Physical and Chemical Characteristics of Microplastic in Beach Sand in Can Gio, Ho Chi Minh City, Vietnam

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Research Article

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Abstract

Microplastics pollution in Vietnam has been received more attention in recent years due to its adverse impacts on the environment. The coastal areas, especially estuary is potential accumulation zone of microplastics. These locations, where inland waters meet the ocean, are heavily impacted by anthropogenic activities and the dynamic of the sea currents. This study aims to investigate the spatial distribution, physical characteristics, and chemical composition of microplastics in beach sand in Can Gio, Ho Chi Minh city, Vietnam. A total of 90 sand samples from five sampling sites were collected in November 2019, they were analyzed for size, shape, color, and identity. The results showed that microplastics concentration ranged from 0 to 6.58 pieces/ kg d.w. Microplastics tend to be distributed along the upper-shore line and in the surface layer of sand. The data revealed that microplastics ranging from 2.8–5 mm were the most abundant (72.46%), pellet shape accounted for the highest proportion (41.31%), white and blue are two popular colours up to 80% in total of detected microplastics. Chemical composition of the microplastics was determined by attenuated total reflection-Fourier transform infrared (FTIR-ATR) spectroscopy, polypropylene and polystyrene are the two most common plastic types in this study. Macroplastics found in beach sand samples were also assessed, the study shows a positive correlation between microplastic and macroplastic, showing the possible origin of microplastics. The findings of this study provided more insights into the microplastic pollution status in beach sand and the foundation for future investigation.

1. Introduction

Plastic production first emerged in the 1950s, with about 1.5 million tonnes of plastic produced annually (Li et al. 2020). As of 2015, worldwide plastic production has increased significantly to 381 million tonnes per year (Hannah Ritchie and Max Roser 2018). The total amount of plastic manufactured over the course from 1950 to 2015 is estimated at 8.3 billion tonnes, which is equivalent to more than 1 tonne per person, and 5.8 billion tonnes (71.6%) were no longer in use. These plastic wastes ended up in the landfill, being incinerated or discarded. Every year, 8 million tonnes of plastic wastes go straight to the ocean without any waste management (Geyer et al. 2017; Lebreton et al. 2017; Hannah Ritchie and Max Roser 2018). Land-based plastic wastes flow into the oceans and accumulate into great garbage patches, which can be found in the Pacific Ocean (Lebreton et al. 2018). If current plastic production and waste management policies prolong, approximately 12 billion tonnes of plastic will be discharged as of 2050 (Geyer et al. 2017). While the benefits of plastics are undeniable, their popularity and convenience in terms of various forms of usage and disposal, such as plastic packaging, have quickly resulted in their accumulation in the environment (Crawford and Quinn 2016). Floating plastic debris continuously affected by wind and waves are quickly distributed over the water surface in a large area (Everaert et al. 2020; Chenillat et al. 2021). In addition to the negative impacts on environmental aesthetic, the rampant plastic waste also causes economic consequences in tourism, the environment's effects of plastic particles including obstruction of the digestive and respiratory system, habitat encroachment, these floating plastic debris can mediate invasive species (2017; Hu et al. 2019; Wang et al. 2020). One of the urgent issues caused by plastic waste recently is microplastics (Sharma and Chatterjee 2017).

There are various definitions of microplastics. In general, they are plastic pieces a size smaller than 5 mm in length (Cole et al. 2011; Imhof et al. 2013; NOAA 2021). Microplastics easily penetrate the food chain due to their tiny size and bioaccumulation in marine species because they were mistaken to consume as prey items. Whenever microplastics enter marine organisms' bodies, they can cause various damage such as obstruction of the digestion tract and other internal injuries leading to starvation and death of animals. In some circumstances, they may reduce the respiration abilities of animals (Digka et al. 2018). Besides physical effects, due to the chemical composition and the large surface area, microplastics also threaten the ecosystem in terms of toxicity. The growth of plastic production led to the rise of additives in commercial plastics to enhance their performance (Al-Malaika et al. 2017). A majority of additives, such as flame retardants and plasticizers, are lipophilic. They easily penetrate cell membranes causing severe effects on consumer's health (Lambert et al.; 2017). On the other hand, toxins and pathogenic microorganisms can adhere to microplastics' surfaces. Some persistent organic pollutants such as polybrominated diphenyl ethers, polychlorinated biphenyls, and pesticides mimic the natural hormones. Therefore, since organism consumes them, they are induced reproductive disorders (Bergmann et al. 2015). These microplastic pieces might be secondarily generated under the physical, biological, or chemical effects of the environment by the fragmentation of plastic wastes (Lots et al. 2017; NOAA 2021). Besides, microplastics are also manufactured small size like the resin pellet – the primary ingredient in the production of plastic items, personal care products, cosmetics, and toothpaste contain microplastics and nano plastics which easily enter the sewage then the ocean (Praveena et al. 2018; Hu et al. 2019; Everaert et al. 2020). Since microplastics cause the above adverse impacts on the environment and organisms, from the 2000s, the issue of microplastics began being paid attention leading to the number of studies increased over time. The first researches mainly focus on analyzing methods and the distribution of microplastics (Thompson, 2006; Cole et al. 2011; Imhof et al. 2013). Microplastics have been detected in many media, including surface water, marine creatures, and sediment (Digka et al. 2018; Reed et al. 2018; Sighicelli et al. 2018; Zhao et al. 2018; Korez et al. 2019).

Coastal areas are microplastics accumulation zone due to the location is the intersection between estuaries and the ocean. In addition, these places are affected by many anthropogenic activities such as aquaculture, tourism, and transportation. Research on microplastics in beach sand in the world shows that garbage discharged from inland and marine activities can drift large amounts of plastic waste to the coastal environment (LI et al. 2016; Auta et al. 2017). The number of researches on microplastics in beach sand has increased over time. Some studies have reported that the concentration of microplastics in beach sand and sea sediment was significant (Lee et al. 2013; Dekiff et al. 2014; Mathalon and Hill 2014). Recently, a number of studies on microplastics in mangroves and estuarine ecosystems concluded that the wetland flora is a potential microplastics storage (Nor and Obbard 2014; Eo et al. 2018; Walther et al. 2018; Garcés-Ordóñez et al. 2019). The concentration of microplastics in beach sand varied in different studies range from 1 piece/ kg d.w to more than 2000 pieces/ kg d.w (Claessens et al. 2011; Vianello et al. 2013; Leslie et al. 2017). The size of microplastics can be determined to tens of µm as in the study in Belgium or Korea up to 38 μm (Claessens et al. 2011; Eo et al. 2018). The distribution of microplastics also shows the difference in tidal lines, whereby, according to some studies, the amount of microplastics is found the most in the upper-shore line (Mathalon and Hill 2014; Eo et al. 2018). The impact of coastal commercial tourism on sampling sites was also surveyed, the results showed that in the bathing sites attracting many tourists. The number of microplastics observed was significantly higher than the deserted areas, steep beaches (Yu et al. 2016; Hien et al. 2020). This difference can be explained by the application of different methods of sampling and separating microplastics as well as how microplastics are identified (Song et al. 2015).

Vietnam owns a long coastline with many anthropogenic activities. Besides, Vietnam is one of the top countries discharging plastic wastes into the environment that leads to the high potential of microplastic pollution (Hannah Ritchie and Max Roser 2018). In recent years, the microplastic issue has gradually gained more attention from scholars. A number of studies were conducted in different environments, including inland water, marine animals, road dust, and even in beach sand (Lahens et al. 2018; Hien et al. 2020; Mỹ and Dũng 2020; Tran Nguyen et al. 2020; Yukioka et al. 2020). However, there is no data of microplastics in beach sand in Can Gio – the suburban district of Ho Chi Minh as known as the most populous city in Vietnam. Can Gio is the place where many rivers bringing the wastes from inland and mangrove forest meet the ocean and suffer the impact of sea currents. In addition, Can Gio has a complicated shoreline, and different activities, including aquaculture, trading, tourism, happen along the coast. Therefore, Can Gio has a high risk of microplastic pollution, especially in beach sand. To get more insights into the pollution level in Can Gio, this study aims to investigate the spatial distribution of microplastics, physical characteristics as well as chemical composition.

2. Materials And Methods

2.1. Sampling area

The shoreline of Can Gio stretching from Dong Hoa cape to Can Gio cape, where the study conducted is approximately 13 km long. Can Gio is located on the estuary of Dong Nai river in a funnel-shaped area, which is indented to the mainland compared to Go Cong coast in the West and Vung Tau cape in the East. Can Gio is contiguous with many large estuaries such as Soai Rap, Dong Tranh, Long Tau, and Nga Bay (Chan and Cohen 2014). Water is transferred from a muddy area of the mangrove, flows into Dong Tranh, Ghenh Rai bays, and then discharges into the ocean. Can Gio coast is an intersection area of rivers and the sea, creating significant influences on the topographic features of Can Gio. Water poured out from the bays carry residues of vegetation from Sac mangrove. These suspended matters accumulate on Can Gio sea. In addition, the coast is composed of fine sand mixed with clay, resulting in the grey color of beach sand. Besides the complicated shoreline, Can Gio also receives the Southeast – Southwest wind that forms a big wave area where sea waves enter the shallow sea, become broken waves with strong destructive power disturbing the bottom, resulting in the sea cloudy on windy days (Chan and Cohen 2014). Waves climb up the shoreline and destroy the coastal dunes leading to continuous erosion. Along Can Gio coast, embankments and groins are encroaching a uniform 100 m distance to prevent eroding that creates consequential significant accretion along with these constructions. The study area has an irregular semidiurnal tide (Le Nguyen and Luong 2019). Beach sand samples were collected from 5 sites along Can Gio coast (Fig. 1), each area has different characteristics in terms of socio-economics: Site 1 is the beach behind a local seafood market, site 2 is near a popular resort in Can Gio, site 3 is a famous tourist beach, while site 4 is a clam farming area, and site 5 is in Can Gio Park's beach.

