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Distribution and characteristics of microplastics in surface water at some beaches in Thanh Hoa province, Viet Nam

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ABSTRACT

Microplastics present in high density in coastal marine environments have been reported by many published works worldwide. Microplastic presence poses a major threat to all organisms that come into direct contact with them in the aquatic environment because they are non-biodegradable and adsorbable to some toxic substances. Besides, through the food chain, it can affect human health. This study provides data on the density and characteristics of microplastics such as shape, size, and color in the aquatic environment of three beaches (Hai Tien, Sam Son, Hai Hoa) in Thanh Hoa province. Microplastics were detected at all sampling locations at high abundance. The largest microplastic abundance was 44.1 items/m^3 at Hai Tien beach, while the smallest was 15.5 items/m^3 at Sam Son beach. The results indicated that the most common microplastic shape was fragment shape which accounted for 50.2 to 80.2% of total microplastics. The size was smaller than 500 µm covered from 66.1 to 87.7 % of total microplastics. Among that, white, yellow, and black are the main colors of microplastics in the aquatic environment of this region.

Introduction

Microplastics are recently defined as plastic particles in the range from 1 µm to 5 mm [1]. They have become an environmental hazard because of the characteristics of being difficult to biodegrade and the ability to adsorb toxic organic substances such as persistent organic pollutants, polycyclic aromatic hydrocarbon, organochlorine pesticides [2,3], heavy metals [4], and antibiotic compounds. These chemicals can degrade the functioning of ecosystems [5–9], and through the food chain, affect human health [10].

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Microplastics are widely distributed and present in almost all parts of the world. Some recent studies have shown that microplastics were even found in the polar ice layers of the earth [11–13] and one of the pristine environments, such as in glaciers in the Tibetan Plateau, China [14]. In the more common area, such as the aquatic and sedimentary environment of major rivers, microplastics are found with relatively high abundance [15–20]. The most prominent and particularly concerning issue today is microplastic pollution in the oceans because it is affecting the marine ecosystem [21–24]. Microplastics exist ubiquitously in water, sediments, coastal estuaries, offshore oceans [25–28]. and coral reefs [29,30]. Microplastics are believed that originate from within the continent, including water from wastewater treatment plants, domestic wastewater, from landfill leakages [31–33], and from other marine areas brought by ocean currents, human activities at sea such as fishing, oil drilling, tourism, and activities of people living on the coast.

Before the situation of microplastic pollution is increasing in quantity and seriously affecting marine ecosystems around the world, there have been several works mentioning this problem [34,35]. However, the study concerning the distribution, properties, and origin of microplastics in the coastal environment in Vietnam is still limited both in quantity and quality. In this study, the abundance, colors, size, and shape of microplastics in the aquatic environment were examined at some beaches in Thanh Hoa province.

Experimental

Sampling area and sampling periods

Microplastics from the mainland can pollute the coastal area of Thanh Hoa province through estuaries such as Lach Hoi estuary, Lach Truong estuary, Lach Gep estuary, Lach Bang estuary. Besides, directly discharging from people living on the coast, tourism activities, and fishing activities are also major microplastic sources. Sampling location for microplastic assessment was carried out at three beaches, including Hai Tien, Sam Son, Hai Hoa, as described in Figure 1. Samples were collected at each beach's three locations in May 2020.

Sampling methods and identification of microplastics

Sampling collection and storage

Samples were collected by net towing method [36], using a Wildco net (figure 2) with a mesh size of 80 µm, a mesh ring diameter of 50 cm, a net length of 150 cm, fitted with a Flowmeter (model 2030R). Microplastic samples were collected by net, then transferred to a 500 ml brown sandblasted bottle and stored at 4 °C, and transported to the laboratory for further experiments.

