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Assessment of microplastic abundance and characteristics in the coastal water of Hai Phong, Vietnam

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ABSTRACT

Microplastics (MPs) in marine environments are currently a source of concern worldwide because they are pollutants to marine organisms and ecosystems. Research on the distribution and characteristics of microplastics can help identify pollution levels or their effects on marine species. In this study, we collected samples from the coastal water of Hai Phong, one of northern Vietnam's most densely populated areas with several industrial, tourism, and aquaculture zones. The concentration of microplastics in the net was 11.1 ± 7.5 items/m^3, and in the bucket was 1,515.4 ± 1,406.4 items/m^3; of the 2,659 microplastics (items), 1,041 were fragments, and 1,618 were fibers, accounting for more than 60% of the total. Microplastics are primarily disseminated type fibers with a size of 2 mm, and most of which are made of polyethylene, polypropylene, and polystyrene. The results will serve as a basis for future research into microplastic features and their effects on the sedimentary environment and species in coastal areas of Hai Phong, Vietnam.

Keywords: Microplastics pollution, coastal water, Hai Phong, Vietnam.

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INTRODUCTION

Since 2004, microplastics have been defined as plastic materials smaller than 5 mm, and Thompson has used these terms to define microplastic pollution in the seawater environment [1]. According to the United Nations Environment Program (UNEP 2005, 2009), marine waste is any solid material that has not decomposed and has been discarded into seawater or the coastal environment.

Plastic materials (plastic bottles, plastic bags, plastic cups, etc.) contain chemical additives during production and they can exist for more than 50 years [2] in the environment, which directly affects the environment and the habitats of marine animals and humans [3]. The amount of waste plastic in the ocean is approximately 275 tons [4], and approximately 80% of microplastics in the ocean originate on land, with the remaining 18% originating from aquaculture or fishing [5]. In addition, the wastewater treatment systems from rivers and lakes can contain microplastics from industrial zones, factory products, clothes, shoes, medical materials, cosmetics, and others. Furthermore, microplastics are present in the water supply to wastewater treatment plant systems, and no steps are taken to eliminate them [6].

Plastics in the ocean are generally large plastic fragments subjected to human impacts [7] or thermal and biological oxidation and decomposition processes [5], and the physical abrasion of ocean waves [8] results in smaller plastic fragments that contribute to the formation of microplastics in the ocean environment [9]. Bivalves and phytoplankton can consume them due to their small size, ranging from a few micrometers to hundreds [10, 11]. Furthermore, persistent organic substances (POPs) such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dichlorodiphenyltrichloroethane (DDTs) adsorbed by microplastics cause harm to marine organisms through the food chain [5] and to humans. In addition, they contain additives made of plastic, such as phthalic acid ester plasticizers [12], brominated flame retardants (BFR) [13], and color stabilizers, all of which contribute to the continued buildup of toxins in plastics.

One of the country's five main centrally administered cities, Hai Phong, is a coastal city in the northern Vietnam with a population of over two million. It serves as a seaport, an industrial hub, and an economic hub for the growth of tourism, seaports, and numerous sizable industrial parks; large estuary systems such as Bach Dang, Cam, Lach Tray, and Van Uc carry water from the city's reservoir and canal systems to the sea [14]. Furthermore, the Cat Ba and Do Son bays are popular tourist sites attracting millions of tourists yearly. However, the plastic garbage from passenger transit activities also contributes significantly to the ugly beaches in these areas.

In Vietnam, some research focused on assessing microplastic pollution in environments (rivers, lakes, coastal areas), such as the Saigon River system [15], the water channel of Da Nang [16]; the coastal areas of Thanh Hoa [17], and Cua Luc Bay; as well as, the accumulation of microplastics in sediments in the Red River [18]; coastal sediments in Da Nang [19]. Research on marine organisms has focused on bivalves such as clams and oysters [20]. However, the lack of a system has resulted in inconsistent data on the status of microplastic pollution. This research is being conducted in the coastal water of Hai Phong, which is a growing development and residential area in Vietnam. Many rivers and estuaries support industrial activity, tourism, aquaculture, and fishing.