2.2 Sampling Method

All sand samples were collected in November 2019 in the intertidal zone during the low tides. The sampling area is defined by a 100-meter wide transect that is parallel to the shoreline and stretches from the water-edge line to the upper shoreline. In between these two lines, a middle line separates these two in half. On each line, a 100 m stretch was marked and divided into intervals where sand samples were collected using a 0.25 m^2 quadrat placed at 0, 50th, 100th m position of the stretch (Fig. 2). Materials pushed ashore by waves mainly concentrated in the intertidal zone from the shoreline to the upper shoreline. Therefore, samples collected in this area could represent the microplastics from the ocean (Lots et al. 2017; Eo et al. 2018). The deposition and accumulation of microplastics on the cross-section of the beach by depth are heterogeneous. In each sampling position, two different depths were selected for sand samples at the surface layer (the top 2 cm) and the 5–7 cm layer to investigate the relationship between microplastics and the depth of sand. A total of 9 sampling positions per site, equivalent to 3 quadrats chosen in each line with two depths. Therefore, for each sampling site, there are 18 samples which means, in total, 90 sand samples were collected in this study. The sand sample was randomly scooped by a metal shovel and transferred to a pre-labeled aluminium zip bag. All samples were stored at room temperature and shipped to the laboratory for further analysis.

2.3. Microplastic Analysis

The sand samples were kept at room temperature before being analyzed. All apparatus used in the analytical process was made of glass to avoid airborne microplastic contamination. They all washed and cleaned with alcohol and let dry before using. The sand was well mixed, and approximately 200 g of sand was collected randomly into a petri dish. The sub-sample was then weighed for exact mass and was dried in the oven at 60°C for 24 h or to constant mass, reweigh the sand after drying. A sieving system, including 5 mm and 0.5 mm sieves, was used for sifting the dried sand to limit the size of microplastics in the study. Plastic pieces larger than 5 mm were weighed then investigated. The microplastic analysis is based on the density separation method using salt solutions with a density heavier than that of plastics (Crawford and Quinn 2016; 2017; Li et al. 2020). In this study, a mixture of sodium chloride NaCl and zinc chloride $ZnCl_2$ with a density of 1.5 g/cm^3 was used for floating plastic pieces from beach sand. 500 ml of flotation solution was poured into a sub-sample contained in a beaker. The mixture was then stirred with a glass rod, and it was allowed to settle for 24 hours. The supernatant was collected, and the above process was repeated until no more floating plastic pieces were detected. After that, the supernatant was treated by hydroperoxide H_2O_2 - an oxidizing agent with Fe (II) solution - a catalyst to eliminate organic matters adhered to the suspected microplastics' surface (Crawford and Quinn 2016). The reaction finished when the liquid turned clear. The solids in the beaker were obtained and rinsed with distilled water to remove all excess reactants. Second density separation was applied to obtain microplastics from oxidizing solution, 100 ml of the flotation solution was added into the beaker containing solid from the above step. The mixture was transferred to a glass funnel connected to a rubber hose locked at the end of the tube. They were let to settle overnight with the glass funnel covered by foil. The settled solids from the separator were drained and discarded, while the floating solids were collected by a vacuum filter. They were then rinsed with distilled water and dried for 24 hours at 60°C (Masura et al. 2015). Microplastic physical characteristics were assessed under an "Embedded Systems connecting with Microscopes" (NHV – CAM) for shape, size, and color. They were then classified based on these characteristics and confirmed identity using infrared spectroscopy (FTIR – 4700 type A infrared spectrometer with Accessory Attenuated Total Reflection PRO ONE).

2.4. Quality Assurance And Quality Control

In this study, to determine the recovery efficiency of the microplastic analytical process, plastic pieces of different types and different sizes were prepared for the recovery experiment. Polyethylene terephthalate (PET) d = 1.38 g/mL; polyethylene (PE) d = 0.91–0.94 g/mL; and expanded polystyrene (EPS) d = 0.001–0.003 g/mL are plastics with different density ranges. These plastic samples were derived from disposable daily plastic items such as mineral water bottles (PET), garbage bags (PE), and styrofoam food containers (EPS). For each type, plastic pieces were prepared in two sizes of less than 1 mm and from 1 mm – 5 mm. For each size and type of plastic, 5 pieces were chosen, a total of 30 microplastics participated in the recovery test. The microplastics samples were added to sand and separated as the analytical process. The obtained yield ranged from 83.33–90%, with an average of 88% after three repetitions.

3. Results And Discussion

3.1. Abundance of microplastics

Analysis results show that microplastics were detected at 4 of 5 investigated sites with 42 pieces and the concentrations of microplastics were in the range of 0–6.58 pieces/kg d.w. The average mass of microplastics at sampling sites was also recorded, showing the number from 0 mg/ kg d.w. to 18.66 mg/kg d.w. Table 1 and Fig. 3 indicate the distribution of microplastics in different sites. Site 2 had the highest average abundance of microplastics with 6.58 pieces/ kg d.w, followed by site 1 with 4.49 pieces/ kg.d.w, and site 3 did not show any appearance of microplastics. In terms of microplastics' load, site 1 found the most contaminated with the weight of microplastics found was about 18.66 mg/kg d.w, followed by site 2 with 13.33 mg/ kg.d.w. This study's results were compared to other previous research on microplastics contamination in beach sand (Table 2). The microplastics average concentration of Can

Gio is similar to that of Maldives (22.8 ± 10.5 pieces/m^2) (Saliu et al. 2018) and Taiwan (0.23–30.4 pieces/kg sand) (Walther et al. 2018), especially the concentration of microplastics in the beach sand of the Korean study (1400–62800 pieces/m^2) (Eo et al. 2018) is much higher than this study. Besides, comparing the results to the concentration of microplastics in the Slovenian beach (0.5 ± 0.5 pieces/kg d.w to 1.0 ± 0.8 pieces/kg d.w) (Korez et al. 2019), the data in Can Gio is higher. These studies' results showed that areas with higher microplastic concentration are in areas with residential activities, commercial location, seaports or shallow seas, large tidal ranges, complex shoreline and farming activities, aquaculture (Eo et al. 2018; Saliu et al. 2018; Walther et al. 2018; Zhao et al. 2018).

Table 1 Concentration of microplastics and plastics in beach sand in Can Gio, Ho Chi Minh city, Vietnam in November 2019

Site symbol	Location	Coordinate	Microplastic concentration		Plastic concentration	
			pieces/ kg d.w	mg/ kg d.w	pieces/ kg d.w	mg/ kg d.w
Site1_DHM	Dong Hoa Market	10.376830, 106.879996	4.49	18.66	3.72	2482.3
Site2_PNPR	Phuong Nam Pearl Resort	10.377025, 106.894204	6.58	13.33	5.71	7019.2
Site3_30AB	30th April Beach	10.389663, 106.928722	–	–	1.37	23.6
Site4_AA	Aquaculture area	10.400064, 106.954130	2.37	6.09	3.39	49.5
Site5_CGP	Can Gio Park	10.413471, 106.974338	0.68	0.20	2.76	1408.5

Table 2
Different researches in beach sand in the world in comparison with this study

Reference	Research area	Sampling area’s characteristics	Microplastics concentration
(Walther et al. 2018)	Northern Taiwan	● rocky shore, narrow sandy beach. ● Sampling beaches proximity to industrial zones, residential areas, estuaries, aquaculture zones, and seaports.	0.23–30.4 pieces/kg d.w
(Eo et al. 2018)	South Korea	beaches with different features: ● polluted beach. ● deserted peninsula. ● Port area, residential. The beaches have different geomorphology and tidal regime.	1400–62800 pieces/m^2 (small microplastics) 0–2088 pieces/m^2 (large microplastics)
(Saliu et al. 2018)	Maldives	2 beaches have different characteristics: ● An area has coral, the banks are gentle, shallow, and polluted. ● An area has strong, deep waves, no anthropogenic activities.	22.8 ± 10.5 pieces/m^2
(Korez et al. 2019)	Slovenia	Slovenian beaches	0.5 ± 0.5 pieces/kg d.w to 1.0 ± 0.8 pieces/kg d.w
(Garcés-Ordóñez et al. 2019)	Colombia Caribbean	Ciénaga Grande de Santa Marta mangrove	31–2863 pieces/kg d.w
(Nor and Obbard 2014)	Singapore	Mangrove Ecosystems	60.7 ± 27.2 pieces/kg d.w
(Naji et al. 2019)	Iran	The Iranian mangrove forest is located between the Persian Gulf and the Oman Sea	19.5 ± 6.36 to 34.5 ± 0.71 pieces/kg d.w
(Zhou et al. 2020)	China	China's Southeast mangroves	8.3–5738.3 pieces/kg d.w
This study, 2019	Vietnam	Sac Mangrove	0 to 6.58 pieces/kg d.w (0–26.32 pieces/ m^2)

Can Gio beach is affected by the sedimentation because Dong Tranh river flowing from Sac mangrove carries alluvium, dead plants, and garbages. The average concentration of microplastics in this study was compared to some similar studies. The results show that microplastics in Can Gio have lower concentration(Garcés-Ordóñez et al. 2019; Zhou et al. 2020). The distribution of microplastics in beach sand in this study can be explained as Can Gio location in the funnel-shaped area on the estuary of Dong Nai river, which is also the intersection area between rivers and the sea. Therefore, plastic wastes and microplastics can be transported from the Sac mangrove as well as from rivers. There are many wharves and local markets along the rivers, so this is also a potential microplastics' source (Critchell and Lambrechts 2016; de Jesus Piñon-Colin et al. 2018). Besides that, erosion frequently happens in Can Gio, leading to microplastics hardly accumulate along the coastline. In addition, the beach sand here is fine, combining with alluvial and clay with small grain size (1 μm – 62.5 μm) (2017) and compact. Therefore, larger pieces of microplastics are not easy to accumulate according to depth. Can Gio is a suburban agricultural district, despite its large area but low population density, mainly living by growing rice, fruit trees, salt making, and aquaculture, tourism activities such as swimming is not much, so this can be an explanation for the low concentration of microplastics in Can Gio compared to other studies. The reasons for this distribution of microplastics are also discussed in the studies by O. Garcés-Ordóñez in Colombia (Garcés-Ordóñez et al. 2019) or in the Singapore mangrove forest (Nor and Obbard 2014), distribution and concentration of microplastics are influenced by population density and sea currents.

