited in the coastal area. There was no significant variation in the amount of microplastic identified between stations and locations ($p>0.05$).

Table 1. *Average amount of microplastics* ***(****pcs/m*^{2}***)*** *at 5 sampling stations in the Lower Gulf of Thailand in dry and rainy season****s*** *2021*

Station	Sampling Line	Dry Season		Rainy Season	
		Microplastics (pcs/m^2)	**Average amount±SD (pcs/m^2)**	**Microplastics (pcs/m^2)**	**Average amount ±SD (pcs/m^2)**
BanBang Dee Beach (BD)	High tide	466	404±88.38	0	148±208.60
	Middle tide	341		295	
Laem Son On Beach ((SO	High tide	1,004	650±500.63	250	263±18.38
	Middle tide	296		276	
Laem Samila Beach (SM)	High tide	269	484±304.06	5	62±79.90
	Middle tide	699		118	
Talo Kapo Beach ((TK	High tide	1,389	1,144±346.48	258	377±167.58
	Middle tide	899		495	
Thaksin Ratchaniwet Palace Beach ((TS	High tide	121	482±509.82	963	974±14.85
	Middle tide	842		984	

In the rainy season, microplastics were most contaminated at TS = 974±14.85 pcs/m^2 followed by TK = 377 ± 167 pcs/m^2, SO = 263 ± 18 pcs/m^2, BD =148 ± 209 pcs/m^2 and SM = 62 ± 79 pcs/m^2. Surprisingly TS is a very restrict area with no human activity and

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has highest amount of microplastics in the sediment samples as compared with the rest stations during the rainy season. The explantion for this unique characteristic is probably caused by counter-clockwise current in the lower Gulf of Thailand (*Fig. 2*) with flowing from south to north. It is expected that in the rainy season, rainfall washes terrestrial microplastics caused by human activities from the coastal areas of the neighboring country to the Gulf of Thailand. Then, gulf current brought these microplastics to deposit in TS. This is probably evidence of transboundary pollution and reveals microplastic contamination existing in the ocean of neighboring country as well. Thus, this is probably the first scientific evidence indicating the existence of transboundary microplastic contamination in the lower Gulf of Thailand.

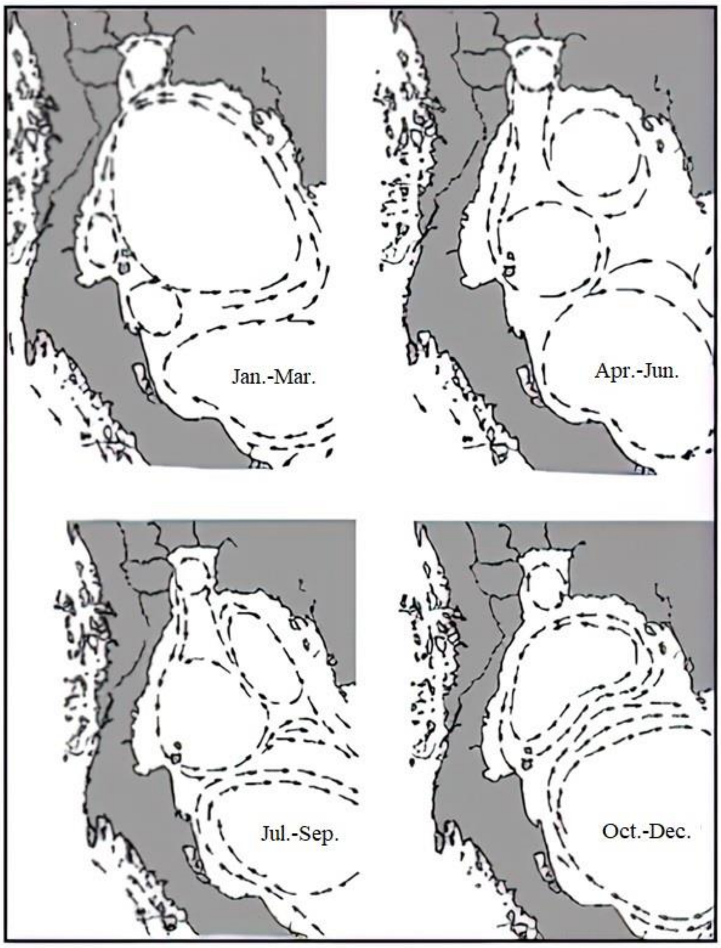

Figure 2. *Seasonal circulation in the Gulf of Thailand by the Hydrographic Department in 1961. Redrawn after Sojisporn et al. (2010)*

Amount of Microplastic Type

The results of the analysis of polymer types of microplastics present in our study areas using Fourier Transform Infrared Spectrometer (FTIR) showed the existence of 6 types: Polyethylene Terephthalate (PET), Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinylchloride (PVC) and Polyamide (PA) (*Fig. 3*).

