

# Changing in Spatial and Temporal Accumulation of Microplastics in the Water Column at Urban Ko Yo Community in Songkhla Lagoon, Thailand

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*Received: 6 September 2024, Revised: 30 September 2024, Accepted: 7 October 2024, Published: 10 November 2024*

## Abstract

Ko Yo, situated at the mouth of Songkhla Lagoon, is an urban ecosystem renowned as one of the active areas of Songkhla Province. Numerous anthropogenic activities occur in this area, including homestay tourism, aquaculture, fishing, and the operation of restaurants, all of which generate significant environmental waste. Microplastics represent a widespread pollutant and have been widely recognized as a critical environmental concern. However, they have received little attention among the general public. Therefore, this study investigated the type and quantity of microplastic accumulation in the water bodies surrounding Ko Yo, Songkhla Province. Water sampling stations were established along the coastline and 1 km into the subtidal area, and sampling was conducted for a year. Microplastics in the water samples were recorded and categorized using a modified size and color sorting protocol. Samples were analyzed via Fourier-transform infrared spectroscopy to identify microplastic polymers. The results revealed the accumulation of 6 types of microplastics around Ko Yo: Cotton polyester blend, polyester, alkyd, polypropylene, polyvinylchloride, and low-density polyethylene. These polymers most frequently occurred during the summer and the northeastern monsoon season. Cotton polyester blend, a synthetic fiber commonly used in clothing, furniture, ropes, nets, and cages, was found in the highest quantities across all months and stations. This update on microplastic contamination in natural environments near household areas could lead the idea of the microplastic status around Ko Yo and provide vital insights into the environmental and health implications of microplastics.

**Keywords:** Anthropogenic, Coastal pollution, FTIR analysis, Global issues, Microplastics, Water quality, Urban community

## Introduction

Plastics have become a fundamental material widely recognized and modified for various types of products used in daily life. Currently, more than 368 million tons of plastics are produced annually. Despite conservation campaigns promoted by organizations to save the planet, the demand for plastics is expected to continue rising in the future [1]. In addition to the weaknesses in waste management systems, especially in

developing countries such as Thailand, plastic waste often escapes or runs off into the environment during disposal processes. Plastic waste accumulating in the ocean has been estimated at 268,940 tons [2].

Plastics can be categorized into many types according to particle size. Among these types, microplastics, with a size range of 1  $\mu\text{m}$  - 5 mm, have raised significant concerns [3,4]. These tiny microplastics can pass

through all processes of nature, and they flow into marine ecosystems. Additionally, microplastics have a large surface area relative to their volume. This property, combined with the hydrophobic properties of plastics, allows microplastics to absorb many toxic chemical suspensions [5], such as persistent organic pollutants, which are highly toxic and resistant to degradation. Biomagnification can release and transfer noxious chemical substances through trophic levels [6]. These toxicants can enter the food chain, exposing higher-level consumers, including humans, to significant amounts of accumulated toxins [7,8]. Recently, microplastics have been found in various food sources such as gastropods, crabs, fish, prawns, and shrimp [9-12], posing serious toxic effects on both animals and humans [13,14]. This evidence underscores the importance of raising awareness about the problem of microplastic contamination in nature.

Even the microplastic pollution was the hot issue in many areas, there is very few along the tourist area in Thailand example in Songkhla. Ko Yo is an urban ecosystem located at the mouth of Songkhla Lagoon and is one of the tourist attractions in Songkhla Province. Numerous anthropogenic activities occur in this area, including homestay tourism, aquaculture, fishing, and dining. Despite the promotion of microplastics as a critical issue, public attention remains limited. Many

people may believe that the problem does not directly affect them. To date, only 1 study from Songkhla Lagoon has documented microplastic contamination in fish [15]. Unfortunately, there are no reports on microplastic accumulation in Ko Yo, Songkhla lagoon. This study aims to examine the type and amount of microplastic accumulation in the water around Ko Yo, Songkhla Province. Geographical island area of Ko Yo provides coastline ecosystem served the mechanisms drive the fragmentation of microplastics. The correlation between possible sources of microplastics and the types of microplastics was expected in this analysis and the correlation between environmental factors and the amounts of microplastics was hypotheses. As mentioned earlier, microplastic contamination has become a critical concern for both the environment and human health. This research will be valuable for managing and updating the situation of microplastics in the Ko Yo community.

## Materials and methods

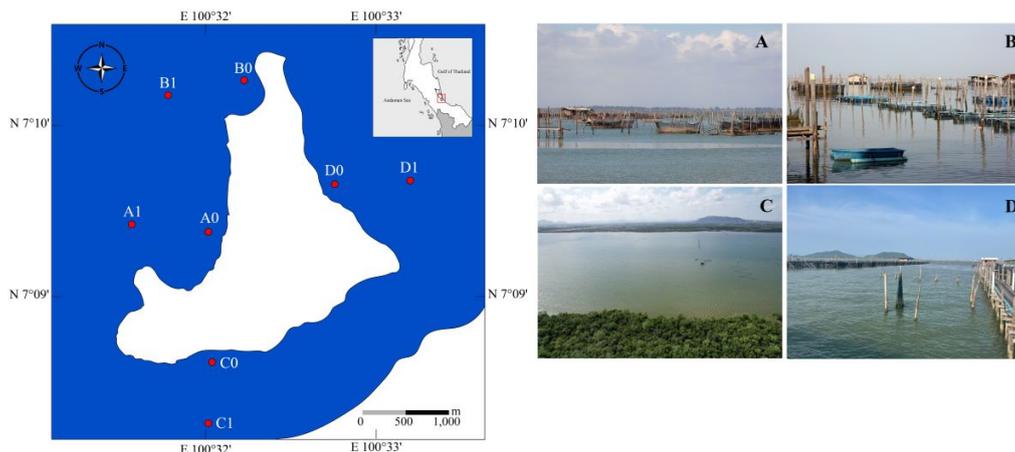
### Study site

Samples were collected along the coast of Ko Yo (Figure 1), Songkhla Province, from May 2019 to February 2020. The study area includes various coastal environments, which were categorized into 4 stations according to their characteristics.

