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Characterization of microplastic pollution in coastal sediments of Vietnam

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ABSTRACT

Microplastics have increasingly been recognized as an emerging pollutant and have attracted considerable global scientific attention due to their potential impacts on ecosystems and human health. However, information on microplastics in Vietnam's marine environment remains limited, fragmented and lacking systematic synthesis. This study provides a systematic review of peer-reviewed publications from 2020 to 2024 that investigated microplastics in coastal marine sediments across Vietnam. Reported concentrations ranged from 0 to 29,232 microplastics/kg (MPs/kg), with mean values ranging between 2.82 and 10,830 MPs/kg. Secondary microplastics were the dominant type, primarily occurring as fibers and fragments. A total of 32 polymer types were identified, among which polyamide (PA), polypropylene (PP), polystyrene (PS) and polyethylene (PE) were the most frequently detected. These findings provide a comprehensive overview of the current status of microplastic pollution in Vietnam's coastal waters, revealing methodological inconsistencies and underscoring the urgent need to standardize future investigation protocols.

Keywords: Microplastics; sedimentary environment; pollution; Vietnam coastal areas.

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Introduction

Plastic waste accounts for approximately 60–80% of total marine debris, representing nearly 10% of global annual plastic production [1]. The quantity and characteristics of plastic waste vary considerably among regions, depending on both the volume of plastic produced and the effectiveness of waste management systems. Due to its persistence and low recycling rates, an estimated 79% of plastic waste ultimately enters the marine environment, contaminating coastlines, the water column, and marine sediments worldwide [2]. Marine plastic debris occurs in diverse shapes and sizes and is commonly classified by size into macroplastics, microplastics, and nanoplastics. Among these, microplastics (MPs) are increasingly recognized as an emerging pollutants owing to their ubiquitous distribution and their ability to adsorb and transport various contaminants, including persistent organic pollutants (POPs), heavy metals (Pb, Cd, Hg) and plastic additives. Microplastics are generally defined as solid plastic particles that are insoluble in water, irregular in shape and less than 5 mm in size [1, 3]. Once released into the marine environment, many MPs may sink through the water column as a result of density alterations induced by physical, chemical, and biological processes [4]. In addition, low-density MPs can be transported by tidal currents to coastal zones and are often detected along the shoreline. Marine sediments, including beaches, coastal areas, and the deep sea, are considered the ultimate sink and one of the most impacted environmental compartments by microplastic pollution [1, 4].

Vietnam ranks among the top 20 countries generating the largest amounts of plastic waste, with levels exceeding the global average. An estimated 0.28–0.73 million tons of plastic waste are discharged into the ocean from Vietnam each year, accounting for approximately 6% of the global total [5]. Overall, the country produces about 3.7 million tons of plastic waste each year, of which only 10–15% is recycled. The per capita plastic consumption in Vietnam increased from 3.8 to approximately 30 kg per person per year between 1990 and 2018 [6]. These figures indicate the increasing risk of plastic waste pollution in Vietnam and emphasize the urgent need for effective plastic waste management and recycling policies.

The main objective of this study is to provide an overview of scientific publications addressing MPs pollution in Vietnam's coastal sediments. The synthesized information is expected to serve as a foundation for future studies aiming to comprehensively assess the extent and characteristics of microplastic contamination in Vietnam's coastal environments.

