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Research Article

Prevalence of Microplastics in Coastal Area of Samae San, Thailand and Its Possible Source

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Abstract

This research explored the abundance, morphology, and polymer composition of microplastics (MPs) in various environmental samples within the Samae San subdistrict involving surface soil nearby the dumping site, road dust soil, beach sand and sediment in the area with distinct land- based activities. Dumping site soil exhibited the highest concentration in items per kg of dry weight at 93,734.3, followed by road dust soil (573.0 ± 583.7), beach sand (99.8 ± 75.3), and sediment (83.1 ± 50.4). Morphological traits revealed similarities between transparent fiber-shaped particles in beach sands and sediment, and those in nearby road dust soil, while green sheet-shaped particles dominated in dumping site soil. Predominant polymer types included PE, PET, and PP, associated with daily plastics, fishing gear, and fishing nets. In beach sand and sediment samples, transparent polyamide (nylon) fibers shaped like microplastics (MPs) were notably observed, as it is a common material used in fishing nets. Cluster analysis indicated a resemblance between MPs in beach sand, sediment, and nearby road dust soil, implying that plastic debris, comprising single-use plastics and fishing equipment, could be a potential source of MPs in coastal areas.

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Introduction

The global production of plastics has surged to reach 368 million tons in 2019, driven by increasing in consumer demand [1]. In contrast, the traditional and environmentally detrimental practice of open dumping sites is still prevalent, particularly in developing countries, due to its cost-effectiveness [2]. This method leads to the dispersion of plastics into the environment, where prolonged exposure to environmental factors like UV radiation, oxygen, and heat results in the degradation of plastic, forming microplastics (MPs) [3]. Currently, there are reports of MPs contamination in and around dumping sites, including leachate, groundwater, and soil [4–5]. The predominant types identified are polypropylene (PP), polyethylene (PE), and polyethylene terephthalate (PET) [4–5]. These identified polymers were commonly used in the production of single-use plastic items such as bags, food containers, and water bottles [6].

In Thailand, approximately 99% of waste management were improperly conducted [10]. An increase in the single-use plastic waste from 8,800 tons per day (in 2020) to 9,600 tons per day (in 2021) has led to the accretion of plastic wastes in the dumping site, creating more and more microplastics to environment. Particularly in the coastal areas of the tropical zone where the weather condition is favorable for enhancing plastic degradation [11]. Recent studies across six Asian countries revealed that MPs contamination in soils from 50 open dumping sites originated from single-used plastic products [6]. Therefore, inefficiently disposed plastic waste, whether in open dumping sites, surface roads, beaches, or marine environments, can serve as sources of microplastics. Hence, for this study, sampling was conducted in the Samae San Subdistrict, Sattahip District, Chon Buri Province where an open dumping site and mismanaged waste are present in the nearby coastal area.

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The contribution of microplastics entering the sea, not only particularly influenced by wind-driven factors [12] but also untreated rivers and wastewater [13]. In addition, factors such as seasonal water circulation patterns [14] and the influence of tides play significant roles in transporting microplastics from land-based sources to the sea [15–16]. It is crucial to considering that over 80% of MPs found in the ocean originate from land-based activities [17]. Thus, in this study, MPs found in the soil collected from surrounding communities and at dumping site, as well as in environmental samples from coastal areas such as beach sand, and sediment, were examined for comparative analysis of types and quantities. The investigation focused on understanding the distribution patterns of MPs in the coastal communities of Samae San Subdistrict, Sattahip District, Chonburi Province. This research aims to provide valuable information on the status of microplastic quantities. This data will contribute to the improvement and development of waste management systems for coastal communities in the specified area, building upon previous studies in the region.

Material and methods

1) Sampling areas

This study divides the sampling area; in Samae San, Sattahip, Chon Buri, Thailand, into 3 zones as shown in (Figure 1-A). The first zone is at the dumping site where domestic waste from the local community, consisting of approximately 6,109 people, along with waste generated from tourist and fishing activities, is managed. The second zone is the Samae San market area, located within a distance less than 1 km from the dumping site. This place is a commercial area for seafood trade with tourists. The third zone is the fishing village area, consisting of several piers for fishing and diving boats and is adjacent to a local community area where school, local market and municipal offices are located. It is approximately 3 km away from the dumping site.

