

Preliminary assessment of marine debris pollution and coastal water quality on some beaches in Thanh Hoa province, Vietnam

Duong Thi Lim^{1*}, Nguyen Thi Lan Huong¹, Nguyen Thi Hue¹, Dang Tran Quan¹,
Nguyen Thi Huong Thuy¹, Tran Thu Thuy¹, Trinh Thi Minh Trang¹, Dao Ngoc Nhiem²,
Nguyen Quang Bac², Mai Van Tien³

¹*Institute of Geography, VAST, Vietnam*

²*Institute of Materials Science, VAST, Vietnam*

³*Hanoi University of Natural Resources and Environment, Hanoi, Vietnam*

*E-mail: duonglim79@gmail.com

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Abstract

Marine debris assessment gives information about their quantity, type, and composition, which provides data to help with their management and control. The authors conducted two surveys at three beaches at Sam Son, Hai Tien, Hai Hoa) in Thanh Hoa province in March 2020 and July 2020, respectively, during an inactive and active tourism period. A total of 3,803 waste units were collected for assessment, of which plastic waste accounts for more than 98%. The density of marine debris at the idle time of tourism ranged from 0.25–1.21 items/m². But the active tourist season recorded from 0.52–1.4 items/m². According to the Clean Coast Index (CCI), the cleanliness of beaches was grade from average clean (i.e., Hai Tien) to filthy (i.e., Hai Hoa). The plastic debris present at these beaches was mainly porous waste derived from fishing boats and food preservation foam boxes. The results also showed that the marine debris was composed of 77% polystyrene (PS), 17% polypropylene (PP) and 6% high-density polyethylene (HDPE). The water parameters were lower than the critical values during the study period according to the QCVN 10-MT:2015/BTNMT for both periods, which indicated the coastal water quality was still suitable for recreational activities.

Keywords: Clean coast index, marine debris, plastics waste properties, coastal water quality, beaches, Thanh Hoa.

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INTRODUCTION

Marine debris is defined as human-created waste that has deliberately or accidentally been released in a sea or ocean [1]. Marine debris can be found on beaches worldwide, but some studies have pointed out that urban areas, resorts, and beach users are the primary sources [2]. It is necessary to determine the period, the density, and the type of waste taken up before it becomes a severe environmental problem. In the last few decades, marine debris pollution has been seen as a critical problem, and its threat has become more and more evident around the world. The composition of marine debris can be derived from products used daily, industrial waste, and fishing gears left at sea. It can be classified into the following main groups: Plastic, metal, glass, paper, processed wood, ceramics, textile products, and rubber. Plastic waste accounts for about 70% of total marine waste [3, 4], and it can be found everywhere in marine environments. Marine debris negatively affects the environment, ecosystems, and marine organisms. They can spread diseases, transports harmful substances to human health. Besides, marine debris also reduces tourist sites' natural aesthetics [5–7], adversely affecting the local economic development in the coastal area. It is reported that 85% of the visitors asked will not come to beaches with a waste density of greater than 15 units/m² [8]. Marine debris can be found worldwide from the polar regions, archipelagos, protected areas, deep seas, and seabed. Some recent studies have suggested that beach users are the main source of marine debris accumulation [7, 9, 10], in which tourism generates the most significant amount of waste to the marine environment [11].

The Thanh Hoa province coast is quite gentle and straight with a relatively shallow and vast continental shelf [12], with great potential for tourism development. The famous beaches such as Sam Son, Hai Tien (Hoang Hoa), Hai Hoa (Tinh Gia) are attractive tourist regions that attract millions of visitors from domestic and foreign [13]. For tourism activities to develop sustainably in Thanh Hoa province, environmental factors are ranked the 2nd out of eight factors affecting the sustainable tourism

development [14]. Therefore, the ecological quality of water and marine debris is essential for the region to have pollution reduction strategies to facilitate sustainable tourism industry development.

Sam Son is one of the most beautiful beaches with a long history of tourism development. Environmental management here is quite good [15]. For example, trash bins are placed at many points on the beach for tourists' garbage disposal. Besides, garbage collection on the beach takes place at 3–4 am daily. Hai Tien is a new operational beach in Thanh Hoa province, the entire coastal area of the beach is solidly reinforced with concrete. The locals have also been concerned about collecting beach waste during the active tourism season [16]. Unlike the two beaches above, Hai Hoa beach is still relatively pristine, the number of tourists is sparse. The beach is mainly the landing place for small fishing boats, where seafood trading occurs [17]. Tourism activities on these beaches usually start at the end of May and at the end of July every year, when the weather is warm and coincides with holidays, especially students' summer holidays. For example, in 2018, the total number of tourists coming to Thanh Hoa province was 8,250,000 arrivals/year [18], of which visitors to Sam Son were 4,285,000 arrivals/year [19], Hai Tien was 1,300,000 arrivals/year [20], and year and Hai Hoa is 300,000 turns/year [17]. During the rest of the year, the beaches are very deserted for tourists.

