The Distribution of Microplastics in Beach Sand in Tien Giang Province and Vung Tau City, Vietnam

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Highlights:

- The upper shoreline was the main accumulation zone of MPs in both areas.
- The samples taken at 2 cm depth from the surface contained the highest concentration of MPs.
- Microplastics smaller than 1 mm were the most abundant.
- Fragments accounted for the highest percentage in Tan Thanh while granules prevailed in Vung Tau.
- PE, PP, PS were the three most commonly found types of plastics at the research sites. PP and PE were the main types in Tan Thanh, while PE and PS (styrofoam) were the main types found in Tien Giang.

Abstract. Microplastics threaten the ecosystem because of undesirable properties such as non-biodegradability, easy-to-absorb persistant organic compounds, etc. They are found worldwide in marine, fresh water and beach sand environments. In this study, microplastics in beach sand samples from two sites in Tien Giang province and two sites in Vung Tau city were investigated. The results showed that the microplastics amount was 0 to 295 pieces/kg dry sand and they mainly distributed near estuarine areas. Microplastics were more prevalent at bathing sites than non-bathing sites. In Tien Giang fragments were the most dominant among the three types of shapes (fragments, fibers, granules) at 60.2%. In Vung Tau granules were most prevalent at 71.7%. The composition of the plastics was confirmed by Fourier-transform infrared spectroscopy. It was revealed that PE, PP and PS were the main types of plastics found in the sampling sites.

Keywords: *beach sand; FTIR; microplastics; Tien Giang; Vietnam; Vung Tau.*

1 Introduction

According to the statistics of Ocean Conservancy (USA), the top countries that discharge garbage into the sea in 2017 were China, Indonesia, Philippines, Thailand and Vietnam, as reported by Leung (2018) [1]. It is estimated that about 60% of the total amount of plastic waste ends up in either landfills or the natural

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environment, as reported by UN Environment [2]. The increasing use of single-use plastic products, uncontrolled waste disposal along with poor waste management and recycling activities are the main reasons for garbage accumulating in the sea. Increasing pollution by plastic waste in marine environments causes risks to marine species due to ingestion or entrapment in plastic debris.

Recently, small plastic particles with a diameter smaller than 5 mm, called microplastics (MP) [3], have been identified as a common component of plastic contamination. MPs have a negative impact on the environment and create great risk to marine organisms, including plankton, fish, birds, mammals, and bivalve animals since these animals may consume MPs. MPs are capable of carrying organic compounds and poisonous substances from the environment to the bodies of humans and organisms, for example polychlorinated biphenyls, polycyclic aromatic hydrocarbons, bisphenol and so on [4-6]. Besides additives, plasticizers in plastic can also cause health problems. The ingestion of microplastics can potentially have harmful effects on humans, such as chromosomal changes, infertility, obesity, and cancer [7,8].

Plastic microbeads in personal care products can penetrate into the marine environment through a variety of sources on land and sea. About 80% of plastics originate from land-based sources such as rivers, storm water runoff, wind, domestic sewages and tourism activities. Marine sources, including fishing, sea fishing and indiscriminate littering, are also responsible for the presence of MPs in the ocean, as reported by Ritchie [9].

Vietnam is the fourth largest solid waste contributor in the world with a discharge of 1.8 million tons of plastic waste into the sea every year, as reported by The Tribune of Hanoi People's Committee in [10]. In Vietnam, research on microplastics has received little attention. Only one study has been published, on macroplastics and microplastics in canal systems and the Sai Gon river [11]; beaches as areas where microplastics can accumulate due to the effects of sea currents and coastal activities have not been investigated thoroughly yet. Tien Giang province and Vung Tau city are two locations in the south of Vietnam with a long coastline. Local economic activities focus on aquaculture, fishing, boat building, watermelon cultivation, and tourism. These activities expose the local environment to plastic pollution. However, no scientific data have been reported on microplastics pollution in these places. Therefore, this study was conducted in Tien Giang province and Vung Tau city, Vietnam. The amount, characterization and composition of microplastics from beach sand samples collected in Tien Giang and Vung Tau were evaluated.