METHODS AND MATERIALS

Study area and sample collection

The sampling locations in the Hai Phong estuary and coastal area (Fig. 1) during the period from April to June 2022 included 7 locations in the southeast direction outside Cat Ba Island; 2 locations in Do Son (1 location opposite the beach and 1 location near the anchorage to Hon Dau resort); and 4 locations in the two estuaries of the Bach Dang and Lach Tray Rivers, which were collected via 80 µm nets (Wildco, USA) [21] on the water surface by boat with a General Oceanic® flowmeter to calculate the volume of water sampled. The sampling locations chosen are those with tourism, aquaculture, fishing, and wastewater from the Hai Phong municipal system caused by human and industrial activity.

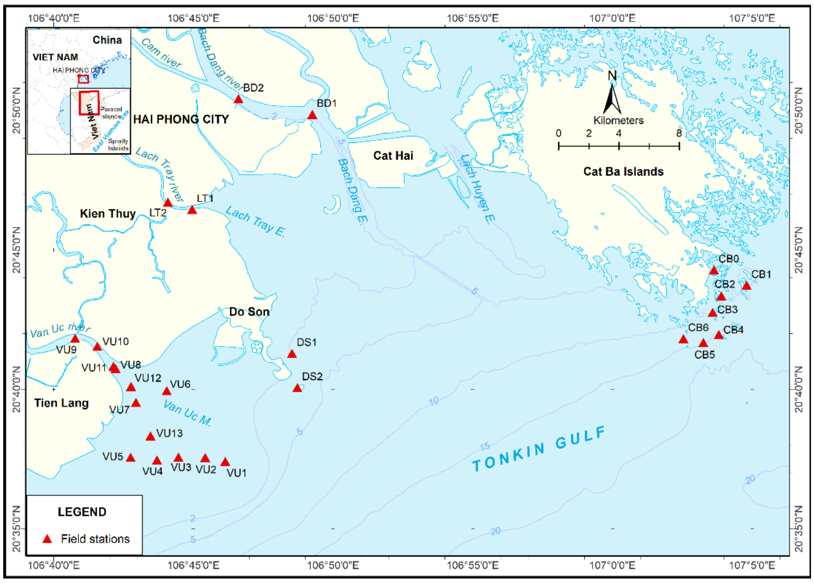

Figure 1. Map of the sampling sites

The sample was washed 3–5 times from the outside of the mesh to avoid being stuck to the mesh and was finally collected in a glass jar with a volume of 300 mL. On the other hand, the sample from the Van Uc estuary was quantitatively collected in a volume of 20 L, filtered through an 80 µm plankton net [22], and then recovered in a glass jar similar to the trawl sample. All the samples were stored at 4°C before being analyzed in the laboratory.

Sampling preparation and analysis

In this study, we used the method of extracting microplastics from samples according to the procedure of Emilie Strady, 2021 [23]. The sample is first sieved through a 5 mm metal sieve to remove objects larger than 5 mm, then passed through a 1 mm metal sieve. If there is plastic, it is carefully collected in a petri dish, checked under a microscope, and photographed. Then, the sample was oxidized with sodium dodecyl sulfate (SDS, Merck®) for 24 hours at 60°C, then it was heated for 48 hours at 50°C with biozym SE and biozym F (Spinnrad®); and finally, hydrogen peroxide (Merck®) was added for 48 hours to oxidize organic compounds in the sample. Then, the microplastics were separated with a NaCl solution (1.18 g/cm^3, Merck®) based on density separation. A 100 µm metal sieve and glass separatory funnel were used to separate the microplastics from NaCl. The sample residue solution continues to be separated again with $ZnCl_2$ solution (1.6 g/cm^3, Merck®). Finally, the separated sample was passed through a glass filter with GF/A 1.6 um Whatman 47 mm filter paper.