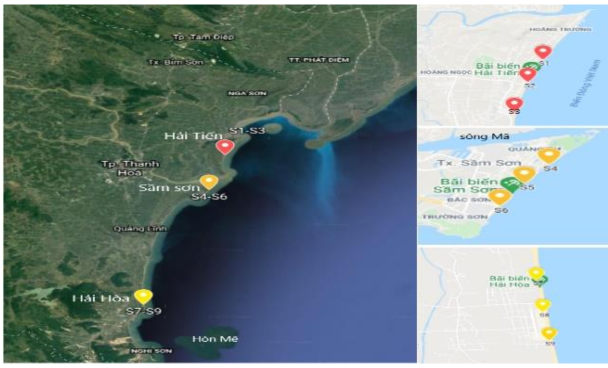

Figure 1: Diagram of sampling area in Thanh Hoa province in May 2020

Sample pretreatment and density separation

Sample pretreatment: After brought to the laboratory, samples were filtered through stainless steel with mesh size sieves of 5 mm and 1 mm. The particles larger than 5 mm were discarded, while the remaining ones on the 1-mm sieve were washed with distilled water, collected in a petri dish, and dried at 50 °C for 24 hours.

Figure 2: Net tows for microplastics collection

All the particles that go through the 1-mm sieve were transferred into a 1000 ml beaker and evaporated on a water bath at 90 °C. The beaker was allowed to dried and cool to room temperature, add 20 ml of 0.05M Fe(II) solution. The solution was prepared by adding 7.5 g of $FeSO_4.7H_2O$ to 500 ml distilled water containing 3 ml concentrated H_2SO_4. In order to avoid the influence of organic matters, 20 ml of 30% H_2O_2 was added into the beaker containing water sample, vibrated

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thoroughly, and let the mixture stand at room temperature for 5 minutes for the decomposition reaction to occur. Next, the mixture was heated on a water bath at 75 °C for 30 minutes. If the organic matters were not completely decomposed, add another 20 ml of 30% H_2O_2, and repeat the above process.

Density separation: Add 6.0 g of NaCl salt per 20 ml of sample to increase the density of the solution. The mixture was heated at 75 °C on a water bath to dissolve the salt completely. Then, the entire mixture was transferred to a density funnel. The funnel was allowed to settle overnight (or 12 hours); visually check if the solids have been settled and separated by clamping in the density funnel, settled solids were discarded. Collect the supernatant into a beaker, rinse all the sample in the density funnel and collect it in a glass flask.

Transfer the obtained solution to a Whatman vacuum filter, filter through a 0.45-μm cellulose acetate membrane, rinse the filter funnel with distilled water. Transfer the membrane filter to a Petri dish to dry at 50 °C for 24 h.

Determine the abundance, shape, color, and size of microplastics

For microplastics on the 1-mm sieve, the size of particles was determined by ruler while color and shape were determined by direct observation.
Microplastics with a diameter of less than 1 mm, on the filter membrane are observed with a Leica S9i stereo microscope with a magnification of 6.1x-55x, microplastic items are counted, measured, and observed by image analysis stools (LAS-X images).

The size of the microplastics is divided into four classes as follows: 100-500 μm, 500-1000 μm, 1000-2000 μm, and 2000-5000 μm.

The microplastic shape is classified into three types, including pellets, fragments (i.e., fragment, film, foam), and fibers.

The color of microplastics is identified through some of the following basic colors: blue, yellow, red, purple, black, and white.

Data analyses

Data on abundance, size, shape, and color analysis were calculated using Microsoft Excel. Microplastic abundance was expressed in items/m^3.

Results and discussion

Microplastics abundance

The total number of microplastics collected in this study was 4897 items, distributed at all sampling locations from S1 to S9. The abundance and quantity of microplastics collected at sampling locations at Hai Tien, Sam Son, Hai Hoa beaches, Thanh Hoa province are given in table 1.