2) Samples collection

Soil sample collection involved sweeping the soil using a brush onto a stainless-steel tray (Supplementary Material (SM) 1-A). Three dumping site soil (DSS) samples were gathered near an open dumping area, while ten samples of road dust soil (RDS) were collected from areas surrounding the dumping site and the main street in the fishing village. Near the Samae San market and fishing village areas, nine beach sand (SAND) samples were randomly collected using an aluminum core (diameter of 10 cm and length of 10 cm) from high tide line on the beach (SM 1-B). Additionally, six SED samples were randomly gathered at depths of 6 to 8 m using scooping with a stainless-steel spoon and tray during skin diving (SM 1-C). Details of sampling location are elaborated in SM 2 and Figure 1.

3) Microplastic analysis and identification

The analytical methodology for microplastics was implemented from Kitahara and Nakata in 2020 [18] with careful adjustments. Individual samples (DSS, RSD, SAND and SED) underwent sieving on 1,000 µm mesh stainless steel sieves. A segment of the sifted soil was placed in a beaker filled with 30% hydrogen peroxide (H_2O_2) (Qrec, New Zealand) for a duration of 3 days at the ambient temperature to decompose the organic matter. Following this, the samples were placed in a 60% sodium iodide (NaI) solution (1.8 g cm^{-3}, Kemaus, Australia) for the purpose of density separation of solid particles including MPs from soil particles. The floating solids present on the surface of the NaI solution were filtered through a nylon filter (mesh size of 100 µm), rinsed thoroughly with filtered water and subsequently dried overnight at 40°C. All solution prepared with filtered tap water with GF/B membrane (pore size of 1.0 µm) to ensure that there is no additional microplastic.

All particles remaining on the nylon filter were individually collected using tweezers and identified under a stereomicroscope (ERM-1, EUROMEX, Netherlands). The non-organic particle has been separated visually with the following criteria (1) no visible cellular or organic structures (2) for the fibers it has to be equally thick throughout their entire length, and (3) particles should exhibit homogenous color throughout the item [19].The potentially non-organic particle are recorded for its morphology (size, shape, and color) then proceeded to the polymer identification using Fourier transform infrared spectrometer (FT-IR, Shimadzu, Japan). Only the count of particles identified by FTIR as plastic (SM 3) is utilized for the calculation of microplastic abundance (items per kg dry weight), determined by the ratio of the number of MP particles to the weight of the respective samples. The standard quality threshold for the identification of MP polymers was established at 80% or greater match to the reference libraries, which included the Aldrich Standard. Rubber micro-plastics, such as styrene butadiene rubber, were not included in the analysis due to the limited handling of samples in this study.