The effect of Can Gio characteristics on microplastics concentration at the sampling sites can be explained as follows: site 1 is the intersection between Dong Tranh River and Can Gio sea, located near Dong Hoa market, this is the place receiving the ruins from the Sac mangrove as well as on this river plus the market is populated, these are probably the sources of plastic and microplastics emissions that lead to the highest concentration of microplastics here accounting for 48.73% of the total number of microplastics found (4.49 pieces/kg d.w or 18.66 mg/kg d.w). Site 2 is located right next to Phuong Nam Pearl Resort, one of Can Gio's most famous tourist resorts. The plastic waste found here is mainly the styrofoam boxes, plastic instant noodle cups, spoons, forks, plastic straws also partly reflect the origins of plastics and microplastics. Site 3 is April 30th beach, the most famous beach in Can Gio, located in the middle of Can Gio coastline. Compared to other sites where stone embarkments are built with a 100 m distance along the coast to prevent erosion since April 30th beach is a tourist attraction. Therefore, this area has no such construction, leading to waves usually climb up the coast, destroying the coastal dunes, causing erosion. In addition, in recent years, volunteer beach cleaning campaigns are regularly held in this area, so this may be the reason why the concentration of microplastics here is the lowest. Site 4 is a clam aquaculture area, which located near Ghenh Rai Bay. Microplastics found there mostly were in the form of fibers like the fishing gears. The source of plastic and microplastic emissions can be from coastal aquaculture and received from sea waves. Site 5 is Can Gio Park - the area receiving wastes flowing out of the Ghenh Rai Bay and swimming activities. Plastic wastes found have similarities with site 2, such as sausage packaging, instant noodles container. This site was offered many beach cleaning activities, leading to the concentration of microplastics was low (0.68 pieces/kg d.w). In conclusion, the source of microplastics of the sampling sites in Can Gio could be from livelihood activities, aquaculture, coastal tourism, and waste receiving from Dong Tranh river and Ghenh Rai bay, as well as the waves washed ashore.

All microplastics were found at the upper-shore line. If only assess the distribution of microplastics at the upper-shore line, the highest concentration of microplastics can be 19.74 pieces /kg d.w at site 2. In total, there were 30 sand samples collected at the upper-shore line, 6 sand samples showing microplastics detected. The t-test showed a significant difference in the concentration of microplastics at this tidal line (p-value < 0.05). The method of determining the sampling location was different in each research. Samples can be collected along the upper-shore line where a lot of plastic wastes accumulated (Young and Elliott 2016; de Jesus Piñon-Colin et al. 2018) or in the middle of the intertidal zone (Walther et al. 2018) or along the water-edge line and the upper-shore line (Eo et al. 2018). The number of sand samples collected in each study was different but ranged from 1 to 12 sand samples/site (Young and Elliott 2016; de Jesus Piñon-Colin et al. 2018; Eo et al. 2018; Walther et al. 2018). The number of sand samples and sampling position can affect the reliability of the study (Besley et al. 2017). According to Besley, among 22 studies on beach sand were compared, the results show that the sampling process is optimal when the number of sand samples collected per 100 m of each tidal line is from 3 to 5 positions, depending on the desired reliability. In this study, Fig. 4 shows that most of the detected microplastics distributed in the surface layer of sand (0–2 cm) accounted for 83.3% of the total microplastics. Only 1 sample of site 2 reported the presence of microplastics at 5 cm depth. There is no consensus on sand sampling depth in published research. A number of studies collected one surface sand layer from 2 to 5 cm thickness (de Jesus Piñon-Colin et al. 2018; Eo et al. 2018; Li et al. 2018). Other studies have examined the distribution of microplastics by depth (Young and Elliott 2016; Besley et al. 2017; Walther et al. 2018), the results preliminarily interpreted that the distribution of microplastics in beach sand at different depths is heterogeneous and featured for each study area, but microplastics tend to accumulate in the sand layers closer to the surface. Thus, the distribution of microplastics in beach sand in Can Gio was pretty similar to other published researches.

3.2. Physical Characteristics

The study focused on microplastics with a size from 0.5–5 mm. The size of microplastics was classified into three ranges from 0.5 to 1 mm, from 1 mm to 2.8 mm, and 2.8 mm to 5 mm. Figure 5 shows that microplastics with the size from 2.8 to 5 mm accounted for the highest percentage, with 71.46% on average. Microplastics with the size of 1 to 2.8 mm show the smallest percent, especially in site 5, with no appearance of microplastics with this size range. Microplastics smaller than 1 mm were often found as secondary microplastics fragmented from larger plastic such as filament or fragmented pieces found in sand samples.

Three shapes of microplastics found are fragment, fiber, and pellet (Fig. 5). Among the four sites detecting microplastics, sites 1 and 4 showed the highest concentration of fragmented microplastics, with 2.86 pieces/kg d.w (63.64% of the total microplastics of site 1) and 1.35 pieces/kg d.w (57.14% of the total microplastics of site 4). In site 2, pellet was dominant with 59.76% equivalent to 3.93 pieces/kg d.w. In total, pellets and fragments accounted for the highest percent, 41.31%, and 38.5%, respectively. Compared with other studies, the distribution of microplastics in this study is similar to those published in Singapore (Nor and Obbard 2014) or the Maldives (Saliu et al. 2018), fragmented microplastics showed a significant proportion while fibrous microplastics accounted for the smallest percentage. The shape of microplastics related to their sources which are primary or secondary. For example, a high percentage of the fiber found in the sampling sites was associated with the effluent discharge because the fibrous microplastics were correlated with the effluent output when the wash-holding process was identified as the primary source of microfiber. The distribution of thin-film microplastics could result from the transport of nearby salt fields or the fragmentation of plastic mulch used in horticulture (de Jesus Piñon-Colin et al. 2018). More than 93% of microplastics in the beach sands and sea sediments of mangroves are fragmented, predicting the origin of microplastics as secondary sources from large plastic fragments (Zhou et al. 2020). These conclusions are relatively appropriate with the proportion of microplastic shapes due to different anthropogenic activities of the sampling sites. Besides, the impacts of other pollutants and environmental processes also affect the appearance of microplastics. Microplastics found in coastal areas can have a basic shape or deformation due to erosion, solar radiation, or biodegradation (Zhou et al. 2020). The basic shapes are discharged directly as primary microplastics such as pellets, granules, and spheres. Others are caused mainly by the decomposition of plastic items (secondary source), consisting of fibers and unspecified shapes. During cracking, the surface morphologies of plastic can change significantly because of erosion and cover by organisms (Imhof et al. 2013). Differences in surface morphologies relate to the longevity in the environment, physical and chemical properties of the plastic, and other environmental characteristics. Therefore, in order to get more insights into the origin of microplastics, in this research, besides monitoring microplastics in beach sand, macroplastics in the same sample, such as foam boxes, disintegrating polystyrene, or small pieces of plastic broken down from the rope, were also studied.

Microplastics with colors white, blue, green were mainly found, and the results show that white and blue were two dominant colors in this study (Fig. 5) with the percentage of 39.09% and 39.94%, respectively. Blue microplastics were detected at most among sampling sites. Its concentration ranged from 0.68 pieces/kg d.w to 2.65 pieces/kg d.w. Only sites 1 and 4 observe green microplastics with almost the same percentage (27% and 29 %). Site 5 only observes blue microplastics' appearance, which can come from the fragmentation of the plastic ropes used to tie the sandbags to prevent corrosion along the coastline. The shape of white microplastics found in site 1 was pellets that if they were observed closer, their surfaces were intact and smooth, possibly primary microplastics. However, the white microplastics found in site 2 are fragments, shards from styrofoam (Expanded polystyrene). Microplastics with similar colors were detected in other studies, such as in Taiwan research (Walther et al. 2018); 60% of the microplastics were white and translucent. White is also a common color for styrofoam fragments found in a mangrove in China (Zhou et al. 2020), while green (23.1%) and blue (19.2%) were two common colors with fibrous microplastics, blue fibrous microplastics accounting for 34.7%. Some other studies also showed the diversity of microplastics. For instance, in Iran's mangroves, black, blue, and white were the most common colors, with the highest percentage is black at 41% (Naji et al. 2019).