This paper conducted a preliminary assessment of pollution levels (marine debris, water quality) on some beaches in Thanh Hoa province, providing scientific data on the density and origin of marine debris and the water quality parameters. It helps managers to understand the threat posed by marine debris to the ecosystem and socio-economic development.

METHODOLOGY

Marine debris pollution on beaches

Sampling and analysis method

Three beaches (Hai Hoa beach, Hai Tien beach, and Sam Son) in Thanh Hoa province are shown in figure 1.

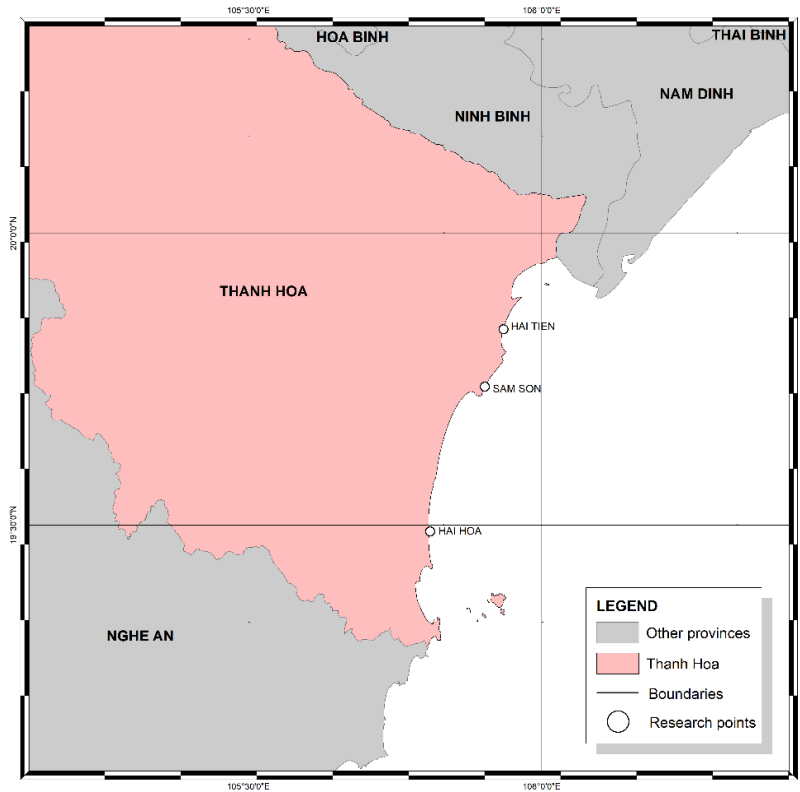


Figure 1. Map of the study area at beaches in Thanh Hoa province

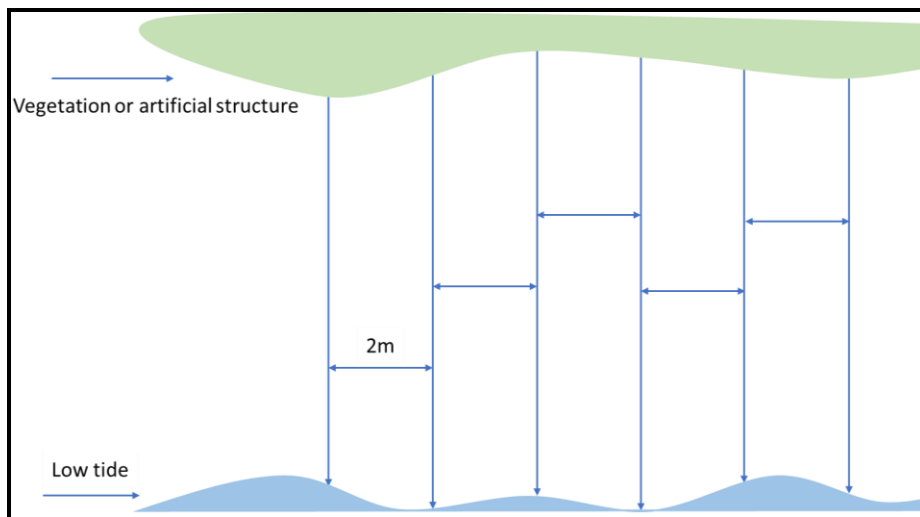


Figure 2. Marine debris sampling design

The marine debris samples were collected in March 2020, (when very few tourists visit the beaches) and in July 2020 (when tourism activities were highly active). Sampling methods were performed according to the

Guidelines for marine debris survey and monitoring [21, 22].