**Table 1** Description of the sampling station.

Code sites	Area descriptions	Latitude and longitude
A	a residential community, and fishes are raised in cages	7°9'45.10"N, 100°32'10.46"E
B	local houses, restaurants, and homestay accommodations	7°10'48.64"N, 100°32'25.55"E
C	an area of mangrove forest and water channels where no houses are established	7°8'51.27"N, 100°32'9.01"E
D	household and restaurants	7°10'3.50"N, 100°33'0.08"E

The sampling stations are divided into 2 groups according to their distance from the shoreline: Adjacent to the coast (A0, B0, C0, and D0) and 1 km away from the shore (A1, B1, C1, and D1).



**Figure 1** Sampling locations around Ko Yo, Songkhla Province. Blue color indicated water, and the white is Ko Yo island. The alphabet codes refer to the station descriptions as explained in **Table 1**.

### Environmental data

Field physical data set was collected daytime along the stations when microplastics sampling. Mean of all data were used in analysis. Depth was measured using a depth sounder (Honde Speedtech Instruments Depthmate Portable Depth Sounder-WeatherHawk: USA). Salinity was determined with a hand refractometer (ATAGO Master S/MillM: ATAGO Co., Ltd.; Tokyo, Japan). Temperature and pH were measured with a multi-probe device (Horiba U-5000G: Horiba, Ltd.; Kyoto, Japan).

### Microplastic sampling and identification

Microplastics in the water column, approximately 50 cm below the surface, were collected using a 50  $\mu\text{m}$  plankton net. For each station, 100 L of water was sampled and filtered in 3 replications. These water samples were then filtered through 1.2  $\mu\text{m}$  GF/C glass microfibre filters. The filters were dried in an air oven at 90 °C for 12 h. Once dried, the solid particles adhering to the filter paper were separated and placed in glass bottles. This process was conducted under a compound microscope at 40 $\times$  magnification. The shape and color of the microplastics were recorded following the standardized size and color sorting (SCS) method [16].

The representative of different samples were analyzed using a Fourier-transform infrared (FTIR) spectrophotometer in the attenuated total reflectance mode to identify their chemical composition. The instrument used was the Spectrum Two, Perkin Elmer Spectrum IR version 10.6.2, equipped with a spotlight 200i, from Perkin Elmer in Seer Green, UK.

Wavelength scanning was conducted in the range of 400 - 4,000 nm. The acquired spectrum was compared with the standard library spectrum.

### Statistical analyses

Spatial and temporal comparisons of the quantity and polymer composition of microplastics in the water column among months and stations were conducted using Bonferroni correction in the Past program, version Polymer 4.04. Unrestricted permutation of transformed data ( $\log(x+1)$ ) was performed for analysis. Cluster analysis was conducted using Bray-Curtis similarity to assess the similarity of microplastics in the water column among stations and months. The correlation between microplastic types and water quality was examined via canonical correspondence analysis with the MVSP program, version 3.22 [17].