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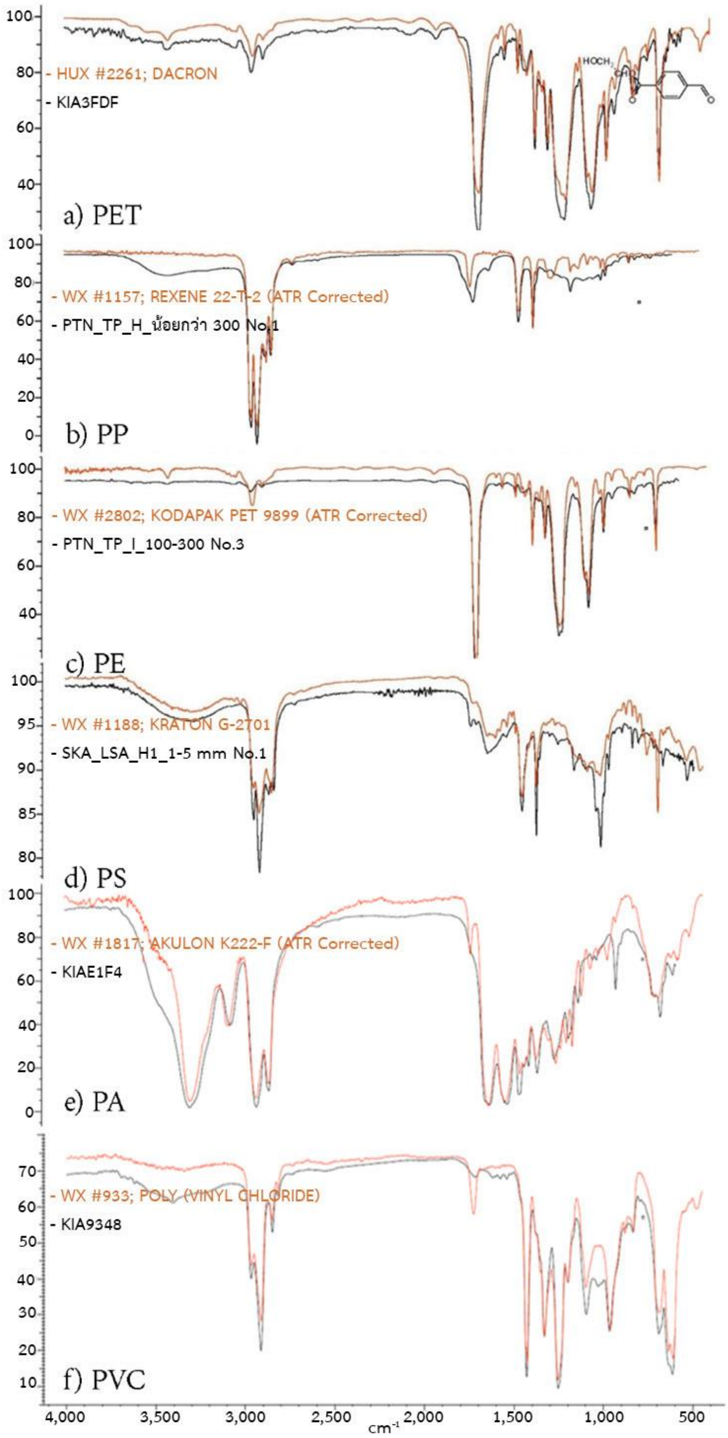

Figure 3. *Example of Fourier Transform Infrared (FTIR) Spectroscopy Analysis of abundant polymers found in this study: (a) Polyethylene Terephthalate (PET), (b) Polypropylene (PP), (c) Polyethylene (PE), (d) Polystyrene (PS), (e) Polyamide (PA) and (f) Polyvinylchloride (PVC)*

Polyethylene terephthalate (PET) in the dry season was found the most, followed by the rainy season approximately 1,995 and 1,415 pcs/m^2 respectively. Considering each station, PET was the most common found in TK during the dry season, followed by TS in the rainy season, amounting to 1,141 and 813 pcs/m^2 respectively.

