THE DISTRIBUTION OF MICROPLASTIC IN SEDIMENT AT KHUAN KHI SIAN WETLAND, SOUTHERN THAILAND

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Abstract. Studies around the world show that there is an increasing accumulation of microplastic pollution in the sediment. This study concerned the accumulation of microplastics in wetlands (Khuan Khi Sian, southern Thailand) sediment cores that are important to the ecosystem. The results showed significant differences in microplastic accumulation in wetlands in two seasons ($p < 0.05$), with more microplastic accumulation found in the wet season compared to the dry season. ‘Filament’ is found to be the most abundant microplastic shape and ‘500 µm – 1 mm’ was the most common size among microplastic in wet and dry seasons. Polymer composition analysis with FTIR with dry season microplastics found five types of polymers, with ‘polyester’ being the most common. Meanwhile, during the wet season, seven types of polymers were recorded, with ‘PET’ being the most common polymer.

Keywords: *coastal, soil, polymer, debris, polyester*

Introduction

From the stone-age era through to the technological era, human productivity and lifestyles have altered considerably as a result of rapid population increases and vast economic development (Liang and Yang, 2019). Thailand’s rapidly expanding population, industrial activities, and expanding economy are highly responsible for the country’s environmental degradation. In 2020, more than 18,000 complaints were lodged in Thailand over environmental pollution, which is a record high since 2016 (Manakitsomboon, 2022). The term “environmental pollution” is defined as “the contamination of the physical and biological components of the environmental system to the extent that normal.

Among the different forms of environmental pollution, microplastic pollution is a worldwide problem since it has been detected on every continent, even in polar areas (Andrady, 2017; Auta et al., 2017). Microplastics are fragments that are classified as microscopic plastic particles less than 5 millimeters in length that occur in a variety of forms and sizes (Hidalgo-Ruz et al., 2012). Microplastic pollution frequently occurs in coastal areas due to direct environmental pressures such as increasing population, maritime traffic, harbors, desalination plants, tourism, and fish farms, all of which result

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in the emission of complex mixtures of pollutants (Llorca et al., 2020). Microplastic pollution can impact the environment especially sediment in coastal areas. Microplastic pollution can be identified through sediment since they act as a reservoir in the marine environment (Beier et al., 2022; Pradit et al., 2022). This is because the microplastic is transported through seawater and accumulates in sediment. Microplastic accumulation in sediments can remain for more than 100 years due to sluggish rates of decomposition under low light and oxygen conditions, having a substantial influence on the biophysical and chemical environment of sediments (Zalasiewicz et al., 2016). The presence of microplastics in soil causes degradation of soil structure, a loss in the soil’s ability to absorb rain and irrigation water, and a detrimental effect on the soil’s ability to retain water (Liu et al., 2014). If assimilated into the soil agglomeration structure, it will impact the bioavailability of the adsorbed organic and inorganic contaminants, hence affecting the soil structure and material cycle (Leed and Smithson, 2019). The accumulation of microplastic in different sediment layers is based on their timeline. According to Willis et al. (2017), fewer microplastics are found in the deeper layer of sediments (older) than in the upper layer (recent) sediments. Therefore, microplastics are found not only on the surface but also in soil layers which include the sediment layer, the organic matter layer, and the soil source layer. In conclusion, sediment cores can reveal the history of contamination in aquatic environments. Over recent decades, sediment core investigations have proven to be a useful tool for revealing the influence of natural processes and anthropogenic activities on depositional settings (Pradit et al., 2022).

Wetlands are important natural protective habitats that have been referred to as the landscape’s kidneys (Lin et al., 2022). Wetlands act as an environmental sieve, helping those who can adapt and screening out those who cannot. They have distinctive soils and vegetation that are influenced by hydrology (Craft, 2022). The wetlands are one of the sources that provide essential advantages to human civilizations such as water purification, flood protection, fish nursery habitats, and biodiversity maintenance. Nonetheless, wetlands are deteriorating due to the input of microplastic through natural and anthropogenic factors (Dang et al., 2022; Barbier, 2013). Natural wetlands are also recognized as places that are frequently employed for the treatment of industrial, agricultural, and household wastewater (Pradit et al., 2022). Several investigations have concluded that wetlands can serve as “sinks” for various types of pollutants released in the region, which accumulate in wetlands and reach harmful quantities over time (Sharley et al., 2017). Microplastics are delivered into wetlands by runoff. Massive amounts of wetland plants capture microplastics suspended (as suspended solids) in wetland water, which may then be deposited on the marsh bed.