Materials and methods

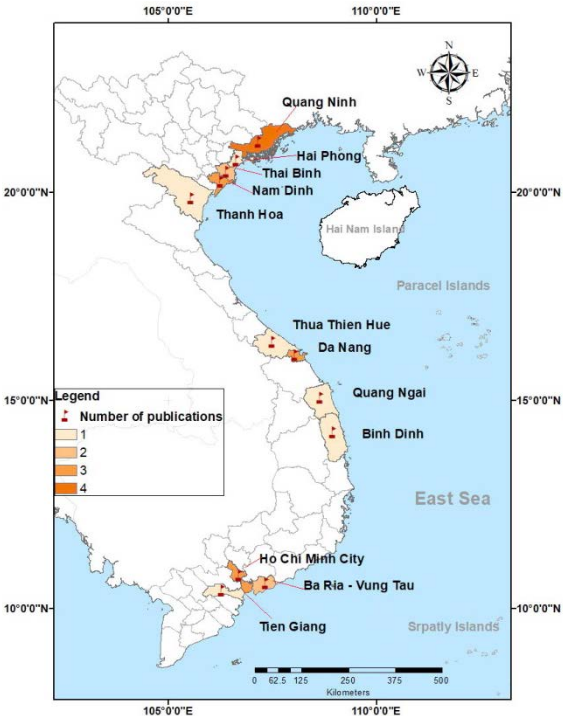

Figure 1. Sampling locations for microplastics in coastal sediments of Vietnam

This study employed a systematic review approach to collect and analyze published research on microplastics in Vietnam's coastal sediments. Data were retrieved from academic databases such as Google Scholar, ScienceDirect, ResearchGate and other scholarly online sources, using combined keywords including "microplastics", "beach sediments", "coastal" and "Vietnam". The selected publications were limited to the period from 2020 to 2024 and focused on coastal sedimentary environments such as estuaries, lagoons, mangroves, tidal flats, and coastal sandbanks. The selection criteria were as follows: (i) studies that quantified microplastic concentrations; (ii) those that reported results in units of particles per kilogram of dry sediment or provided sufficient data for conversion into this unit; and (iii) studies that included detailed descriptions of microplastic morphology, size, and polymer types. The provinces and cities covered by the selected studies are presented in Figure 1. Their names and administrative units are reported according to the designations and administrative divisions as they existed before 1 July 2025. All eligible data were compiled into a unified dataset to facilitate comparison, and synthesis. In addition to concentration data, information on particle size, shape, and polymer composition was extracted to analyze distribution patterns and common characteristics of microplastics in the study area.

A one-way analysis of variance (One-way ANOVA) was performed to examine differences in microplastic concentrations in coastal sediment samples among three regions: Northern, Central, and Southern Vietnam. Differences were considered statistically significant at $p < 0.05$. Maps of the sampling locations were generated using ArcGIS 10.8 software (ESRI). Graphs were plotted using Origin 2021 (OriginLab).

Results and discussion

Concentration of microplastics

To date, approximately twenty published studies have investigated MPs in sediments from coastal areas of Vietnam. Reported concentrations of MPs in coastal sediments range from 0 to 29,232 particles per kilogram of dry sediment (MPs/kg), with mean concentrations ranging from 2.82 to 10,830 MPs/kg. Detailed information on the characteristics of these MPs is summarized in Table 1.

Table 1. Summary of microplastic pollution in coastal sediments of Vietnam from 2020 to 2024

Location	Year of publication	MPs concentrations (MPs/kg)		MPs size (µm)	MPs shape	Polymer types	References
		Range	Mean				
Northern Coastal Waters							
Bach Dang estuary, Hai Phong City	2020	1,700–6,500	3,730	250–5,000	Fragments; fibers	-	[7]
Cua Luc bay, Quang Ninh Province	2020	1,500–4,260	2,680	250–5,000	Fragments; fibers	-	[8]
Tidal flat, Thanh Hoa Province	2020	2,921–5,365	4,123	250–5,000	Fragments; fibers; foams; films	-	[9]
Tien Yen bay, Quang Ninh Province	2020	236–1,324	664 ± 68	250–5,000	Fibers; fragments; foams; films	6 types: PE; PP; PA; PVC; PS; PET	[10]
Ba Lat estuary, Nam Dinh Province	2021	70–2,830	856,9 ± 682,0	300–5,000 (> 88% of total particles)	Fibers; fragments; granules	4 types: PE; PP; PA; PS	[11]
Mangrove forest, Red River Delta, Thai Binh Province	2021	0–4,941	-	300–5,000	Fibers; fragments; foams; films	6 types: PE; PP; PS; PET; PA; PES	[12]