The sampling design at each beach is shown in figure 2. Briefly, the sampling location was sketched out a 10 m shoreline site

and divided into 2 m segments. There should be five of them. Each 2 m segment runs from the lowest tide to the back, reaching the first barrier (e.g., vegetation, artificial structures). Therefore, the total sampling area at three beaches was varied, which were 970 m², 435 m², and 800 m² for Hai Hoa, Hai Tien, and Sam Son, respectively. All waste types with dimensions (≥ 5 mm) were collected at each sampling unit. The results were expressed in terms of quantity and density.

Assessment of the cleanliness of the beaches

The *CCI* has been widely used to assess marine debris pollution worldwide. It provides information that allows for more appropriate and accurate beach cleanliness classifications on five levels (i.e., very clean, clean, medium clean, filthy and highly filthy). The *CCI* was calculated by the suggestion of Alkalay et al., (2007) [21]; the calculation is shown below:

$$CCI = \frac{\text{Total plastic parts counted in } Z \text{ lines}}{Z \times 2[m] \times \text{beach width } [m]} \times K$$

Where: *CCI* is plastic parts/m²; *Z* is the number of divisions in the study area; *K* is the coefficient (generally use $K = 20$ [21]).

The cleanliness of the beaches is assessed by the value of the *CCI* index as follows: 0–2 means very clean (no litter); 2–5 means clean (no waste is seen over a large area); 5–10 means moderate (detecting fewer waste pieces); 10–20 means dirty (a lot of waste on the beach); 20 or more means extremely filthy (most of the coast is covered with plastic debris) [21].

Classification of marine debris

Marine waste is classified according to material properties [22], including plastics, metal, glass, paper, rubber, cloth, wood, and ceramics. The plastic waste was classified as items, including bottles, bottle caps, cans with a volume of more than 2 liters, plastic bags, bags of fast food (e.g., candy, snacks, drinks, cups, others), styrofoam (e.g., sponge, food packaging foam, foam buoy, foam insulation, others), fishing gear (e.g., fishing nets, traps), gloves, children's toys, medical instruments, and some other form.

The properties of plastic waste

For this study, we used an Agilent's FTIR Carry 630 device and the universal library Agilent Polymer Handheld ATR Library for analysis. Plastic waste samples collected at beaches were washed with distilled water, then dried at 60°C. The samples were allowed to cool to room temperature. FTIR measurements on these samples were conducted to obtain an infrared spectrum and compare it with those available in the library. The obtained results provide the polymer names in the samples [23].

Water quality at the beaches

Sampling and analytical method

Surface water samples at beaches were also collected during the two surveys. Water samples were stored and analyzed according to the national and international standard methods such as TCVN, SMEWW [24, 25]. pH and DO parameters were quickly measured in the field by the YSI 650MD device (USA). Total Suspended Solids (TSS) were determined by the gravimetric method, dried at 105°C. F⁻, NH₄⁺, PO₄³⁻, CN⁻ and Cr⁶⁺ components were determined by colorimetric method using UV/Vis spectrometer on the Lambda 25 equipment (Perkin Elmer, USA). The group of heavy metals including As, Cd, Pb, total Cr, Cu, Zn, Mn, Fe and Hg was determined by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) on an Agilent Technologies 7900 instrument (USA). The group of organic compounds, including Aldrin, BHC, Dieldrin, DDTs, Heptachlor & Heptachloepoxide, and total phenol, were determined by gas chromatography coupled mass spectrometry (GC/MS) on instrument 7890B GC System - 7000C GC/MS Triple Quad from Agilent (USA). Total mineral grease (i.e., oil and grease) and the properties of plastics waste were determined by Partition - Infrared Method on an Agilent Cary 630 FTIR instrument (USA).

Assessment of water quality

The beach water quality was assessed based on the national technical regulation on marine water quality, i.e., QCVN 10-MT:2015/BTNMT, for swimming and water sports [26].