Microplastics were counted, sized, and photographed via an optical microscope (Leica-S9i, Germany) equipped with LAS-X software (Leica Application Suite X). Microplastics were found in seven colors (black, white, red, yellow, grey, blue, and green) and two different shapes (fragment and fiber). That is, the fragments range from larger than 20,000 µm^2 to smaller 25,000,000 µm^2, and the fibers range from larger than 100 µm to smaller 5,000 µm. Fourier transform infrared identification of the chemical composition was performed (Cary 630 ATR-FTIR Agilent). Compared with the plastic spectrum of the device, the FTIR spectrum provides information about the type of plastic, showing greater than 70% reliability for recognized results [24]. The microplastic concentration is reported as items/m^3. The washing water and solution, as well as the analytical equipment, were all washed with water from a water purification system (Thermo, Genpure UV/UF) with a 0.2 µm final filter to prevent microplastics from entering the laboratory air. In addition, the sample cups were wrapped with aluminum foil during the sample analysis procedure to prevent microplastic contamination.

Data processing

Data was collected using Microsoft Excel Office 16 software and presented on an image using ArcGIS v10.5. The base map was created and utilized to show the sampling site and microplastic distribution based on density, shape, and kind of plastic. The information was processed using ArGIS software, which combined existing base map data with updated fresh data to assure accuracy.

RESULTS

Distribution of microplastics in seawater

The concentration of microplastics detected via the flowmeter net method (Cat Ba, Lach Tray, Bach Dang, Do Son areas) was 11.1 ± 7.5 items/m^3; the Cat Ba area reached 14.05 ± 8.52 items/m^3; the Do Son area reached 14.05 ± 8.52 items/m^3; the Bach Dang and Lach Tray estuaries were 6.14 ± 0.48 items/m^3, 13.36 ± 1.08 items/m^3 respectively; and the concentration of microplastics detected in the Van Uc estuaries was 1,515.4 ± 1,406.4 items/m^3 (Figs. 2 and 3).