Location	Year of publication	MPs concentrations (MPs/kg)		MPs size (µm)	MPs shape	Polymer types	References
		Range	Mean				
Mangrove forest, Tien Yen bay, Quang Ninh Province	2021	0–815	-	300–5,000	Fibers; fragments; foams; films	6 types: PE; PP; PS; PET; PA; PES	[12]
From Ba Lat estuary to Day estuary, Nam Dinh Province	2022	10–20	11,6	700–2,600	Fragments	1 type: PS	[13]
Ba Lat estuary (Thai Binh, and Nam Dinh Provinces)	2023	800–3,817	2,188 ± 1,499	< 500–5,000	Fibers; fragments	5 types: PE; PP; PS; PU; PA	[14]
Quang Ninh Province coastline	2024	1,700–7,600	4,800 ± 1,776	22.3–1,032.3	Fragments; fibers; beads	11 types: PET; PA; PTFE; MUF; PVA; PF; EVOH; CP; UF; MF; HDPE	[3]
Central, Coastal Waters							
Eight beaches in Da Nang City	2020	5,100–11,000	9,238 ± 2,097	303–4,996	Fibers; fragments	6 types: PA; EVOH; PES; PET; PAN; Polyacrylate	[5]
Three beaches in Da Nang City	2021	1,460–29,232	10,830	22.7–1,272.6	-	18 types: PTFE; EVOH; PA; MUF; PES; CP; PF; PVA; PDMS; PVDF; UF; MF; ABS; PMMA; CPP; SBR; MF; EP	[15]
Quy Nhon beach, Binh Dinh Province	2022	1,700–3,100	2,400	300–5,000	Fibers; fragments	-	[16]
Thuan An estuary, Thua Thien Hue Province	2023	300–2,800	-	300–5,000	Fibers; fragments	2 types: PP; PE	[17]
Seven beaches in Da Nang City	2023	2,094–9,116	5,565 ± 2,359	22.4–2,797.2	Fragments; fibers; beads	21 types: PA; PTFE; PES; EVOH; MUF; PDMS; CP; PVDF; CPP; UF; PU; SBR; PMMA; MF; EP; PF; PVA; PEI; LDPE; POM; Ionomer resin	[18]
Le Thuy beach, Quang Ngai Province	2023	833–2,767	1,582 ± 660	22.5–539.3	Fibers; fragments	11 types: PET; MUF; PEI; PTFE; PVA; PF; PA; EVOH; CP; PU; PAM	[1]

Location	Year of publication	MPs concentrations (MPs/kg)		MPs size (µm)	MPs shape	Polymer types	References
		Range	Mean				
Southern Coastal Waters							
Beach sand in Vung Tau City	2020	0–295	44.6	500–5,000	Granules; fragments; fibers	4 types: PS; PE; PP; PVC	[19]
Beach sand in Tien Giang Province	2020	0–281.4	42.5	500–5,000	Fragments; granules; fibers	4 types: PP; PE; PS; PVC	[19]
UNESCO Can Gio Mangrove Biosphere Reserve	2021	31.99–92.56	60.22 ± 19.85	25.12–640.11	Fragments; fibers	7 types: PE; PP; PS; PET; PA; PMMA; PVC	[20]
Dau beach and Sau beach, Ba Ria - Vung Tau Province	2021	1,542–2,024		250–5,000	Fibers; fragments	-	[21]
Can Gio coast, Ho Chi Minh City	2022	0–6.58	2.82	500–5,000	Granules; fragments; fibers	3 types: PP; PE; PS	[22]
Can Thanh beach, Ho Chi Minh City	2022	-	80.4±13.7	300–5,000	Films; fibers; fragments	4 types: PO; PE; PP/PA; PS	[23]

Note: The full names of the abbreviated polymers are presented in Table 2.

The results of one-way ANOVA indicated statistically significant differences in MPs concentrations in coastal sediments among the three regions of Northern, Central, and Southern Vietnam ($p < 0.05$). MPs concentrations were highest in the Central coastal region (1,582–10,830 MPs/kg), followed by the Northern region (11.6–4,800 MPs/kg) and the Southern region (2.82–1,783 MPs/kg) (Fig. 2a). This pattern is consistent with the fact that most studies conducted in the Central region focused on tourist beaches, where tourism activities are considered one of the main contributors to plastic waste and MPs generation in coastal areas [24]. Furthermore, when considering different environmental types, MPs concentrations in mangrove forests and bays were comparable (0–4,941 and 236–4,257 MPs/kg, respectively), followed by estuarine areas (10–6,500 MPs/kg) and highest at beaches (0–29,232 MPs/kg) (Fig. 2b). Globally, the highest average MPs concentrations in sediments have been reported in narrow bays (7,000 MPs/kg), followed by estuaries (300 MPs/kg), beaches and shallow coastal areas (200 MPs/kg), continental shelves (50 MPs/kg), and the lowest in deep-sea environments (80 MPs/kg) [25]. This comparison suggests that MPs pollution in Vietnam's coastal sediments is relatively high compared with many other regions worldwide.

The data presented in Table 1 indicate significant variations in MPs concentrations among the sampling sites ($p < 0.05$). In addition to the specific environmental characteristics of each study area, inconsistencies in sampling and analytical procedures may also contribute to these differences. Regarding sampling methods, some studies focused on core sediments [12, 17] or on bottom sediments collected using Petersen grab samplers [7, 8]. Meanwhile, most studies targeted surface sediments, employing specialized equipment such as grab samplers [10, 14], stainless steel trowels [9], metal tubes [5, 16] or PVC pipes [21]. The grid sampling approach was most commonly applied, typically at depths of 5 cm

[1, 3, 15, 18, 19, 23], 7 cm [22], 20 cm [20], or 3–50 cm [13]. The range of MPs sizes determined was also inconsistent across studies. Most studies focused on larger MPs, with sizes of 250 µm [7–10, 21], 300 µm [5, 11, 12, 16, 17, 23] or 500 µm [19, 22], which may have led to the omission of smaller-sized particles. Additionally, several studies used density separation solutions with relatively low densities, such as saturated NaCl (d ~1.2 g/cm³) [5, 7, 8, 14, 16, 17, 20, 21, 23], which may not be effective for extracting higher-density MPs.