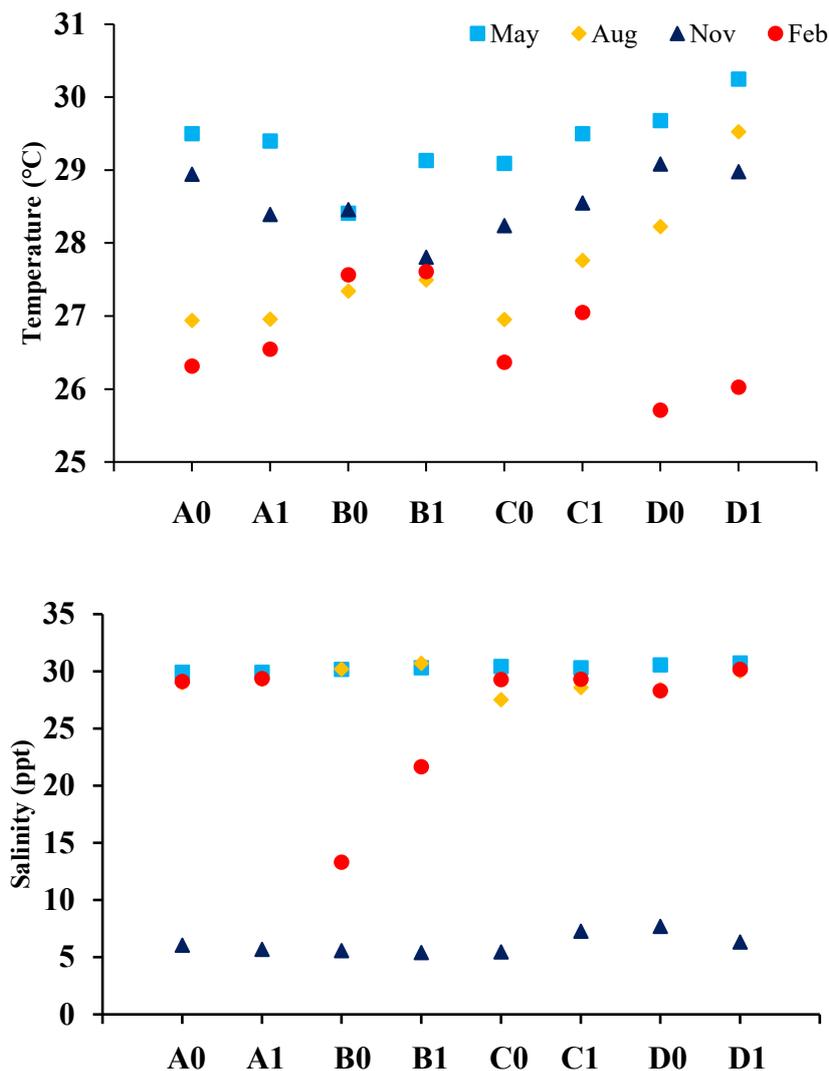
## Results and discussion

### Environmental data

Environmental data, including temperature, depth, salinity, pH, and velocity, were recorded for 4 months (February, May, August, and November) at 8 stations (**Figure 2**). Seasonal changes were observed and correlated with all water physical factors. The highest average temperature occurred in May, at  $29.37 \pm 0.19$  °C (ranging from 29.09 to 30.25 °C), while the lowest average water temperature occurred in February, at  $26.65 \pm 0.25$  °C (ranging from 25.71 to 27.61 °C). Salinity remained relatively constant at all stations, ranging from 29 to 30 ppt from May to August. However, high fluctuations in salinity were observed in

February, particularly at B stations. In November, low salinity occurred at all stations, with an average of  $6.18 \pm 0.31$  ppt (ranging from 5.40 to 7.27 ppt). Additionally, pH, depth, and velocity exhibited fluctuations among stations and months. These 3 parameters reached their highest averages in August, with an average pH of  $7.67 \pm 0.10$  (ranging from 7.20 to 8.05), an average depth of  $1.38 \pm 0.11$  m (ranging from 1.10 to 2.00 m), and an

average current velocity of  $15.85 \pm 3.23$  cm/s (ranging from 3.89 to 28.47 cm/s), respectively. In contrast, the lowest values of the parameters were recorded in February, with an average pH of  $6.85 \pm 0.16$  (ranging from 6.26 to 7.39), an average depth of  $0.96 \pm 0.15$  m (ranging from 0.50 to 1.60 m), and an average current velocity of  $7.21 \pm 1.09$  cm/s (ranging from 3.89 to 12.50 cm/s), respectively.



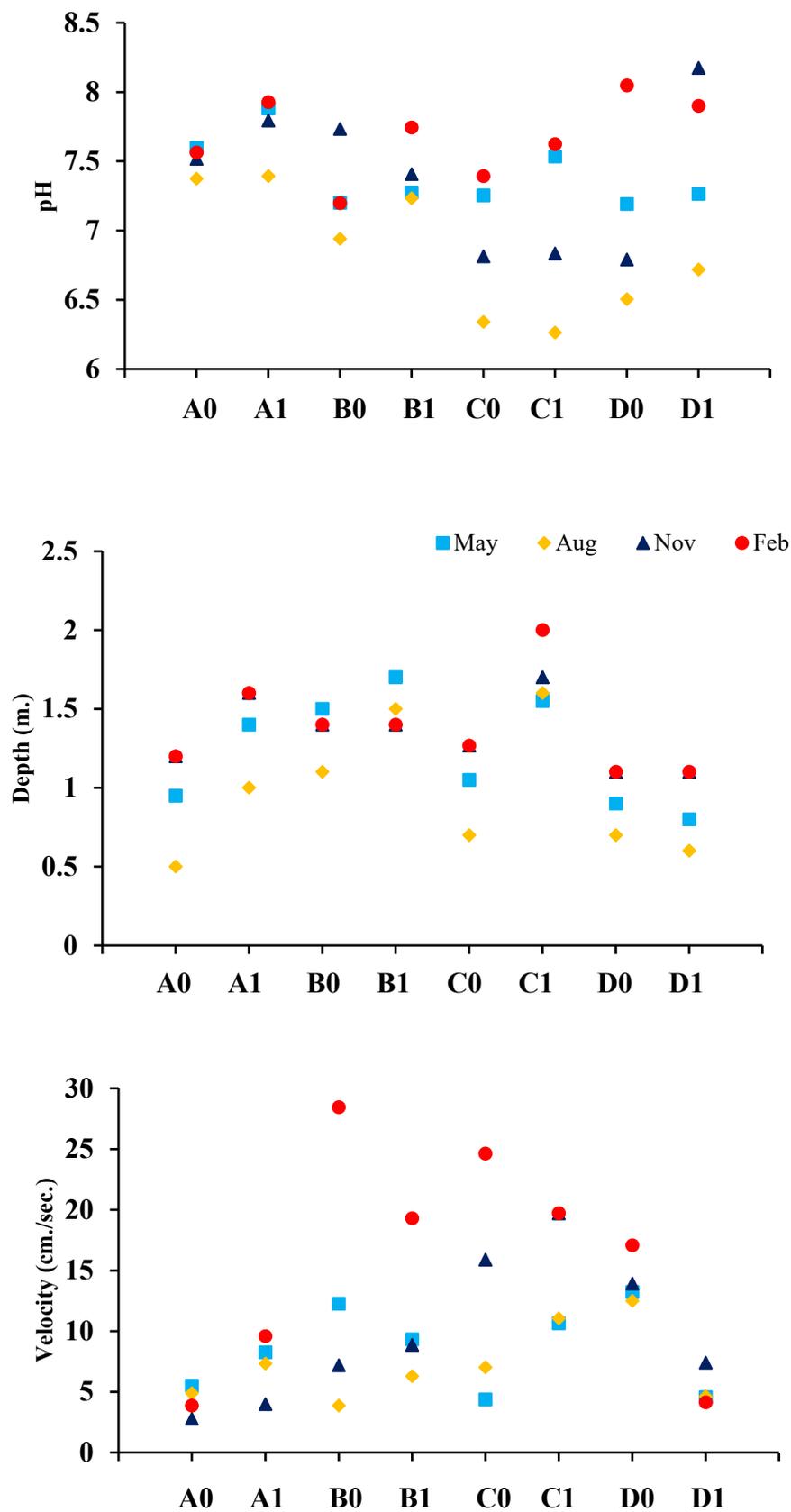
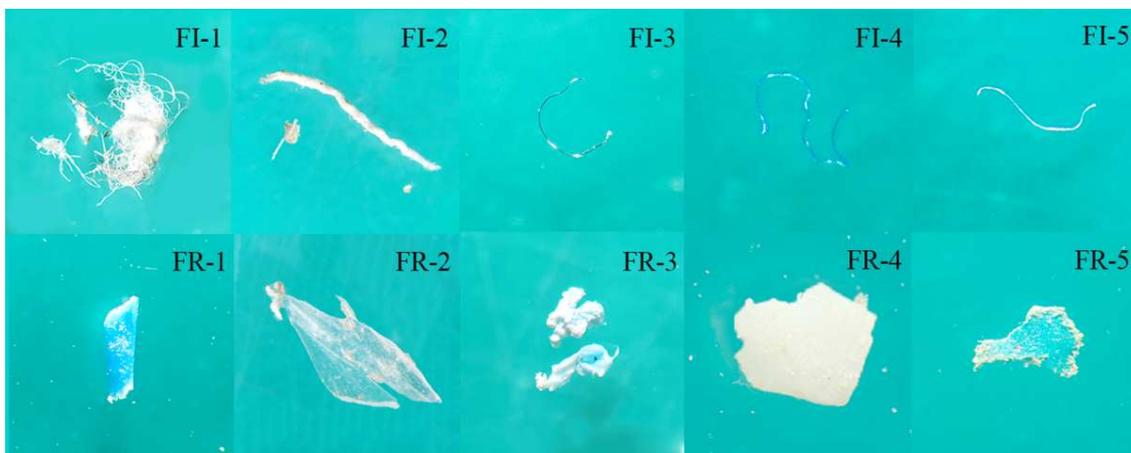