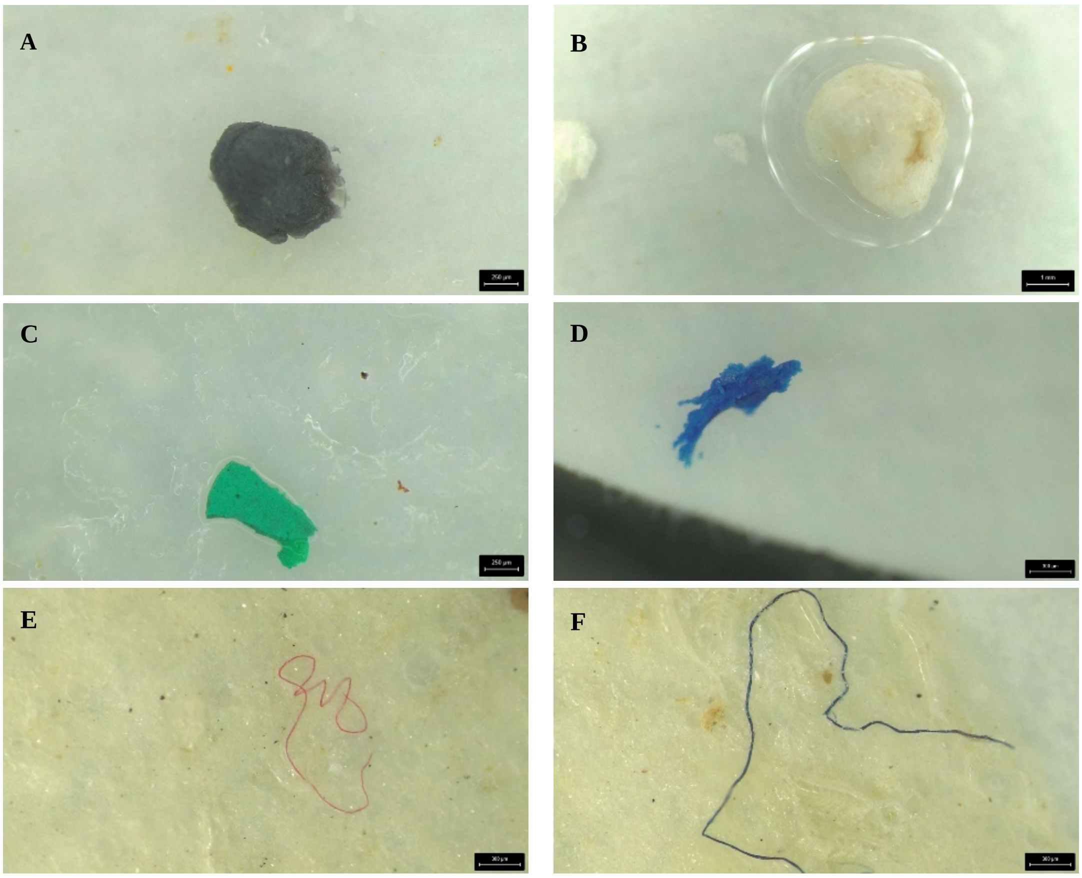

Figure 2. Microplastic fibers and microplastic fragments. A: black fragment; B: white fragment; C: green fragment; D: blue fragment; E: red fiber; F: blue fiber