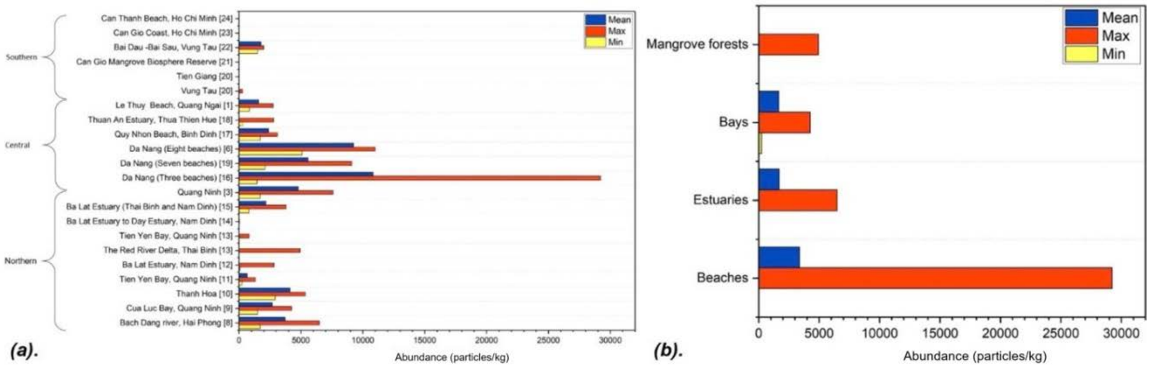

Figure 2. Summary of microplastic concentrations in coastal sediments of Vietnam based on studies conducted during 2020–2024

Size of microplastics

Overall, the size distribution of MPs varied among studies. In the coastal areas of Nam Dinh Province, from the Ba Lat to the Day estuaries, MPs exhibited relatively large sizes, with an average of 1,500 ± 514 µm [13], which was comparable to those found in the Thuan An estuary, Thua Thien Hue Province (1,573 ± 996 µm) [17] and on eight beaches in Da Nang City (1,701 ± 1,029 µm) [5]. Do et al. (2021) reported that MPs in sediments from three beaches in Da Nang City ranged from 22.7 to 1,272.6 µm, with an average size of 113.9 ± 152.8 µm [15]. Similarly, another study on sediments from seven beaches in Da Nang recorded MPs with an average length of 93.4 µm, ranging from 22.4 to 2,797.2 µm [18]. In contrast, MPs in beach sediments of Quy Nhon, Binh Dinh Province were mainly within the 1,000–2,000 µm range, [16] whereas most MPs in the sediments of the Thuan An estuary in Thua Thien Hue Province were smaller than 2,895 µm [17].

In the Southern coastal areas, most studies have focused on MPs larger than 300 µm [19, 22, 23]. Research by To et al. (2020), conducted on two beaches in Vung Tau and Tien Giang provinces, revealed that MPs smaller than 1,000 µm were predominant [19]. In contrast, at the Can Gio coast, MPs ranging from 2,800 to 5,000 µm accounted for the majority [22]. In the UNESCO Can Gio Mangrove Biosphere Reserve, MPs ranged from 25.12 to 640.11 µm [20], similar to those reported in Quang Ngai Province, which ranged from 22.5 to 539.3 µm [1]. In sediments from clam aquaculture sites in the Can Thanh coastal area, the size distribution of MPs showed no significant differences among size classes, with MPs larger than 4 mm being dominant [23].

A clear inverse relationship between MPs concentrations and size was observed in several studies. Le et al. (2023) reported an R^2 value of 0.9603 in sediment samples from coastal areas of Central Vietnam (Quang Ngai Province) [1]. Do et al. (2024) reported a similar trend in northern coastal sediments (Quang Ninh Province) with an R^2 value of 0.9092 [3]. Similarly, To et al. (2020) observed the same trend on beaches in Tien Giang Province and Vung Tau City [19]. These findings are consistent with other studies conducted worldwide [26–29]. The predominance of smaller-sized MPs may result from the fragmentation of larger plastic pieces due to physical, chemical, and biological processes [30]. Smaller MPs are more likely to be retained within sediments, whereas larger particles tend to be washed away through sand pores [31]. Additionally, smaller MPs possess higher adsorption capacities for pollutants and may pose greater toxicity risks to aquatic organisms [1].