3.3. Chemical Composition

Microplastics were confirmed the identity by using FTIR-ATR. The microplastics selected for chemical composition confirmation must satisfy the condition that they represent a group of microplastics from the same sand sample with the same color, size, shape, and similar surface morphology. In this study, polypropylene (PP), polyethylene (PE), and polystyrene (PS) were found, PE accounted for the lowest percentage with 25.69% compared to PP (32%) and PS (42.31%) (Fig. 6). PP microplastics appeared in all sampling sites, accounted for 4.55–100% of each site (from 0.34 to 2.64 pieces/kg d.w). PS was dominant in site 2, which is the tourist area with 59.09% equivalent to 4.40 pieces/kg d.w. There was only the presence of PP in site 5, other sampling sites showed all three types of plastic, with different distribution of each site. In site 1, PP was the plastic type that accounted for the majority of microplastics with 64%, and PE was the one with the lowest proportion with 9% in site 1. Site 2 showed the dominance of PS with 59%, which can be explained since most of the microplastic pieces obtained there were fragmentation from styrofoam packaging. Site 4 reported that PP was the most popular plastic type with 41%, whereas PS and PE shared the same proportion. In general, PS was detected near the tourist attraction area without regular cleaning activities. PP and PE were popular in the aquaculture location or near the market; the origin was usually plastic ropes or packaging. The data showed that the microplastics' shape and their composition are related. From the results of this study, most of pellet microplastics were PS and they were in white color. Meanwhile, the fragmented and fibrous shapes were either PP or PE (Fig. 7).

3.4. Interpretations Of Microplastics Origin In Sand Samples

Besides investigating the presence of microplastics in sand samples, the distribution of macroplastic pieces was also assessed to interpret the relationship between them. Macroplastic wastes found in all sampling sites with an average concentration range from 1.37 pieces/kg d.w (site 3) to 5.71 pieces/kg d.w (site 2) (Fig. 3). The mass of macroplastic waste was quite large, up to 7019.2 mg/kg d.w (site 2). The concentration of macroplastic was compared to the corresponding concentration of microplastics, showing a similarity in all sampling sites. Macroplastic were mostly detected in a 2 cm surface layer of sand with 87.29%. In addition, the distribution of macroplastics at three sampling tide lines was similar to microplastics' distribution, 76.34% of macroplastics found at the upper-shore line. White macroplastics accounted for the highest percentage with 33.79%, followed by green and transparent with 22.71% and 18.17%, respectively. Transparent macroplastics, possibly due to the fragmentation of plastic bags, were not found as microplastics. On the other hand, blue was still the color found in all sites with 15.51%. Macroplastics were also identified by FTIR-ATR and the result showed that PP was the plastic type showing the highest percentage with 46.99%, followed by 35.33% of PE, PS accounted for only 17.67%. PP, PE, and PS are also three popular plastic types used in everyday life. Macroplastics in the sand samples were mainly plastic bags, confectionery packaging, spoons, and forks. These are common items found on the beach that has anthropogenic activities. They are mostly made from PP and PE, explaining for the higher proportion of them. The PS pieces found were mostly styrofoam packaging, which may be the source of the corresponding microplastics in the same sand sample. PS was observed with the highest percentage at site 2 with 39.59% - this is also the sampling area with the highest PS microplastic concentration.

The preliminary origin of the microplastics was predicted based on the shape, color, and composition of the microplastics and macroplastics found in the same sand sample. As in some sand samples of site 1, microplastics had a cylinder shape with a smooth surface. These pieces were created in such an original shape and identified as resin pellets, which were the raw material for manufacturing plastic products. These microplastics were diagnosed to be brought ashore by ocean waves due to leakage during transportation. Meanwhile, in some sand samples, microplastics were found in fragmented or fibrous shapes. They had the same color, composition, and surface morphologies as some of the macroplastics. These microplastics can be created secondarily due to environmental degradation from larger pieces (Fig. 8). Pearson correlation coefficient was calculated to conclude the relationship between microplastics and macroplastic wastes in color and chemical composition. The results show a positive correlation of average concentration of white macroplastic and white microplastic at the corresponding sites. Concentrations of microplastic and microplastic with PP or PS composition also showed correlation. Therefore, microplastics were possibly degraded from macroplastics of the same sand sample with similar characteristics or composition (Fig. 9).

Out of the five sampling sites, sites 1, 2, and 4 had a higher concentration of microplastics and macroplastics. It can be explained that site 1 located behind Dong Hoa market, where received flows from the Dong Tranh river, carried the remnants of the Sac mangrove while site 2 was the location next to Ngoc Phuong Nam tourist, the plastic wastes here were mainly single-use products such as foam packaging, plastic cups. Site 4 is the aquaculture area that observed the presence of agricultural tools. Whereas sites 3 and 5 had a much lower microplastic concentration compared to other areas. Common characteristics of these places were tourist destinations, frequently visited by tourists and residents. However, these places often have beach cleaning campaigns, resulting in a small number of plastic wastes. In addition, sites 1, 2, and 4 were constructed with stone embankments to prevent erosion, leading to more microplastic accumulation than other sites. The results showed some similarities to the research in the same region: Tien Giang and Vung Tau (Hien et al. 2020). Microplastics in both investigations shared some common characteristics in terms of the distribution, the chemical composition of the plastic. These study areas had similar characteristics of wind regime, tidal regime, and received the currents of Dong Nai River, Saigon River. Therefore, researches on the effect of marine dynamics on microplastics migration should be investigated further for more insights into the fate of microplastics in the environment.

4. Conclusions

From the results of the study on five beaches along Can Gio coast, some conclusions shown:

● Microplastics were detected in four of five sampling areas with different concentrations. The distribution of microplastics on the coast of Can Gio can be explained by coastal morphologies, wind regime, waves, and coastal anthropogenic activities.

● 83.3% of microplastics concentrated mainly in the 2 cm surface layer of sand. All the microplastics found in this study concentrated in the upper-shore line.

● Microplastics with sizes from 2.8 to 5 mm were found most in the sampling areas. Pellet shape accounted for the majority of the number of microplastics. White and blue were the two colors that made up a large proportion.

● The typical chemical compositions of the microplastics include PP, PE, and PS. PS and PP accounted for the majority of the microplastics. The results showed that pellet microplastics mostly were PS composition; other shapes were PP or PE.

● The distributions of microplastics and macroplastic were correlated.

● Our study opened a premise of the investigation on the origin of microplastics in this sea area and the hydrodynamics of Can Gio sea to get more insights into microplastic migration.

5. Declarations

Ethics approval

The authors confirm that the manuscript has been read and approved by all authors. The authors declare that this manuscript has not been published and not under consideration for publication elsewhere.

Consent to participate

The authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

Consent for publication

The authors consent to publish this research.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no conflict of interest.

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Authors' contributions

Nguyen Thi Thanh Nhon: Conceptualization; methodology; investigation; data curation; writing, review, and editing
Nguyen Thao Nguyen: Investigation; data curation; review
Ho Truong Nam Hai: Investigation; data curation
To Thi Hien: Conceptualization; methodology; review, and editing; supervision; and funding acquisition

All authors read and approved the final manuscript.

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6. References

1. Al-Malaika S, Axtell F, Rothon R, Gilbert M (2017) Additives for Plastics
2. Auta HS, Emenike CU, Fauziah SH (2017) Screening of Bacillus strains isolated from mangrove ecosystems in Peninsular Malaysia for microplastic degradation. Environ Pollut 231:1552–1559
3. Bergmann M, Gutow L, Klages M (2015) Marine anthropogenic litter. Mar Anthropog Litter 1–447. https://doi.org/10.1007/978-3-319-16510-3
4. Besley A, Vijver MG, Behrens P, Bosker T (2017) A standardized method for sampling and extraction methods for quantifying microplastics in beach sand. Mar Pollut Bull 114:77–83
5. Chan HT, Cohen M (2014) Studies in Can Gio Mangrove Biosphere Reserve, Ho Chi Minh City, Vietnam. Mangrove Syst Tech Reports Vol 6 75
6. Chenillat F, Huck T, Maes C, et al (2021) Fate of floating plastic debris released along the coasts in a global ocean model. Mar. Pollut. Bull. 165
7. Claessens M, De Meester S, Van Landuyt L, et al (2011) Occurrence and distribution of microplastics in marine sediments along the Belgian coast. Mar Pollut Bull 62:2199–2204
8. Cole M, Lindeque P, Halsband C, Galloway TS (2011) Microplastics as contaminants in the marine environment: a review. Mar Pollut Bull 62:2588–2597
9. Crawford CB, Quinn B (2016) Microplastic Pollutants

10. Critchell K, Lambrechts J (2016) Modelling accumulation of marine plastics in the coastal zone; what are the dominant physical processes? Estuar Coast Shelf Sci 171:111–122
11. de Jesus Piñon-Colin T, Rodriguez-Jimenez R, Pastrana-Corral MA, et al (2018) Microplastics on sandy beaches of the Baja California Peninsula, Mexico. Mar Pollut Bull 131:63–71
12. Dekiff JH, Remy D, Klasmeier J, Fries E (2014) Occurrence and spatial distribution of microplastics in sediments from Norderney. Environ Pollut 186:248–256
13. Digka N, Tsangaris C, Torre M, et al (2018) Microplastics in mussels and fish from the Northern Ionian Sea. Mar Pollut Bull 135:30–40
14. Eo S, Hong SH, Song YK, et al (2018) Abundance, composition, and distribution of microplastics larger than 20 $µ$m in sand beaches of South Korea. Environ Pollut 238:894–902
15. Everaert G, De Rijcke M, Lonneville B, et al (2020) Risks of floating microplastic in the global ocean. Environ Pollut 267:. https://doi.org/10.1016/j.envpol.2020.115499
16. Garcés-Ordóñez O, Castillo-Olaya VA, Granados-Briceño AF, et al (2019) Marine litter and microplastic pollution on mangrove soils of the Ciénaga Grande de Santa Marta, Colombian Caribbean. Mar Pollut Bull 145:455–462
17. Geyer R, Jambeck JR, Law KL (2017) Production, use, and fate of all plastics ever made. Sci Adv 3:e1700782
18. Hannah Ritchie and Max Roser (2018) Plastic Pollution. In: Our World Data. https://ourworldindata.org/plastic-pollution. Accessed 28 May 2021
19. Hien TT, Nhon NTT, Thu VTM, et al (2020) The Distribution of Microplastics in Beach Sand in Tien Giang Province and Vung Tau City, Vietnam. J Eng Technol Sci 52:
20. Hu Y, Gong M, Wang J, Bassi A (2019) Current research trends on microplastic pollution from wastewater systems: a critical review. Rev Environ Sci Biotechnol 18:207–230. https://doi.org/10.1007/s11157-019-09498-w
21. Imhof HK, Ivleva NP, Schmid J, et al (2013) Contamination of beach sediments of a subalpine lake with microplastic particles. Curr Biol 23:R867–R868
22. Korez Š, Gutow L, Saborowski R (2019) Microplastics at the strandlines of Slovenian beaches. Mar Pollut Bull 145:334–342. https://doi.org/10.1016/j.marpolbul.2019.05.054
23. Lahens L, Strady E, Kieu-Le T-C, et al (2018) Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. Environ Pollut 236:661–671
24. Lambert S, Sinclair C, Boxall A Occurrence , Degradation , and Effect of Polymer-Based Materials in the Environment
25. Le Nguyen HT, Luong HPV (2019) Erosion and deposition processes from field experiments of hydrodynamics in the coastal mangrove area of Can Gio, Vietnam. Oceanologia 61:252–264
26. Lebreton L, Slat B, Ferrari F, et al (2018) Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Sci Rep 8:1–15. https://doi.org/10.1038/s41598-018-22939-w