The Khuan Khi Sian is one of Thailand’s most significant natural and diverse wetlands, a region that is entirely covered by water year-round and is referred to as a wetland. This wetland has an area of 494 hectares (19,281.25 acres) and is situated around 5 km north of Thale Noi Lake (Kaewdee et al., 2002). The Khuan Khi Sian area is home to local communities, hosting tourists and serving other human purposes, and includes a high diversity of wetland habitats, including grassland, freshwater lake, Melaleuca swamp forest, rice fields, rubber plantations, mixed orchards, and more (Pradit et al., 2022). However, environmental pollution has been introduced to the Khuan Khi Sian wetland which has resulted in biodiversity degradation especially in sediment soil structure due to industrialization and population expansion. Several studies conducted on microplastic in sediment since microplastic pollution show an

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increasing trend (Seeley et al., 2020; Bellasi et al., 2021). But there is a lack of knowledge about microplastic accumulation in the sediment layer of Khuan Khi Sian. Therefore, this study sought to identify the accumulation of microplastic in wetlands in two seasons. The study's findings will serve as a baseline for the current status of microplastic in the wetland sediment.

Materials and methods

Sample collection and storage

Sediment samples were collected from the Khuan Khi Sian swamp area, located in southern Thailand at 7 stations as shown in *Figure 1*. The samples were collected from the study area during two seasons, in March 2022 (dry season) and June 2022 (wet season). The depth of collection for each station varied due to the different sediment textures (soft or hard texture) at each sampling station. The soft texture consisted of a high presence of organic materials at the top, whereas the hard texture comprised the bed sediment beneath the soft texture. *Table 1* shows the latitude, longitude, and depth of sediment collected at each sampling station.

The sediment samples were collected using acrylic sediment cores with a diameter of 7 cm and 65-70 cm in height. The sediment depth is divided into 5 layers (surface 0-12 cm, medium surface 12-24 cm, medium 24-36 cm, medium bottom 36-48 cm, and bottom 48-62 cm), which were subsequently oven-dried at roughly 60°C. After they dried, they were ground using a mortar and pestle, the grounded sediments were kept in resealable bags and stored away for laboratory analysis later on.

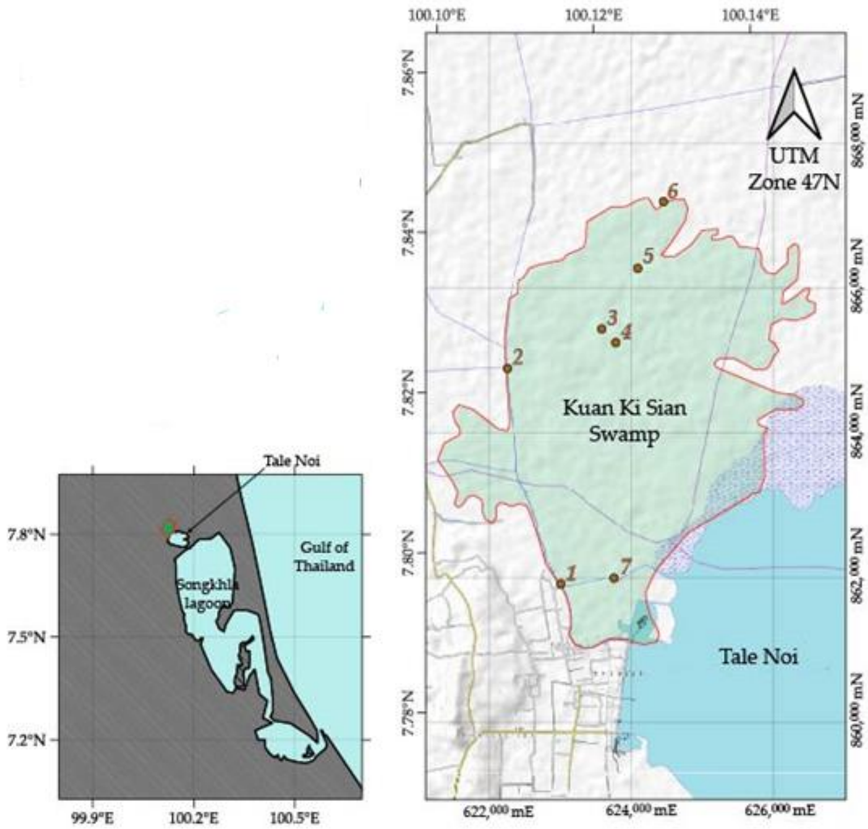

Figure 1. *Study area and the location of the sampling site*

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Table 1. *Latitude, longitude, and depth of sediment collection at each sampling station for dry season and wet season 2022*

Station	Dry (March 2022)			Wet (June 2022)		
	Latitude	Longitude	Depth	Latitude	Longitude	Sediment depth
1	47 N 0623009	E 861906	33 cm	47 N 0622788	E 861996	20 cm
2	47 N 0622257	E 864881	33 cm	47 N 0622302	E 864889	20 cm
3	47 N 0623584	E 865428	33 cm	47 N 0623554	E 865428	56 cm
4	47 N 0623781	E 865239	33 cm	47 N 0623764	E 865268	24 cm
5	47 N 0624091	E 866265	42 cm	47 N 0623654	E 865650	54 cm
6	47 N 0624453	E 867188	62 cm	47 N 0623917	E 865852	62 cm
7	47 N 0623756	E 861987	29 cm	47 N 0623806	E 862198	54 cm