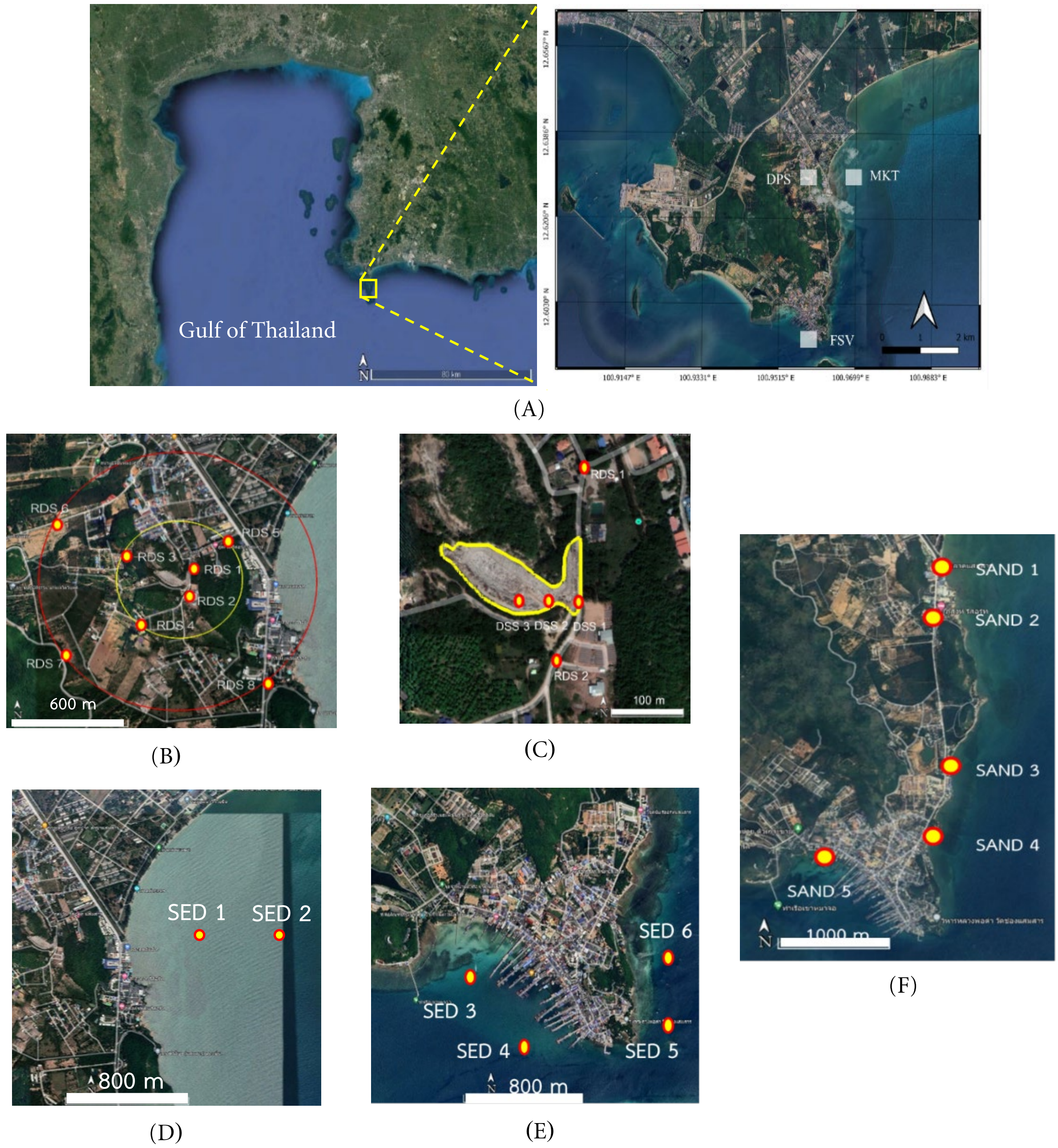

Figure 1 Sampling points; (A) location of sampling area including DPS: dumping site, MKT: Samae San market and FSV: fishing village (B) road dust soil (RDS) sample (C) dumping site soil (DSS) sample (D) and (E) sediment (SED) sample (F) beach sand (SAND) sample.

4) Quality assurance and quality control

To ensure quality assurance and quality control, a recovery test was conducted. To be certain, 15 particles each of PE and polymethyl methacrylate (PMMA), with particle sizes of 250 μm and 1000 μm, were introduced into 5 g of dried sand and subjected to the above-mentioned analysis. The recoveries for PE particle sizes of 250 μm and 1000 μm were at 95 ± 3% and 97 ± 3%, respectively. For PMMA particle sizes of 250 μm and 1000 μm, the recoveries were 84 ± 3% and 93 ± 6%, respectively. This outcome indicates that the analytical procedure possesses acceptable reproducibility.

Results and discussion

1) Abundance of microplastics

The average and range of microplastic abundance in item per kg dry weight of all sample types (DSS, RSD, SAND and SED) are shown in Table 1. Comparing for all environmental samples as an average abundance, the MPs accumulation is in the following order: DSS > RDS > SAND > SED. The number of plastic and non-plastic pieces shown in SM 3 reveals that DSS samples exhibit a significantly high concentration of MPs, reaching up to 289 pieces per 3 g of dry soil. In contrast, SED samples from the seafloor, with a dry weight of 30 g, show the highest accumulation of MPs at 5 pieces.

