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Microplastics distribution in surface sediment during dry season at Can Gio beach, Ho Chi Minh City, Vietnam

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Abstract: *The study aims to determine the characteristics of microplastics (MPs), including their abundance and shape, in surface sediment samples at Can Gio Beach, Ho Chi Minh City, Vietnam. Well-established methods, such as organic matter digestion, density separation, sample filtration, and microscopic observation, were utilized. Surface sediment samples were collected in April 2023 along two transects perpendicular to the shoreline (from sample CG-1 (at low tide) to sample CG-5 (at the highest tide)) and along to the shoreline (from sample CG-6 to sample CG-9). The results indicate that, perpendicular to the shoreline, the average microplastic abundance is 6.28 ± 0.16 items/g. Microplastic abundance tends to increase towards the shore, with the highest abundance at sample CG-5 (17.97 items/g) and the lowest at CG-1 (0.46 items/g). Microplastic shape includes fragments, fibers, foams, and films, with fragments comprising the highest proportion at 74.46%. Along the shoreline, the average microplastic abundance reaches 21.60 items/g. The results of the analysis of the relationship between MPs and sediment particle size showed that MPs were concentrated in the "medium sand", "coarse sand" and "very coarse sand" types. Thus, the abundance of MPs along the shoreline is higher than that to the offshore.*
Keywords: *microplastics; surface sediment; density separation method; sediment particle size; Can Gio*

1. Introduction

In 2004, Thompson was the first to publish a study highlighting the long-term buildup of small plastic fragments in the environment and coined the term "microplastics" (MPs). Thompson et al. (2004) were pioneers in MPs research, emphasizing their worldwide presence, possible movement from the digestive system to the circulatory system, and their function in carrying chemical contaminants. Later, MPs began to be studied in various subjects such as sediment samples, water samples, and biological samples from different regions around the world.

Research on MPs in sediments from mudflats, beaches, and mangroves reveals that tidal currents and mangrove species affect MPs distribution. A study in southern China (Futian and Mai Po mangrove forests) found similar MPs levels in mudflats and forests, but more fibers in mudflats, likely due to mangrove roots blocking fiber entry. MPs abundance at the forest edge was higher than in the mudflat, showing that plant species influence MPs distribution in mangroves (Jiehan Duan et al., 2021). Furthermore, the distribution of MPs in mangrove sediments is affected by tidal current velocity and tidal range. Zhang et al. (2020) found a strong linear relationship between tidal current velocity and MPs content, with higher concentrations near the landward boundary. MPs levels increased with tidal flow velocity but showed no correlation with tidal range, highlighting the importance of flow velocity in understanding MPs distribution in mangroves.

Moreover, sediment grain size or different areas of the beach also affect the distribution of MPs. Additionally, waves and storms are factors that influence the transport of MPs. Xu et al. (2023) discovered that intense wave activity displaced a greater number of buried microplastic particles from sediments. Additionally, storms were found to significantly impact the retention of MPs, with retention levels increasing proportionally to sediment density. The study by Vermeiren et al. (2021) on MPs sized 66 μm - 5 mm in the coastal areas of La Coronilla and Barra del Chuy, Uruguay, found that MPs abundance decreased exponentially as particle size increased. Furthermore, the beach's proximity to freshwater zones with the presence of organisms also influenced MPs distribution. The authors provided several key characteristics to consider when sampling MPs, including beach morphology, ecological features, and sediment particle size.

In recent years, Vietnam has begun conducting research on MPs. Similar to studies worldwide, some of the main research subjects in Vietnam are MPs in sediment, in water, and in organisms. For MPs in surface sediment samples, the studied areas often include beaches, tidal flats, or mangrove areas. The results typically reveal the quantity, distribution, and shape of MPs.

In northern Vietnam, in the Ba Lat estuary, the analysis of surface sediment samples by L.N. Da et al. (2022) showed that number of MPs in the rainy season was around 800 items/kg, and in the dry season, it was 3817 items/kg, with an average value of 2188 ± 1499 items/kg. MPs were primarily in two forms: fibers (94%) and fragments (6%). The predominant colors of MPs included green (36%), white (21%), and red (11%). The main plastic components were five types: PP, PE, PU, PA, and PS with PP and PE being the most prevalent. In some provinces of central Vietnam, D. V. Manh et al. (2021) studied MPs on Da Nang's coastal beaches (My Khe, T20, and Son Thuy) using μFTIR analysis. The main polymers identified were PTFE, EVOH, and PA. In the coastal tidal flats of Da Loc, Hau Loc, Thanh Hoa, L. V. Dung et al. (2021) found that MPs mass ranged from 6.41 ± 1.27 mg/kg to 53.05 ± 5.27 mg/kg, averaging 22.95 ± 8.9 mg/kg. Sediment analysis showed 2921 to 5635 microplastic pieces per kilogram, mainly fragments (65.09%), foams (8.41%), fibers (24.08%), and films (2.42%), originating from coastal activities like aquaculture, fishing, and household waste. Recently, N. H. N. Y et al. (2023) identified MPs in sediment at the Thuan An estuary, Thua Thien Hue. The results showed that the concentration of MPs in the sediment varied between 300 and 2800 items/kg. White MPs dominated the environment (56%), and 90% of the fragment-shaped MPs were smaller than 261.447 μm^2. The high proportion of small-sized MPs resulted from the continuous fragmentation of larger plastic fragments under environmental impacts.