Sample analysis

In the laboratory, 60 g of the grounded sediment samples was place in a 600 ml beaker, 10 g of dry sediment was weighed and added. The beaker was then filled with 200 ml of saturated and filtered sodium chloride (NaCl) solution. After mixing with a glass rod, the mixture was placed aside for 1 h to allow the sediment particles to settle. Following that, 100 ml of supernatant were filtered through a 300 µm filter. Another 100 µm of NaCl was added to the initial sample beaker and was placed aside for 1 h. The process was repeated 3 times before taking the 300 µm filter cloth to another beaker and washing the contents with distilled water and covering it with aluminum foil. Then, the sample water that was filtered through the 300 µm filter cloth was filtered again through a 20 µm filter cloth. Later, that 20 µm filter cloth was placed in another beaker, washed the contents with distilled water and covered the beaker with aluminum foil. After that, 10 ml of H_2SO_4 and H_2O_2 each were added to the samples and left to heat on the hot plate (controlled temperature of not more than 75°C) to digest the contents. Then, 6 g of NaCl reagent powder was added to the sample beakers and left for 24 h at room temperature. The samples were then filtered using another clean set of 300 µm filter cloth and glass microfiber GF/C and were placed in individual Petri dishes. The Petri dishes were then placed in a hot oven at 60°C for 3 h to let the samples dry completely before viewing them under the microscope.

Microplastic identification

Under a stereo microscope, the microplastics (MPs) in the filter paper were visually identified using the physical and morphological characteristics of the plastic particles. This technique made use of a Leica EZ4 W Stereomicroscope. The Leica Application Suite was used to capture the particle photos. There was no bias in the light reflection from the microscope since the filters were entirely dry. We used Hidalgo-Ruz's rules (Hidalgo-Ruz et al., 2012), which are Rule 1: no cellular or organic structures visible, Rule 2: fibers should be equally thick along their entire length, and Rule 3: particles should have uniform color throughout the item, to distinguish between organic and non-organic materials (plastic). In cases where we were unable to distinguish between plastic and organic debris, we additionally used the hot needle test (de Witte et al., 2014) for suspected cases. Plastic bits melt or curl in the presence of a hot needle. The microplastic particles are categorized by their type (filament, fragment, and other), size

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(<500 µm, <1 mm, and >1 mm), and colors (blue, black, red, white, and other). All these categories of microplastic were observed and recorded. In order to distinguish the microplastic polymers, Fourier Transform Infrared Spectroscopy (FTIR) was employed. The spectral range was defined at 4 cm^{-1} resolution and 4000 cm^{-1} to 400 cm^{-1} wavelength. The microplastic spectrum found in the sediment samples was compared to the spectrum library of each type of polymer.

Statistical analysis

Using MS Excel, data on MP abundance, size, color, and shape were analyzed. Test of Normality was performed. The statistical difference in microplastic by depth and season was identified by an independent sample t-test. A significance threshold of 0.05 was taken into account.

Contamination control

Extensive precautions were taken during the separation process of the sediment samples to prevent any contamination when handling and processing them. To ensure that the experiment was as contaminant-free as possible, cotton lab coats and polymer-free grove were used (Jiwarungrueangkul et al., 2021). Distilled water and saturated NaCl were filtered before use in the experiment to prevent microplastic contamination. Clean filter papers were used during the filtration procedure to avoid contamination.

Result and discussion

Microplastic accumulation in sediment depth in two seasons

The total amount of microplastic accumulation at all sediment depth during the two seasons as shown in *Table 2* and *Figure 2*.

Table 2. *Distribution of microplastics in all sediment depths during two seasons*