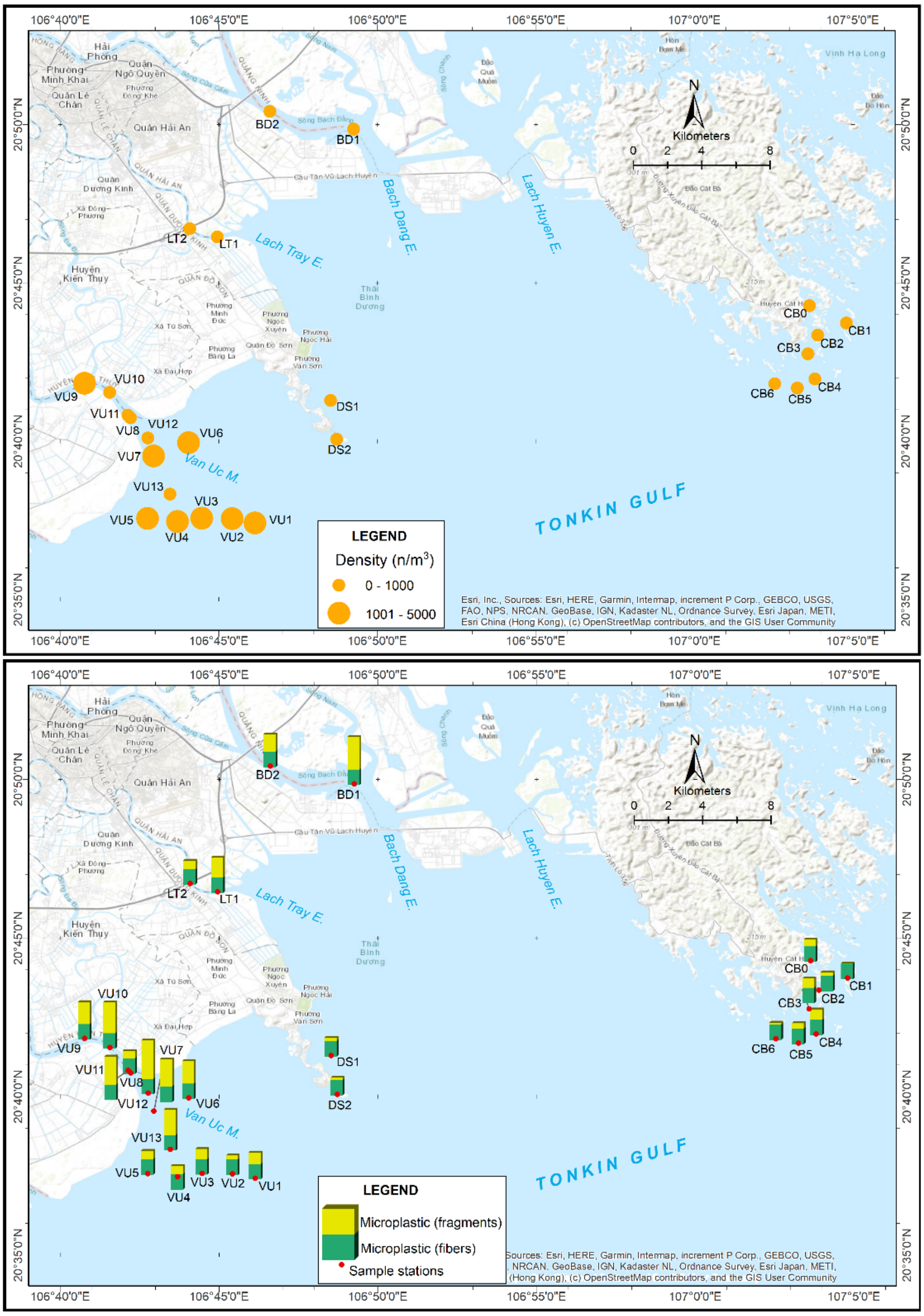

Figure 3. Distribution of microplastics in the coastal water of Hai Phong for density and shape

There were 1,041 microplastics in the form of fragments and 1,618 microplastics in the form of fibers among the 2,659 total microplastics (items) observed. Fiber distribution accounts for 61% of the sample and is widespread in estuary waters, especially Lach Tray and Van Uc and beyond sea area Cat Ba where microplastics are plentiful at CB0 locations (residential areas, aquaculture, mooring piers) and distant CB4, CB5, and CB6 locations, with densities ranging from 15.28 to 23.49 items/m^3; the density is lower in the Bach Dang estuary and Lach Tray estuary than in the Van Uc estuary.

Shape and color of microplastics in seawater

Although the number of microplastics identified at Van Uc was lower than that in the other four areas, the concentration (1,515.4 ± 1,406.4 items/m^3) of the 20 L samples collected through an 80 µm grid was many times greater. The remaining areas (11.1 ± 7.5 items/m^3) were sampled by trawling 80 µm size on the water surface. Seven different colors were found in the Hai Phong coastal seawater sample, with black, blue, and red microplastics accounting for 30, 29, and 16%, respectively, of the total number of microplastics. Those green, yellow, white, and grey colors account for 3% to 10% of the total microplastics (Fig. 4). The distribution of the five study sites is as follows: the corresponding proportions of black and blue colors are found in Cat Ba (23% - 39%), Do Son (38% - 27%), Bach Dang (49% - 18%), Lach Tray (32% - 21%), and Van Uc (32% - 29%); additionally, the red color is abundant in Do Son, Lach Tray, and Van Uc (21% - 24% and 15%, respectively); and the green color is abundant in Cat Ba (16%).