Table 1 Microplastic abundance in environmental samples

Sample type/location	Microplastic abundance (items/kg dry weight)			Mesh size (µm)	Solution for density separation	FTIR determination	References
	Min	Max	Mean ± SD				
Dumping site soil (DSS)							
Bantar Gebang, Indonesia	336	43,704	10,929 ± 13,547	100	NaI	PE>PET>PP	[6]
Chon Buri, Thailand	-	-	1076.39	330	NaCl, $ZnCl_2$	PP>PE>PET	[5]
Chon Buri, Thailand	5,246	93,831	14,375 ± 49,245	100	NaI	PE>PU>PET	This study
Road dust soil (RDS)							
Nay Pyi Taw, Myanmar	0	2,119	285	100	NaI	PE>PP>PVC	[18]
Tokyo, Japan	180	340	230 ± 50	100	NaI	PES>PP	[20]
Chon Buri, Thailand	100	1,948	625 ± 593	100	NaI	PET>PE>PP	This study
Beach sand (SAND)							
Eastern Gulf of Thailand	-	-	1360 ± 500	GF/C (1.2)	NaCl	-	[21]
Chantha Buri, Thailand	-	-	17 ± 8.49	GF/C (1.2)	NaCl	PET, PA	[14]
Chon Buri, Thailand	-	-	21 ± 3.54				
Rayong, Thailand	-	-	33 ± 26.16				
Trat, Thailand	-	-	20 ± 8.49				
Chon Buri, Thailand	33	299	102 ± 79	100	NaI	PP>PA>PET	This study
Sediment (SED)							
Changjiang, China	20	340	121 ± 9	GF/B (1.0)	NaCl	RY>PES>AC	[23]
Gulf of Thailand	25	362	150.4 ± 86.2	20	NaCl	PES, RY	[22]
Chon Buri, Thailand	33	166	83 ± 50	100	NaI	PA>PE>PET	This study

Remark: AC= acrylic, PA= polyamide, PE= polyethylene, PES= polyester, PET= polyethylene terephthalate, PP= polypropylene, PU= polyurethane, PVC= polyvinyl chloride, and RY=rayon

This study reveals that the quantity of MPs detected in soil samples from dumping sites exceeds that in other environmental samples by approximately 20 times, suggesting that these sites serve as possible sources of microplastic pollution in the investigated region. A comparison with Puthcharoen in 2019 [5], which sampled 12 dumping sites soils in Thailand, shows that the average microplastic count in this research is over 10 times higher. This difference may arise from variations in sampling locations, as well as differences in sample collection, extraction process and scope of microplastic size (Table 1). The current study used sodium iodide (density 1.8 g cm^{-1}) as the extraction solvent, whereas previous study used NaCl (density 1.3 g cm^{-1}) with a lower density. When comparing results on DSS samples in Indonesia [6], which also used NaI as the solvent, a similar count of 10,929 pieces kg^{-1} is observed. Regarding RDS samples, a comparison with average values from urban communities in Nay Pyi Taw, Myanmar (285 pieces kg^{-1}), and Tokyo, Japan (230 pieces kg^{-1}) [18, 20] indicates that the MP count in this study is approximately three times higher.

In contrast to previous investigations in the eastern Gulf of Thailand, this study reveals a higher average concentration of MPs in beach sand samples than those documented at Chantha Buri, Chon Buri, Rayong, and Trat Province [14] during the same season (March 2018). Conversely, Bissen and Chawchai in 2020 [21] found a lower microplastic count in coastal sediment along Chonburi Province, from Laem Chabang to Sai Kaew Beach (n=5), averaging 1,360 items/kg—approximately 10 times less than the current study. This difference may be attributed to the diverse characteristics of the sampling area, encompassing tourist hubs, industrial zones, and fishing areas, potentially contributing to elevated microplastic quantities compared to the report of Bissen and Chawchai [21].

For SED samples compared with result of Wang et al. in 2020 [22], which collected surface sediment samples in the Gulf of Thailand from the mouth of the Chao Phraya River to the lower Gulf of Thailand, the current study found a microplastic quantity approximately two times higher. However, it was observed that the count was close to the average value (121 ± 9 items kg^{-1}) reported in the Changjiang Estuary, China [23].