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The second most common type of microplastics was Polyethylene (PE), which was found most frequently in the dry season, followed by the rainy season approximately 1,476 and 1,351 pcs/m^2 respectively. Consider the stations with the most PE found, SO in the dry season followed by TS in the rainy season, amounting to 949 and 766 pcs/m^2 respectively (*Fig. 4 and Table 2*).

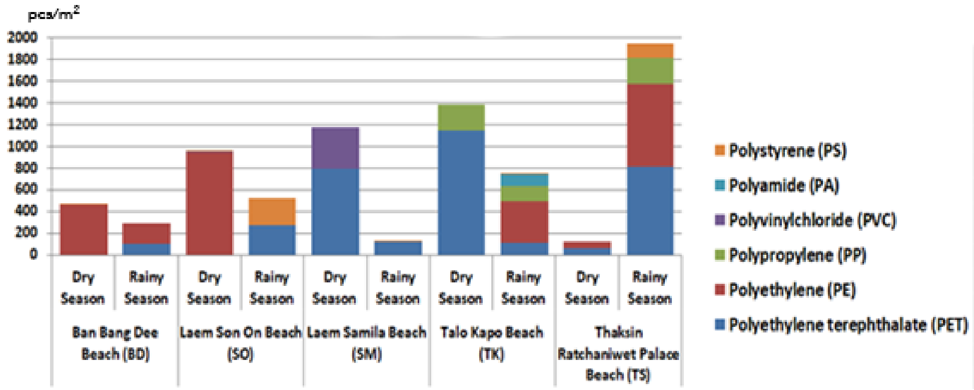

***Figure 4.** Types of microplastics (pcs/m^2) found in the collected sediment samples in dry and rainy seasons in the Lower Gulf of Thailand 2021*

***Table 2.** Microplastic types (pcs/m^2) present in the sediment samples in dry and rainy seasons in the Lower Gulf of Thailand 2021*

Types of microplastic	Ban Bang Dee Beach (pcs/m^2)		Laem Son On Beach (pcs/m^2)		Laem Samila Beach (pcs/m^2)		Talo Kapo Beach (pcs/m^2)		Thaksin Ratchaniwet Palace Beach (pcs/m^2)		Total Dry Season (pcs/m^2)	Total Wet Season (pcs/m^2)
	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season		
Polyethylene terephthalate (PET)	0	98	0	276	793	118	1141	110	61	813	1,995	1,415
Polyethylene (PE)	464	196	949	0	2	1	0	387	61	766	1,476	1,351
Polypropylene (PP)	0	0	0	0	3	0	248	139	0	240	251	379
Polyvinylchloride (PVC)	0	0	1	0	373	0	0	0	0	0	374	0
Polyamide (PA)	0	0	0	0	0	0	0	110	0	0	0	110
Polystyrene (PS)	2	0	4	250	0	4	0	6	0	128	6	388

The highest percentage of PET was observed since this type of plastic is commonly used in the food and beverage industries. It's also cheap and can accumulate in sediment more than other types of plastic. It has been classified as a plastic used in the production of drinking water bottles, soft drink bottles and snack bags (Magnusson and Norén, 2014). PE microplastics were also found abundant since the Lower Gulf of Thailand is one of the most abundant fishing activities in the Gulf of Thailand. Fishermen commonly use

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mainly nets, strings and ropes, and studies have found a large number of polyethylene (PE) plastics, which are precursors to the manufacture of such fishing gear (Goh et al., 2021).

Size of Microplastic

- Size 5000-1000 µm, were largely found at SO, followed by SM during the dry season at the high tide area, 22 and 9 pcs/m^2 respectively. As expected, the high energy from high tide was probably responsible for carrying the large size microplatics to deposit at the high tide area.
- Size 1000-300 µm were mostly observed at BD, followed by SM during the dry season at the high tide area amounting to 893 and 622 pcs/m^2 respectively.
- Size 300-20 µm, were largely observed at TS at the high tide area during the rainy season, followed by SO at middle tide area during the dry season, amounting to 958 and 699 pcs/m^2 respectively, as shown in *Fig. 5*. Surprisingly the considerable amount of small size microplastics at TS was deposited at the high tide area (high energy zone) in the rainy season. This was probably caused by the substantial amount of rain water during the rainy season flowing seaward encountering the high tidal current and eventually decreasing the tide velocity for the small size ones to deposit at the high tide area.