In the Saigon-Dong Nai river system, H. Phu et al. (2021) analyzed MPs at 18 locations, finding fragment-, fiber, and bead-shaped particles ranging from 0.1 to 5 mm. MPs concentrations in sediment averaged 21.77 ± 6.9 mg/kg, with PE (51.2%), PP (27.1%), and PVC (13.4%) being the dominant types. In Mekong delta provinces, N. T. G. Hang's (2021) research also mentioned the amount of MPs in sediment samples from clam farming areas, such as Tan Thanh beach (Tien Giang province), Ba Tri beach (Ben Tre province), Ba Dong beach (Tra Vinh province), and Ganh Hao beach (Bac Lieu province). MPs in surface sediment had an average value of 169.34 ± 42.01 items/kg of wet sediment. Ba Dong beach, Tra Vinh, had the highest number of MPs (318.14 ± 136.40) compared to Ba Tri beach, Ben Tre (130.59 ± 33.18), or Tan Thanh beach, Tien Giang (128.46 ± 44.53). The beach with the fewest MPs was Ganh Hao, Bac Lieu (100.18 ± 45.81).

In the Can Gio area, Ho Chi Minh City, P. D. Thanh et al. (2022) found that microplastic concentration in sediment was 3233 pieces/m² (or 20.3 mg/kg). The sediment samples contained films, fragments, and fibers, but no microplastic beads. In terms of color, white MPs were dominant, accounting for 41% in sediments and 55% in organisms. V. T. K. Khuyen et al. (2021) found that coastal pollution primarily originated from land-based activities, with polyethylene (PE) being the most prevalent polymer, largely linked to single-use plastic items commonly used in beach activities. Commonly identified polymers included PET and polyamide, mainly in the form of colored fibers and white particles from tourists' clothing and food packaging waste. Fragments made up 40-88% of the MPs, predominantly small (25-100 μm), indicating secondary sources from plastic waste breakdown on beaches. MPs densities in sand layers ranged from 31.99 to 92.56 MPs/gram. N. T. T. Nhon et al. (2022) obtained data from five beaches along the Can Gio coast, each exhibiting unique characteristics and varying human activities. The findings revealed that microplastic concentrations varied from 0 to 6.58 pieces per kilogram of dry weight, predominantly located in the surface sand along the upper shoreline. Sizes were 2.8 to 5 mm (71.4%), with granules as the dominant shape (42.9%). White and blue were the most common colors (81%). Polystyrene, polypropylene, and polyethylene were the primary polymers, likely originating from resin pellets, tourism, and aquaculture.

There are many methods used for MPs analysis, each of which is effectively applied to different research subjects (Razeghi et al., 2021; Radford et al., 2021; Schütze et al., 2022). The methods used to extract and quantify MPs in different environments, such as water samples, sediment samples, and biological samples, are not yet consistent across studies. One of the methods for separating MPs is the flotation method by density separation. Saturated salt solutions, such as sodium chloride (NaCl), zinc chloride ($ZnCl_2$) and/or sodium iodide (NaI), are often added to separate solid plastics from water samples. NaCl works well for the recovery of PP, PE, PS, PA, nylon but has difficulty recovering PVC or PET. The use of $ZnCl_2$ and NaI is more effective but the cost of $ZnCl_2$ and NaI is quite high (Rodriguesa et al., 2020). In addition to salt solutions, Mani et al. (2019) also proposed the use of castor oil as a plastic absorbent to separate MPs. Therefore, it is evident that MPs remain a relatively new research area and require extensive further investigation.

2. Methodology

2.1 Study site and sample collection

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The surface sediment samples were collected at Can Gio beach, Ho Chi Minh City. The sampling location is near the Dong Tranh River and residential areas, and it is also a site for clam farming. The beach has a large amount of garbage, mainly plastic bottles, plastic cups, bottles, styrofoam boxes, plastic boxes, etc., and many clam and snail shells. Aquaculture activities and sand mining activities have emitted additional waste such as nets and plastic bags (Fig. 1).

Sampling was conducted in April 2023. The samples were taken in two directions:

• In the perpendicular direction to the shoreline, five surface sediment samples were collected from the lowest tide level (CG-1) to the highest tide level (CG-5), with interval distance of 60 meters.