Shapes of microplastics

A synthesis of published studies indicates that fibers and fragments are the two the most dominant dominant morphological categories of MPs in coastal sediments of Vietnam. These two forms are widely reported as the predominant types in nearshore marine sediments [4]. Fiber-shaped MPs were the most prevalent in studies conducted in Tien Yen Bay [10], the Ba Lat estuary (Thai Binh and Nam Dinh Provinces) [14], the Thuan An estuary [17], eight beaches in Da Nang City [5], Le Thuy Beach in Quang Ngai Province [1] and Dau and Sau beaches in Ba Ria-Vung Tau Province [21]. In contrast, fragment-shaped MPs were predominant in the Bach Dang estuary [7], Cua Luc Bay [8], the coastal intertidal area of Thanh Hoa Province [9], from the Ba Lat to the Day estuaries in Nam Dinh Province [13], along the Quang Ninh coastline [3], seven beaches in Da Nang City [18], and beaches in Tien Giang Province [19]. In addition, MPs in the form of films, granules, beads, and foams have also been reported in several studies. Granules were among the dominant MPs shapes observed at southern beaches such as Can Gio, Ho Chi Minh City [22], as well as Vung Tau City and Tien Giang Province [19]. In the Northern and Central coastal regions, granules were reported only in the Ba Lat estuary [11], whereas bead-shaped MPs were found on beaches in Da Nang City [18], and along the Quang Ninh coast [3]. Film-shape MPs were identified at Can Thanh Beach [23] and in several Northern sites [9, 10]. Foam-shape MPs were commonly found in northern areas such as Tien Yen Bay [10] the coastal intertidal zone of Da Loc Commune, Thanh Hoa Province [9] and the Thuan An estuary of Central Vietnam [17].

The shape of MPs found in coastal marine sediments of Vietnam indicates that the majority are secondary MPs. These particles are likely derived from the fragmentation of larger plastic debris originating from terrestrial and coastal sources, as reported in several studies [9, 12]. The high concentration of fiber-shaped MPs may be attributed to synthetic textiles used in clothing and diapers, as well as to the degradation of fishing nets, ropes, and aquaculture gear [1, 3, 9, 17]. Additionally, fiber MPs may originate from urban and industrial wastewater, or stormwater runoff that carries fibers from inland areas into rivers and eventually to the sea [1, 5]. In a study conducted at eight beaches in Da Nang City, Tran Nguyen et al. (2020) found that 99.2% of MPs were fibers and attributed their presence mainly to industrial and domestic wastewater discharged from nearby residential, and resort areas [5]. Similarly, Hien and Cuc (2021) suggested that the dominance of fiber MPs may be related to synthetic fibers from textile industries in the Red River Delta region [11]. Fiber-shaped MPs were particularly abundant in areas associated with aquaculture (clam farming, cage fish culture, and fishing activities) and in coastal zones influenced by textile dyeing, and garment manufacturing [10]. In contrast, fragment-shaped MPs are believed to originate from the breakdown of rigid, and flexible plastic materials, including single-use products, packaging, plastic bottles, and household items, due to mechanical abrasion, wave action, thermal stress and ultraviolet radiation [1, 3, 8–11, 17, 18, 20]. Foam-shape MPs mainly derive from expanded polystyrene (EPS) materials used in packaging, fish boxes, and food containers, whereas film-type MPs typically result from the degradation of plastic bags, and nylon packaging [9]. Granular MPs may also originate from industrial production processes or personal care products.

Polymer types of microplastics

The polymer composition of MPs in coastal sediments of Vietnam is generally diverse, with approximately 32 types of polymers identified (Table 1). However, some studies provided only limited analysis of polymer composition [5, 14, 22] and therefore their results cannot be generalized to the entire dataset. Several other studies did not report any information on polymer types [7–9, 16]. The compiled data indicate that PA, PP, PS, and PE are the dominant polymer types of MPs in coastal sediments of Vietnam. This pattern is consistent with global findings, where these polymers are also among the most commonly reported in marine environments [2].