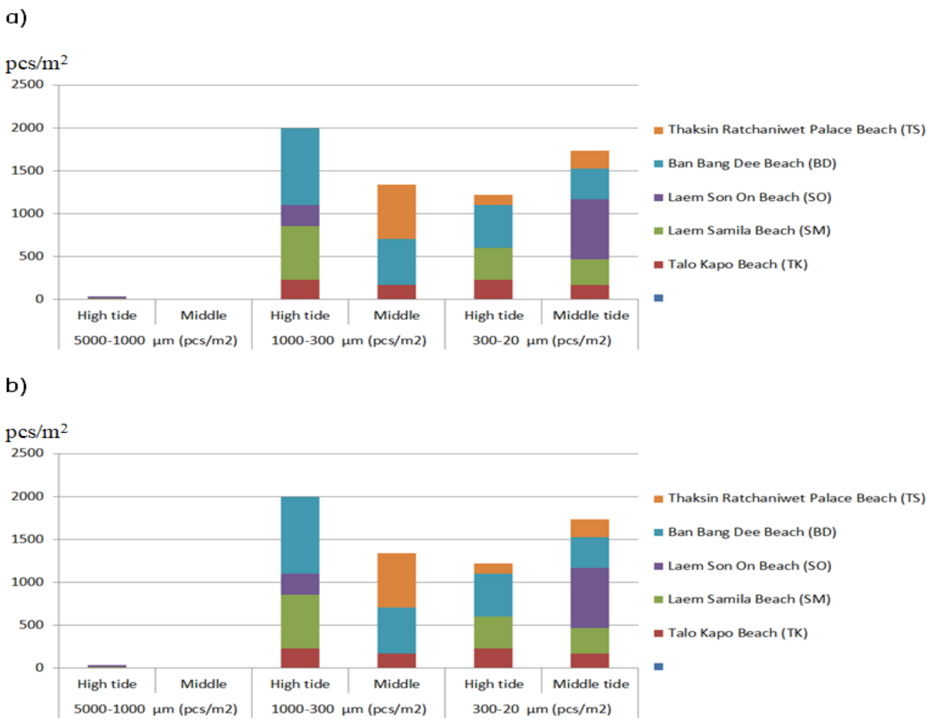

Figure 5. *Size of microplastics during (a) the dry season and (b) the rainy season in the Lower Gulf of Thailand, 2021*

Color of Microplastic

The color classification of microplastics is shown in *Fig. 6a,b*. The color characteristics of all the microplastics found are black, red, clear white, milky white,

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yellow, and blue. In the dry season, clear white microplastics were found the most with a percentage found at 29.75%, followed by yellow at 20.07%. The clear white ones probably derived from the PET drinking water bottles and soft drink bottles since the PET was majority of microplastics found in our study areas. In the rainy season, black microplastics were found for 31.94% followed by clear white, representing 25.13% which could be separated into stations as shown in *Fig. 6.* The black ones were likely to be the fragments of the PET snack bags and PE fishing gear because both of them were microplastic polymer types mostly existing in the study areas in the rainy seasons. Example of microplastic found in beach sediment is shown in *Fig. 7*.