• Along the shoreline, four surface sediment samples were collected at the highest tide level (from CG-6 to CG-9), interval distance of 20 meters.

The surface sediment samples were collected from a 250 cm² square area. Sediment was collected from the surface of the square using a metal scoop, with an effort to maintain a consistent sampling depth of 1 cm. However, due to the irregular surface and potential human error, the depth varied slightly around 1 cm and occasionally reached up to 2 cm in some areas. The sediment was then passed through a 5 mm mesh sieve to filter out particles larger than 5 mm, retaining only those smaller than 5 mm, which were preserved in zip bags.

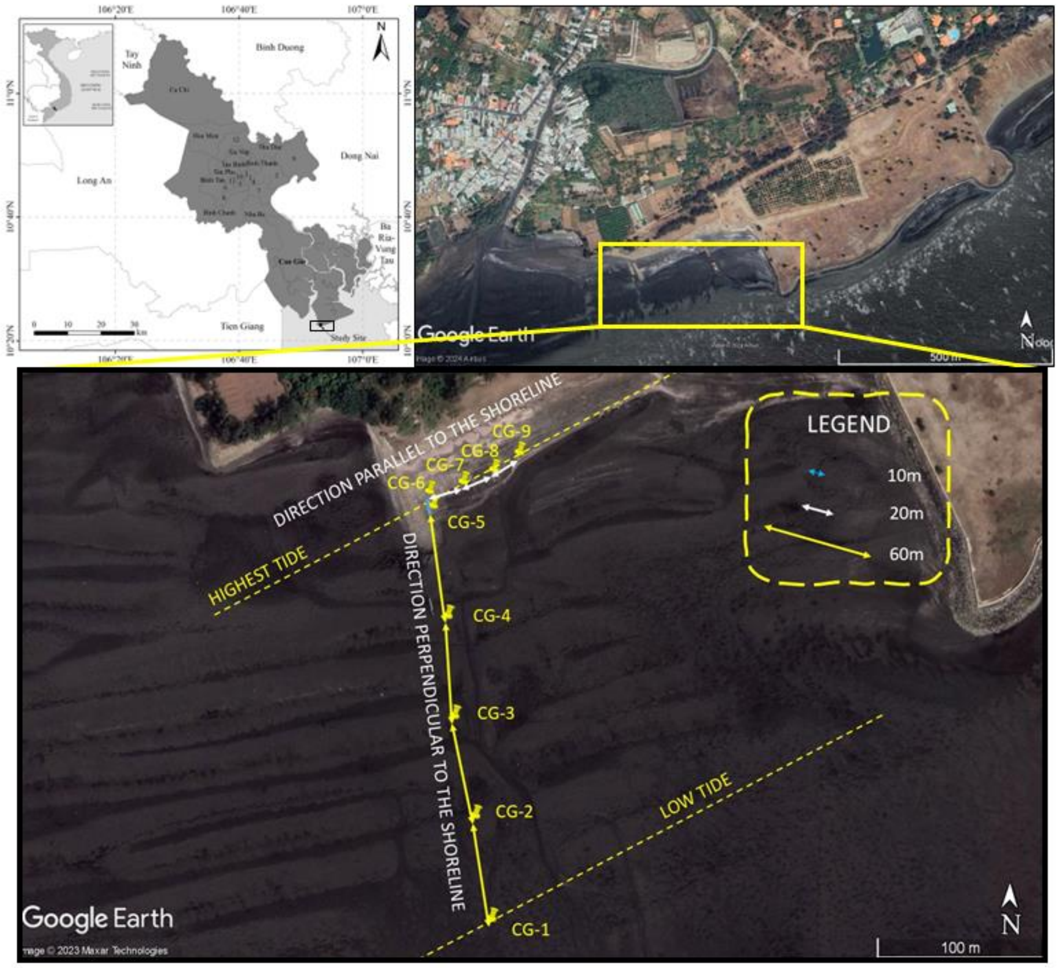

Fig. 1. The study site at Can Gio, Ho Chi Minh City, Vietnam

2.2 Identification of microplastics

The wet sieving method was used to classify particle sizes based on the Wentworth scale (Wentworth, 1922) 20, using sieve sizes of 0.063 mm, 0.1 mm, 0.125 mm, 0.25 mm, 0.5 mm, 1 mm, and 2 mm.

After drying, the samples were treated with 30 ml of 30% hydrogen peroxide (H_2O_2) solution and 30 ml of Fe(II)SO_4 solution as a catalyst. The solution was allowed to heat to over 70°C before cooling to room temperature. A stirring bar was then added, and the mixture was heated on a magnetic stirrer at 75°C for 30 minutes. If any natural organic matter remained visible, an extra 20 ml of 30% H_2O_2 solution was added until the complete removal of the organic matter was achieved. The samples were then dried at 60°C until completely dry (Masura et al., 2015) 21.