2 Experimental Method

2.1 Sampling Method

Two beaches in Tien Giang province and two beaches in Vung Tau city were investigated in this study (Figure 1). Both sampling sites have different topographic characteristics and anthropogenic activities. Tien Giang province, site A (10.2681° N, 106.7571° E) is near an estuary where many aquaculture activities such as oyster and clam farming are conducted. Site B (10.2903° N, 106.7818° E) is Tan Thanh, a tourism destination that attracts many visitors from Tien Giang province and neighboring provinces. Due to the turbidity of the alluvial sea as well as aquaculture, water recreation and tourism activities are not available at this site. Pineapple Beach (site C, 10.3274° N, 107.0806° E) and Back Beach (site D, 10.3374° N, 107.0937° E) are located in Vung Tau city. Site C is a place that attracts many tourists due to its beautiful scenery and clear seawater but not for swimming activities because of the rough sea and the narrow and rocky coast. Site D is one of the most popular beaches in Vung Tau and the southern region due to its long seashore and gentle waves all year round.

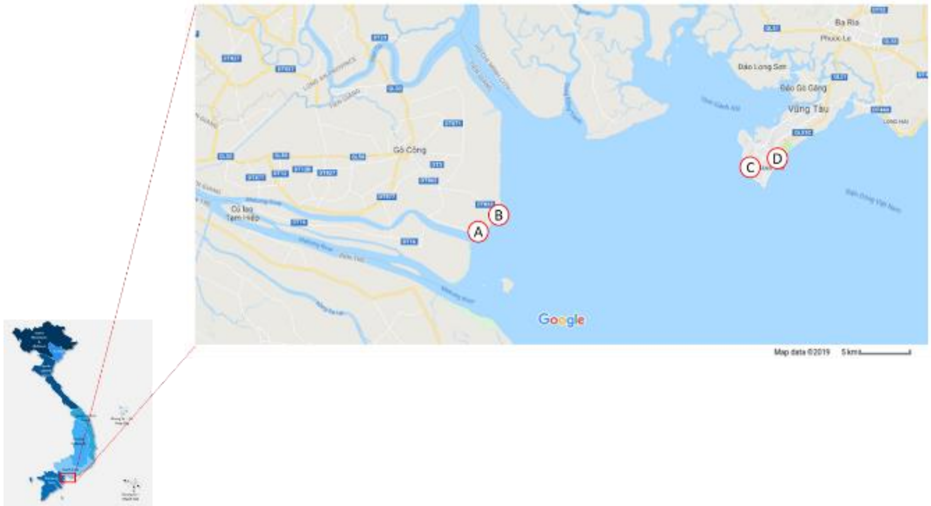


Figure 1 Map of sampling sites.

The sampling method was based on Brito, *et al.* [12], Eo, *et al.* [13], and Li, *et al.* [14] and adjusted to fit the actual conditions of the study. The sampling areas were chosen by marking out a transect of 100 m in width, parallel to the coastline. Samples were collected along the upper shoreline, the middle shoreline and the water-edge line. Each tidal line was divided into four equal distances and sand samples were randomly taken in these four intervals (Figure 2). A quadrat with dimensions of 50 x 50 cm was used. Two samples were collected at two different depths: 2 cm and 5 cm from the surface (Figure 3). There were 24 sand samples from each beach. Due to the narrow and short coastline, only 12 samples were collected from site C. In total, 84 sand samples from the 4 sampling sites were investigated. They were stored in aluminum zip bags and transferred to a laboratory for further analysis.

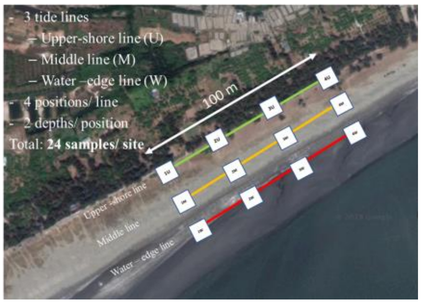


Figure 2 Example of sampling area.