Table 1: Current status of microplastics in marine water in Thanh Hoa province

Sample name	Location	Number of microplastics (items)	Abundance (items/m^3)
S1		969	26.2
S2	Hai Tien	495	44.1
S3		523	38.9
S4		348	18.7
S5	Sam Son	524	15.5
S6		318	24.5
S7		787	41.6
S8	Hai Hoa	417	33.8
S9		516	30.1
Average abundance			30.1

The microplastics abundance in the studied area varied from 15.5 to 44.1 (items/m^3), with the average value was 30.1 (items/m^3). S2 sample on the Hai Tien beach presented the largest value (i.e., 44.1 items/m^3), whereas the minimum value was at S5 on Sam Son beach (i.e., 15.5 items/m^3). The results indicated that despite a close distance from the Lach Hoi estuary, the microplastic abundance in Hai Tien and Hai Hoa beaches was higher than in Sam Son, where all wastewater from Thanh Hoa city discharge to. This result can be explained by microplastics properties such as small size, low density, and existing suspended in water. Besides, the abundance of microplastics at a location in the aquatic environment depends on two main factors, including sources from estuaries (referred to as continental sources) such as wastewater from people living on the coast, fishing, processing, and preservation of aquatic products and exchange or dilution by cleaner water blocks on the sea (reducing

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microplastic density). Thus, for Sam Son beach, the wave dynamics are the strongest due to the lack of shielding in front of the beach. The small-grained (e.g., sediment components, microplastics) are less likely to exist and are mostly swept away. In comparison, Hai Tien and Hai Hoa beaches are hidden in the bay area and Hon Me island cluster, respectively. The wave dynamics of these beaches are weak, creating conditions for the convergence of microplastics. Besides, Sam Son beach protrudes to the sea (figure 1), so the water exchange with the deepwater area of the Gulf of Tonkin takes place better than the rest of the beaches, the dilution of the content of microplastic particles occurs out strong.

Currently, there is no national standard for microplastic monitoring worldwide. Some common sampling methods include net tow, injecting a defined volume through a filter, or injecting a defined volume through a sieve. Mesh size and sieve size were often different in published works. In this study, the data used for comparison were used with the same net-based method (i.e., net tow). Table 2 showed that the microplastics abundance in water at the beach of Thanh Hoa province ranges from 15.5-44.1 items/m^3, much higher than that of the Bach Dang estuary, Vietnam, and other areas such as Bohai Sea, China; Scotland; Benoa Bay, Indonesia; Qatar; Northern Gulf, Mexico. This indicated the level of microplastic pollution caused by wastewater from anthropogenic activities such as living, running restaurants, hotels, aquaculture, and fishing heavily affected the coast, which needs attention for mitigation solutions.

Table 2: Comparison with some previous studies

Location	Sampling method	Abundance (items/m^3)	Ref.
Bohai Sea, China	Net tow, mesh size: 330 µm	0.49	[37]
Scotland	Net tow, mesh size: 330 µm	0.627	[38]
Benoa Bay, Indonesia	Net tow, mesh size: 330 µm	0.7	[25]
Quatar	Net tow, mesh size: 120 µm	0.71	[39]
Bach Dang estuary, Vietnam	Net tow, mesh size: 80 µm	0.97-3.42	[35]
Colombia Caribbean and Pacific	Net tow, mesh size: 500 µm	0.01-8.96	[40]
Northern Gulf, Mexico	Net tow, mesh size: 335 µm	5.0-18.4	[41]
Thanh Hoa, Vietnam	Net tow, mesh size: 80 µm	15.5-44.1	This study
Nakdong River mouth, Korea	Net tow, mesh size: 330 µm	0.62-57	[42]
North Sea, Germany	Net tow, mesh size: 100 µm	0.1-245.4	[22]
Black Sea	Net tow, mesh size: 200 µm	1200	[43]