Figure 2 Fluctuations in the physical water environment at Ko Yo from May to February.

(Fragment; FR). The fiber types were classified into 5 colors according to their appearance: Small white fibers (FI-1), thickly curled white fibers (FI-2), small black fibers (FI-3), small blue fibers (FI-4), and clear colorless fibers (FI-5). Similarly, the fragment types were

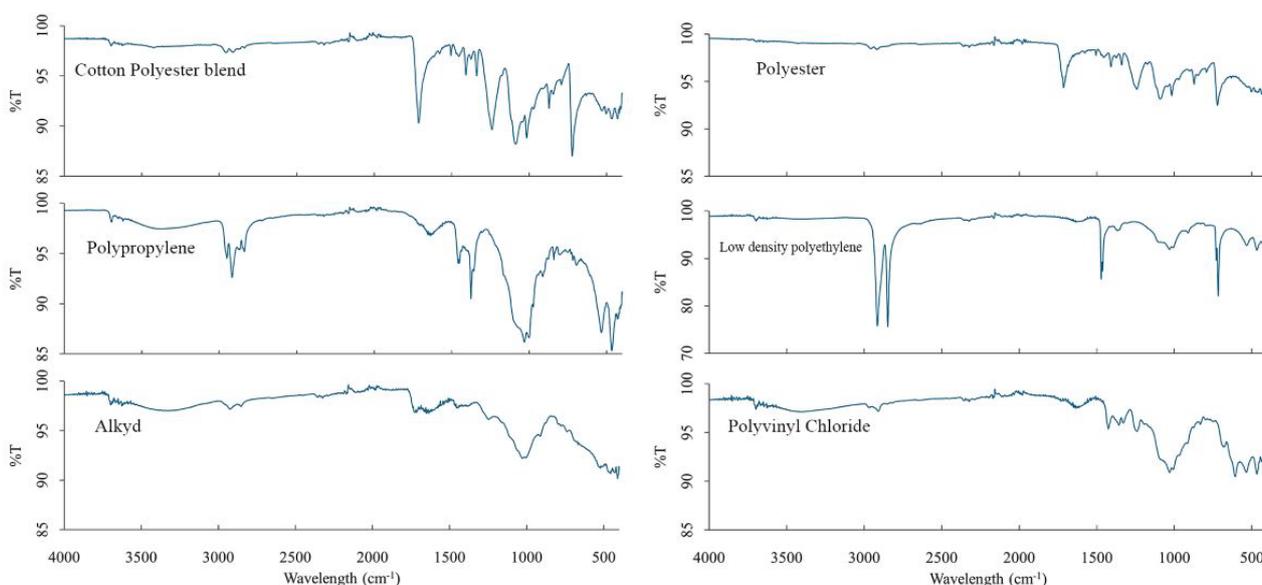
identified in 5 colors: Blue fragments (FR-1), clear colorless fragments (FR-2), blue fragments (FR-3), white fragment sheeting (FR-4), and blue fragment sheeting (FR-5).