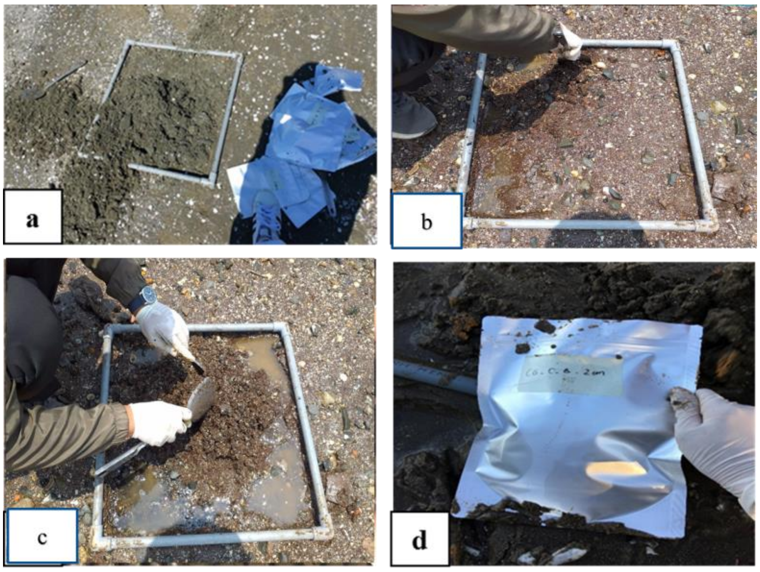


Figure 3 Sampling procedure of MPs investigation in beach sand.

2.2 Analyzing Method

MPs were extracted from the samples following the procedure of Besley, *et al.* in [15] and Brito, *et al.* in [12] with minor modification. The samples were dried to a constant mass and sieved through 5 mm and 0.5 mm mesh size sieve to limit the size of the microplastics. 200 g of sand was weighed and floated by zinc chloride solution (d = 1.8 g/ml), the microplastics were oxidized with hydrogen dioxide 30% and iron (II) solution to remove all organic matter. The floating pieces were filtered on Whatman glass microfiber filter paper (1.5 µm, 47 mm Ø). After that the MPs pieces were measured and classified into different groups by color and shape using observation under a microscope. The composition of the MPs was identified by FTIR-ATR (JASCO FT/IR-6000 FTIR spectrometer – ATR PRO ONE).

3 Results and Discussion

The amount and distribution of MPs at the four sites are shown in Figure 4 and Table 1. MPs were detected in 71.4% of all samples. They accumulated mostly at the upper shoreline of the beaches. Some samples in the middle shoreline showed the presence of MPs, mainly at sites A and D. At the water-edge line, MPs only appeared at sites C and D.

The average concentration of MPs at three tide lines is shown in Figure 5 with the upper shoreline ranging from 1.3 to 112.2 pieces/kg dry sand, the middle shoreline from 0 to 16.9 pieces/kg and the water-edge line from 0 to 5 pieces/kg dry sand. On average, the concentration of MPs was distributed at the upper shoreline, middle shoreline, and water-edge line at 59.5, 8.4 and 1.4 pieces/kg dry sand, respectively.

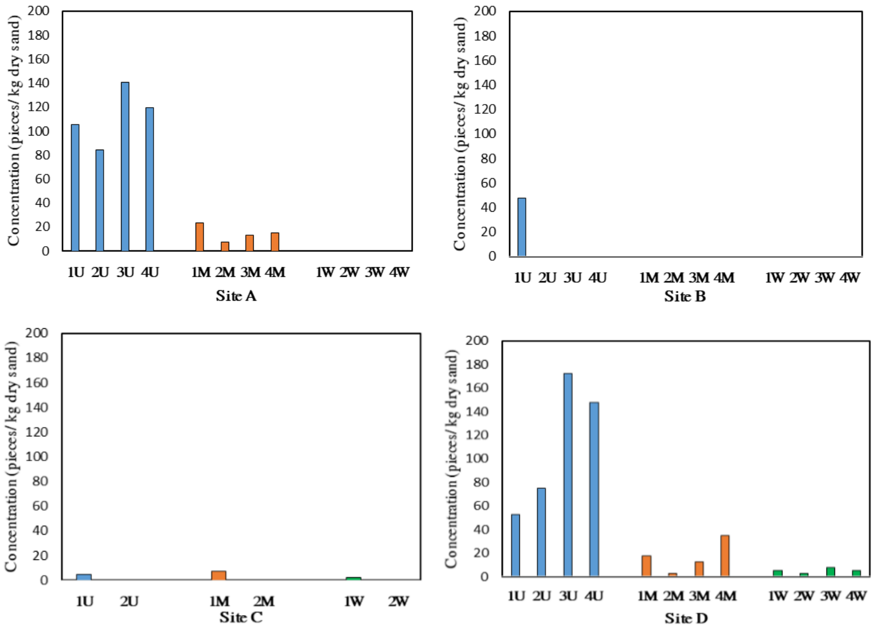


Figure 4 Concentration of microplastics at each site.

Table 1 Concentration of microplastics in each position.