Station	Season	Abundance of microplastics in sediment depth (particles/g)					Abundance of MPs in season (particles/g)
		Surface (0-12, 0-4 cm)	Medium surface (12-24 cm)	Medium (24-36 cm)	Medium bottom (36-48 cm)	Bottom (48-62 cm)	
1	Dry season	0.97 ± 0.29, 0.5	0.33 ± 0.15	1.73 ± 0.64	None	None	1.82 ± 1.00
	Wet season	0.73 ± 0.17, 0.9	0.57 ± 0.43	None	None	None	0.78 ± 0.48
2	Dry season	0.57 ± 0.26, 0.1	0.43 ± 0.15	0.17	None	None	0.92 ± 0.46
	Wet season	0.70 ± 0.23, 1.1	0.30 ± 0.15	None	None	None	1.44 ± 1.00
3	Dry season	2.13 ± 0.79, 1.2	0.40 ± 0.25	None	None	None	1.52 ± 1.24
	Wet season	11.00 ± 0.36, 11.7	2.47 ± 1.87	0.77 ± 0.13	0.87 ± 0.33	0.23 ± 0.14	9.24 ± 6.04
4	Dry season	0.70 ± 0.26, 0.3	0.60 ± 0.15	0.10	None	None	0.84 ± 0.46
	Wet season	1.77 ± 0.41, 2.4	1.43 ± 0.38	None	None	None	1.92 ± 1.19
5	Dry season	0.43 ± 0.17, 0.6	0.17 ± 0.03	0.17 ± 0.09	0.23 ± 0.12	None	0.56 ± 0.22
	Wet season	0.90 ± 0.32, 1.0	0.70 ± 0.15	0.67 ± 0.18	0.87 ± 0.19	0.25 ± 0.15	2.08 ± 0.30
6	Dry season	0.53 ± 0.13, 0.4	0.47 ± 0.09	0.30 ± 0.12	0.33 ± 0.15	0.45 ± 0.17	1.34 ± 0.17
	Wet season	0.63 ± 0.18, 0.9	0.50 ± 0.6	0.40 ± 0.17	0.33 ± 0.09	0.30 ± 0.14	1.36 ± 0.16
7	Dry season	1.20 ± 0.82, 0.1	0.30 ± 0.06	0.23 ± 0.15	None	None	1.04 ± 0.67
	Wet season	1.40 ± 0.12, 1.6	1.00 ± 0.06	1.80 ± 0.95	1.33 ± 0.34	0.35 ± 0.21	3.60 ± 0.67

None = Microplastics have not been studied in depth

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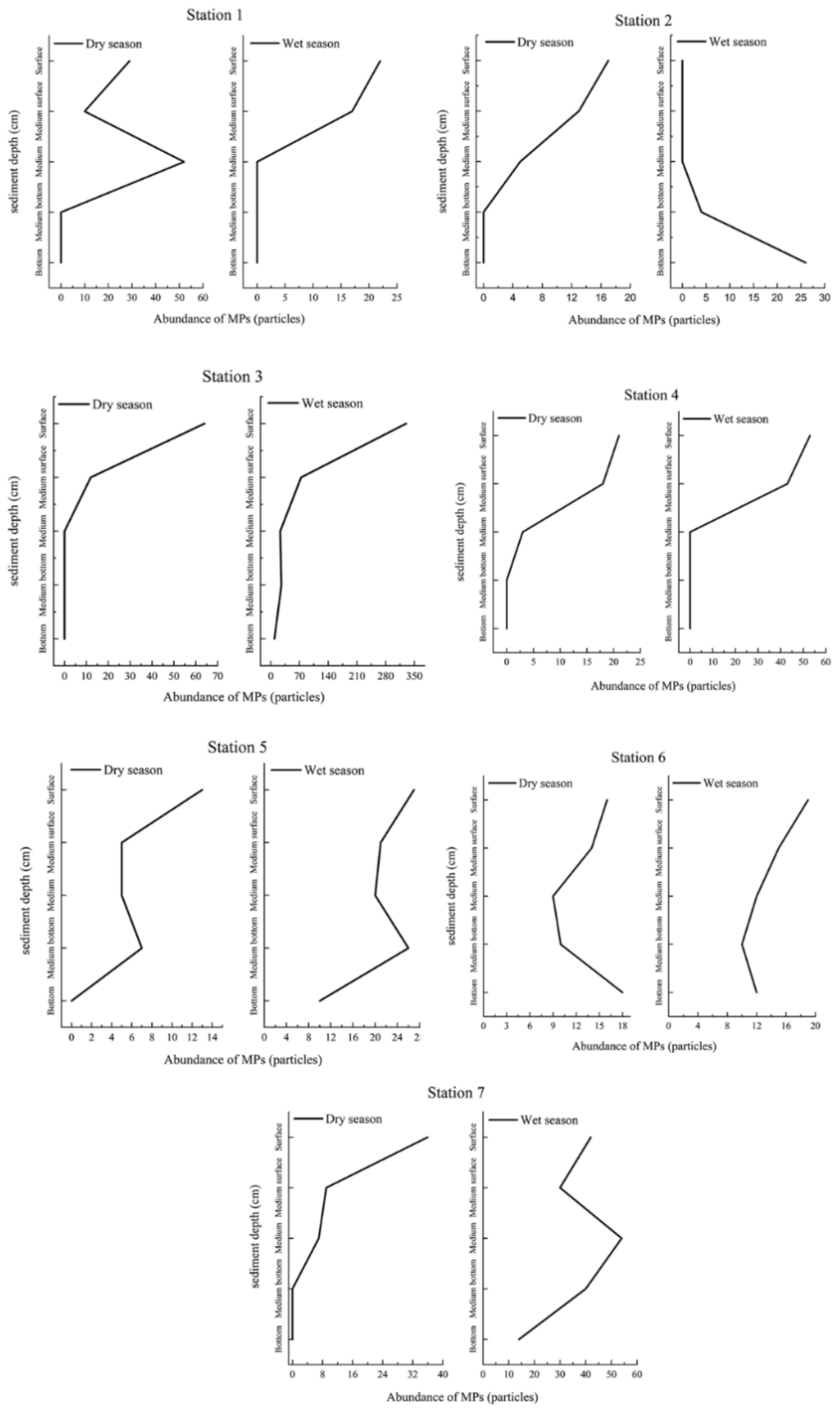