Shape features

Many studies have been published to divide microplastics into many categories: pellets, fragments, fibers, films, ropes and filaments, and foam. In this study, microplastics were identified with three characteristic forms: pellets, fragments, and fibers. The shape characteristics of the microplastics in this study are shown in Figure 3. Fragments were the predominant shape in most of the studied locations accounting for 43.4 to 80.2 %, followed by filaments attributed for 6.9 to 37.6 %, and the lowest contribution were pellets which accounted for 0 to 42.9% of the total founded items. Microplastics composed a large part of fragments because they were derived from various types of sources such as plastic bags, food packaging, fishing gear, means of transportations. Prolonged under the sea weather, mechanical processes, and possibly waste incineration also increase plastic fragments. Fibrous microplastics account for the second major after fragments because this type is mainly derived from fibers in the washing process of textiles [44]. It is also the most commonly ingested microplastic by marine organisms [45], posing a significant threat to marine life in the area.

Samples S7, S8, and S9 belonging to Hai Hoa beach contained a large number of pellets microplastic (i.e., 17.6 to 42.9 % of total microplastics) larger than the other two areas (i.e., Hai Tien and Sam Son beaches). This difference can be explained for two reasons. Firstly, it was reported that microplastics in the shape of pellets are present in many cleaning products such as facial cleansers, shampoos, detergents, skincare products [46]. Secondly, it is due to the management of domestic wastewater treatment. The actual survey (also included in this study) showed that, in Hai Tien and Sam Son beaches, domestic wastewater from households, hotels, and restaurants on the coast is collected into the sewer system for centralized treatment, while in Hai Hoa, these wastes are discharged directly to the beach. This is the reason why microplastics present in Hai Hoa beach water are significantly higher than in Sam Son and Hai Tien.

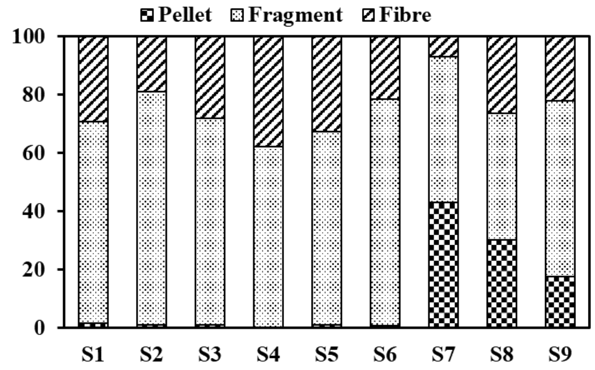

Figure 3: Microplastics identification in shape features

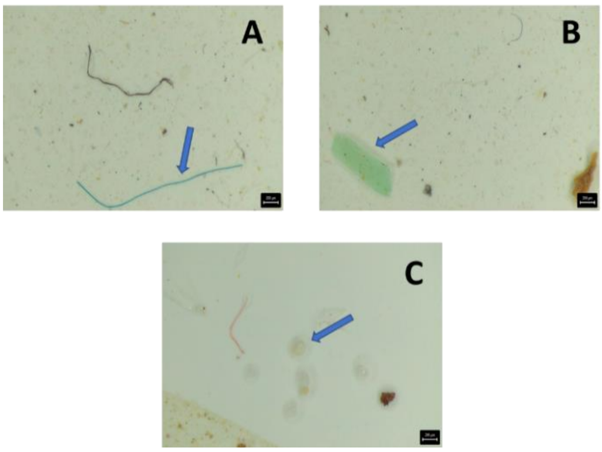

Figure 4: Examples of different types of microplastics observed using stereo microscopy. (A) fiber, (B) fragment, and (C) pellet.

Size features

Size features of microplastics were shown in figure 5. Among collected samples at three beaches (i.e., Hai Tien, Sam Son, and Hai Hoa), microplastics with small sizes in the range of 100-500 µm were the main proportion, accounting for 66.1 to 87.7 % of total particles; followed by microplastics with sizes in the range of 500-1000 µm, accounting for 10.3 to 27.5 % of total items. The microplastics with sizes ranging from 1000-2000 µm (or 1.9 to 12.9 % of total items). The size range of 2000-5000 µm attributed to the smallest part (i.e., 0.3 to 4.0 % of the total number of items). With the predominant small-sized microplastic composition, the result implied that the microplastics originated mainly from domestic wastewater sources including: wastewater from clothes washing machines, wastewater from cleaning activities (additives of detergents, cosmetics, toothpastes), and activities of transportation (microplastics are formed by worn tires).