Concentration (items/ kg dry sand)				
Sample No.	**Site A**	**Site B**	**Site C**	**Site D**
1U	105.7	47.9	5.0	52.5
2U	84.5	0.0	0.0	75.0
3U	140.7	0.0	N/A	172.5
4U	119.8	0.0	N/A	147.5
1M	23.2	0.0	7.5	17.5
2M	7.7	0.0	0.0	2.5
3M	13.0	0.0	N/A	12.5
4M	15.4	0.0	N/A	35.0
1W	0.0	0.0	2.5	5.0
2W	0.0	0.0	0.0	2.5
3W	0.0	0.0	N/A	7.5
4W	0.0	0.0	N/A	5.0

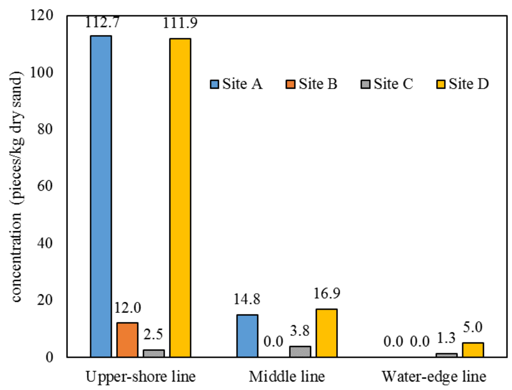


Figure 5 Concentration of microplastics at tide lines.

Figure 6 indicates the distribution of MPs at all sites. The average concentration of MPs at all sampling sites ranged from 2.5 to 44.6 pieces/kg dry sand (Table 2). The estuarine site (site A) and Back Beach (site D) showed that most MPs ranged from 0 to 281.4 pieces/kg dry sand at site A and 0 to 295 pieces/kg dry sand at site D. The average concentration at these two beaches was 42.5 pieces/kg (site A) and 44.6 pieces/kg (site D). These two sites are also the places where most human activities take place, with the sources being inland rivers and beaches. In contrast, the sand samples from the Tan Thanh tourist site (site B) and Pineapple Beach (site C) did not contain large amounts of MPs. The average MPs concentration at these two beaches was 4.0 pieces/kg dry sand and 2.5 pieces/kg dry sand, respectively.

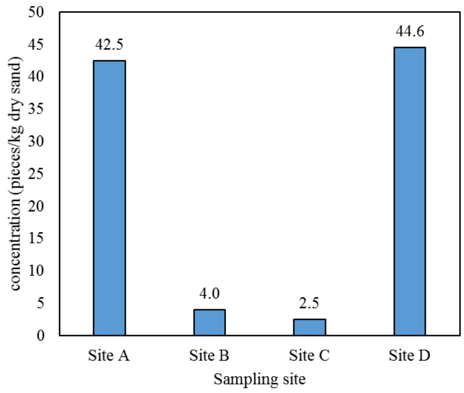
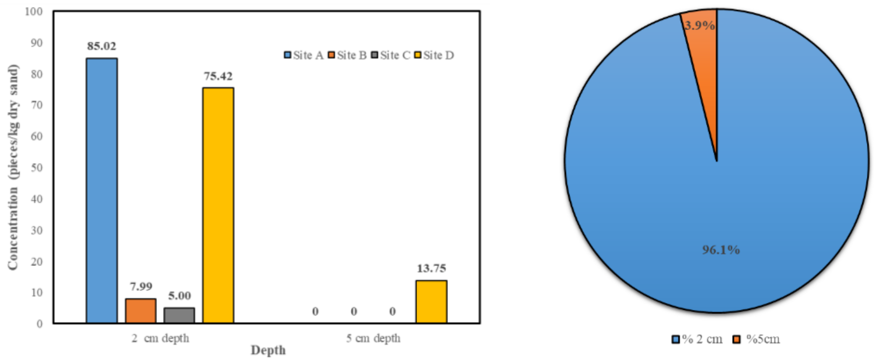


Figure 6 Average concentrations of microplastics.

Table 2 Concentration of Microplastics at the Sampling Sites

Sampling site	Location	Number of samples	Concentration (pieces/kg dry sand)	
			Min-Max	Average
A	Tien Giang	24	0-281.4	42.5
B	Tien Giang	24	0-95.9	4.0
C	Vung Tau	12	0-15.0	2.5
D	Vung Tau	24	0-295.0	44.6

The majority of MPs was detected in the 2-cm depth sand samples, accounting for 96.1% of the total number of MPs (Table 3). Only site D had MPs in the 5-cm depth samples. Considering the 2-cm layer of the upper shoreline, the average concentration was 43.4 pieces/kg dry sand, i.e. 10 times more than in the 5-cm sand layer with 3.4 pieces/kg dry sand (Figure 7).