Figure 2. *The distribution of microplastics by sediment depth at each station in two seasons at the Khuan Khi Sian wetland area*

The studied wetland is a supply of water, a reservoir for rainfall, and a basin. The area has a diverse ecosystem (fishing and tourism). The region may flood if it is overlaid or otherwise changed which may result in soil pollution and the accumulation of microplastics in water sources into sediment soil. Microplastics are often found in large quantities at depths of 0–12 cm, with microplastic sizes being 500–1000 μm (Uddin et al., 2021; Zhou et al., 2021) and as it deepens, microplastics with reduced amounts are

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observed from the surface layer, according by Wang et al. (2019) and Zhou et al. (2021). The sediment layer that currently is present is the top layer of soil. The older soil in the lower strata was created by deposition. In this study, the exact age of the soil in the area could not be known. However, the number of microplastics found in older soils, such as 10-20 years ago, may show a link to the use of plastic products in previous times when humans began using plastics. But that plastic waste can be disposed of controlled which shows the importance of putting more pressure on the disposal of biodegradable plastic waste (Thomson, 2006). In addition, there may be other factors, such as that the area was not yet a tourist attraction and not heavily populated, the area was also completely forested, no outsiders bothering, and there were no humans farming. As a result, the accumulation of microplastics in the soil was still not as large as it is today.

Microplastics in sediment core at the surface (0-12 cm) and medium surface (12-24 cm)

The statistical analysis found that, at the significance level of $p = 0.630$, the amount of microplastics at the medium surface sediment (depths of 12 to 24 cm) was not different among the seven stations, and that the microplastics at the surface sediment (depths of 0 to 12 cm) were different among stations ($p = 0.049$). Station 3 had the highest amount of microplastics in both seasons, in the dry season the accumulation of 6.4 particles/g average of 2.13 ± 0.79 particles/g, the wet season the accumulation of 33 particles/g average of 11.00 ± 0.36 particles/g. There was a difference in the depth distribution of microplastics between the two seasons ($p = 0.017$).

In the dry season, station 3 had the highest concentration of microplastics in the surface layer, with a value of 6.4 particles/g, and station 5 had the lowest, with a value of 1.3 particles/g. Station 4 had the highest concentration of microplastics with a value 1.8 particles/g in medium surface layers, while station 5 had the lowest with a value of 0.5 particles/g. In the wet season, station 3 had the greatest concentration of microplastics in both surface and medium surface layers, with a value of 33 particles per gram and 7.4 particles per gram, respectively. Station 6 had the lowest concentration (1.9 particles/g) in surface layers, and in medium surface layers, the least amount was recorded at station 2, with a value of 0.9 particles per gram, respectively.

For the average amount of microplastic in sediment on wetland, this study found higher amounts than several other studies, including wetland in China which found 0.252 ± 0.100 particles/g (Zhou et al., 2021), 0.035 ± 0.002 particles/g (Wang et al., 2022) and wetland in Iran which found 0.362 ± 0.328 particles/g (Birami et al., 2022), 0.049 ± 0.015 particles/g (Ashjar et al., 2023), 0.784 ± 0.878 particles/g (June) and 0.520 ± 1.024 particles/g (January) (Rasta et al., 2020). In addition, more microplastics were found in this study than other studies with different sediment types including canals in Japan which found 1.800 particles/g (Matsuguma et al., 2017), canals in which Thailand found 0.450 ± 0.196 particles/g (Dry season) and 0.200 ± 0.105 particles/g (Wet season), estuary in China which found 0.0094–0.0050 particles/g (Liu et al., 2021), bay in Thailand which found 0.015 – 0.135 particles/g [31], lake in China which found 0.017 – 2.644 particles/g (Liang et al., 2022), pond in China which found 0.059 ± 0.046 particles/g (summer) and 0.039 ± 0.019 particles/g (winter), and beach in China which found 0.256 ± 0.002 particles/g (Venkatramanan et al., 2022). However, considering the season, it is noted that the study found more microplastics in the wet season (June) than in the dry season (March), in accordance with the findings of Rasta et al. (2020) and different from other studies that found more microplastics during the dry season than the wet season (Jiwarungrueangkul et al., 2021).