27. Lebreton LCM, Van Der Zwet J, Damsteeg JW, et al (2017) River plastic emissions to the world's oceans. Nat Commun 8:1–10. https://doi.org/10.1038/ncomms15611
28. Lee J, Hong S, Song YK, et al (2013) Relationships among the abundances of plastic debris in different size classes on beaches in South Korea. Mar Pollut Bull 77:349–354
29. Leslie HA, Brandsma SH, Van Velzen MJM, Vethaak AD (2017) Microplastics en route: Field measurements in the Dutch river delta and Amsterdam canals, wastewater treatment plants, North Sea sediments and biota. Environ Int 101:133–142
30. Li J, Zhang H, Zhang K, et al (2018) Characterization, source, and retention of microplastic in sandy beaches and mangrove wetlands of the Qinzhou Bay, China. Mar Pollut Bull 136:401–406
31. Li P, Wang X, Su M, et al (2020) Characteristics of Plastic Pollution in the Environment: A Review. Bull Environ Contam Toxicol. https://doi.org/10.1007/s00128-020-02820-1
32. LI WC, Tse HF, Fok L (2016) Plastic waste in the marine environment: A review of sources, occurrence and effects. Sci Total Environ 566:333–349
33. Lots FAE, Behrens P, Vijver MG, et al (2017) A large-scale investigation of microplastic contamination: abundance and characteristics of microplastics in European beach sediment. Mar Pollut Bull 123:219–226
34. Masura J, Baker JE, Foster GD, et al (2015) Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments
35. Mathalon A, Hill P (2014) Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Mar Pollut Bull 81:69–79
36. Mỹ TTÁ, Dũng PT (2020) Analytical conditions for determination of microplastics in fish. Hue Univ J Sci Nat Sci 129:85–92. https://doi.org/10.26459/hueuni-jns.v129i1c.5822
37. Naji A, Nuri M, Amiri P, Niyogi S (2019) Small microplastic particles (S-MPPs) in sediments of mangrove ecosystem on the northern coast of the Persian Gulf. Mar Pollut Bull 146:305–311
38. NOAA (2021) What are microplastics? https://oceanservice.noaa.gov/facts/microplastics.html. Accessed 14 May 2021
39. Nor NHM, Obbard JP (2014) Microplastics in Singapore's coastal mangrove ecosystems. Mar Pollut Bull 79:278–283
40. Praveena SM, Shaifuddin SNM, Akizuki S (2018) Exploration of microplastics from personal care and cosmetic products and its estimated emissions to marine environment: An evidence from Malaysia. Mar Pollut Bull 136:135–140. https://doi.org/10.1016/j.marpolbul.2018.09.012
41. Reed S, Clark M, Thompson R, Hughes KA (2018) Microplastics in marine sediments near Rothera research station, Antarctica. Mar Pollut Bull 133:460–463
42. Saliu F, Montano S, Garavaglia MG, et al (2018) Microplastic and charred microplastic in the Faafu Atoll, Maldives. Mar Pollut Bull 136:464–471

43. Sharma S, Chatterjee S (2017) Microplastic pollution, a threat to marine ecosystem and human health: a short review. Environ Sci Pollut Res 24:21530–21547
44. Sighicelli M, Pietrelli L, Lecce F, et al (2018) Microplastic pollution in the surface waters of Italian Subalpine Lakes. Environ Pollut 236:645–651
45. Song YK, Hong SH, Jang M, et al (2015) A comparison of microscopic and spectroscopic identification methods for analysis of microplastics in environmental samples. Mar Pollut Bull 93:202–209
46. Thompson RC (2006) Plastic debris in the marine environment: consequences and solutions. Mar Nat Conserv Eur 193:107–115
47. Tran Nguyen QA, Nguyen HNY, Strady E, et al (2020) Characteristics of microplastics in shoreline sediments from a tropical and urbanized beach (Da Nang, Vietnam). Mar Pollut Bull 161:. https://doi.org/10.1016/j.marpolbul.2020.111768
48. Vianello A, Boldrin A, Guerriero P, et al (2013) Microplastic particles in sediments of Lagoon of Venice, Italy: First observations on occurrence, spatial patterns and identification. Estuar Coast Shelf Sci 130:54–61
49. Walther BA, Kunz A, Hu C-S (2018) Type and quantity of coastal debris pollution in Taiwan: A 12-year nationwide assessment using citizen science data. Mar Pollut Bull 135:862–872
50. Wang F, Wang B, Duan L, et al (2020) Occurrence and distribution of microplastics in domestic, industrial, agricultural and aquacultural wastewater sources: A case study in Changzhou, China. Water Res 182:115956. https://doi.org/10.1016/j.watres.2020.115956
51. Young AM, Elliott JA (2016) Characterization of microplastic and mesoplastic debris in sediments from Kamilo Beach and Kahuku Beach, Hawai'i. Mar Pollut Bull 113:477–482
52. Yu X, Peng J, Wang J, et al (2016) Occurrence of microplastics in the beach sand of the Chinese inner sea: the Bohai Sea. Environ Pollut 214:722–730
53. Yukioka S, Tanaka S, Nabetani Y, et al (2020) Occurrence and characteristics of microplastics in surface road dust in Kusatsu (Japan), Da Nang (Vietnam), and Kathmandu (Nepal). Environ Pollut 256:. https://doi.org/10.1016/j.envpol.2019.113447
54. Zhao J, Ran W, Teng J, et al (2018) Microplastic pollution in sediments from the Bohai Sea and the Yellow Sea, China. Sci Total Environ 640:637–645
55. Zhou Q, Tu C, Fu C, et al (2020) Characteristics and distribution of microplastics in the coastal mangrove sediments of China. Sci Total Environ 703:134807
56. (2017) Characterization and Analysis of Microplastics

Figures

Figure 1

Five sampling sites of beach sand on Can Gio coast, Ho Chi Minh City, in November 2019 (Site1_DHM: Dong Hoa Market, Site 2_PNPR: Phuong Nam Pearl Resort, Site 3_30AB: 30th April Beach, Site4_AA: Aquaculture area, Site5_CGP: Can Gio Park)