After the samples were dried, a 50 ml solution of $ZnCl_2$ was introduced into the beaker containing the sample, which was then placed into a density separation funnel and covered with aluminum foil. The solid was allowed to settle for 1 hour at room temperature. The floating MPs were collected into a flask using forceps and a glass Pasteur pipette. The Mohr clip was then released, and the settled solid (if any) and $ZnCl_2$ solution were drained into an Erlenmeyer flask. The density separation apparatus was rinsed several times with distilled water to transfer all the solid into the container holding the recovered MPs (Masura et al., 2015; Rodriguesa, 2020) **Error! Reference source not found.Error! Reference source not found.**. The $ZnCl_2$ solution and settled solid (if any) were filtered through Whatman filter paper (1 µm pore size, 47 mm diameter) using a funnel connected to a vacuum system. Once the filtration was complete, the filter paper with the sample was transferred to a Petri dish, dried, and observed under a 100x microscope to identify and classify MPs morphologies such as fragments, fibers, foams, and films.

The procedure for processing and identifying MPs in surface sediment samples is illustrated in the following diagram:

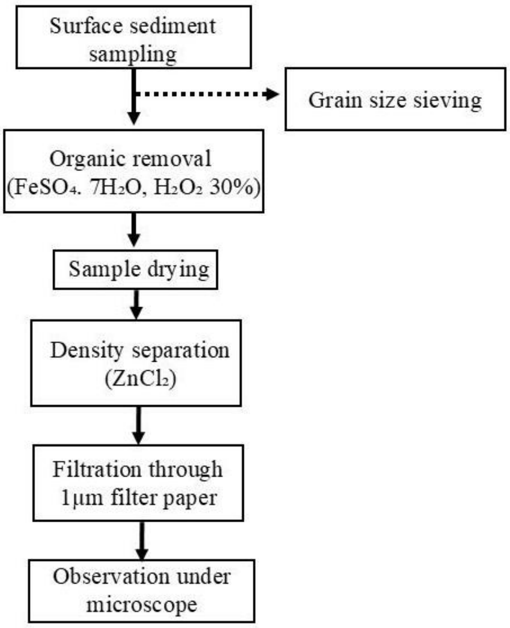

Fig. 2. Processing and identifying MPs in surface sediment samples

3. Results and Discussion

3.1 The abundance of microplastics

The study selected five sediment samples lying perpendicular to the shoreline (from sample CG-1 to sample CG-5, Fig. 1 - yellow line) to analyze the characteristics of MPs in surface sediment, such as abundance and shape of MPs. The average MPs density for these five sediment samples is 6.28 ± 0.16 items/g. The analysis results show that the highest MPs density was found in sample CG-5 (17.97 items/g), which is located where the water level is highest. The lowest MPs density was in sample CG-1 at the lowest water level, with 0.46 items/g. The results indicate that as one approaches the shore, the amount of MPs increases. This may be due to the deposition of waste (including plastic waste) in areas with high water levels; under the conditions of temperature and sunlight, waste breaks down into smaller fragments and accumulates (Khuyen et al. 2021). Subsequently, MPs can also be transported offshore due to hydrodynamic factors (Lo et al., 2018)22. Additionally, the results show that along the same cross-section at equal distances, abundance of MPs increases unevenly. Specifically, the MPs density for samples CG-1 and sample CG-2 is only 0.46 items/g and 0.56 items/g, but for sample CG-3, the MPs density starts to increase

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(1.72 items/g), with the highest concentrations found in samples CG-4 and CG-5, where the microplastic amounts in CG-4 and CG-5 are 6 to 10 times greater than in CG-3.