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Comparing the number of microplastics in surface sediments (0-4 cm, *Table 2*) between seasons, the number of microplastics appeared to be highest during the wet season (June). This is due to the enormous amount of water entering the marsh. Urban microplastics are carried by runoff to wetlands, where they are captured by dense vegetation and then deposited in the surface sediment. This finding is consistent with the result of Jiwarungrueangkul et al. (2021), who studied estuarine sediments on the west coast of Thailand.

Size, shape, color, and polymer of microplastics in wetland sediment

In this study, three different sizes of microplastics were chosen and studied: <500 µm, 1 mm–500 µm, and > 1 mm for March and June show as *Figure 3*. In March, the highest number of microplastics were found in the size of less than 500 µm, followed by 1 mm–500 µm, and the least was recorded in more than 1 mm. Station 3 recorded the most particles (70 particles) of less than 500 µm size, while stations 5 and 6 recorded the fewest (18 particles). In June, Station 3 recorded the most particles (426 particles) which were less than 500 µm, while station 2 recorded the fewest (1 particle).

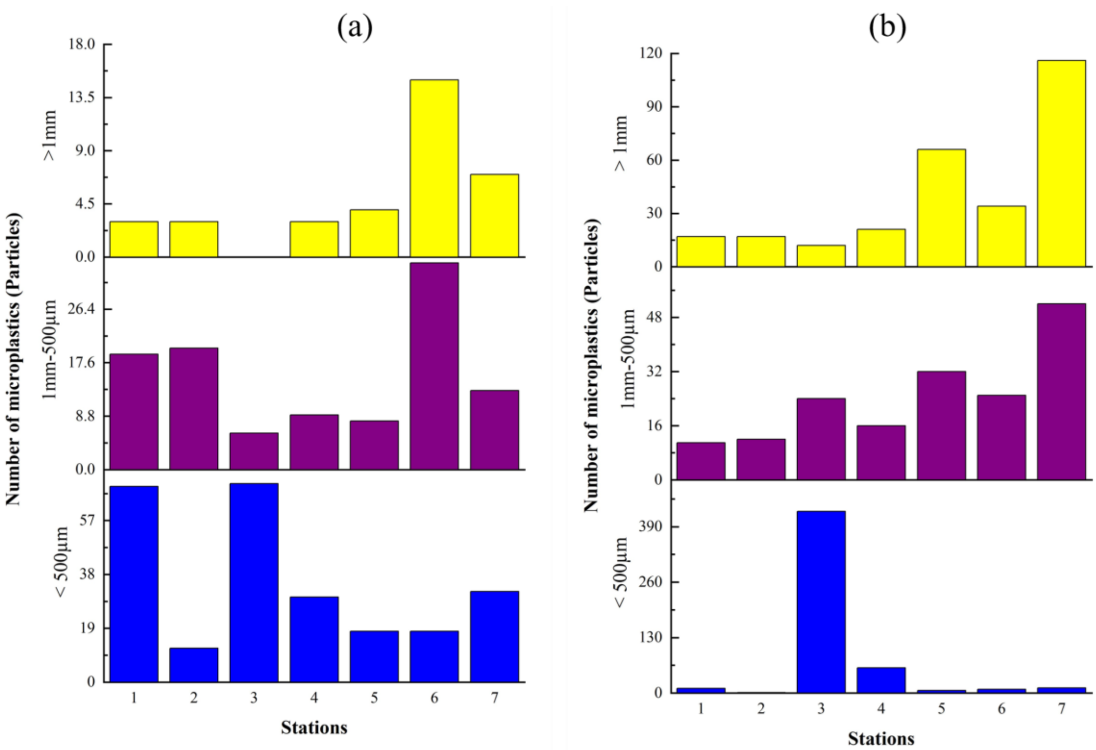

***Figure 3.** The abundance of different size microplastics in different seasons: dry season (a) and wet season (b)*

At seven stations, three different types of microplastic filament, fragment, and other were categorized in the dry and wet seasons, as shown in *Figure 4*. In total, the highest number of microplastics were filament type, followed by other types and then fragment type. In the dry season, most microplastic were found filament (313 particles), followed by others (80 particles) and fragment (9 particles). Station 1 recorded the most microplastics (91 particles), while station 5 recorded the least (30 particles). In June, a

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filament was the most common microplastic (494 particles), followed by others (474 particles) and then fragment (11 particles). The highest concentration of microplastics was found at station 3 (462 particles), while the lowest concentration was found at station 2, which contained only 30 particles.