**Figure 3** Microscopic image depicting plastic types identified in this study. Characteristics and colors were classified according to the principles of SCS. (FI: Fiber; FR: Fragment).

All groups were identified via FTIR spectroscopy. The chromatograph data were analyzed and compared with the standard wavelength curve for each polymer type (Figure 4). Six polymers were identified in this study. Groups FI-1 and FI-2 were identified as cotton polyester blend plastics, while plastics in groups FI-3-

FI-5 were identified as polyester plastics. FR-1 and FR-4 were identified as polypropylene (PP) plastics, while group FR-2 was identified as low-density polyethylene (LDPE) plastic. Group FR-3 was identified as polyvinyl chloride (PVC) plastic, and FR-5 plastics were identified as alkyd.



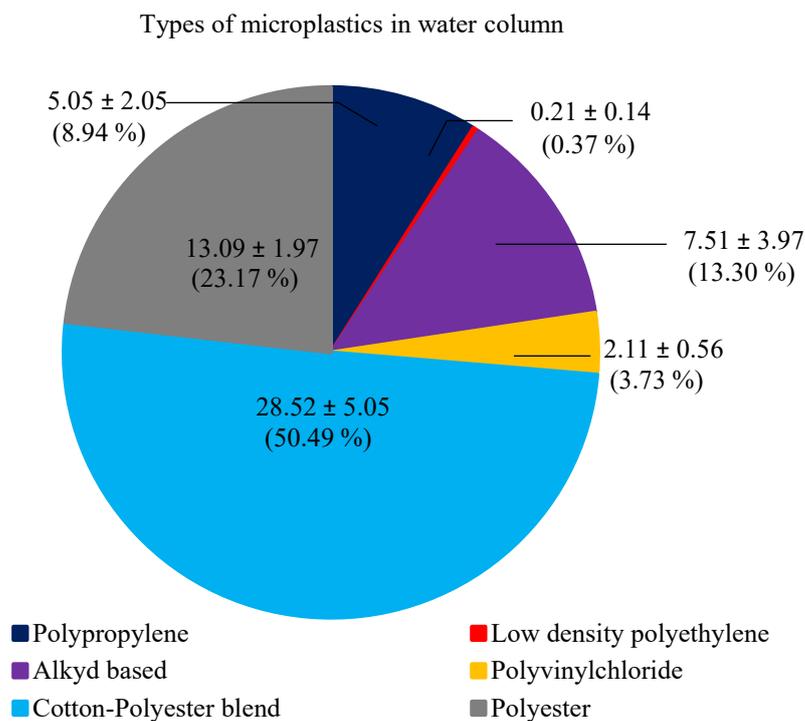
**Figure 4** Polymer wavelength of microplastics identified via FTIR analysis.

### Overall quantity of microplastics accumulated in the water column at Ko Yo

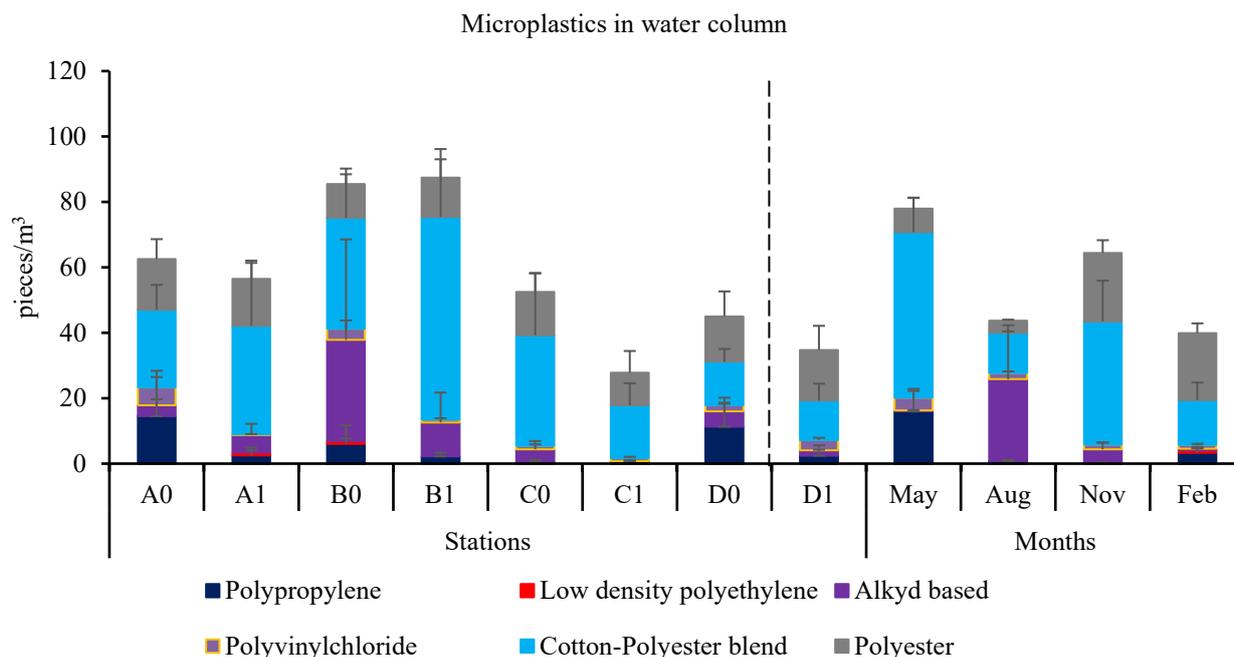
Six types of microplastics were identified in the water column. The proportions of the plastic types are compared and illustrated in **Figure 5**. The cotton polyester blend exhibited the highest accumulation, averaging  $28.52 \pm 9.36$  pieces/m<sup>3</sup>, followed by polyester ( $13.09 \pm 4.48$  pieces/m<sup>3</sup>), alkyd ( $7.51 \pm 5.92$  pieces/m<sup>3</sup>), PP ( $5.05 \pm 3.70$  pieces/m<sup>3</sup>), polyvinylchloride ( $2.11 \pm 0.62$  pieces/m<sup>3</sup>), and LDPE ( $0.21 \pm 0.21$  pieces/m<sup>3</sup>).