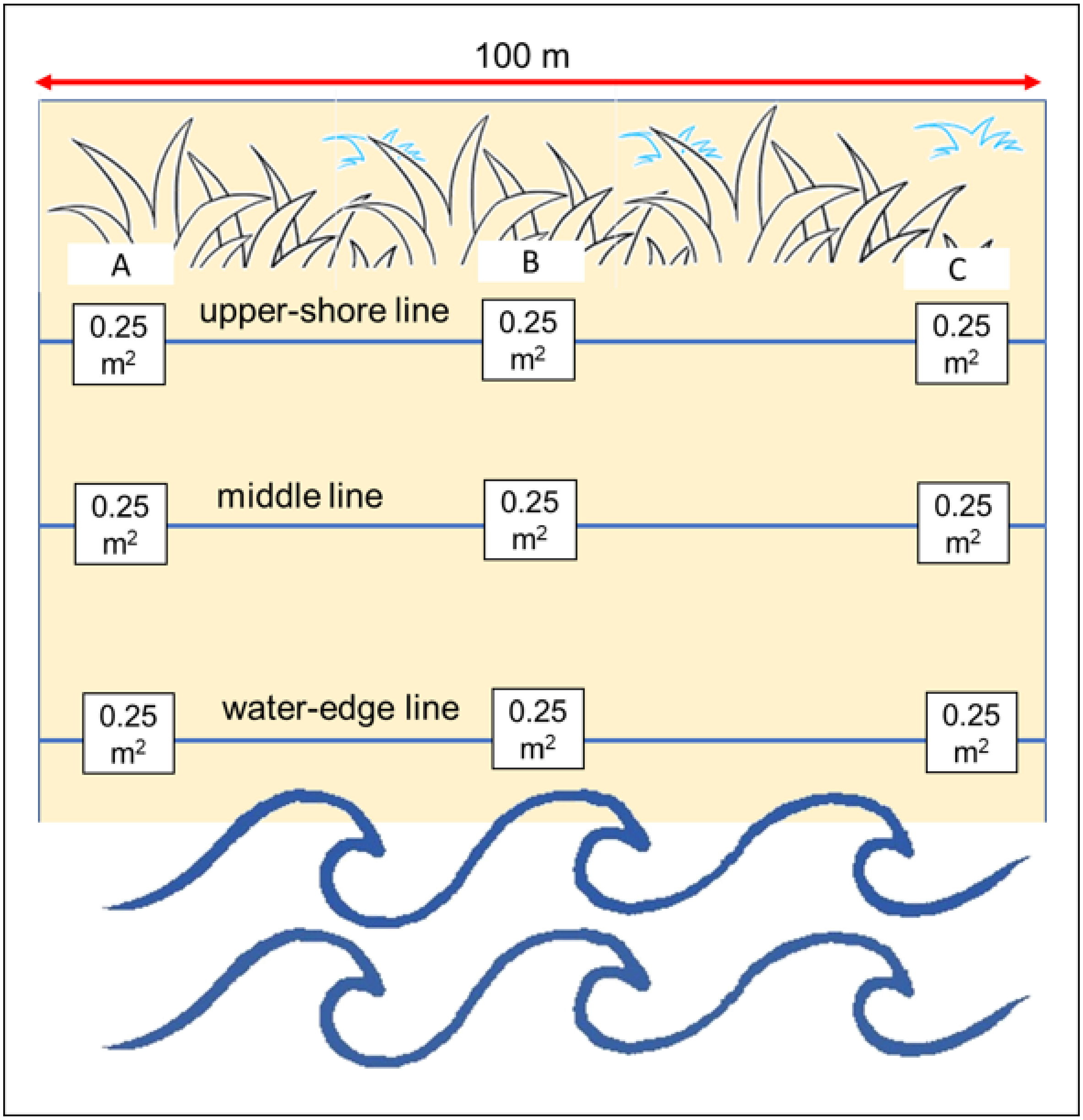


Figure 2

Sampling points on Can Gio coast, Ho Chi Minh City, Vietnam, in November 2019

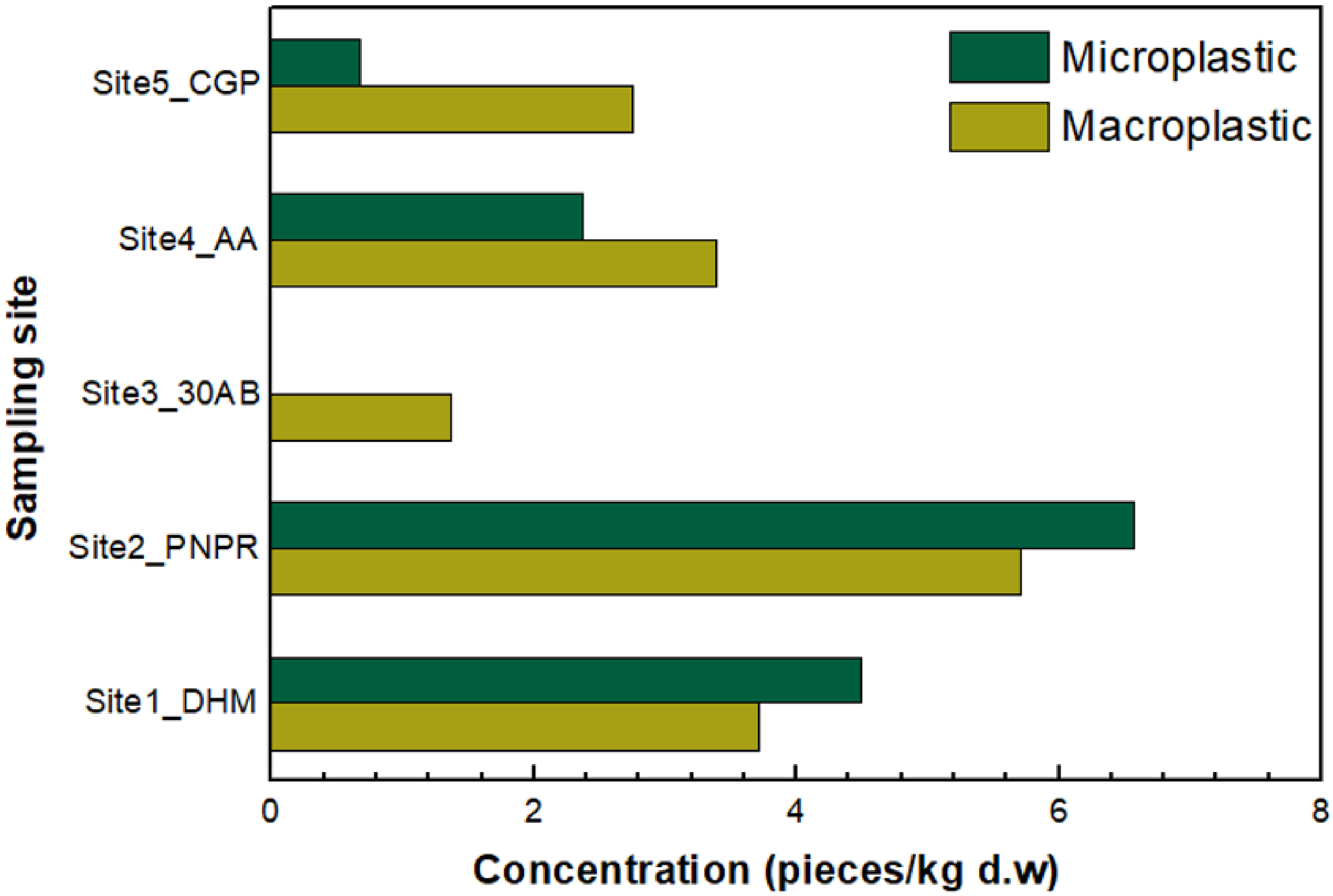


Figure 3

Concentration of microplastics and plastics in each sampling site on Can Gio coast, Ho Chi Minh city in November 2019

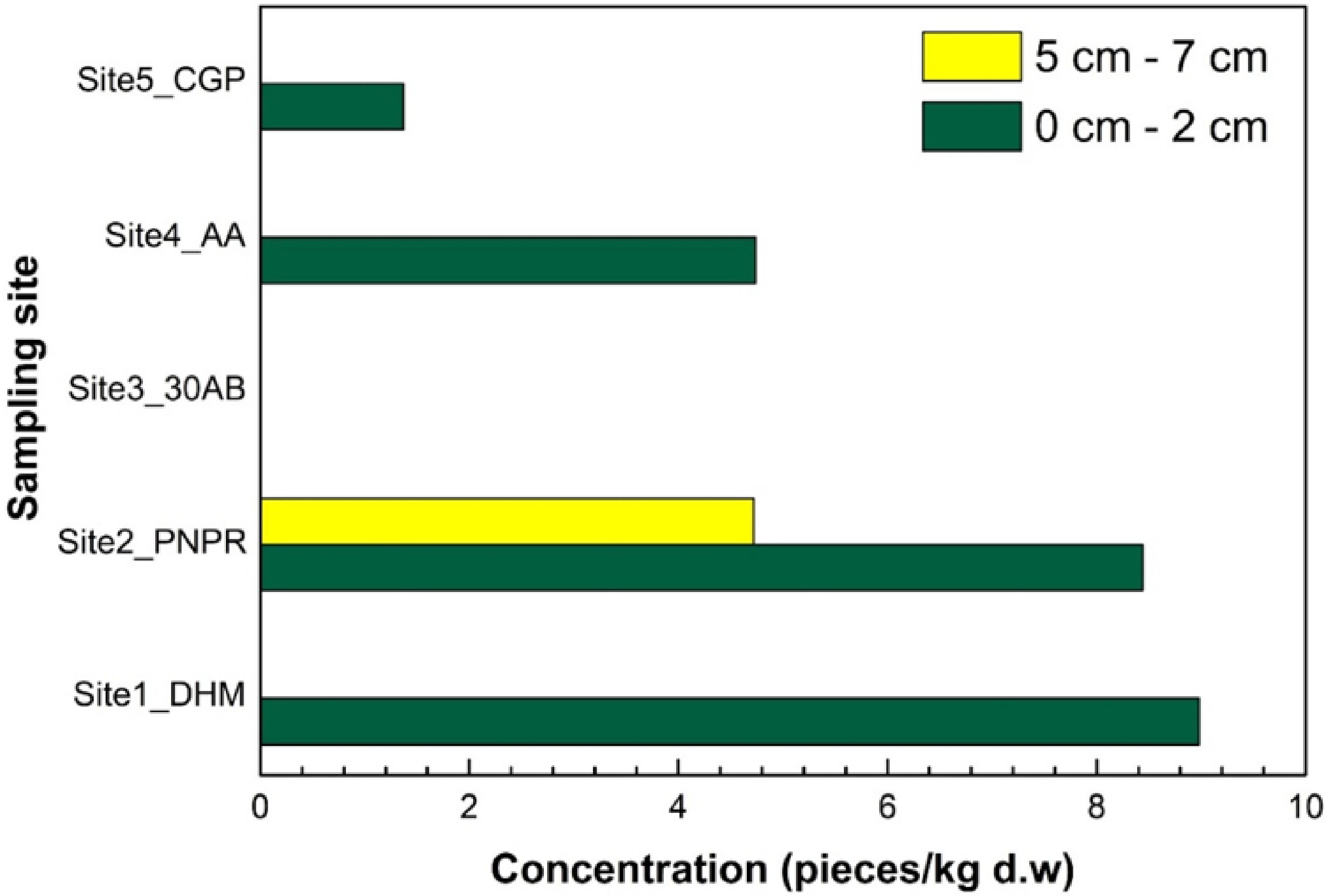


Figure 4

Distribution by depth of microplastics in beach sand on Can Gio coast, Ho Chi Minh city in November 2019