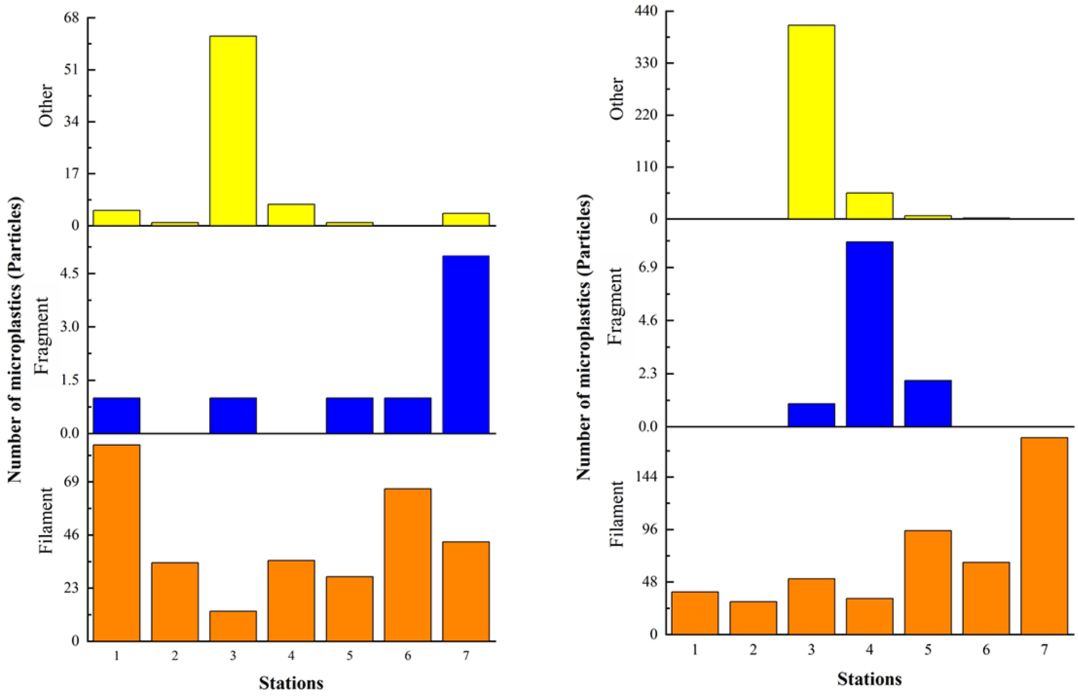

Figure 4. *Abundance of different types of microplastics in different seasons: in dry season (left) and wet season (right)*

Four types of colors, blue, white, transparent, and other, were detected among the seven stations in March and June as shown in *Figure 5*. Transparent color recorded the highest abundance in March, followed by white, other, and blue. In the wet season, transparent color recorded the highest abundance in June, followed by white, blue, and other.

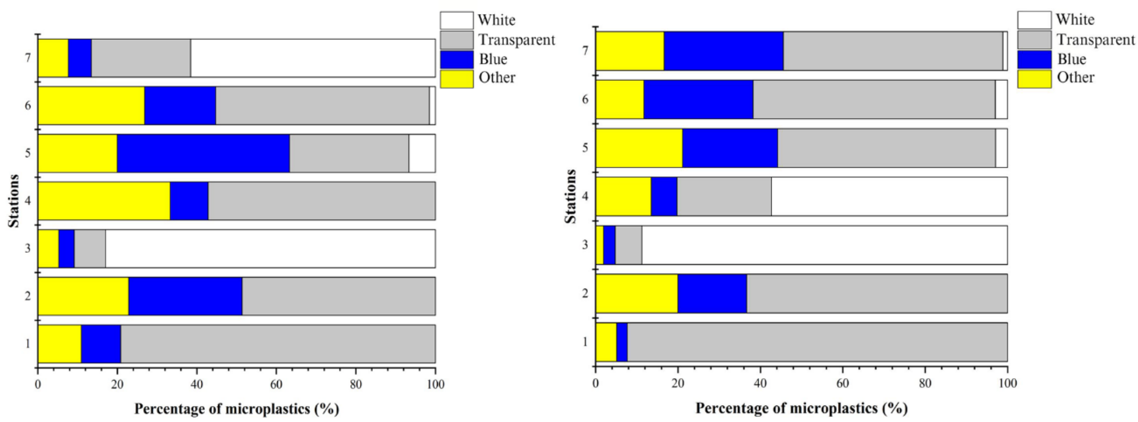

Figure 5. *Percentage of different colors of microplastics in different seasons: in the dry season (left) and wet season (right)*

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Microplastics of various polymers were identified by FTIR. Differences of polymers in both seasons are shown in *Figure 6* and examples of microplastic found are shown in *Figure 7*. During the dry season five types of polymers were found; polyester 45%, PE 23%, PP 14%, copolymer (including Poly (Ethylene: Propylene: Diene), PP + PET, PP + Poly (Polypropylene: Polyethylene)) 14%, and nylon 5%, respectively. In the wet season, seven types of polymers were recorded, PET 48%, rayon 28%, nylon 7%, PP 7%, polyurethane 3%, PE 3%, and polyester 3%, respectively.