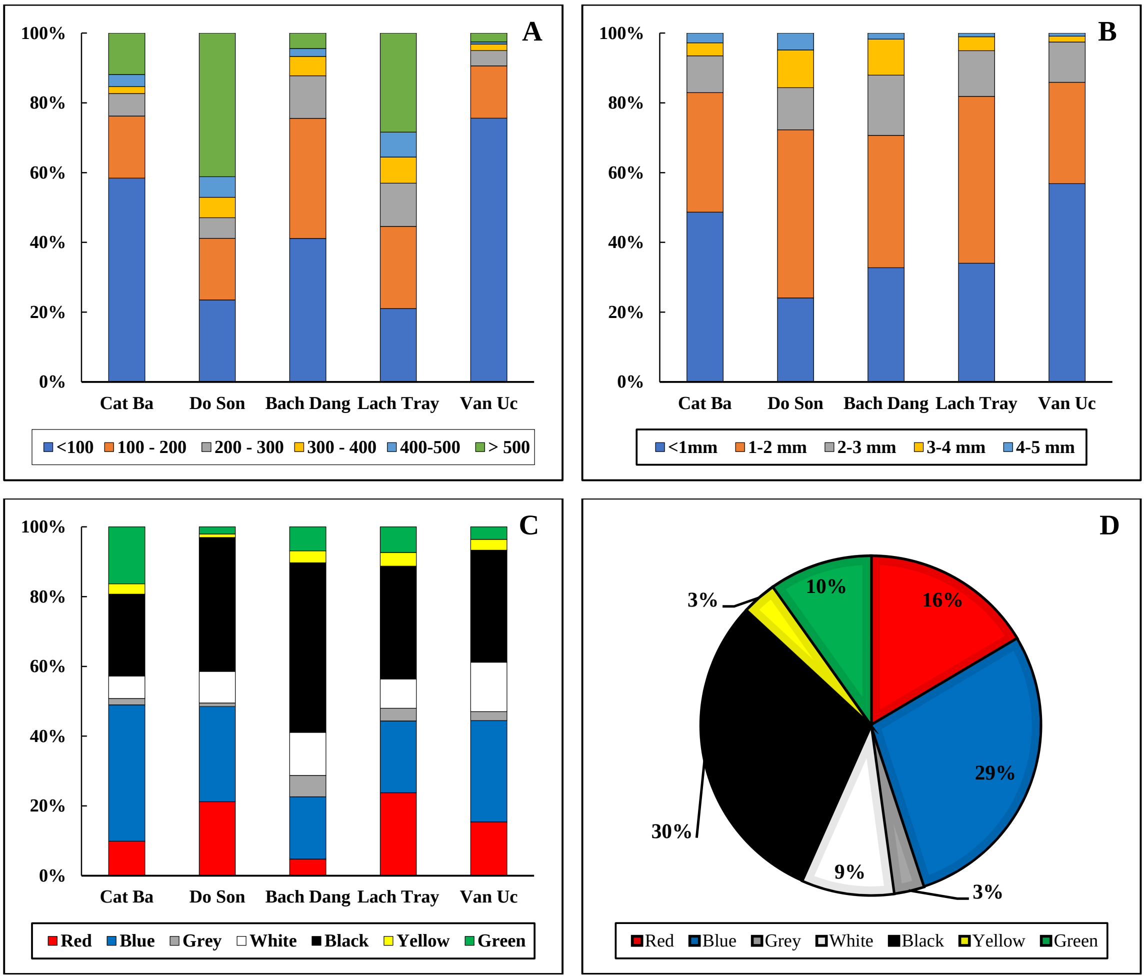

Figure 4. Microplastic size distribution and color of the coastal water of Hai Phong. A: fragment size; B: fiber size; C: color of each station; D: color of the study area

Microplastics with sizes ranging from $20*10^3$ µm^2 to less than $200*10^3$ µm^2 account for 66% of the total number of microplastics, whereas large plastic fragments can be observed with the naked eye (> $500*10^3$ µm^2) account for 18% of the total microplastics; the majority are sponges, fibers from ropes or aquaculture nets, while medium-sized fragments ranging from $200*10^3$ µm^2 to $500*10^3$ µm^2 account for only 4% to 8% of the total microplastics. Small plastic fragments accounted for 91% (Van Uc) and 76% (Cat Ba - Bach Dang) of the total fragments; most large pieces of plastic were discovered in water samples from Do Son (41%), Lach Tray (28%), and Cat Ba (12%).

Among the 89 plastic samples analyzed, most were identified as PE, PP, or PS (Fig. 5). Plastics PE and PP are the most commonly used plastics by humans, accounting for approximately 50% of all plastics (according to Plastics Europe, 2021) [25], and are among the top seven most commonly used plastics. Other plastics identified (representing 10% of the total samples analyzed) include ethylene vinyl alcohol, chlorobutyl, polyphenylene sulfide, polyacrylamide, and neoprene, all based on common resins. Plastic's chemical and physical properties should be improved to produce materials for various purposes, such as high-temperature-resistant food wraps and rubber products used to manufacture clothing.