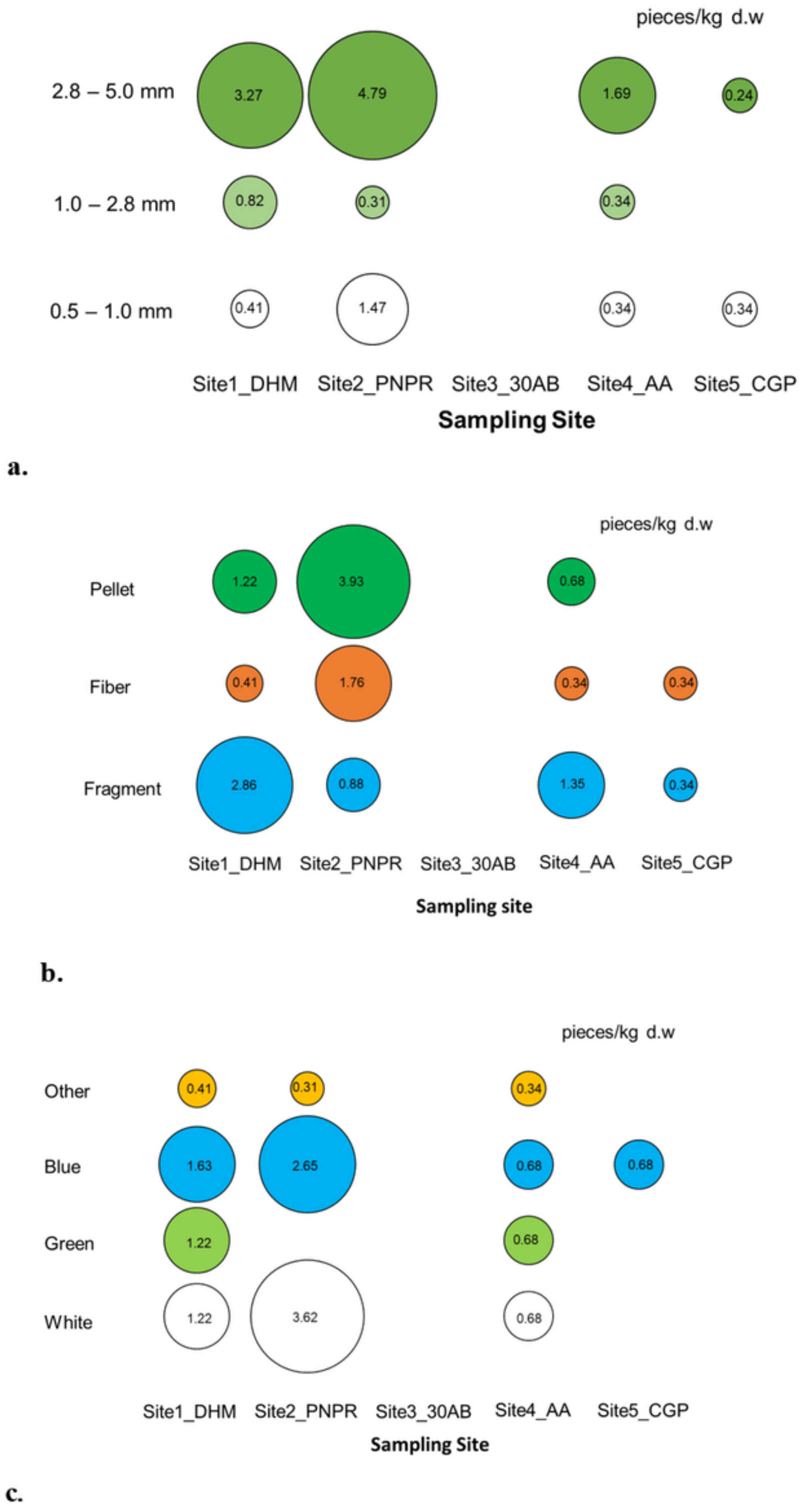


Figure 5

Physical characteristics of microplastics in beach sand of this study (a. distribution by size; b. distribution by shape; c. distribution by color)

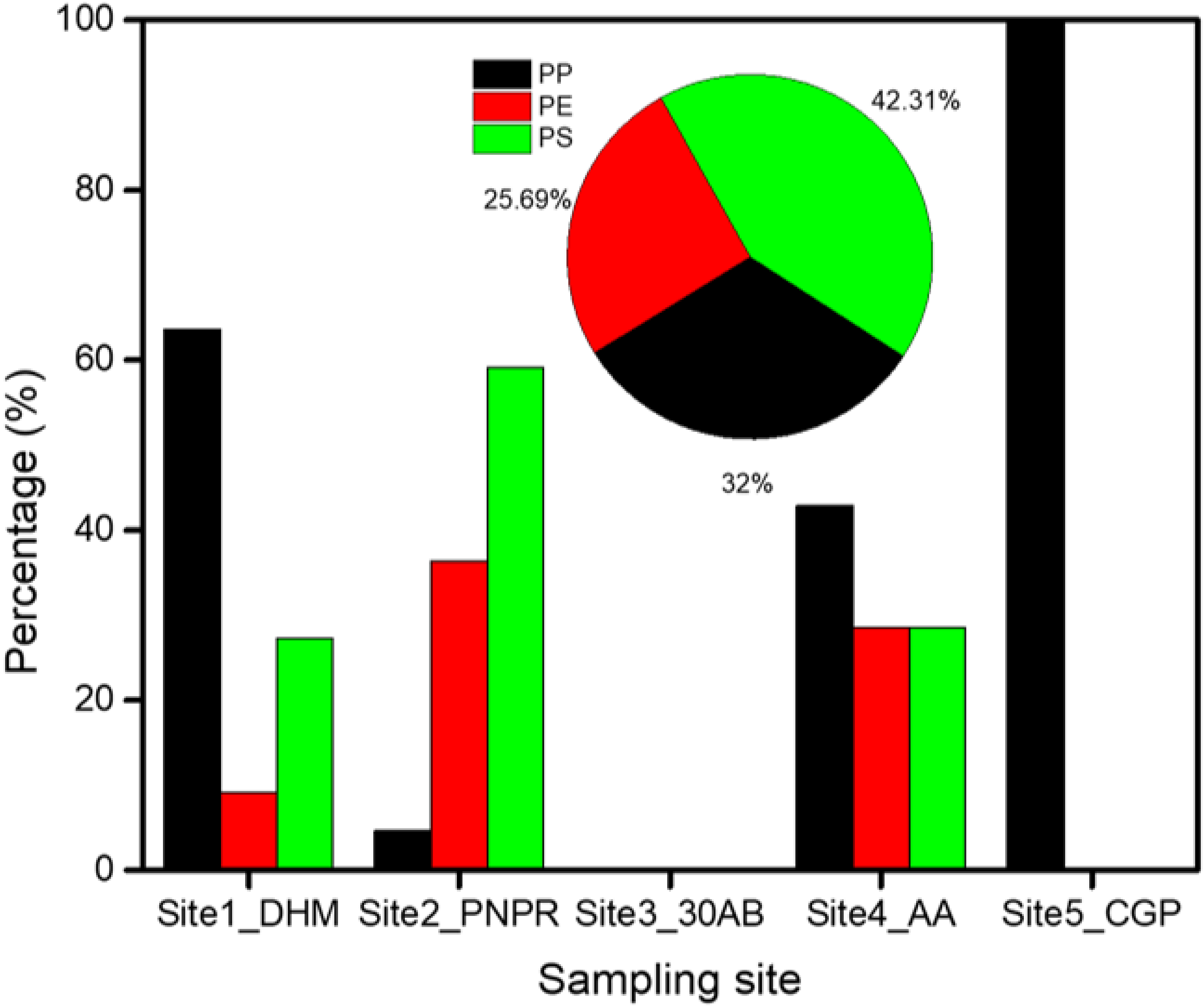


Figure 6

Distribution by chemical composition of microplastics in beach sand of this study