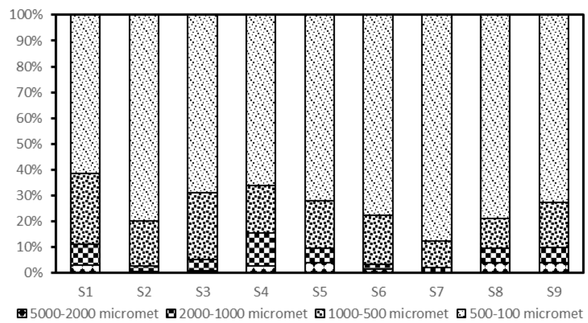

Figure 5: Microplastic identification in size features

Color features

Microplastic colors were identified with seven colors, including blue, red, purple, yellow, white, and black. The result was presented in Figure 6 and Table 3. A total of 4897 microplastics items in water at three beaches (i.e., Hai Tien, Sam Son, and Hai Hoa) were found. In which, white pieces were 1451 items, accounting for 29.6 %; yellow pieces were 1431 items, accounting for 29.2 %; black pieces were 992 items, accounting for 20.3 %; blue pieces were 691 items, accounting for 14.1 %; red pieces were 186 items, accounting for 3.8 %; purple pieces were 146 items, accounting for 3 % (table 3, figure 5). Thus, the color of microplastics was ranked in order from highest to lowest as follows: White > yellow > black > blue > red > purple. Yellow, white, and black were the colors that account for a large percentage of microplastics in the study area. These are also commonly used colors in products that are likely to emit microplastics into the marine environment, such as synthetic fiber clothing, additives in shampoo, toothpaste, facial cleansers, cosmetics, dust caused by worn tires during operation.

Figure 6: The color distribution of microplastics in Hai Tien, Sam Son, Hai Hoa beaches, Thanh Hoa province

Table 3: The color composition of microplastics in the marine environment of Hai Tien, Hai Hoa, and Sam Son.

Sample name	Beach	Color composition (%)					
		Blue	Red	Purple	Yellow	White	Black
S1	Hai Tien	11.0	1.5	1.9	50.5	20.7	14.3
S2		12.3	14.5	1.6	37.6	9.9	24.0
S3		19.9	0.4	1.1	33.5	23.3	21.8
S4	Sam Son	12.1	7.8	13.8	20.7	18.1	27.6
S5		19.8	2.5	4.4	15.8	36.6	20.8
S6		13.5	3.1	2.2	32.7	35.2	13.2
S7	Hai Hoa	7.9	1.5	1.0	13.9	56.2	19.6
S8		15.6	3.1	3.4	34.1	21.8	22.1
S9		20.0	4.3	2.7	13.8	34.7	24.6
Average		14.1	3.8	3.0	29.2	29.6	20.3

Conclusion

Microplastics were present in the marine water at all sampling points of three beaches (i.e., Hai Tien, Sam Son, Hai Hoa) in Thanh Hoa province. The abundance of microplastics was relatively high compared to published works in Vietnam as well as worldwide, which poses a severe threat to marine life in the aquatic environment. The abundance of microplastics at beaches depends mainly on factors such as source of discharge, topographical, and hydrological factors of the beach area. The characteristics such as the shape, size, and color of microplastics show that the origin of microplastics comes from wastes in the continent released by rivers through estuaries. Besides, other anthropogenic activities are also the main sources such as domestic wastewater of people living on the coast, fishing, aquaculture, and seafood processing activities. On the other hand, we also hope that this study provides information and data as a reference for establishing control and monitoring measures for microplastics in the future.

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