2) Morphology and polymer of microplastics

Distribution of MPs size was grouped into three categories as 100–500, 500–1,000, and 1,000> µm respectively. A dominant size-distribution was found in the size of 500 – 1,000 µm and accounting for 40% of total MPs. Approximately 70% in all sample, MPs size was found to be <1,000 µm (Figure 2). This predominant size range of MPs observed was corresponded well with other studies conducted in the Gulf of Thailand [14, 21]. However, certain fibrous microplastics remained longer than 1,000 µm, with the smallest and the longest piece were 185 and 4,300 µm respectively, due to the pre-sieving procedure before extraction.

For the other MPs shapes the particle greater than 1,000 µm cannot be observed. Interestingly, in the DSS sample, an increase in the smaller MPs size (Figure 2B) were observed and is attributed to the increase of fragmentation and degradation process over time that also found in the study of MPs in China landfills [24].

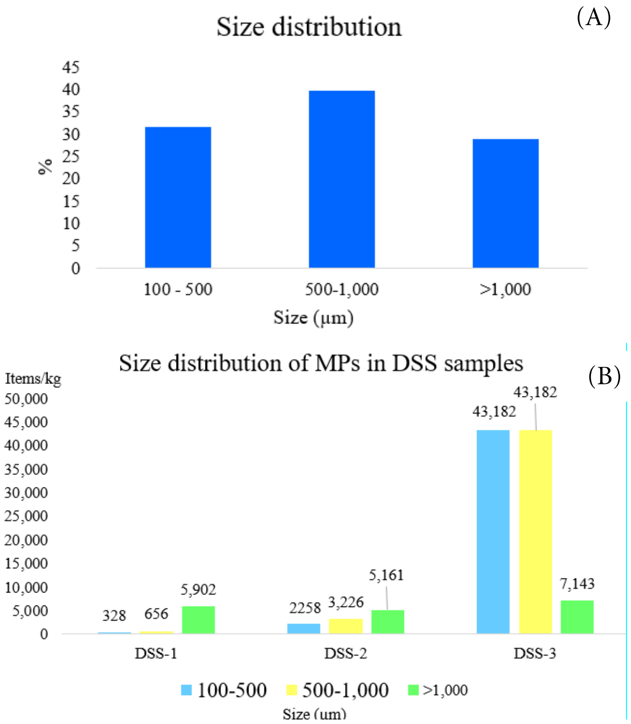

Figure 2 Size distribution of MPs;
(A) all samples and (B) DSS samples.

The shape of MPs found in DSS samples were mostly sheet and fragment (Figure 3). In contrast with the RDS, SAND and SED sample, where fiber was the most predominant shape types. The MPs colors (Figure 4) varied among sample types. Predominantly, green, and yellow colors constituted 33% of MPs in DSS, whereas transparent particles were more prevalent in RDS, SAND, and SED. The transparent-fibrous were also observed as the most abundant MPs in beach sand and sediment found in other study in the Gulf of Thailand [14, 21], similar to microplastics studies in China and Canada that exhibited the highest-fiber types of microplastics found on beaches [25-26].

PE, PET, and PP were the most dominant MPs polymers found in all sample types (Figure 5). However, in RDS and DSS, polyurethane (PU) was also observed as another distinguished MPs polymer type. In addition, PU in RDS samples were detected abundantly only at the sampling location near the dumping site (RDS1 and RDS2) implying the MPs migration to the nearby surroundings. However, the most predominant MPs particles in RDS was still PET. While in SAND and SED samples, polyamide (PA) was recognized as another dominance types of MPs polymer (> 31%).

The characteristics and polymer types of MPs in DSS samples revealed their sources, primarily originating from plastic products, remarkably single-use plastics, household disposals, and refuse from nearby activities, including tourism and fisheries. The results of this study are in accordance with prior research concerning the typical accumulation of MPs in DSS regarding the presence of PU polymers were identified in dumping site soil in the Philippines [6]. Since the study site is predominantly engaged with fishing as its primary livelihood. Consequently, waste associated with fishing activities, such as nets, traps, and fish-drying racks, can be observed along the main roads within the community. Noticeably, transparent fibers of PE and PA types were predominantly found in SAND, SED, and RDS samples collected along the village roads frequently traveled by fishermen. This discovery not only aligns with the shapes of MPs found on beaches in Canada and China [25–26] but also with those found in invertebrate tissue in Thailand [27], where fibers were identified as the prevailing form of MPs. Consistently, the observation by Peng et al. in 2017 [23] suggested such MPs polymer derived from fishing net and plastic debris on the beach. Still, the dominant polymers (PE, PP and PET) that are highly abundance are polymers likewise the polymer of single-use plastic that can be found in surrounding environments including the dumping site [28].