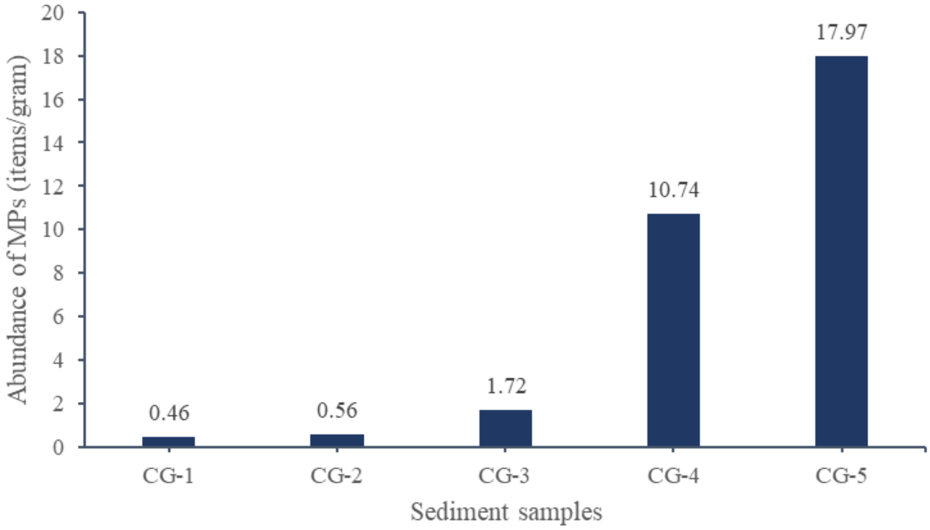

Fig. 3. Abudance of MPs in sediment samples perpendicular to the shoreline

Regarding shape characteristics, the study classified MPs into the following types: fibers, fragments, foams, and films (Fig. 4). The predominant shape of MPs is fragments, accounting for 74.46% of the total MPs in the sediment. Fragments come in various shapes and colors, with blue and sometimes opaque white fragments observed among the samples.

Fibers make up 24.59%, characterized by long, thin, transparent shapes, occasionally blue or brown (Fig. 5). These fibers are derived from the breakdown of thread bundles or fishing nets (Dung et al., 2020). Foams are present in low proportions, just 0.44%, typically round or sponge-like, in white, opaque, or yellow colors (Dung et al., 2020). They originate from the decomposition of foam containers or dish sponges, with small holes due to air bubbles. Films represent 0.51%, having thin shapes, larger than other microplastic fragments, mainly from the breakdown of plastic bags, often white or blue in color (Dung et al., 2020).

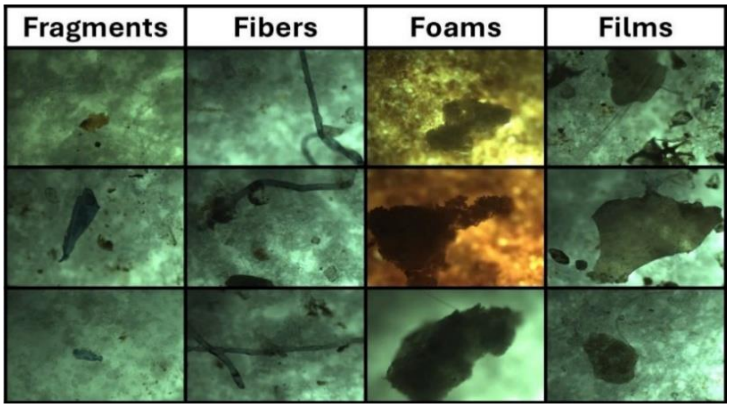

Fig. 4. Types of microplastic shape, namely fragment, fiber, foam and film

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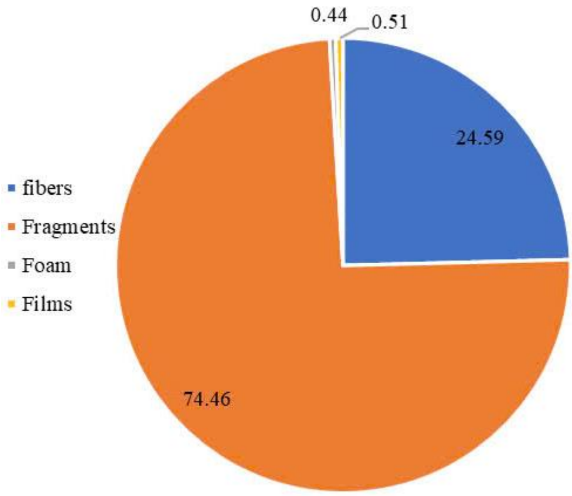
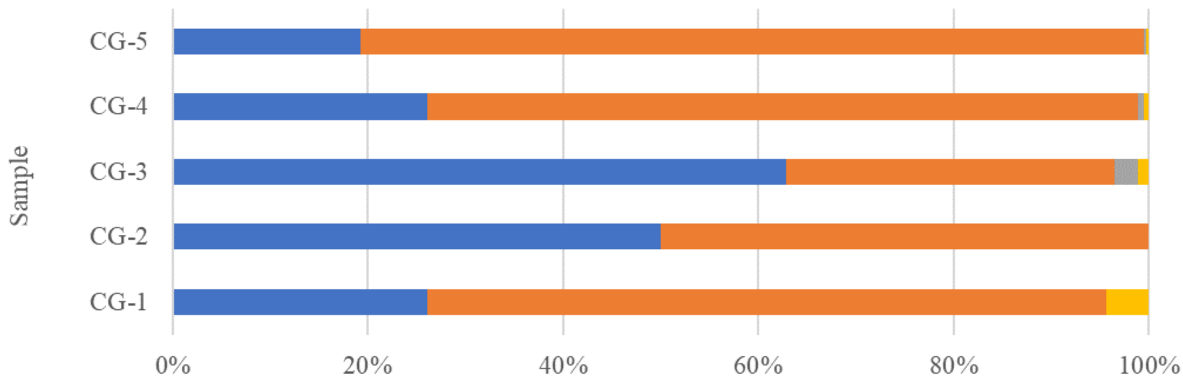


