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Occurrence of Microplastics in River Water in Southern Thailand

Siriporn Pradit [1], Prakrit Noppradit [1,*], Karnda Sengloyluan [2], Phudith Suwanno [3], Varaporn Tanrattanakul [4], Kittiwara Sornplang [1], Narissara Nuthammachot [3], Preyanuch Jitkaew [1] and Thongchai Nitiratsuwan [5]

[1] Coastal Oceanography and Climate Change Research Center, Faculty of Environmental Management, Prince of Songkla University, Songkhla 90110, Thailand
[2] International College, Prince of Songkla University, Songkhla 90110, Thailand
[3] Faculty of Environmental Management, Prince of Songkla University, Songkhla 90110, Thailand
[4] Faculty of Science, Prince of Songkla University, Songkhla 90110, Thailand
[5] Faculty of Science and Fisheries Technology, Rajamangala University of Technology Srivijava, Trang 92150, Thailand
* Correspondence: prakrit.n@psu.ac.th

Abstract: Microplastic (MP) contamination in the marine environment has received growing attention. In 2022, the surface water of the U-Taphao River was sampled four times, in February, April, June, and August. The surface water samples were taken at seven different locations, ranging from upstream to downstream parts of the river. The results reveal that the number of MPs detected at the U-Taphao River in February, April, June, and August were 0.41 ± 0.08, 0.25 ±0.06, 0.24 ± 0.11, and 0.26 ± 0.06 particles/L, respectively. The MPs in the U-Taphao River each month were not statistically different (p = 0.190). The trend of the number of MPs found declined from upstream to downstream. Fibers were the most commonly found MPs in the U-Taphao River in this study and were found at more than 80% of all stations during all sample collection periods. Our results indicate that MP contamination is present in the river water, but it is noted that slightly different polymer types were found during each collection month. MPs can be transferred through the food chain and potentially to humans. Regular monitoring of MPs in the riverine system is, therefore, important, for which the findings of the present study can be used as a baseline for the number of MPs in the river water in the region.

Keywords: marine litter; surface water; lagoon; microplastic

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1. Introduction

Rivers can be both a source and a sink for waste from surrounding area, such as plastic litter and microplastics (MPs). Many MPs from urban wastewater end up settling near river mouths and take a long time to make their way downstream to the ocean [1]. As the population grows and human activities and production activities in the industrial and agricultural sectors increase, plastic waste in rivers or aquatic ecosystems has become an important issue [2]. As a result, untreated waste water or plastic particles are released into the environment via river runoff and atmospheric deposition [3]. MPs are polymer compounds that come in the form of beads, plastic fragments, and fibers [4]. MPs (<5 mm) [5,6], microscopic flecks, fibers, fragments, and granules, are abundant and have a high potential for ingestion by a diverse range of marine organisms [7–9]. MPs have been identified as a threat to the marine ecosystem, particularly marine organisms, due to their persistence in the marine environment [10]. Polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyethylene (PE), and polyvinylchloride (PVC) are the most commonly reported MPs in the marine environment [11]. Since chemicals are added during the manufacturing process to give MPs a durable color and other properties [12], MPs are considered water hazardous waste [13]. MPs can absorb persistent organic pollutants (POPs) and heavy metals [14]. If MPs are shown to accumulate in the gastrointestinal (GI) tract of fish, they may cause internal blockages and damage to the GI tract, causing the fish to eat less and eventually die [6,15,16] MPs spread throughout the environment, including rivers and seas, and accumulate in organisms [17]. It is necessary to better understand where MPs come from to enable appropriate management and reduce the number of MPs being transported into the ocean [18].

The U-Taphao River is the main river flowing into the Songkhla Lagoon, where one of only five freshwater subpopulations of the Irrawaddy dolphin is found. A population report by the Department of Marine and Coastal Resources [19] indicated that there are just 14 Irrawaddy dolphins in the lagoon. The present situation is extremely critical due to the death statistics of the Irrawaddy dolphins in the Songkhla Lagoon. One of the serious problems facing the Irrawaddy dolphins in the Songkhla Lagoon is the amount of water contaminated with chemicals that may affect newly born and juvenile dolphins. To date, no study of the MPs in the river flowing into the lagoon has been undertaken. Therefore, the goal of this study is to look into the presence of MPs in the U-Taphao River. The data may be used as supporting information to develop plans to protect the last group of freshwater dolphins in the Songkhla Lagoon from extinction.