Table 2. Information on microplastic polymers in coastal sediments of Vietnam

No.	Polymer	Density (g/cm^3)	Application
1	Polyamide (Nylon, PA)	1.13–1.15	Fishing nets, nylon packaging, cables, textiles, swimwear, lingerie, and gowns, mechanical, and automotive parts, wear-resistant components, structural drive elements, and chemical machinery components, gears, bearings, kitchen appliances, wiring, cabinets, and buttons for electronic devices, fuel tanks, etc.
2	Polyethylene (PE)	0.88–0.96	Plastic bags, jerry cans, disposable cups, raincoats, plastic bottles, multilayer milk, and juice cartons, drinking straws, etc.
3	Polystyrene (PS)	1.04–1.07	Foam food containers, plastic packaging, disposable cups, and utensils, single-use trays, and coffee cups, aquaculture, and fishing equipment, buoys, insulated boxes, CD cases, household goods, electronic appliances, etc.
4	Polypropylene (PP)	0.9–0.92	Fishing gear such as fishing lines, and nets, packaging materials, food wraps, plastic bags, non-woven fabrics, ropes, plastic pipes, carpets, plastic containers, bottle caps, straws, yogurt cups, suction systems, etc.
5	Polyester (PES)	1.0–1.51	Clothing and industrial textiles, furniture, tires, conveyor belts, seat belts, upholstery, insulating gloves, plastic bottles, sporting goods, sportswear, coverings, tablecloths, etc.
6	Polyethylene terephthalate (PET)	1.34–1.39	Plastic bottles, food packaging materials, water bottles, textile fibers, electronic devices, construction and automotive materials, fishing nets, carpets, etc.
7	Cellophane (CP)	1.5–1.52	Food packaging, textiles, etc.
8	Ethylene vinyl alcohol (EVOH)	1.1–1.2	Food wraps, protective clothing, cosmetic containers, and tubes, etc.
9	Melamine (MF)	1.57	Household items, tableware, food packaging, etc.
10	Melamine-urea-formaldehyde resin (MUF)	1.8–2.0	Outdoor panels, adhesives, plywood and wood coatings with water-resistant, thermal insulation, and fire-retardant properties, etc.
11	Phenol resin (PF)	1.2–1.4	Wood coatings with water-resistant, thermal insulation and fire-retardant properties, molded products such as billiard balls, and laboratory benchtops, coatings and adhesives, etc.
12	Polytetrafluoroethylene (Teflon, PTFE)	2.1–2.2	Cosmetics and personal care products, such as moisturizers, sunscreens, and makeup; water-resistant clothing items like swimwear, and flotation devices, heat-resistant, low-friction coatings, such as non-stick surfaces of frying pans, plumber’s tape and water slide linings, etc.
13	Polyvinyl alcohol (PVA)	1.19–1.31	The textile adhesive industry for the production of garment products
14	Polyvinyl chloride (PVC)	1.44–1.48	Water pipes, waterproof plastics, coatings for corrosion-prone metals, wire, and cable manufacturing, anti-slip flooring, jump ropes, sports backpacks and premium sports mats, etc.

No.	Polymer	Density (g/cm^3)	Application
15	Polyurethane (PU)	1.20–1.26	Wheels, axles, floors, pipe liners, conveyors, fashion industry such as leather skirt tailoring, leather jackets, leather shoes, handbags, belts, furniture, electronics, etc.
16	Urea-formaldehyde (UF)	1.2–1.31	Textiles, paper, wrinkle-resistant fabrics, cotton-foam composites, used as coatings for electrical devices such as desk lamps, etc.
17	Polymethyl methacrylate (PMMA)	1.15–1.19	Furniture industry such as TV shelves, kitchen cabinets, wardrobes, shoe cabinets, wine cabinets, etc.; packaging products, bottles, cosmetic sets, plastic bottles, windows and doors, canopies, panels, automotive windows, motorcycle windshields, interior, and exterior panels, mudguards, automotive light housings, interior light housings, ship windows and aerospace purposes
18	Chlorinated polypropylene (CPP)	0.93	Coatings, paints and the adhesive industries
19	Epoxy resin (EP)	1.2–1.3	Metal coatings and composite materials used in electronics, electrical components, LEDs, high-voltage insulators, paintbrush, fiber-reinforced plastics, and adhesives for structural applications, etc.
20	Polydimethylsiloxane (PDMS)	0.97–1.03	Primarily used in cosmetics and skincare products, etc.
21	Polyethyleneimine (PEI)	1.03	Electronic components, food packaging, etc.
22	Polyvinylidene fluoride (PVDF)	1.78	Petrochemical, chemical, metallurgical and food industries, gear machining, sliding rails, pharmaceutical components, etc.
23	Styrene butadiene rubber (SBR)	1.1	Wire insulation, cables, household products, etc.
24	Acrylonitrile butadiene styrene (ABS)	1.0–1.05	Household appliances, helmets, computer keyboards, kitchen shelves, rice containers, spice jars, etc.
25	High-density polyethylene (HDPE)	0.93–0.97	Containers for milk, motor oil, shampoo and conditioner, soap bottles, detergents and bleaches, plastic pipes, optical cable sheaths, plastic cabinets, etc.
26	Inomer resin	-	Product packaging
27	Low-density polyethylene (LDPE)	0.91–0.94	Trays and containers for general items and food products, juice and milk cartons, enclosures for computer hardware, graphics cards and optical drives; plastic bags, clips and bins, water pipes, household appliances, battery cases; electronic components, automotive parts, etc.
28	Polyacrylamide (PAM)	1,302	Applications in electroplating, especially in wastewater treatment
29	Polyacrylonitrile (PAN)	1,184	Ultrafiltration membranes, hollow fiber reverse osmosis membranes, textile fibers, pressure vessels, fishing rods, tennis rackets, badminton rackets, bicycle technology, etc.
30	Polyolefin (PO)	0.90–0.96	Manufacturing of thin-film packaging and products such as cups, stationery, toys, cosmetics, beverages, bottles, etc.
31	Polyacrylate	1.05–1.1	Paints and other surface coatings, adhesives and textiles, etc.
32	Polyoxymethylene (POM)	1.41	Automotive industry, electrical industry, consumer goods, healthcare and medical sectors; industrial machinery, etc.