Fig. 5. Percentage of microplastic shape

The classification results of microplastic shape for each sediment sample are shown in Figure 6. The analysis of sample CG-1 revealed no foam-type MPs; fragments accounted for the highest proportion at 69.57%, followed by fibers at 26.9%, and films at 4.35%. For sample CG-2, the results showed no foam or film MPs, only fiber and fragment types. In contrast, samples CG-3, CG-4, and CG-5 showed MPs in all four forms: fiber, fragment, foam, and film. In sample CG-3, fibers were the most abundant (62.79%), followed by fragments at 33.72%, with foam and film accounting for lower proportions of 2.33% and 1.16%, respectively. Sample CG-4 had fragments as the dominant type (72.81%), fibers at 26.07%, with foam and film making up a very small percentage. Sample CG-5 is similar the results of CG-4, with fragments dominating at 80.22%, followed by fibers at 19.22%, while foam and film were negligible. Overall, in the samples perpendicular to the shore, fragments were the most dominant form, particularly in samples CG-5 (80.22%) and CG-4 (72.81%), while foam and film were the least common, ranging from 0% to 5%.

In terms of microplastic density for each classification, the results showed that fragment-type MPs were the most prevalent, with a density of about 4.68 items/g of sediment, followed by fibers at a density of 1.55 items/g of sediment. Foam and film types had the lowest densities, at 0.03 items/g of sediment.



	CG-1	CG-2	CG-3	CG-4	CG-5
fibers	26.09	50.00	62.79	26.07	19.22
Fragments	69.57	50.00	33.72	72.81	80.22
Foam	0.00	0.00	2.33	0.56	0.22
Films	4.35	0.00	1.16	0.56	0.33

Fig. 6. Comparison of the percentage of individual microplastic shapes

3.2 The relationship between the abudance of MPs and sediment grain size

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The study selected four sediment samples along the shoreline (from sample CG-6 to sample CG-9) at the highest tidal level to analyze the relationship between abudance of MPs and sediment grain size.

Regarding sediment grain size, the study classified the grain sizes as follows: *silt, very fine sand, fine sand, medium sand, coarse sand, very coarse sand,* and *very fine granule*, according to the Wentworth scale (Wentworth, 1922) 20. Within the scope of this study, abundance of MPs was only determined for sediment ranging from *very fine sand* to *very coarse sand* ("sand" group).

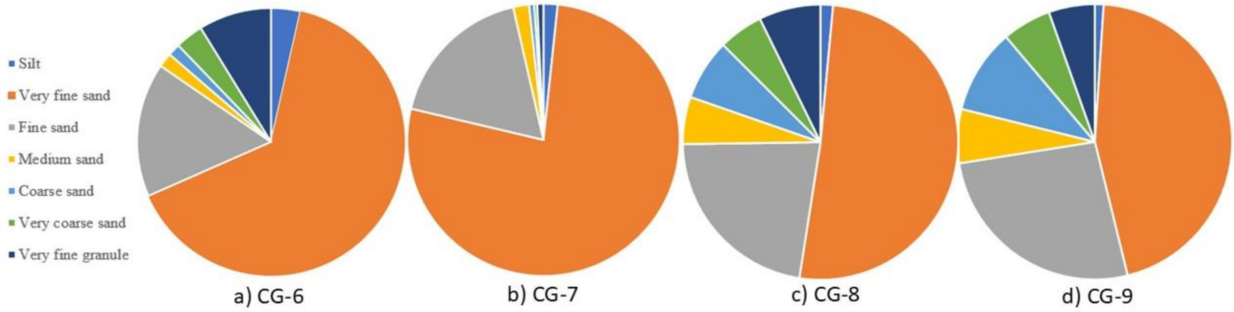

Fig. 7. The particle size distribution of sediment samples (along to shoreline)