The number of accumulated microplastics varied among sites (A - D), with those closer to the shoreline generally exhibiting lower counts (except at site B). Additionally, as illustrated in **Figure 6**, station B, surrounded by restaurants and homestays, displayed the highest accumulation of microplastics (Station B1

averaging  $87.46 \pm 14.91$  pieces/m<sup>3</sup>, followed by Station B0 averaging  $85.47 \pm 26.11$  pieces/m<sup>3</sup>), while the lowest accumulation was observed at station C1, situated in a natural mangrove habitat, with an average of  $27.76 \pm 3.47$  pieces/m<sup>3</sup>. However, the statistical analysis did not support significant differences in the type and quantity of microplastics among stations (**Table 2**;  $p > 0.05$ ), as confirmed by pairwise analysis (**Table 3**;  $p > 0.05$ ). Conversely, significant differences were observed in sampling times (**Table 2**;  $p < 0.05$ ). Microplastic accumulation was highest in May, averaging  $77.91 \pm 13.43$  pieces/m<sup>3</sup>, followed by November, August, and February, averaging  $64.43 \pm 14.52$ ,  $43.68 \pm 15.68$ , and  $39.94 \pm 6.31$  pieces/m<sup>3</sup>, respectively. These differences among months were supported by pairwise analysis (**Table 4**;  $p < 0.05$ ).



**Figure 5** Proportion of polymer types accumulated in the water column at Ko Yo (mean  $\pm$  SE).



**Figure 6** Spatial and temporal variations in the quantity of microplastic accumulation in the water column at Ko Yo (mean ± SE).

**Table 2** Analysis of variance for the quantity of microplastics among stations and months. Significant *p*-values (*p* < 0.01) are indicated in bold.

Source of variance	Within group	F	<i>p</i> -value
Station	5.6060	0.5957	0.9394
Month	4.0830	5.7050	<b>0.0001</b>
Sum of Square	6.5790		

Six types of microplastics were found accumulated in the water along Ko Yo: Cotton polyester blend, polyester, alkyd, PP, polyvinylchloride, and LDPE. These microplastics were observed both near the shoreline and within 1,000 m of the shore. Among them, cotton polyester blend microplastics were the most abundant. Cotton polyester blend plastics consist of synthetic fibers commonly used in clothing, bedding, and furniture [18]. The results of this study suggest that some of the cotton polyester blend plastic originates from wastewater discharged from laundry activities. The mechanical action of washing can cause fibers to break off and enter household wastewater, which then mixes with coastal wastewater. The literature indicates that a single washing cycle can release up to 1,900 microplastic fibers [19]. Furthermore, 1 L of wastewater can contain up to 100 microplastic fibers [20]. In

addition to household wastewater, Ko Yo also faces contamination from fishing and aquatic culture activities around the island. Fibrous plastic materials such as ropes, nets, and cages [21] are already present in the water and are abundant around Ko Yo. These materials degrade over time owing to exposure to sunlight ultraviolet rays [4,22-26] or break into small particles through wave action [27].

A study investigating the quantity and composition of polymers in the water column revealed no statistical differences in spatial variation between locations near the shore and those farther away in the subtidal area. This lack of distinction is attributable to the considerable variation among stations, as all areas are surrounded by human communities. Anthropogenic activities are widespread and disturb the entire coastline along Ko Yo.

**Temporal accumulation of microplastic type and quantity**

Analysis of polymer quantity and type according to pairwise differences (Table 4) revealed that the composition, type, and quantity of microplastics varied between each month. August exhibited significant differences from other months at a statistical level ( $p = 0.0012 - 0.0030$ ), while no significant differences existed between May and November ( $p = 0.2178$ ) or between November and February ( $p = 1.0000$ ).

Variations of microplastics were influenced by the time of year. The proximity of Ko Yo to the mouth of the lake exposes it to constant tidal exchanges [28], impacting the accumulation of microplastics over time.

May and November exhibited a statistically higher accumulation of microplastics than other months, presumably because these periods mark the end of summer. May, in particular, exhibited high levels of microplastics, possibly because plastic waste is exposed to prolonged sunlight and ultraviolet rays during the summer months [22-26]. This leads to the erosion and breakdown of plastic into small particles that accumulate in the water. During the rainy season, particularly in November, heavy rainfall occurs owing to the northeast monsoon in the study area. During this time, waste from landfills or improperly discarded plastic washed away by rainwater can accumulate in water sources [29-31].