2. Materials and Methods

2.1. Study Area

U-Taphao (Figure 1) is one of the most important rivers in Songkhla Province, Thailand. It is 130 km long [20] and flows through Hat Yai district, Thailand's major southern economic city, before entering the lower Songkhla lagoon, which connects to the Gulf of Thailand. Songkhla Lagoon is the largest lagoon in Southeast Asia, with a unique three-water ecosystem (fresh water in the upper section, brackish water in the middle section, and saline water in the lower section). Songkhla Lagoon is home to the freshwater Irrawaddy dolphin. The Irrawaddy dolphin population is on the verge of extinction and is present in only five places on the planet, one of which is Songkhla Lagoon. The surrounding areas are watersheds, with communities located along the river's banks, agricultural areas, factories, and an important business center for the southern region of Thailand.

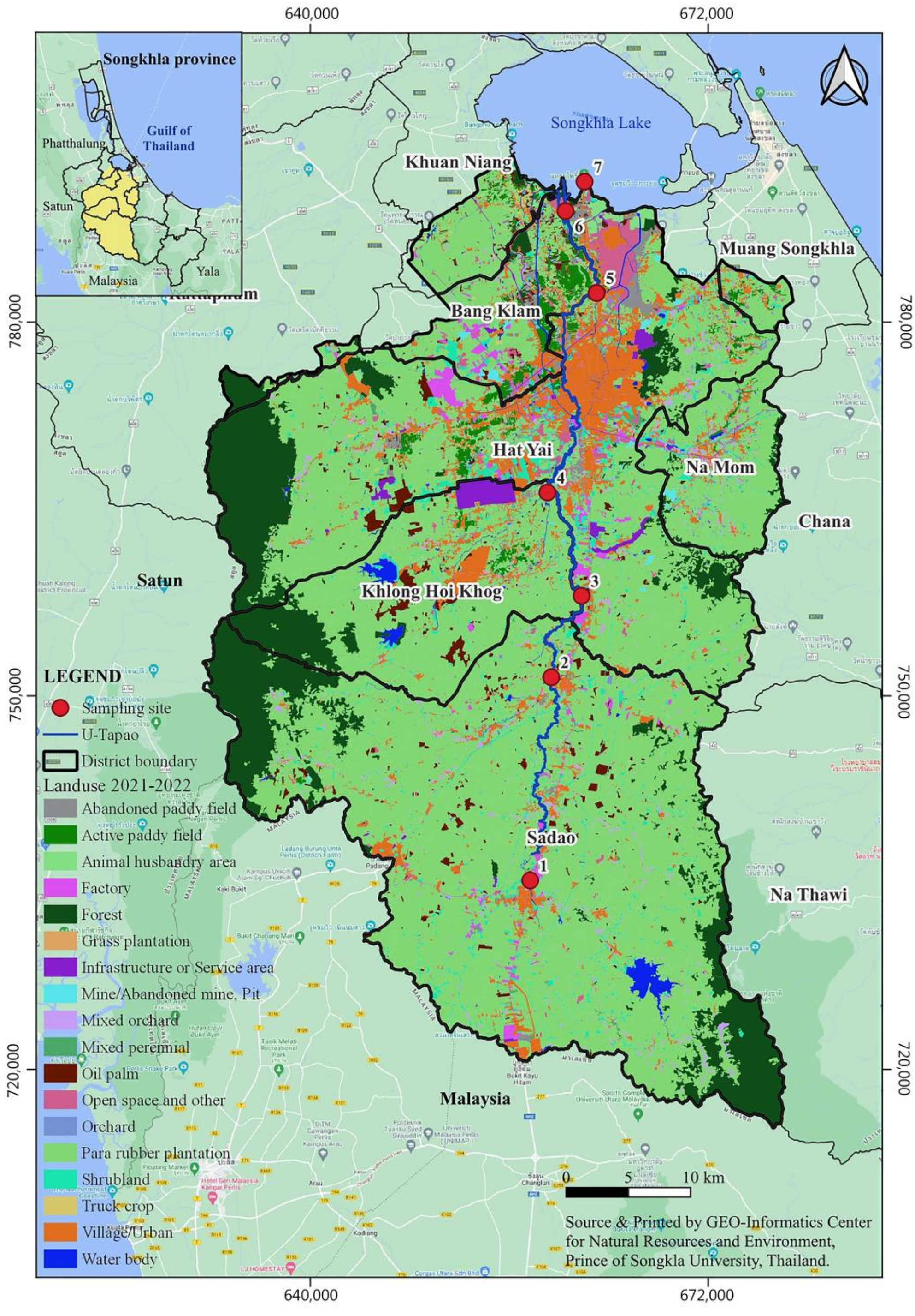

Figure 1. Map of the study area and the locations of the sampling sites. Sampling sites' locations are marked with a solid red circle.