RESULTS AND DISCUSSIONS**Marine debris pollution on beaches*****The quantity and density of marine debris***

The total amount of marine debris collected in two surveys at three beaches (i.e., Hai Tien, Sam Son, Hai Hoa) was 3,803 items, of which

1684 in March 2020 and 2119 units in July 2020 (table 1). The average waste collected in previous worldwide surveys ranged from 1,484–17,000 units [5–7, 10, 27, 28]. Thus, the number of wastes items contained in this study was in the range of worldwide surveys.

Table 1. Quantity, the density of marine debris, CCI at beaches in Thanh Hoa province in 2020

Location	Sampling time	Total waste items	Waste density (items/m ²)	CCI (Cleanliness of the beaches)
Hai Tien	March	122	0.28	5.6 (Moderately clean)
	July	229	0.52	10.5 (Dirty)
Sam Son	March	391	0.49	9.7 (Moderately clean)
	July	528	0.66	13.2 (Dirty)
Hai Hoa	March	1,171	1.21	24.1 (Extremely dirty)
	July	1,362	1.40	28.0 (Extremely dirty)
Total waste units in March		1,684	-	-
Total waste units in July		2,119	-	-
Total		3,803	-	-

The density of marine debris at the time of inactive tourism (i.e., March 2020) ranged from 0.28–1.2 items/m², while at the time of active tourism (i.e., July 2020), it varied from 0.52–1.4 items/m². Thus, tourism activities at these beaches contribute to increasing the density of marine debris. Specifically, in Hai Tien beach, the waste density in the active tourist season increased 1.85 times compared to the season without tourists, while Sam Son beach and Hai Hoa beach were 1.34 times and 1.15 times (table 1), respectively. Notably, due to the activities of fishers as they usually used Styrofoam as buoyancy

material for boats, waste density in both seasons of Hai Hoa beach was higher than Hai Tien and Sam Son beaches, even though it was a relatively pristine beach (figure 3). These foams were mainly made of polystyrene, which can be easily decomposed in the environment [29] to form a considerable amount of debris. As a result, the waste density was relatively high compared to the other tourist-active beaches.

According to the data in table 2, the waste density of the beaches in Thanh Hoa province was relatively high compared to the worldwide beaches.

Table 2. Marine debris density of some other beaches

Country	Year	Number of surveyed beaches	Density (items/m ²)	Reference
Turkey	2018	1	0.43–3.68	Yahya Terzi and Coworkers (2020) [30]
China	2019	6	0.05–2.75	Xuehua Ma and Coworkers (2021) [31]
Spain	2018	40	0.022–2.26	F. Asensio Montesinos and Coworkers (2020) [32]
Vietnam	2020	3	0.28–1.4	This study
Italy	2015	5	0.17–0.57	Cristina Munari and Coworkers (2016) [33]
Albania	2018	5	0.009–0.21	Laura Gjyli and Coworkers (2020) [34]
Morocco	2015–2017	17	0.005–0.154	Driss Nachite and Coworkers (2019) [35]

Assessment of the cleanliness of the beaches

CCI values in the study sites (table 1) indicate that Hai Tien and Sam Son beaches in March and July 2020 were classified as average clean and dirty, respectively. Hai Hoa beach in both periods was classified as extremely dirty (i.e., CCI > 20). As explained above, it is because the boat-building technique of the fishermen was quite simple. The used of Styrofoam increases the CCI of the Hai Hoa beach even though it was still a pristine beach. During the active tourism season, the CCI at Sam Son beach, Hai Tien, Hai Hoa, was higher than inactive tourism. Notably, the highest increasing rate was at Hai Tien (1.9 times), followed by 1.4 times at Sam Son beach and the lowest increasing rate was at Hai Hoa beach (1.2 times). This result implied that the presence of tourists combined with the food and beverage business on the beach was evident for the increase in waste, consistent with the study of Victor V. Ribeiro et al., (2021) on tourism activity and beach cleaning, which had a clear correlation with the CCI [36]. It is noted that depending on the physical conditions, management experience, tourist density and the awareness of those participating in activities on the beach, the amount of waste present increased differently.

Classification of marine debris

The types of waste found at Hai Tien, Sam Son and Hai Hoa beaches in Thanh Hoa province are shown in table 3 and figure 3. Plastic waste was a major component of marine debris at beaches in Thanh Hoa province, accounting for 98.2–99.5% of the total marine debris. Glass, paper, textile products, processed wood were also present on the beaches, but the amount was tiny, accounting for 0.5–1.8% of the total marine debris in the studied area.