**Table 3** Pairwise analysis of microplastics in the water column between stations. Values are represented as  $p$ -values.

Pairwise	A0	A1	B0	B1	C0	C1	D0	D1
A0	x	1	1	1	1	1	1	1
A1	1	x	1	1	1	1	1	1
B0	1	1	x	1	1	1	1	1
B1	1	1	1	x	1	1	1	1
C0	1	1	1	1	x	1	1	1
C1	1	1	1	1	1	x	1	1
D0	1	1	1	1	1	1	x	1
D1	1	1	1	1	1	1	1	x

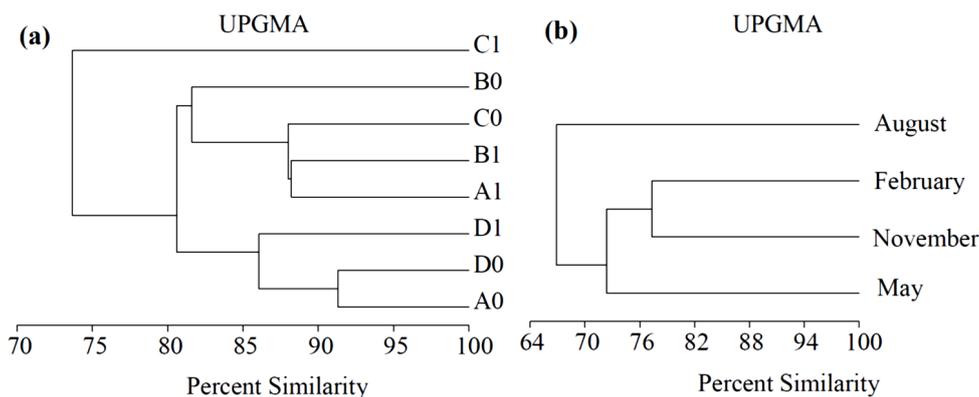
**Table 4** Pairwise analysis of microplastics in the water column between months. Values are represented as  $p$ -values. Significant  $p$ -values ( $p < 0.01$ ) are indicated in bold.

Pairwise	May	August	November	February
May	x	<b>0.0012</b>	0.2178	<b>0.0036</b>
August	<b>0.0012</b>	x	<b>0.0030</b>	<b>0.0018</b>
November	0.2178	0.0030	x	1.0000
February	<b>0.0036</b>	<b>0.0018</b>	1.0000	x

**Similarities in the quantity and type of microplastics around Ko Yo**

Cluster analysis revealed that the similarity in quantity and type of microplastics was higher among stations (Figure 7(a); 73.68 - 91.31 %) than among months (Figure 7(b); 66.88 - 72.37 %). Most stations exhibited high similarity, exceeding 80 %, except for station C1. Therefore, proximity to the coastline and

stations located 1 km away did not affect the differences. However, the time of year affected the quality and quantity of microplastics. August exhibited notable differences in similarity compared with other months, with a similarity rate of only 66.88 %. February and November were the most similar in terms of the number and type of microplastics found in this study, with ~80 % similarity, closely followed by May (72.37 %).



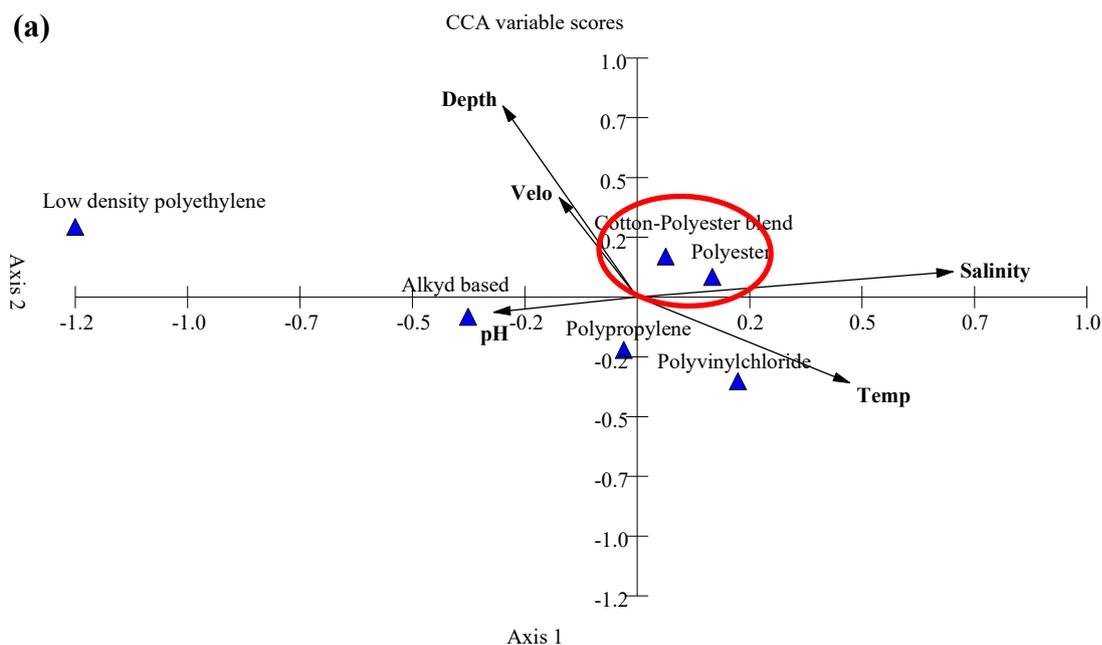
**Figure 7** Cluster analysis showing the similarity of microplastics in the water column among stations (a) and months (b).