(a) (b)

Figure 7 Concentration of microplastics by depth: (a) distribution of MPs by depth, (b) percentage of MPs at each depth.

Table 3 Distribution of MPs in beach sand by depth.

Concentration (pieces/kg dry sand)			Percentage (%)	
Site	**2-cm depth**	**5-cm depth**	**2 cm**	**5 cm**
Site A	85.0	0	100	0
Site B	8.0	0	100	0
Site C	5.0	0	100	0
Site D	75.4	13.8	84.6	15.4
Average	**43.4**	**3.4**	**96.1**	**3.9**

The concentration of MPs in this research was lower than that in Bohai, China [16] and India [17] (Figure 8); China and India are two other top countries that dump huge amounts of plastics into the ocean. However, the concentration of MPs in the present study was much higher than in Slovenia according to the results given by Korez, *et al.* [18].

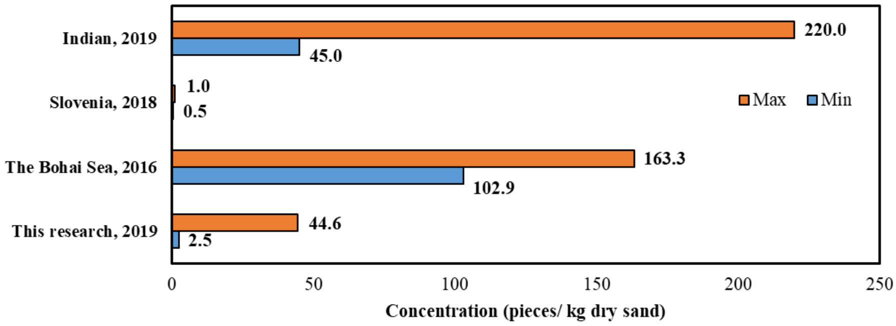
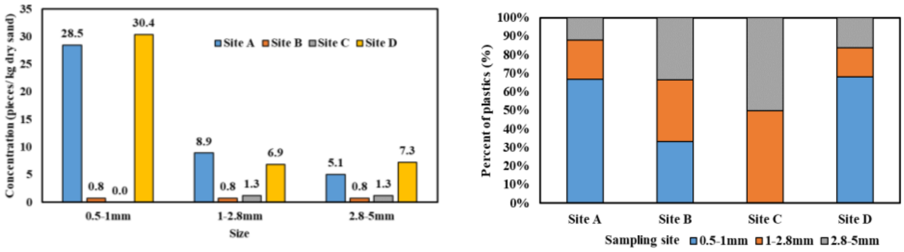


Figure 8 Comparison of the concentration of microplastics with other researches.

In this study, the size of the MPs was only analyzed from 0.5 to 5 mm due to the limitations of our facilities. In the above size range, the MPs were classified into three main groups from: 0.5 to 1 mm, 1 to 2.8 mm and 2.8 to 5 mm. MPs with a size of 0.5 to 1 mm accounted for the highest proportion (42.1% of the total number of MPs found) (Figure 9 and Table 4), while the sizes of 1 to 2.8 mm and 2.8 to 5 mm had similar percentages, 30.0% and 27.9%, respectively.

MPs with a size 0.5 to 1 mm appeared in all sand samples from the 2-cm layer. This result shows that the concentration of MPs was inversely proportional to their size. MPs with a size of 0.5 to 1 mm were the most abundant at the upper shoreline and were barely found at the middle shoreline, while at the water-edge line almost no 0.5 to 1 mm MPs were found. The number of MPs of 1 to 2.8 and 2.8 to 5 mm was quite small but they appeared at all three lines with the number decreasing gradually from the upper shoreline, middle shoreline, and water-edge line. Figure 10 shows the MPs of different sizes.