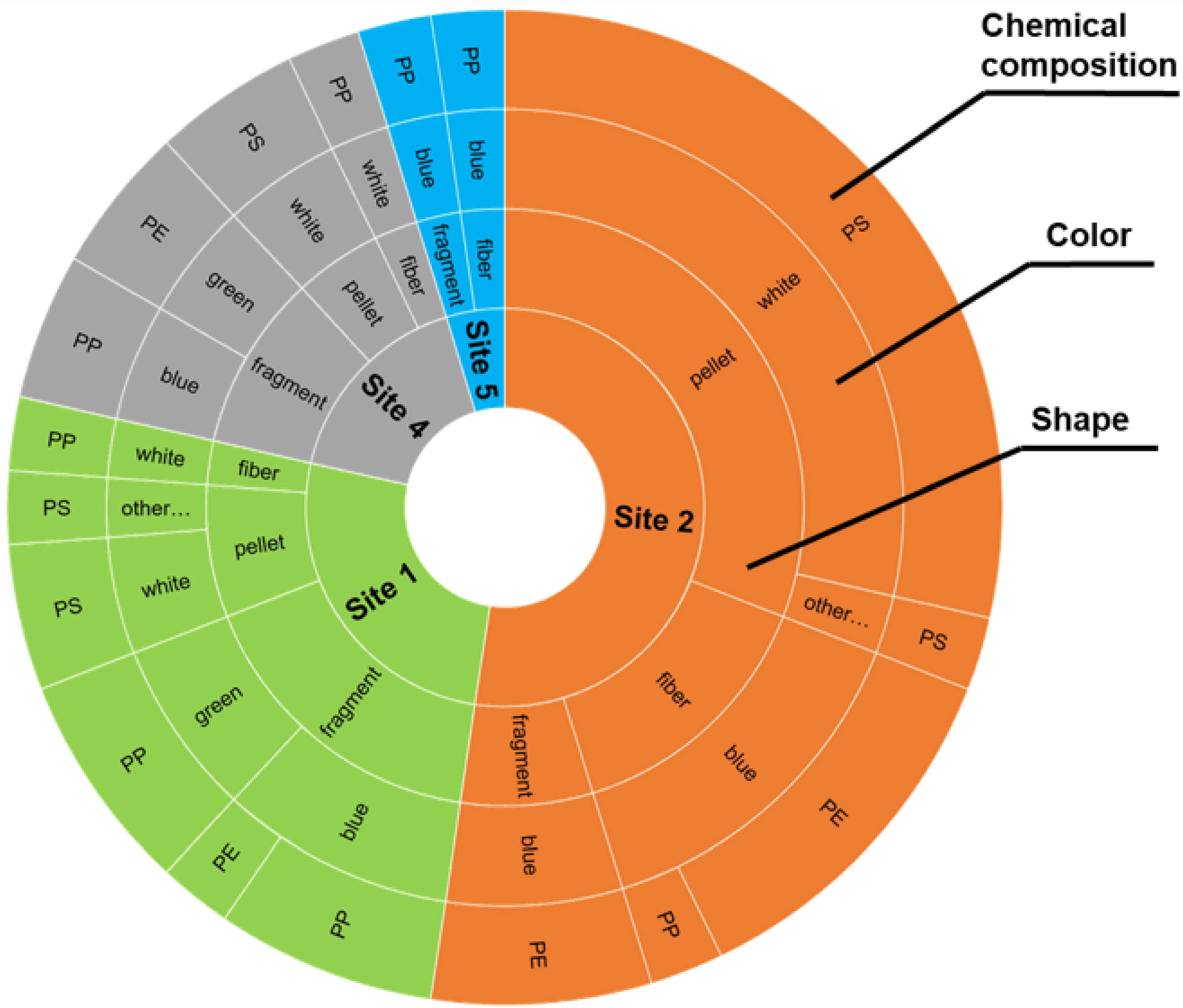


Figure 7

Distribution of chemical composition, shape, and color of microplastics in beach sand in Can Gio, Ho Chi Minh City, Vietnam in November 2019

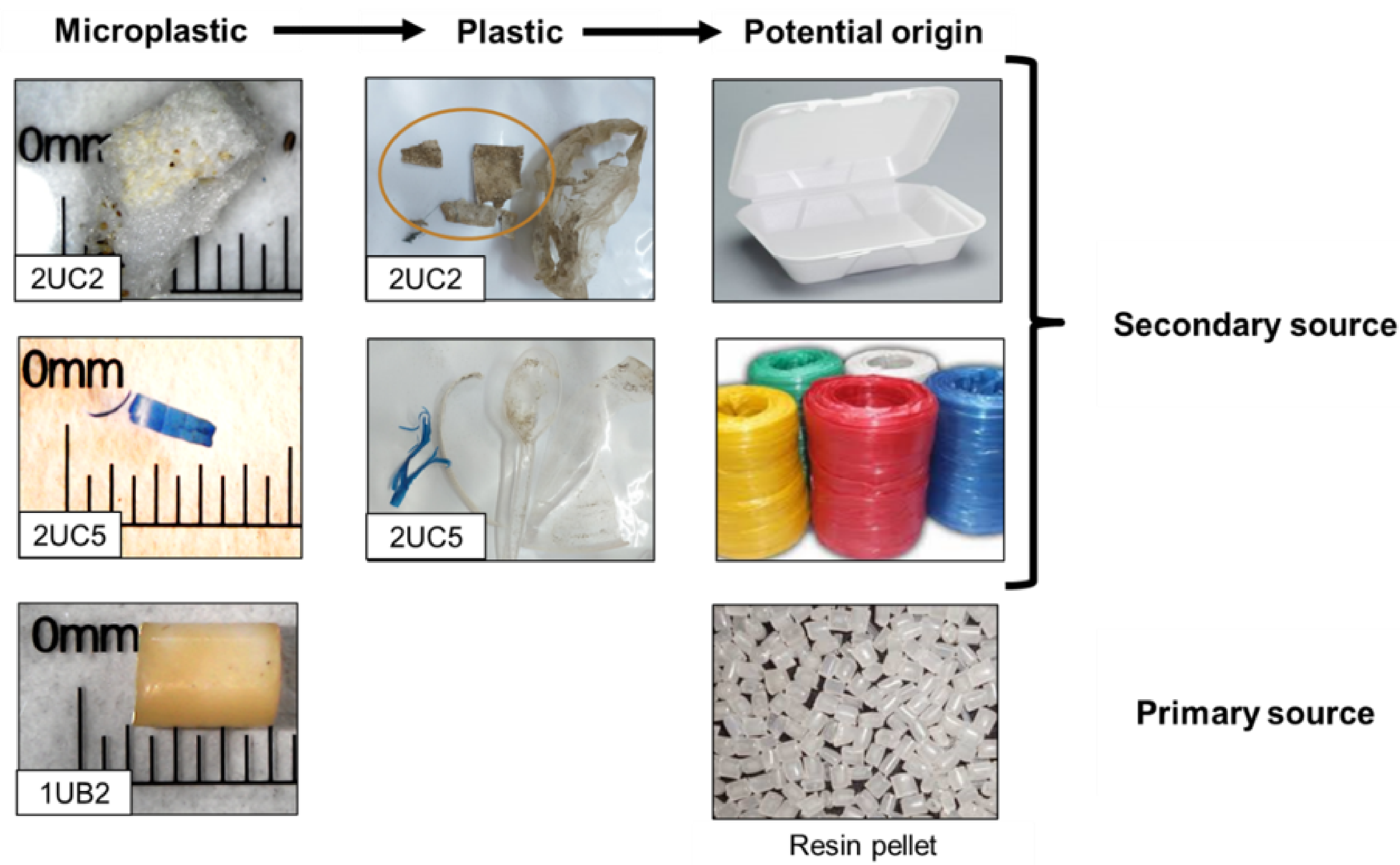
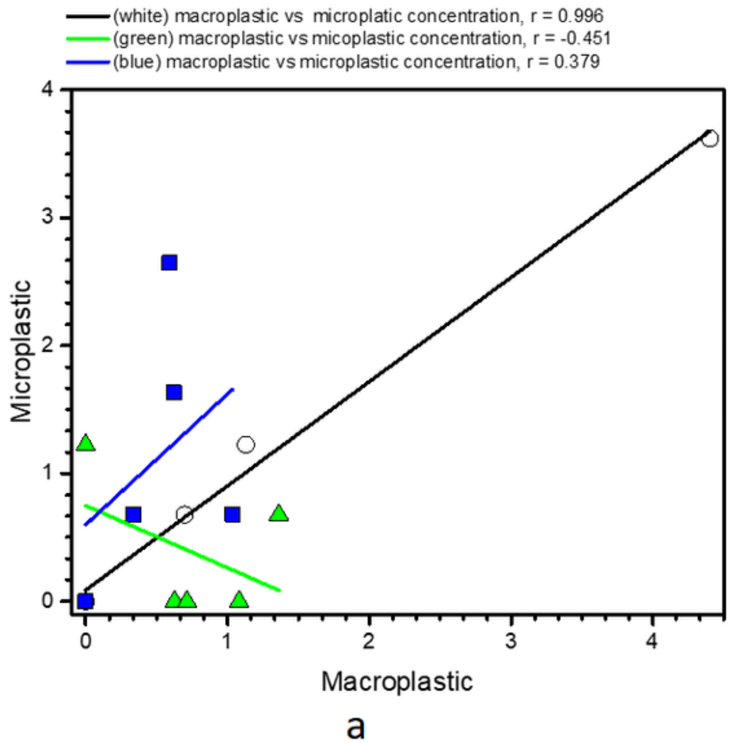


Figure 8

Potential origin of microplastic and plastic in beach sand in this study (2UC2, 2UC5, 1UB2: beach sand sample code)



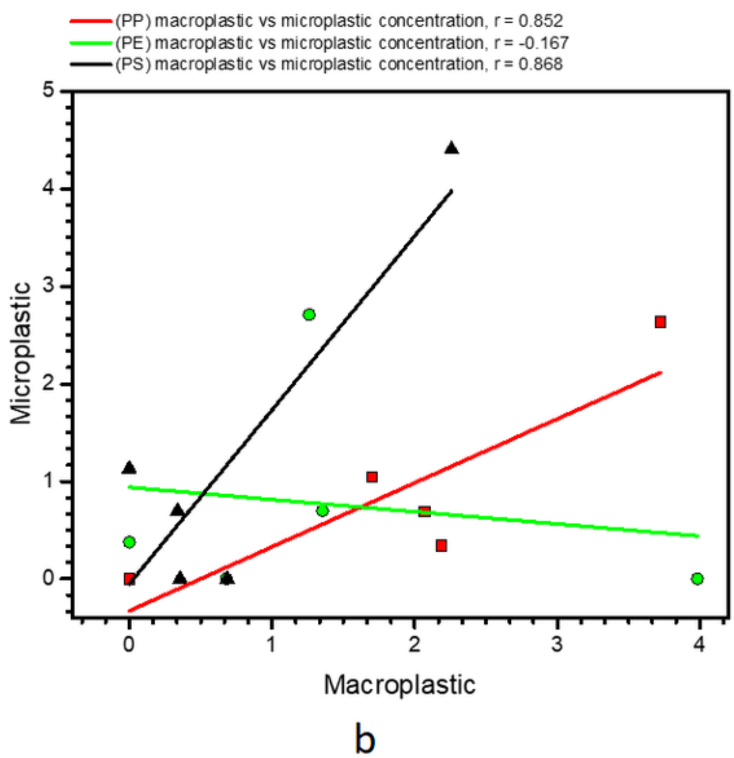


Figure 9

Correlation analysis between macroplastic and microplastic concentration in beach sand in Can Gio, Ho Chi Minh city, Vietnam in November 2019; a. Color; b. Chemical composition