### Correlation between polymer type and water quality

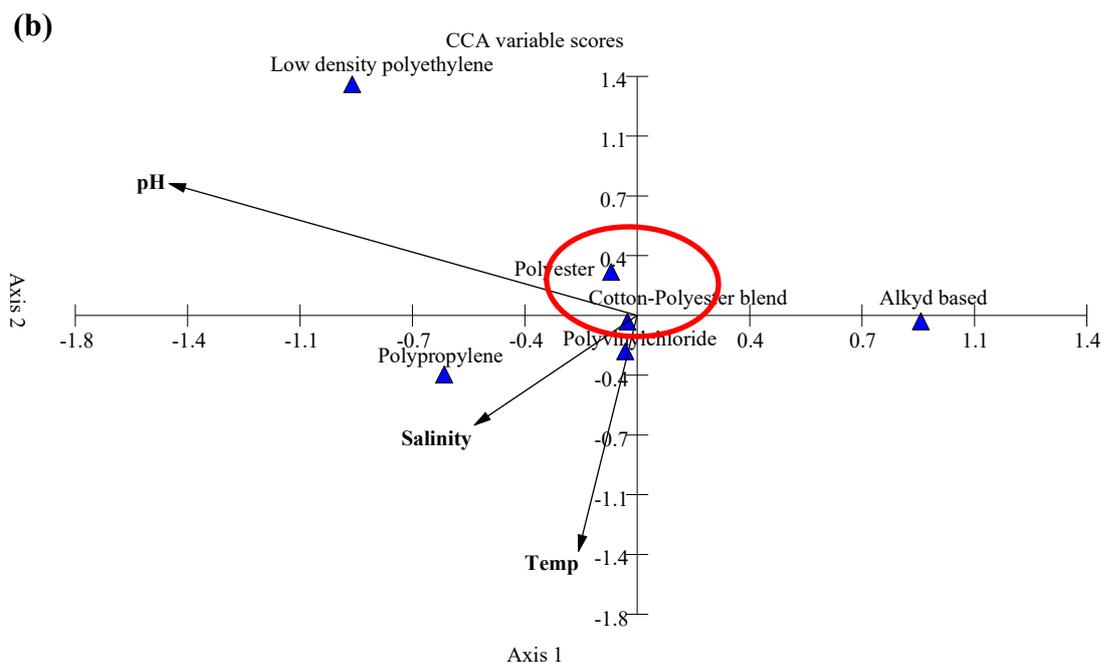
The analysis of the relationship between environmental factors and microplastics (**Figure 8**) revealed that environmental factors were not directly correlated with the distribution of the predominant types of microplastics (cotton polyester blend and polyester) either spatially or temporally. The findings of this study align with the similarity analysis, which indicated that microplastic accumulations were more similar between stations than across seasons. Correspondence analysis of microplastics revealed that the studied environmental factors were not directly associated with the distribution of the dominant microplastic groups (cotton polyester blend and polyester) at both station and monthly levels, presumably because cotton polyester blend and polyester consist of low-density fibers. Plastics with lower density than the surrounding liquid medium, such as seawater, tend to float to the surface [32,33], remaining suspended in the water and easily transported by wind and waves [34]. Consequently, these fibrous plastics were present in the water at every station and during every month sampled. Conversely, plastics with higher density than the surrounding liquid medium, such

as PP and PVC, tend to sink to the bottom [32] and therefore may only be found in select stations. The accumulation of microplastics in the environment is influenced by various complex factors, including geographical location [35]. Factors such as pH, depth, and velocity may contribute to microplastic production through mechanical and photochemical processes, leading to fragmentation and degradation into micro/nanoparticles accelerated by wave action and sunlight [13]. However, this study revealed that microplastics have accumulated around Ko Yo, Songkhla Province, which is a crucial fishing and aquaculture area in Thailand. Without suitable measures or management, human exposure to toxicity may increase in the future, which is also a concern in current research [14,36].

As global climate conditions continue to worsen, disrupting ecosystems, they can also exacerbate the processes leading to microplastic formation, such as low pH and high-water temperatures. This can accelerate the fragmentation mechanism, posing additional risks. Consequently, animals and humans may face greater challenges in adapting to and coping with these hazardous environmental conditions.



Vector scaling: 0.97



Vector scaling: 1.72

**Figure 8** Canonical correspondence analysis of the relationship between environmental factors and microplastics in water masses for each station (a) and month (b). Red circle indicated the high correlation in each data set.

**Conclusions**

Six types of microplastic polymers were found to accumulate around Ko Yo: Cotton polyester blend, polyester, alkyd, PP, polyvinylchloride, and LDPE. These polymers were most frequently observed during the summer and the northeastern monsoon season.

Cotton polyester blend, a synthetic fiber commonly used in clothing, furniture, ropes, nets, and cages, was found in the highest quantities across all months and stations. Despite the lack of statistical significance supporting differences between sampling sites, the data suggest a higher mean accumulation in anthropogenic areas than

in other areas and during the dry season compared with the rainy season.

### Acknowledgements

The authors thank members of marine benthic fauna LAB, Aquatic Science and Innovative Management Division, Faculty of Natural Resources for sampling collection. This research was funded by a Thai Government Budget Grant (Integrated Research and Innovation) in the fiscal year B.E. 2562 (research code NAT6201013S), and supported by National Science, Research and Innovation Fund (NSRF) and Prince of Songkla University, Thailand (Grant No ENV6505026e).

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