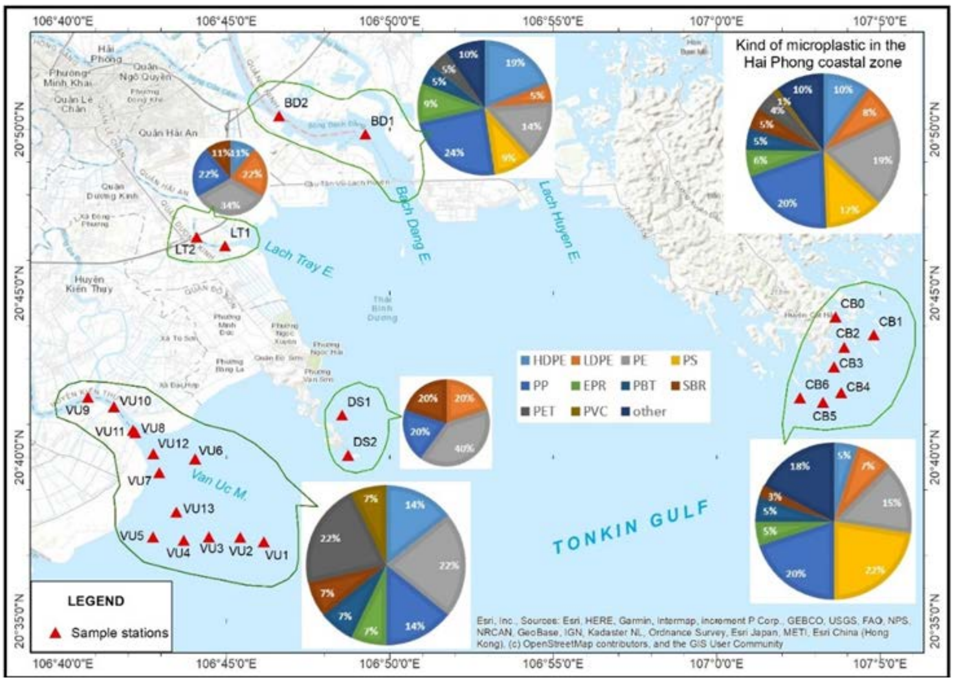

Figure 5. Distribution of microplastic chemical characteristics in the coastal water of Hai Phong

DISCUSSION

Distribution of microplastics in the study area

When the composition of microplastics in the coastal water of Hai Phong is determined to be mostly PE and PP plastic, it is similar to research from the Baram estuary area in Malaysia, the Estuary of the Yangtze River in China, studies in Vietnam on the Da Nang canal, the Saigon River system, or coastal areas in Taiwan, Korea, and China (Table 1).

The sampling method influences the results of microplastic quantification, resulting in data differences. The use of the same nets (ephemeral nets, neuston nets, manta nets) but different sizes affects the amount of plastic recovered [21], not to mention the use of various devices such as water collection, the use of water pumps, the collection of water with specialized tools (e.g. Van Dorn, Niskin), the sample scooping of water with a bucket.

This difference has been demonstrated in the study of Yifan Zheng et al., (2021) [22], who evaluated the difference in data when using 3 different sampling methods: the direct metal sieve sample was 1,600–4,000 items/m^3, the mesh sample is 10–50 items/m^3, and the trawl sample was 0.13–0.24 items/m^3; or the result of Kinsley McEachern et al., (2019), who used Van Dorn equipment was 940 ± 520 items/m^3, and the trawl sample was 4.5 ± 2.3 items/m^3 [26]. Thus, selecting a sample collection method is the first step in evaluating microplastics in the aquatic environment . Ngoc Nam Phuong assessed the level of microplastic pollution in 15 Asian countries, including Vietnam, and other purposeful and methodical studies yielded different results depending on the type of microplastic depending on the research location, sampling method, and sample processing method [27].