2.2. Sample Collection and Storage

In 2022, the surface water (depth: 50 cm from the surface; distance: 3 m from the shore) was sampled four times in February, April, June, and August. Water samples were taken at seven different locations, ranging from upstream to downstream (Figure 1 and Table 1). A total of 100 L of water were sampled at each station and then sequentially transferred to sieves of 1000, 500, and 63 µm. All particles were then transferred from the sieves into a glass bottle. After that, particles were preserved at −4 °C for further analysis.

Table 1. Sampling station positions along the U-Taphao River.

Station	Latitude–Longitude	Description
1	47 N 0657679, E 0735178	Upstream
2	47 N 0659374, E 0751493	Upstream
3	47 N 0661806, E 0758027	Upstream
4	47 N 0659067, E 0766325	Midstream
5	47 N 0663018, E 0782344	Downstream
6	47 N 0660512, E 0788918	Downstream
7	47 N 0662050, E 0791279	Downstream

2.3. Microplastic Extraction and Identification

MPs were extracted using the wet peroxide oxidation method to remove organic substances before density separation [21]. Briefly, the sample (in a glass bottle) was placed in a 500 mL beaker. Next, 10 mL of ferrous sulfate solution and 20 mL of 30% hydrogen peroxide (H_2O_2) (Merck) were added to remove organic matter. The mixture was then stirred and placed in a fume hood with a temperature limit of 70 °C. The slurry mixture was then treated with NaCl (Kemaus), 6 g per sample solution 20 mL, and allowed to settle for one hour in order to separate the densities of the particle MPs. The supernatant was filtered through GF/C filter paper using a vacuum system. After filtering, the filter paper was dried in oven at 60 °C. The dry filter paper was examined using a Swiss-made Leica EZ4 W Stereomicroscope and the Leica Application Suite to determine the quantities, sizes, colors, and shapes and capture photographs of MPs samples. Next, a random sample of the MPs was selected for Fourier-transform infrared (FTIR) spectroscopy (Spectrum Two with Spotlight 200i, PerkinElmer).

2.4. Contamination Prevention

The laboratory was free from disturbances such as wind or smoke, and a blank test using distilled water was performed in various locations throughout the laboratory's operation. At the conclusion of the analysis, no MPs were discovered. All individuals in the laboratory wore a gown, surgical cap, surgical mask, and gloves at all times during the experiment.

2.5. Data Analysis

All calculations and statistics were conducted using MS Excel 2007 (Office Professional Plus 2019). The mean and standard deviation are used to represent the number of MPs. All data were tested for normal distribution and variance homogeneity before statistical analysis. Analysis of variance (ANOVA) was performed to investigate the concentration of MPs at each station and month. The threshold for statistical significance was set at 0.05.

3. Result and Discussion

3.1. Abundance and Distribution of Microplastics in River

The results reveal that the number of MPs detected at the U-Taphao River in February, April, June, and August were 0.41 ± 0.08, 0.25 ± 0.06, 0.24 ± 0.11, and 0.26 ± 0.06 particles/L, respectively. According to the analysis of MPs from the seven stations, 1–7, the average number of MPs detected all year was 0.66 ± 0.09, 0.23 ± 0.05, 0.31 ± 0.08, 0.22 ± 0.06, 0.32 ± 0.14, 0.19 ± 0.03, and 0.11 ± 0.02 particles/L, respectively, as shown in Table 1. One-way ANOVA discovered that the number of MPs in the U-Taphao River each month was not statistically significant ($p = 0.190$). MPs in the river were more likely to decline from upstream to downstream areas (Figure 2). This indicates that seasonal changes had no effect on the shapes, sizes, and colors of the microplastics detected in the river water. This is consistent with a study conducted by [22]. Every sample-collection period at all seven stations indicated that the number of MPs was more likely to decline from upstream to downstream areas, with a statistical significance level of $p < 0.05$. Potential explanations for more MPs being sampled in upstream areas than downstream areas include that (1) the upstream areas (station 1 and station 2) are far from the lagoon (about 120 km), and there is no influence of tides and tidal currents. A similar phenomenon was found in another lagoonal system on the East Coast of the USA, using surface drifter observation [23], (2) The retention time of the MPs exposed to water in the upstream areas is probably higher than in the downstream areas, since there is less water circulation, and (3) It is likely that more untreated water activities such as those by industries, agriculture, and communities enter the upstream river area than the downstream river area. Therefore, seasons may not be a major factor for an increase or decrease in the number of MPs, if the sources of these MPs continue to discharge waste in conjunction with a lack of wastewater management or treatment before discharging into the river. Consistently, a previous study on wastewater treatment before discharging found that wastewater treatment can reduce the distribution of MPs in rivers [24].