The occurrence and distribution of MP polymers in coastal marine sediments can be explained by the characteristics of the study area, anthropogenic activities, surrounding environmental conditions, and natural factors such as weather, tides, currents, and temperature [1, 10, 19, 20]. Information on the potential sources of these polymers, as summarized in Table 2, shows consistency with the household and industrial activities of the investigated regions. Several polymers with densities lower than that of seawater (1.03 g/cm^3), such as polyethylene (PE), polypropylene (PP), polystyrene (PS), chlorinated polypropylene (CPP), polydimethylsiloxane (PDMS), polyethyleneimine (PEI), acrylonitrile butadiene styrene (ABS), high-density polyethylene (HDPE), low-density polyethylene (LDPE) and polyolefin (PO) can remain buoyant in the surface water layer before gradually settling into sediments. This process may be attributed to the formation of biofilms on MP surfaces, which increase their overall density and promote deposition [1]. In contrast, the remaining 22 polymer types have densities greater than that of seawater, allowing them to settle more readily into sediment layers.

Furthermore, the ecological risk associated with the polymer composition of microplastics (PHI) revealed several concerning indications. This assessment is further supported by the results of microplastic concentrations and their polymer compositions. In coastal sediments of Quang Ninh Province, the average PHI value was 45.17 ± 33.48, corresponding to risk level II [3]. Meanwhile, in the coastal area of Quang Ngai Province, the mean PHI reached 256.10, placing it between hazard levels III (≥ 100) and IV (≥ 1,000) [1]. Notably, in the study by Le et al. (2023), although polyurethane (PU) accounted for only 0.8% of the total identified microplastics [1], it exhibited a remarkably high individual hazard score (S_n = 13,844, classified as severe risk (level V) according to Lithner et al. (2011) [32]. Therefore, evaluating the polymer composition of microplastics is crucial for accurately assessing their potential ecological and human health risks.

Potential sources of microplastic pollution

The Vietnamese coastline extends over 13 degrees of latitude, stretching 3,260 km and includes 28 coastal provinces and cities, with about 114 river mouths and estuaries flowing into the sea. On average, there is one river mouth every 25–30 km of coastline [33]. The coastal marine environment is a complex ecosystem, so the distribution of MPs is often influenced by a combination of multiple interacting factors. Coastal tourism is one of the key priorities for economic and coastal development, accounting for up to 70% of Vietnam’s tourism sector. Currently, Vietnam has about 23 destinations with potential for national tourism development located along the coastal strip [33]. Tourism activities often involve accommodations such as hotels, guesthouses, resorts, and food, and entertainment services, which generate waste, wastewater, laundry water, etc., containing MPs. Additionally, visitors can experience basket boat fishing with local fishermen along the coastal areas. Numerous studies have shown that MPs tend to accumulate more on beaches with concentrated tourist activity, where visitors frequently come, compared to remote areas with little or no tourism and the concentration decreases farther offshore [1, 7, 19, 20]. Furthermore, tourists’ use of personal care products such as lip balm, skin cream, sunscreen, and makeup, as well as wearing synthetic fiber clothing and swimwear, can release significant amounts of MPs [1]. Recreational activities on the beach and water sports also commonly involve various plastic items. As a result, tourists generate and leave behind considerable plastic waste at tourist sites or deposit it along the shoreline [1].