Fig. 7 illustrates the particle size distribution of sediment samples collected from four shoreline locations: CG-6, CG-7, CG-8, and CG-9. Fig. 7 represents the percentage composition of different sediment grain sizes at each site, including *silt*, very fine sand, fine sand, medium sand, *coarse sand*, *very coarse sand*, and *very fine granule*. Observations show that "*very fine sand"* is the dominant grain size across most samples, particularly at CG-6, CG-7, and CG-8. CG-7 has the highest proportion of "*very fine sand"* at 77.01%, followed by CG-6 at 64.86%, and CG-8 at 51.00%. CG-9 has a lower proportion of "*very fine sand"*, comprising only 45.13%, and displays a more diverse particle size distribution with significant amounts of *fine sand* (26.34%) and *coarse sand* (9.97%). *Fine sand* also appears in smaller quantities and is the second most abundant sediment type, with percentages as follows: CG-6 (16.20%), CG-7 (17.74%), CG-8 (22.32%), and CG-9 (26.34%). Additionally, the proportion of *medium sand - coarse sand - very corse sand - very fine granule* in sample CG-9 is about 27.5% (highest compared to other samples), indicating a coarser sediment compared to the other samples. Meanwhile, *silt* are present in small amounts across all locations, with CG-6 showing the highest *silt* content (3.54%). In summary, the sediment samples indicate a general trend of *very fine sand* dominance, especially pronounced at CG-7. However, CG-9 shows a more varied particle size distribution, suggesting a more complex and diverse sediment deposition environment at this site.

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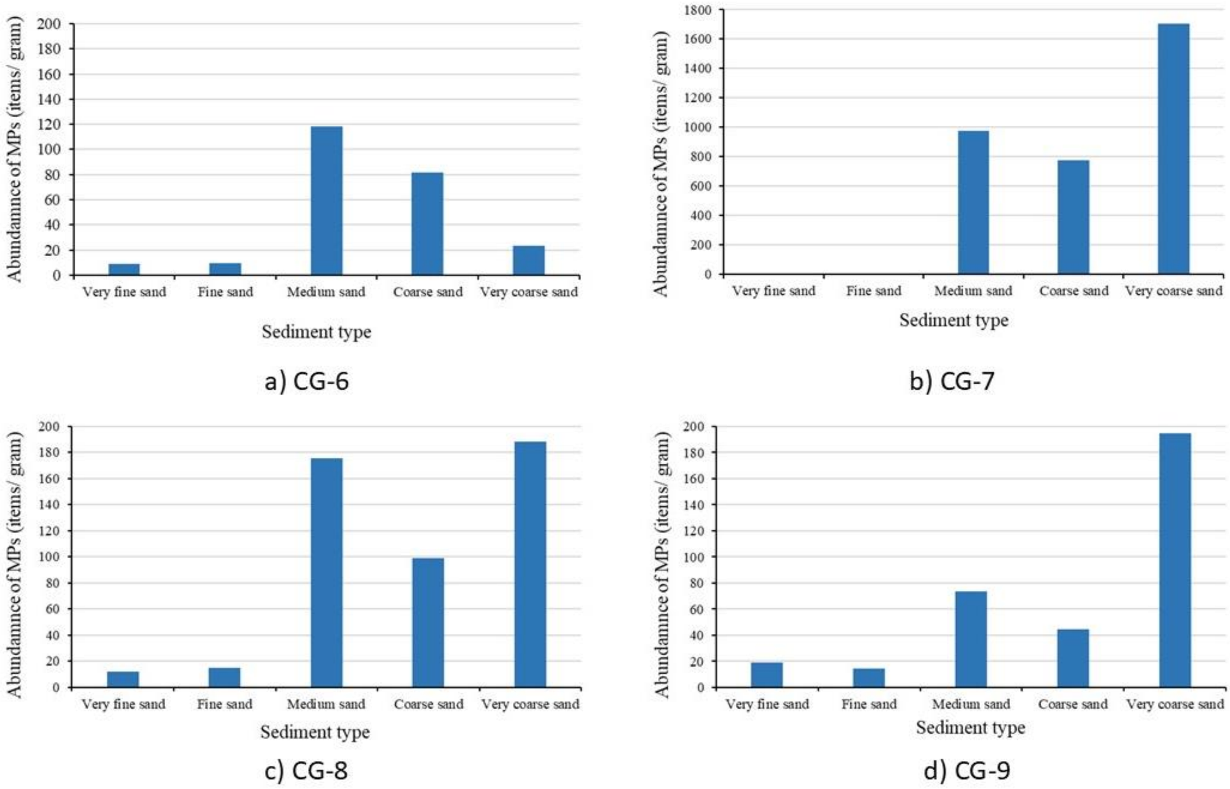

Fig. 8. Abundance of MPs of sediment samples (along to shoreline)