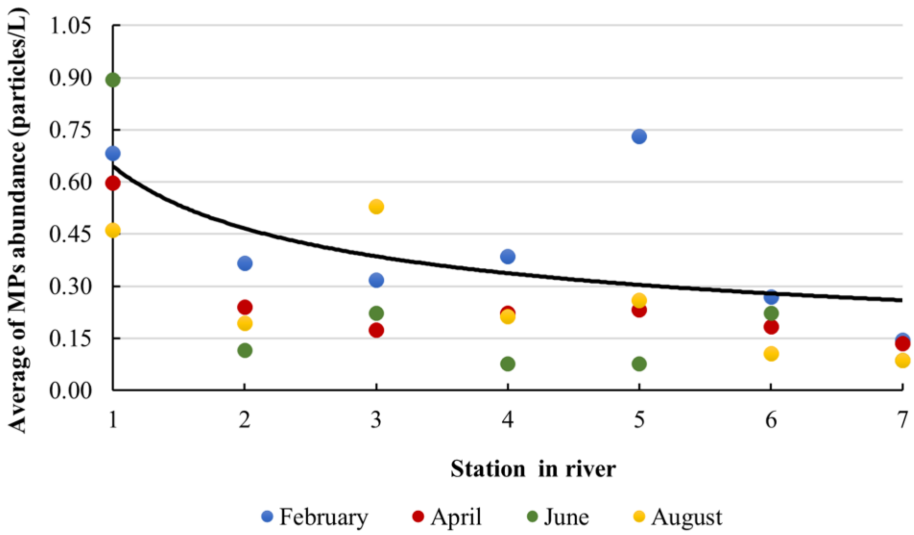

Figure 2. Microplastic abundance from upstream (station 1) to downstream (station 7). Note: the black solid line stands for trendline from upstream to downstream.

3.2. Shape, Size, and Color of Microplastics

With regard to the shapes of the MPs classified by the stereomicroscope, the most common shapes detected each month from all the stations were fibers (710 pieces, 88%) and fragments (97 pieces, 12%) (Figure 3). In February, April, June, and August, fibers accounted for 31%, 21%, 17%, and 20% of the sampled MPs, respectively, while fragments accounted for 1%, 2%, 5%, and 4% of the sampled MPs, respectively. A statistical test found statistically significant differences in the number of MP fibers at each station ($p < 0.05$). In February, fibers made up the highest percentage of the MPs sampled at every station. The majority of plastics are resistant to biodegradation, although they will mechanically deteriorate over time [25]. Larger-sized plastic debris is how MPs are naturally present in fragment form. This could happen by MPs being trapped at the deposited spot (river bank or river bottom). Why were fibers the highest percentage of the MPs in the river water? The possible answer of this study is fibers come from several sources (sites and materials) such as sewing waste from households, clothes washing, fishing gear, rope, etc. It is possible that lightweight fibers drift with the currents from the river into the lagoon and eventually enter into the bodies of aquatic animals [8,12].

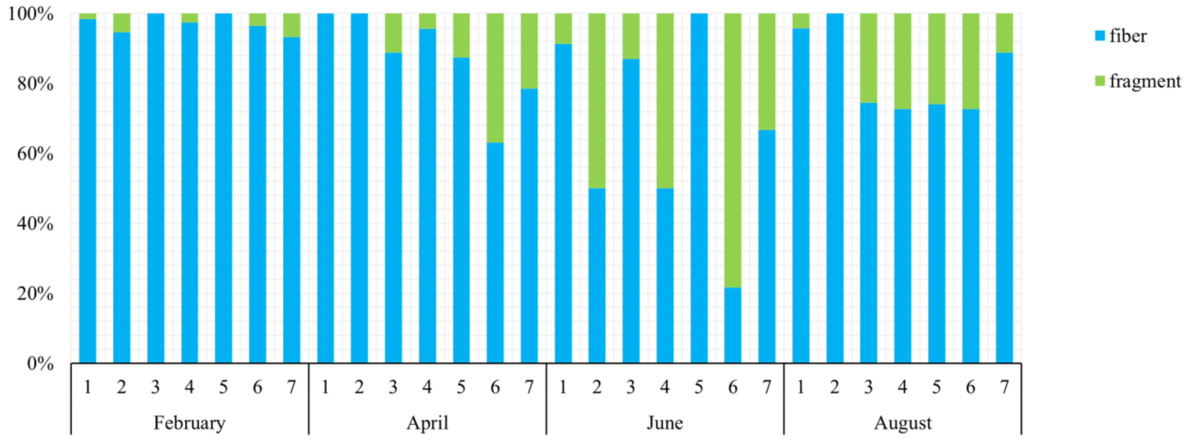

Figure 3. Shape of microplastics in surface water in the U-Taphao River, Thailand.