Plastic waste generated from activities at sea and on land can cause significant amounts of plastic debris to drift into coastal environments [17, 19, 22]. Most plastic waste in the marine environment remains near coastal areas for many years [1]. In these areas, plastic waste can become buried in the deeper sand layers and undergo photodegradation and oxidation processes within the sand dunes under favorable temperature and sunlight conditions. Subsequently, its fragmentation products continue to disintegrate and disperse along the shore. The surface sand layer exchanges components directly with the seawater, resulting in higher retention of MPs in the upper layers compared to subsurface samples.

Furthermore, before settling on beaches, MPs may be influenced by surface drifting, vertical mixing, bottom load, and suspended load transport processes. MPs can also be transported from highly industrialized and tourist areas to less industrialized and tourist regions, contributing to spatial variations in MP distribution [1].

Additionally, the generation and distribution of MPs in coastal marine sediments can also be influenced by activities such as local population presence, wastewater discharge, aquaculture, fishing, and industrial operations [1, 7]. In the study by Vo Thi Kim Khuyen et al. (2021), it was shown that various human interventions within sand dunes may be the main influencing factors rather than waves, as the sand is very dry and seawater does not reach these locations during the day [20]. According to Chi and Hien (2022), variations in MPs concentration may be attributed to anthropogenic developments such as industrial expansion, and tourism. Typically, MPs are more concentrated in densely populated areas [16]. The research by Le et al. (2023) indicated no significant seasonal differences in MPs concentrations in the sediments of the Red River estuary between the rainy and dry seasons [14], highlighting the complexity of MP pollution sources in the region. Le et al. (2023) suggested that terrestrial sources, including tourism activities (such as swimming, sports and picnics), local residents' activities, fishing, and wastewater discharge from adjacent residential areas and industrial operations, are likely the main contributors of MPs in coastal sediments along the studied coastline in Quang Ngai province [1]. Research by Strady et al. (2021) indicated that the presence of MPs in the environment may be linked to human activities involving plastic use, such as fishing, aquaculture, household waste, landfills, and urban pressures and the direct discharge of treated or even untreated wastewater [21]. At intertidal beaches in Thanh Hoa province, MPs pollution was attributed to domestic waste, fishing, and aquaculture activities carried out by local communities in the study area [9]. At eight beaches in Da Nang city, MPs pollution may originate from various sources, including domestic wastewater discharged into the sea, solid waste, and leachate from landfills and fishing activities [5]. Consistently, beaches with greater anthropogenic activity tend to exhibit higher MP concentrations. Plastic waste and MPs can also be transported by rivers from inland areas and accumulate on the coast [22]. Domestic waste, solid waste, industrial, and craft village wastewater, agricultural activities, and aquaculture have also been identified as potential sources of MPs pollution at the Ba Lat estuary in the Red River basin [14]. A study conducted in the UNESCO Can Gio Mangrove Biosphere Reserve suggested that MPs pollution may be influenced by population density, proximity to urban areas and other human pressures, all of which are major contributors to coastal environmental contamination [20]. Several international studies have similarly identified these sources as the primary causes of microplastic pollution in coastal marine environments [34–36].

Conclusion

This study synthesized and analyzed data from 20 studies published between 2020 and 2024 on MPs pollution levels in coastal marine sediments in Vietnam, thereby providing the first comprehensive and systematic overview of MPs contamination in sedimentary environments. Although current studies have not yet covered all 28 coastal provinces and cities and methodological differences remain, the aggregated results indicate that MPs concentrations vary widely, from 2.82 to 10,830 MPs/kg. Notably, higher levels of pollution were generally recorded in the central coastal region compared to the northern, and southern areas. Furthermore, the distribution characteristics of MPs show a predominance of fragments and fibers, with the main polymers identified as PA, PP, PS, and PE. These compiled data not only reflect the pollution trends in the studied areas but also serve as a critical scientific foundation for future in-depth investigations. Further research is needed to focus on the methodological standardization, the expansion of spatial coverage, and a better understanding of the relationship between MPs pollution and coastal socio-economic activities. These efforts will be essential for supporting the development of effective monitoring strategies, improving management practices, and promoting the sustainable use of marine resources amid increasing anthropogenic pressures.

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