The results show that abundance of MPs increases with sediment grain size (Fig. 8). Note that the scale of the y axis is not the same on all plots. In all samples, MPs is generally highest in larger sediment grains (*medium, coarse* and *very coarse sand*) and lowest in finer grains (*fine* and *very fine sand*). This indicates that MPs tend to concentrate more in coarser sediment types. In addition, there are significant differences between sediment types. In sediment sample CG-7, the concentration of MPs in *very coarse sand* (1706.90 items/g), *medium sand* (974.78 items/g), and *coarse sand* (776.63 items/g) is significantly higher than in the other samples, particularly when compared to sample CG-6, sample CG-8, and sample CG-9. In other samples, such as CG-6, CG-8, and CG-9, while MPs is higher in coarser sediment types, the differences are not as pronounced as in CG-7. However, we can see general trend across sediment types. In all samples, *fine* and *very fine sand* always exhibit the lowest MPs density, ranging from approximately 0.43 items/g to 18.91 items/g. This may be because finer grains are less effective at retaining MPs compared to larger grains. Lastly, the results show consistency across samples, it means that athough there are specific density differences among samples, the trend of higher abundance of MPs in larger grain types (*medium, coarse* and *very coarse sand*) remains consistent. This could be due to the larger surface area of coarser grains, which allows MPs to adhere or be retained more easily. Therefore, the charts reveal a relationship between sediment grain size and microplastic accumulation, with coarser sediments showing higher microplastic densities.

Tab. 1. Summary grain size and abundance of MPs for the sediment samples along the shoreline

Types	CG-6		CG-7		CG-8		CG-9		Average MP (items/g) for a total of four sediment
	Grain size percentage (%)	Abundance of MPs (items/g)	Grain size percentage (%)	Abundance of MPs (items/g)	Grain size percentage (%)	Abundance of MPs (items/g)	Grain size percentage (%)	Abundance of MPs (items/g)	
Very fine sand	64.86	9.17	77.01	3.27	51.00	11.81	45.13	18.91	**10.79**
Fine sand	16.20	9.63	17.74	0.43	22.32	14.69	26.34	14.42	**9.79**
Medium sand	1.74	118.53	1.88	974.78	5.54	175.23	6.34	73.35	**335.47**
Coarse sand	1.49	81.88	0.60	776.63	7.17	98.86	9.97	44.83	**250.55**
Very coarse sand	3.38	23.67	0.36	1706.90	5.25	188.13	5.76	194.86	**528.39**

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The results for average microplastic density in each particle size for a total of four sediment samples along the shoreline (Table 1) show that the *very coarse sand* group has the highest microplastic density (528.39 items/g), followed by *medium sand* with 335.47 items/g and *coarse sand* with 250.55 items/g. The lowest densities are found in *very fine sand* (10.79 items/g) and *fine sand* (9.79 items/g). In addition, the results also showed that the proportion of finer sand (*very fine sand* and *fine sand*) in the sediment samples was higher than that in the coarser sand group (*medium sand, coarse sand*, and *very coarse sand*), but the abundance of MPs in the "finer" sand group was very low compared to the "coarse" sand group (Table 1).

While a clear correlation between sediment grain size and MPs abundance has been observed and documented in previous studies, this relationship is not always consistent. For instance, several studies have reported that MPs are more abundant in sediment samples with finer grain sizes, such as clay or silt (Vermeiren et al., 2021; Mendes et al., 2021; Corcoran et al., 2020). In contrast, certain studies found no significant link between sediment particle size and the concentration of MPs (Peng et al., 2017; Amrutha et al., 2023). Alternatively, another study demonstrated a negative correlation between particle size and MPs concentration 28. Although most previous studies have suggested that microplastic abundance decreases with increasing sediment particle size, this study provides contradictory results, indicating that microplastic density tends to increase with larger sediment sizes. This may be due to a lack of comprehensive datasets on the interactions between MPs movement, deposition, or the mechanisms controlling the retention, accumulation or resuspension of MPs are complicated and not yet fully understood 29, and the sampling area is located near coastal protection structures, which are influenced by hydrodynamic factors. Further research is needed to provide a detailed understanding of MPs accumulation in sediments, taking into account factors like sediment particle types and wave-current conditions.

4. Conclusion and Discussion

In summary, the study present a preliminary results about the characteristics of MPs such as abundance and shape in surface sediment samples at Can Gio Beach, Ho Chi Minh City, Vietnam. Results indicate that perpendicular to the shoreline, the average MPs abundance is 6.28 ± 0.16 items/g. MPs abundance tends to increase towards the shore, with the highest abundance at sample CG-5 (17.97 items/g) and the lowest at CG-1 (0.46 items/g). MPs shape includes fragments, fibers, foams, and films, with fragments comprising the highest proportion at 74.46%. Along the shoreline, the average microplastic abundance reaches 21.60 items/g. It means that the abundance of MPs along the shoreline is higher than that to the offshore. The results of the analysis of the relationship between MPs and sediment particle size showed that MPs were concentrated in the *medium sand, coarse sand* and *very coarse sand.* In future, the study aims to improve microplastic identification methods, as microscopy relies on the researcher's experience, and to expand the study area, collect more sediment samples, and examine the effect of hydrodynamic factors on the accumulation and movement of MPs.

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