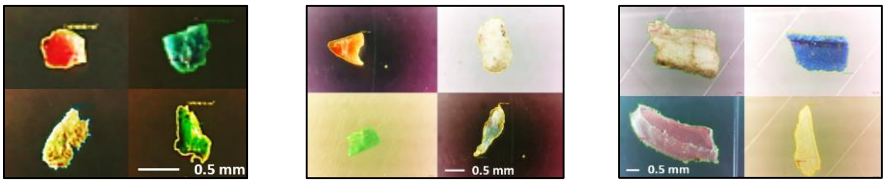


(a) (b)

Figure 9 Distribution of microplastics by size: (a) concentration of MPs at each site, (b) percentage of MPs at each site.

Table 4 Distribution of MPs by size.

	Concentration (pieces/ kg dry sand)			Percentage (%)		
Site	0.5-1 mm	1-2.8 mm	2.8-5 mm	0.5-1 mm	1-2.8 mm	2.8-5 mm
Site A	28.47	8.95	5.09	67.0	21.0	12.0
Site B	0.79	0.79	0.79	33.3	33.3	33.3
Site C	0.00	1.25	1.25	0.0	50.0	50.0
Site D	30.42	6.88	7.29	68.2	15.4	16.4
Average	14.92	4.47	3.61	42.1	30.0	27.9



(a) (b) (c)

Figure 10 MPs of different sizes: (a) 0.5-1 mm, (b) 1-2.8 mm, (c) 2.8-5 mm. All scale bars are 0.5 millimeter.

White and green were the two colors of plastics found on all beaches, where white was the predominant color with a concentration of 1.3 to 17.7 pieces/kg dry sand. Blue was also a color that appeared in many samples. Figure 11 indicates that the percentage of white, green, and blue MPs was quite similar in the estuarine area in Tien Giang (site A) and Back Beach (site D). The different colors of the MPs are presented in Figure 12.

Three main types of plastic were found, i.e. fragments, fibers and granules (Figure 13). Fragments and fibers dominated in the total number of MPs pieces (382 pieces out of 429 pieces, accounting for 88.6% of the total number of pieces) (Figure 14). At both Tien Giang's sites, fragments had the higher percentage (60.0% and 73.7% at site A and site B), whereas in Vung Tau at Back Beach (site D) granules dominated, with 72.0% of the total number of MPs pieces. The correlation between type and color was also quite clear. Figure 15 shows that at all beaches most of the MPs were white in color (51.8% to 74.4%), whereas the fibers were mostly green (76.5% to 100%).

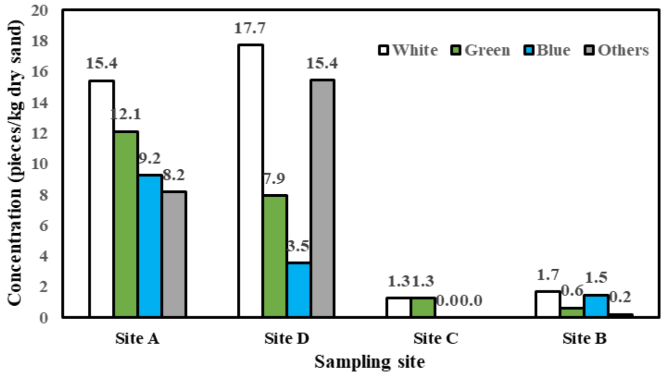


Figure 11 Distribution of microplastics by color.

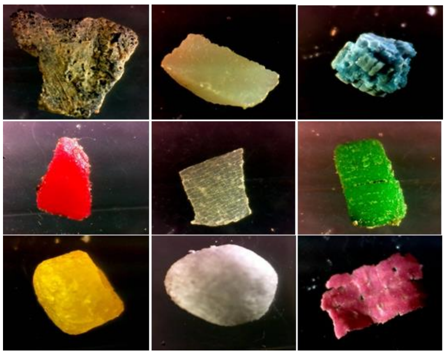


Figure 12 MPs in different colors.

Figure 13 Different types of MPs: (a) granule, (b) fragments, (c) fibers.

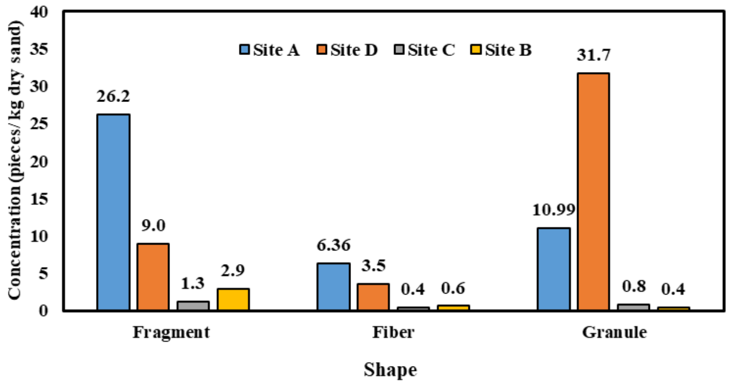


Figure 14 Concentration of microplastics by shape.