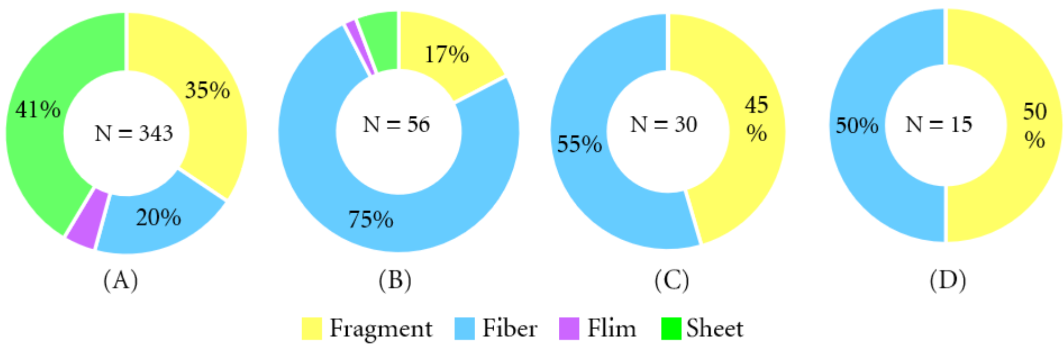

Figure 3 Shape composition of MPs; (A) DSS samples (B) RDS samples
(C) SAND samples and (D) SED samples.

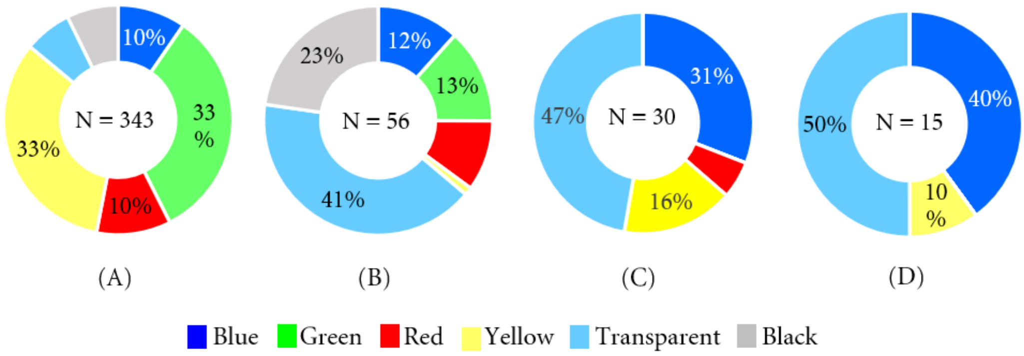

Figure 4 Color composition of MPs; (A) DSS samples (B) RDS samples (C) SAND samples and (D) SED samples.