Thus, the proportion of plastic waste in the total marine waste of Thanh Hoa beaches was high compared to the world average of 36–94.88% [27, 36–39]. The reason for this result might come from the anthropogenic activities in the studied area. However, many people in these localities are not fully aware of marine pollution. Therefore, the discharge of plastic waste into the environment was predictable.



Figure 3a. Fishing boats are made of foam material



Figure 3b. Picture of marine debris

Table 3. Classification of marine debris in Thanh Hoa beaches in 2020

Types	Hai Tien		Sam Son		Hai Hoa	
	Mar.	Jul.	Mar.	Jul.	Mar.	Jul.
Plastic waste (%)	98.3	98.2	98.5	99.4	99.5	99.1
Other waste (%)	1.7	1.8	1.5	0.6	0.5	0.9

Various types of plastics were littered on the beaches of Thanh Hoa province, including

Styrofoam debris, plastic bags, disposable cups, beverage bottle caps, disposable straws,

confectionery cases, snack bags, fishing net, rope, plastic fragments, bags fragments, glass fragments, garments, marine processed wood fragments, cigarette packs, milk cartons and hair ties. This finding shows that the source of marine waste on these beaches was mainly from local people’s fishing activities and recreational activities on the beach.

Properties of plastic waste at beaches

Plastic waste was found at beaches in Thanh Hoa province with materials, mainly foam debris, plastic bags, food covers, mesh fibers (table 4).

Table 4 shows that the main component of plastic waste on beaches was foam debris (from 48–86%), which came from the foam bins that stored seafood and food from local people and tourists. In addition, the use of foam to manufacture fishing boats had been identified as the main source of foam debris that occurred on the beaches of the province.

The properties of plastic waste are shown in figure 4. The actual sample analysis results indicated that 77% of plastic waste was polystyrene (PS), 17% of plastic waste was high-density polyethylene (HDPE), 6% of plastic waste was polypropylene (PP). These polymers are widely used to manufacture products in everyday life. In particular, PS accounts for a major component of plastic waste, which was thermoplastic, hard, light and insulating materials. PS substance was widely

used in packaging, construction materials and marine time but low recyclability. The presence of PS resin in the marine environment comes from rivers, rainwater, water treatment plants, structural damage, boats, or direct discharge [40]. Due to its lightweight, it is quickly washed away by waves and wind. As a result, they can be easily dispersed into the environment. PS resin was tough to remove during beach cleaning. More importantly, it has been noted to affect many types of marine organisms that float-eating on the surface of the water, such as it clogs the gastrointestinal tract or exposes the animal to toxic chemicals [41].

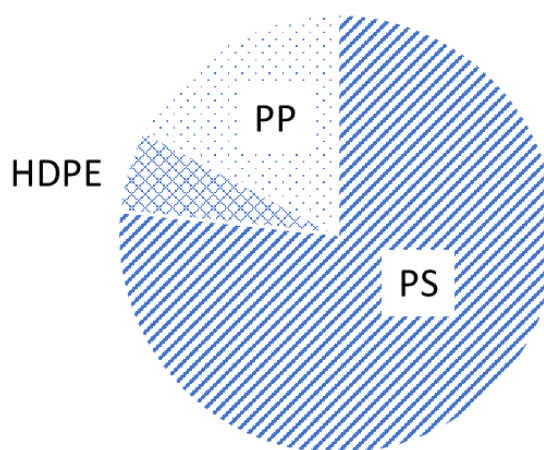


Figure 4. Plastic composition of marine debris: PP: Polypropylene, PS: Polystyrene, HDPE: High-density polyethylene

Table 4. Plastic waste composition by item classification in 2020

Items	Hai Tien		Sam Son		Hai Hoa	
	Mar.	Jul.	Mar.	Jul.	Mar.	Jul.
Foam (%)	81.7	48.4	62.9	56.0	85.9	85.0
Plastic bags (%)	5.8	5.3	7.5	7.0	3.9	3.6
Food covers (%)	5.0	41.8	8.6	22.7	7.6	9.1
Net fibers (%)	5.8	1.3	16.4	11.4	0.2	0.2
Others (%)	1.7	3.1	4.7	2.9	2.4	2.1

Water quality at the beaches

The study used the QCVN 10-MT:2015/BTNMT-based standards to assess seawater quality in coastal areas; the results are shown in table 5.

pH, DO, TSS, NH₄⁺, PO₄³⁻ and Coliform present in water are greatly influenced by

domestic wastewater, which was still within the allowable threshold of the QCVN 10-MT:2015/BTNMT. The range of these parameters fluctuates between two periods (i.e., inactive tourism and active tourism) at all three beaches were relatively small, suggesting that tourism activities at the beaches had not yet

affected the water quality. The values of NH_4^+ , PO_4^{3-} ranged from 0.01–0.04 mgN/L and 0.03–0.06 mgP/L, respectively, which were very low compared to the critical values in the standard.