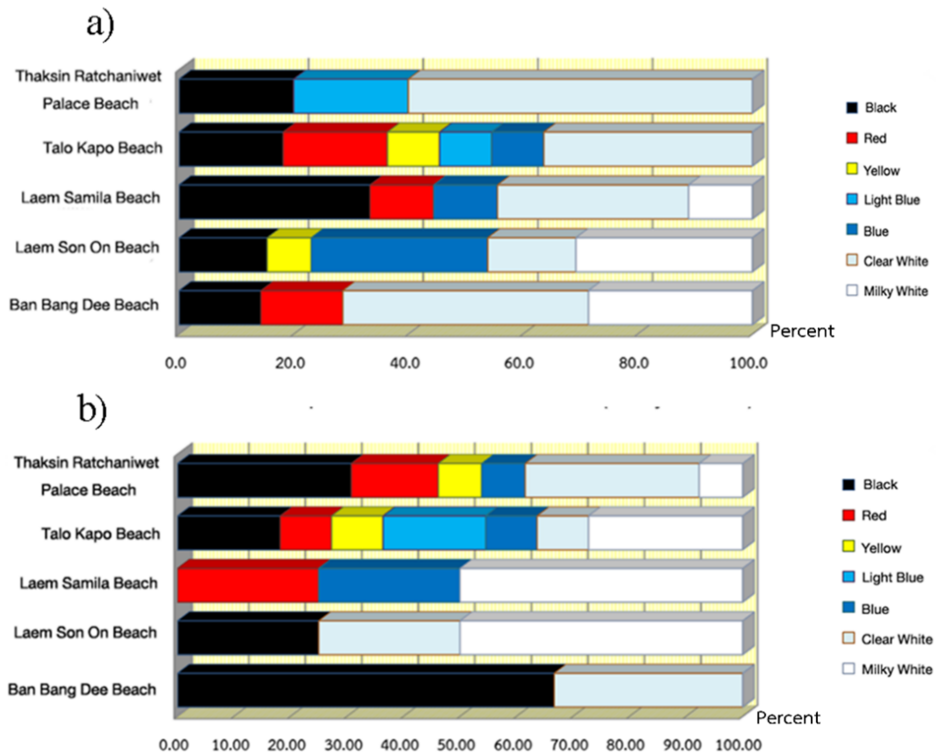

Figure 6. *The percentage of color of microplastics for each station during (a) dry season and (b) rainy season in the Lower Gulf of Thailand, 2021*

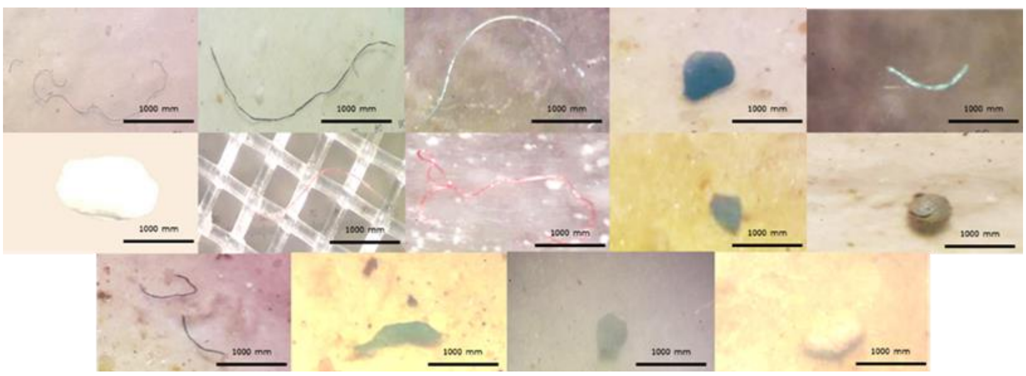

Figure 7. *Example of microplastic found from beach sediment on the Lower Gulf of Thailand*

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Conclusion

Microplastic contamination in beach sediments was found in all the study sites. These are the areas that have been used for intensive tourism activity. Season is certainly a key factor influencing the accumulation of microplastics on beaches. Dilution effect for reducing the amount of microplasic in water and sediment of coastal areas by substantial amount of rain water during rainy season was probably responsible for lowering microplastic accumulation on most of the lower gulf beach than that of the dry season. Gulf current is certainly another factor influencing the accumulation of microplastics on beaches. The beach of TS is a controlled area with absence of human activity and the nature of the bay is open and probably receives transboundary microplastic pollution transported by counter-clockwise gulf current from neighbouring country and the lower gulf coast area. Hence, this is the first scientific evidence showing the occurrence of transboundary microplastic contamination in the Lower Gulf of Thailand. PET, clear microplastics were mostly found and caused by disintegrated plastic wastes of drinking water bottle, soft drink bottles and snack bags, widely used in tourism activities in our study areas whereas PE microplastics obtained from the breakdown of fishing gear were also considerably observed. The accumulation of microplastic debris in the beach area was partly a result of the waste being dumped into water sources both intentionally and unintentionally and swept out to sea. Some of them were dumped through tourism industries, fishing activities and community sewers even though there was a wastewater treatment system before being discharged into the sea. Hence, human activities along coastal areas are significant point sources of microplastic debris accumalation on the Lower Gulf of Thailand. Reducing plastic gabage from ecoomic activities along the Thai coastal areas is urgently carried out to solve this global problem and prevent the transboundary pollution in Southeast Asia.

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