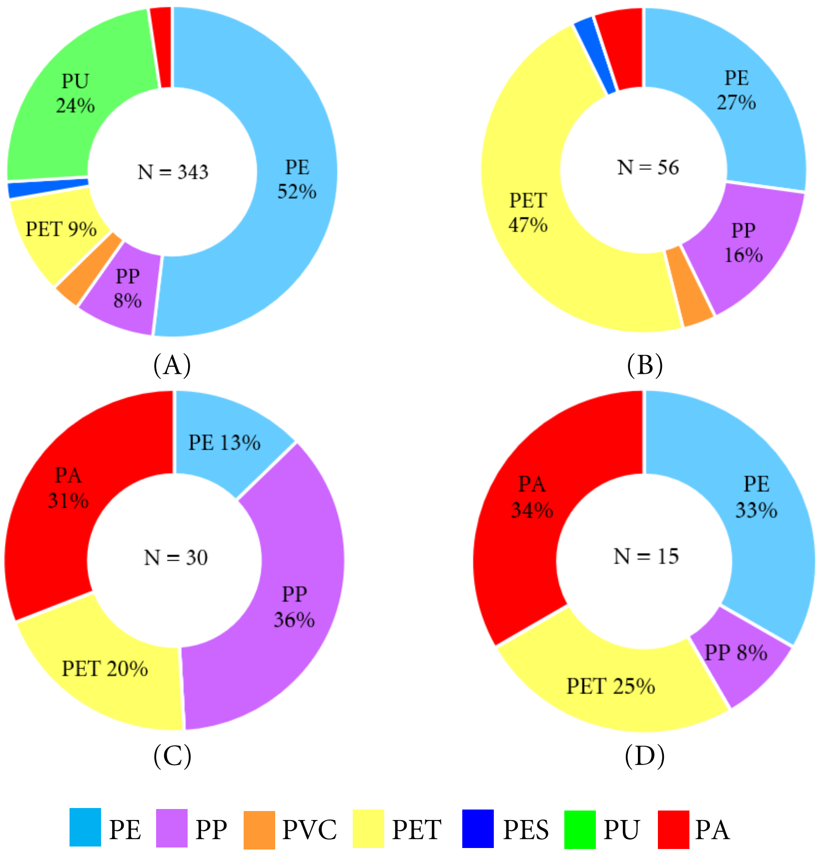

Figure 5 Polymer types of MPs; (A) DSS samples (B) RDS samples (C) SAND samples and (D) SED samples.
Remark: PA= polyamide, PE= polyethylene, PES= polyester, PET= polyethylene terephthalate, PP= polypropylene, PU= polyurethane, PVC= polyvinyl chloride

3) Potential source of MPs in Samae San area

The Samae San area confronts a pronounced challenge of MP pollution, due to the activities of both residents and tourists. Disposal of waste originating from diverse activities to the dumping site leading to the accretion of plastic and MPs pollution concerns. The quantity of MPs discovered in the dumping site soil surpassed that of other environmental samples by approximately 20 times and exhibit a diverse array of shapes and colors stemming from household products. Consequently, upon fragmentation, these plastics tend to manifest as fragments and sheets. Through cluster analysis with other sampling area in Samae San (SM 4), the similarity of MPs characteristics and polymers is only exhibited with the RDS sample near the dumping site. This MPs can be dispersed and accumulated in nearby areas due to wind-driven transport [29]. Therefore, there is a likelihood that DSS can be served as a source of MP pollution in this area. Additionally, it represents a location where new plastic waste is consistently introduced daily, thereby contributing to the ongoing accumulation of MPs.

In addition, on road surfaces and beaches, plastic waste derived from household activities including single-use plastics and abandoned fishing gear disposal can also be another source of MPs in each respective locality. MPs observed at the Samae San market, and the fishing village areas exhibit indifferences in all sample types. Upon comparison, the shapes, colors, and polymer types predominantly resemble those MPs found on beaches. For instance, transparent fiber microplastics identified as PA are frequently found in areas where fishing equipment is discarded. The lack of color is possibly due to the shedding of colorless nets or degradation. This is confirmed through the cluster analysis (SM 4) depicting the similarity of microplastics in both SAND and SED samples, regardless of their location.

Although predominant MPs found in Samae San District are PE, PP and PET which are the commonly polymers used in household plastic products. PA polymer in fiber shape, which might degrade from the fishing net are noticeably detected along the coastline. This observed pattern is likely to result from the mismanagement of plastic waste, leading to the fragmentation and accumulation of MPs in the coastal environment. Such breakdown process makes them easily transportable, enhancing the potential harmful release of plastic additives and increasing their dispersal potential from the point of origin. However, marine plastic debris may potentially be transported from other areas by wind and current. Hence, an efficient waste management strategy not only tackles the challenge of accumulated plastic waste in the environment but also plays a pivotal role in mitigating the issue of MPs.

Conclusion

In Samae San subdistrict, we observed that PE, PET, and PP were the most prevalence MPs in the coastal area as well as DSS samples. These polymers are the common polymers of single-use plastics in which it can be derived from the degradation in the dumping site or plastic debris in the beach and marine environment. In addition, activities along the coastline such as fishing, fishing piers, and tourism can escalate specific types of MPs. In this study, transparent PA particles from fishing net was observed as one of the dominant MP in fishing village, in which can be confirmed that human activities along coastal area have influence the composition MPs and adding to the local dumping area can be another potential source of microplastics in coastal environments.

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