Table 1. Microplastic data in some countries around the world

Location	Sample method	Concentration of microplastics (items/m^3)	Type plastics	References
Estuary of the Yangtze River, China	Pumps 100 L	157.2 ± 75.8	PE, PET, PP, PA, other	[28]
Tampa Bay, Florida	1 L - Van Dorn	940 ± 520	-	[26]
Danang drainage channels, Vietnam	Bucket 100 L	1482 ± 1060	PE, PP, PS, PET, PVC	[16]
Coastal Zhuhai, China	Bucket 20 L	16610	PE, PP, PS, PVC, PET, PA	[29]
Baram Estuary, Malaysia	Bucket 10 L	9,300–18,000	PE, PS, PET, nitrile, silicon polymer	[30]
Van Uc Estuary, Hai Phong,Vietnam	Bucket 20 L - net 80 µm	1515 ± 1406	PE, PS, PP, PET, PVC, other.	This study
Taiwan Coastal	Manta net 330 µm	0,026	PE, HDPE, PP, PET	[31]
Bohai Sea, China	Net 330 µm	0.33 ± 0.34	PE, PP, PS	[32]
Benoa Bay, Bali, Indonesia	Manta net 300 µm	0.61 – 0.62	PE, PP, PS, PA, other	[33]
East Asia Sea	Neuston net 350 µm	3.7 ± 10.4	-	[34]
Tampa Bay, Florida	Plankton net 330 µm	4.5 ± 2.3	-	[26]
Korea Coastal	Manta net 300 µm	1.92–5.51 (< 2 mm); 2.30–38.77 (2–5 mm)	PE, PS, polyester alkyd	[35]
Thanh Hoa, Coastal VietNam	Plankton net 330 µm	15.5–44.1	-	[17]
Hai Phong Coastal,Vietnam	Plankton net 80 µm	11.1 ± 7.5	PE, PS, PP, PET, PVC, other.	This study
Korea Coastal	Net 50 µm	582–924 (< 2 mm); 10–375 (2–5 mm)	PE, PS, polyester alkyd	[35]
Saigon River,Vietnam	Plankton net 80 µm	172000–519000 (fiber); 10–233 (fragment)	PE, PP, polyester, other	[15]

Impacts of socioeconomics on microplastic distribution

The city’s industrial and domestic waste sources also contribute plastic waste to river systems and beaches. The average daily waste production is estimated to be approximately 1,700 tons, with each person producing an average of 0.85 kg/day, greater than the global average of 0.74 kg/day [36].

The city has implemented trash collection activities at beaches, propaganda to increase people's awareness of the use of disposable plastic waste, and policies to relocate cage aquaculture sites away from tourist destinations (Cat Ba) to reduce the amount of plastic waste in the environment. The domestic wastewater generated contains plastic fibers from the washing process [21] or industrial wastewater from textile factories; if the plastic part is not initially treated, it will be discharged directly into the city's river system before being released into the marine environment. Small-sized fibrous microplastics are easily absorbed by the bodies of creatures that build up in the meat tissue or digestive tract, such as shrimp [37], bivalves [38], and fish [39], leading to an accumulation of microplastics and other materials. On their surface, other poisons are adsorbed. Humans can accumulate microplastics by eating them, as evidenced by studies on a few bivalve species in grocery stores, supermarkets, and seafood markets [40].

CONCLUSION

This study provides comprehensive documentation of the properties and distribution of microplastics in the coastal water of Hai Phong, including their size, color, composition, and dispersion. The characteristics and distributions are comparable to those of other study locations worldwide. These results indicate that the net sampling approach accurately reflects the assessment of microplastic pollution. Fibers accounted for over 60% of all, with 1,618 items measuring less than 2000µm. PE and PP were the primary components, accounting for significant amounts in both sampling periods. It is critical to investigate their origin and impact on the environment, which highlights the importance of rapidly monitoring and tracking the presence of microplastics in various ecosystems, such as creatures and sediments, to monitor the accumulation of microplastics in marine ecosystems, particularly seafood intended for human consumption. In Vietnam, aquaculture areas must be planned and more environmentally friendly products than foams must be used. In addition, it is important to disseminate and enhance awareness among coastal residents not to dump plastic waste into the marine environment, which will significantly help reduce plastic waste and microplastic pollution in the marine environment in the future.

Authors' contributions: Concept and design: Dinh Hai Ngoc, Duong Thanh Nghi. The material preparation, data collection, and analyses were performed by Dinh Hai Ngoc, Duong Thanh Nghi, Nguyen Dac Ve, Le Van Nam. The first manuscript, which was revised, was written by Dinh Hai Ngoc. All the authors have read and approved the final manuscript.

Availability of data and materials: The raw data will be made available upon request.

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