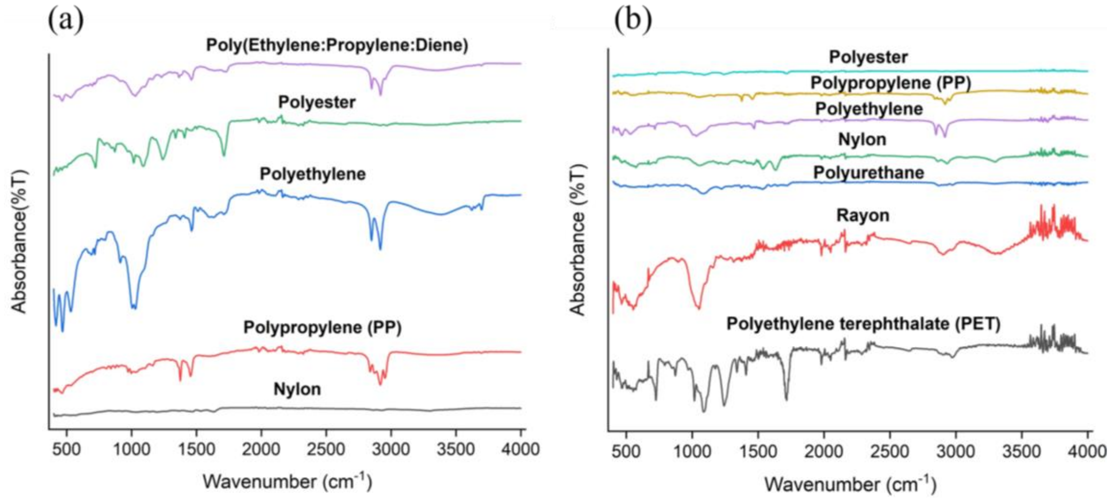

***Figure 6.** Distribution of microplastics in different seasons: dry season (a) and wet season (b)*

***Figure 7.** Examples of microplastic found in the sediment core*

The results of the study show several types of polymers in each season because the wetlands are used for agriculture and fishing activities. The polymers found are PP, PE, polyester, and nylon since these polymers are employed as a primary material to create goods that are used for a variety of purposes such as textiles, water bottles, and straps made from PET. Common uses of PP include dishware and bottle caps while PE is commonly used for packaging (Choong et al., 2021; Driedger et al., 2015). In addition, polymers found only in the wet seasons include PET, rayon, and polyurethane. Polyester is found to be the most common frequency from FTIR assays, while wet season PET is the highest, probably due to different environments in different seasons. This causes differences in the polymer type found (Tian et al., 2022). The size of most microplastics is found in the range of 500 μm – 1 mm, but the size of microplastics may not have much of a different impact on soil (Piccardo et al., 2020). Microplastics greater

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than 1 mm, found in both seasons, are the most common filament microplastics, much like soils in other wetlands such as estuaries (Liu et al., 2021), canals (Jiwarungrueangkul et al., 2021), and bays (Chinfak et al., 2021). There are reasons consistent with the distribution of filament from communal areas, washing machines, and washing water which feed into sewerage sources. Therefore, it is easily contaminated and comes from the use of fishing nets and ropes in the area (Jiwarungrueangkul et al., 2021). Now, it can be turned into clothing made from natural fibers. However, the shape, color, and polymer of microplastic can have many physical and chemical effects on sediment soil (Wang et al., 2022). When it is contaminated with the soil, the physical and chemical properties of the soil, such as soil structure, porosity, soil moisture, and soil air, can be altered and microplastics can affect the functioning of certain bacteria in the soil. Ultimately, it will result in increased nitrogen requirements and decreased organic carbon minerals (Wang et al., 2022; Zhang et al., 2023). In addition, some polymers absorb heavy metals such as Cd and As (Zhang et al., 2020). On the other hand, in the future, this adsorption property may be used to absorb soil pollution using microplastics.

Conclusion

Large amounts of microplastics were found at the surface of the sediment, and their amount decreased with depth of sediment. This has been demonstrated in both the wet season and dry season, indicating higher amounts of microplastic contamination in the present compared to the past. This reflects human activities that affect the amount of plastic waste, although at present there are laws to control the reduction and elimination of certain types of plastic. This ultimately contributes to microplastic pollution by analyzing the size, shape, color, and polymer type found in this study which can physically and chemically affect the sediment including microorganisms and other biota in the sediment. These effects may have an indirect effect on humans in terms of land use. When soil deteriorates, the use of that area may be reduced for agriculture or fishing activities. Therefore, plastic materials or facilities should be used in a safe and environmentally friendly way by minimizing the amount of plastic waste that can contaminate the environment because, in the end, the cycle of microplastics will return to humans, whether in the environment or in human food.

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