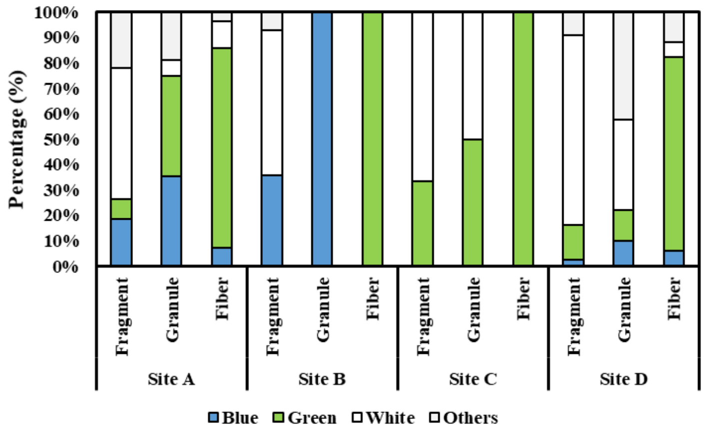


Figure 15 Distribution of shape by color.

All MPs from sites A and site D were analyzed for their chemical composition. Four main types of plastics were found in the sand samples, i.e. polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). At site A, PE and PP accounted for the majority of MPs (91.2% total); they were found in all samples with MPs. At site D, PS and PE were the dominant plastics, with 40% and 38%, respectively. PP and PVC accounted for only about 20% of the MPs (Figure 16).

The composition of microplastics varying between sites may be associated with anthropogenic activities in these places. At site A most of the MPs were fragments, consisting mainly of PP and PE, which could be explained by the degradation of plastic bags. Meanwhile, at site D the MPs were mostly granules, consisting of PS. The presence of these types of plastics may due to swimming and styrofoam packaging from food. There are some swimming tools such as pull buoys and kickboards made from styrofoam that can loose fragments during use, forming microplastics. There are many fast-food stores located along the beach that sell food contained in styrofoam boxes. Tourists usually buy take-away food and eat on the beach and then leave the packaging there. The degradation of these plastic items may lead to the formation of microplastics.

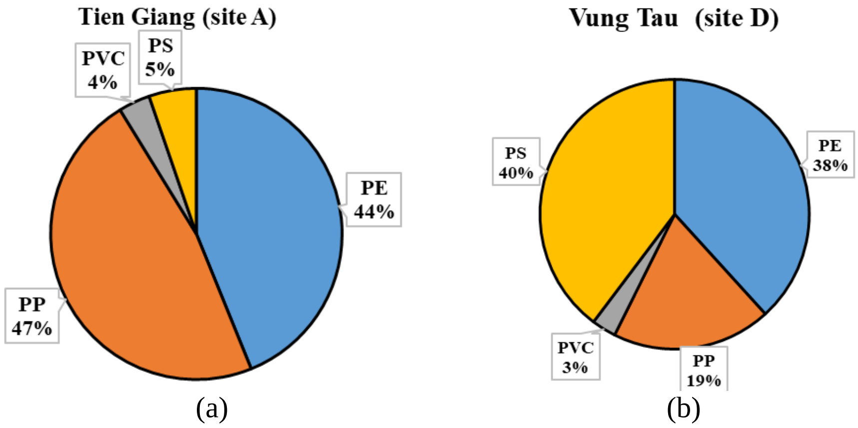


Figure 16 Concentration of microplastics by composition: (a) site A, (b) site D.

4 Conclusion

MPs were investigated at four beaches based on a total of 84 samples from two different regions in Vietnam (Tien Giang and Vung Tau). The upper shoreline was the most important accumulation zone of MPs, while the 2-cm layer from the surface was the place where the most MPs appeared. PE was the most prevalent plastic type. Most MPs fragments were PE or PP, while granular MPs accounted for a high percentage of PS pieces. White was the dominant color among the MPs fragments and the majority of MPs fibers were green. The distribution of MPs at different sites also indicated negative impact of local human activities.

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