Table 5. Parameter of water quality at beaches in Thanh Hoa province in 2020

Parameters	Unit	Hai Tien		Sam Son		Hai Hoa		QCVN 10-MT:2015/BTNMT
		Mar.	Jul.	Mar.	Jul.	Mar.	Jul.	
Sampling time		Mar.	Jul.	Mar.	Jul.	Mar.	Jul.	
pH	-	8.17	8.02	8.09	8.10	8.12	8.05	6.5–8.5
DO	mg/L	6.12	6.05	6.17	6.21	7.03	6.58	≥ 4
TSS	mg/L	25	21	18	20	15	19	50
NH_4^+	mgN/L	0.02	0.01	0.03	0.04	0.01	0.02	0.5
PO_4^{3-}	mgP/L	0.04	0.05	0.03	0.06	0.03	0.04	0.3
F ⁻	mg/L	1.36	1.38	1.42	1.39	1.48	1.47	1.5
CN^-	mg/L	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	0.01
As	mg/L	0.002	0.003	0.003	0.002	0.002	0.004	0.04
Cd	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.005
Pb	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.05
Cr^{6+}	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.05
Total Cr	mg/L	0.002	0.003	0.005	0.004	0.003	0.002	0.2
Cu	mg/L	0.062	0.056	0.074	0.042	0.067	0.035	0.5
Zn	mg/L	0.043	0.035	0.021	0.018	0.033	0.042	1.0
Mn	mg/L	0.015	0.012	0.023	0.019	0.011	0.013	0.5
Fe	mg/L	0.08	0.16	0.06	0.08	0.09	0.17	0.5
Hg	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002
Aldrin	$\mu\text{g/L}$	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1
BHC	$\mu\text{g/L}$	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02
Dieldrin	$\mu\text{g/L}$	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1
DDTs	$\mu\text{g/L}$	< 0.05		< 0.05		< 0.05		1.0
Heptachlor & Heptachlorepoide	$\mu\text{g/L}$	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2
Total Phenol	mg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03
Total mineral oil	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.5
Coliform	MPN/100 mL	0		0		0		1,000

The parameters, including C^- , As, Cd, Pb, Cr^{6+} , total Cr, Cu, Zn, Mn, Fe, Hg, mineral oil, and phenol which are mainly derived from industrial wastewater, fishing activities, were also low compared to the critical values. The result shows that there was little difference between the two studied periods and among sampling locations. Toxic parameters such as CN^- , Cd, Pb, Cr^{6+} and Hg were almost undetectable in most water samples at all three beaches. The concentration of other heavy metals such as

As ranged from 0.002–0.004 mg/L, total Cr ranged from 0.002–0.005 mg/L, Cu ranged from 0.035–0.074 mg/L, Zn ranged from 0.018–0.043 mg/L, Mn ranged from 0.011–0.023 mg/L and Fe ranged from 0.06–0.16 mg/L. Notably, the study has not detected pesticides (i.e., Aldrin, BHC, Dieldrin, DDTs, Heptachlor & Heptachlorepoide) mainly derived from agricultural activities in all water samples.

In general, the coastal water quality at the beaches was good according to the QCVN 10-

MT:2015/BTNMT for swimming and entertainment activities.

CONCLUSIONS

To summarize, 3,803 microplastic particles were found in the study area with the density varied from 0.25–1.21 items/m² and 0.52–1.4 items/m² for inactive and active tourism, respectively. The results showed that microplastic (especially polystyrene) makes up the main marine debris component, a persistent waste with low recyclability. It is an increasing threat to the marine environment and marine life as well as human health.

The cleanliness of beaches in Thanh Hoa was moderately clean (i.e., Hai Tien in the idle tourism period), dirty (i.e., Sam Son and Hai Tien in the active tourism period) and highly filthy (i.e., Hai Hoa in both periods). However, coastal water quality in the three beaches was quite good in both periods, indicating that the studied area is still suitable for water activities.

The origin of marine debris on beaches was mainly from fishing, seafood trading, food trading, tourists and beach users. In particular, boats made of foam sheets was the leading cause of foam debris that pollutes the beach environment.

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