MPs of all class sizes (63 µm–500 µm; >500 μm^{-1} mm; >1 mm) were found in the water surface in February, April, and June, except in August, when MPs 63 µm–500 µm in size were not detected (Figure 4). This study found the most MPs 500 μm^{-1} mm in size and number. This is most likely the result of laundry activities, which release more clothes fibers into the drain water that eventually enter the river. It should be noted that fibers of this size were found in the river and mostly at the downstream stations, which is likely because they can easily be transported in the river water, whereas the size larger than 1 mm was dominant upstream and could be trapped on the river bank or at the river bottom. According to Yang et al. [26], a pulsator laundry machine's lint filter bag retained longer microfibers (>1000 µm) but not shorter ones (500 µm), which were then released into the drainage system. The smaller size of MPs is caused by larger pieces of litter breaking down in the environment. However, studying the size of MPs depends on the efficiency of the instruments used to classify the sizes of MPs. Many studies found the distribution of MPs 50 µm–500 µm in size [27,28]. Smaller MPs increase the area for pollutants to attach to, such as heavy metals [29,30]; thus, the sizes of MPs, both microfibers and microfragments, have an effect on ingestion by and contamination in aquatic animals. For example, MPs ranging from 1.61 ± 1.05 mm to 2.04 ± 2.51 mm were found in clams [31], MPs in sizes of 0.15–0.5 mm, 0.5–1 mm, and 1–1.5 mm were found in fish [2,12], and MPs of 0.16–4.1 mm were found in cockles and shrimps [32].

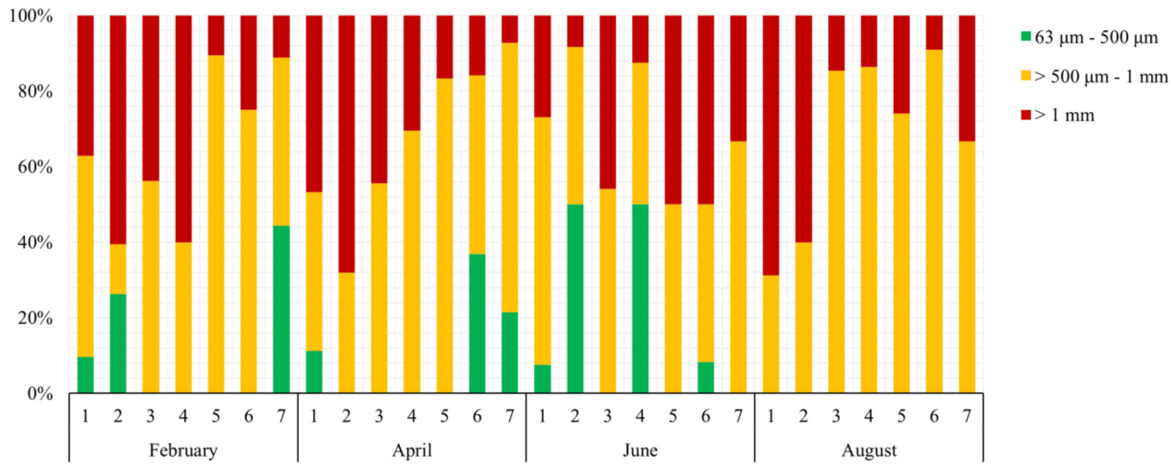

Figure 4. Size distribution of microplastics found in the U-Taphao River.

The colors of MPs found in this study are shown in Figure 5. Blue-colored MPs were found in a large quantity at every station and during every collection period, followed by transparent, red, and other colors (black, white, green, purple, pink, and yellow). Why is blue so common? It is difficult to comment on the color because bleaching processes occur in the river and marine ecosystem [33]. This could be a regional characteristic. In Thailand, the official uniform for students at schools and universities is mostly blue, so blue fibers may be released from the laundry. Aside from that, blue fibers could be from fishing nets, fishing wires, or other fabrics or yarns made of thermoplastic materials that could degrade to a smaller size via hydrolytic, photodegradation, or thermo-oxidative degradation. Plastic wastes such as plastic nets, yarns, and fabrics were reduced to smaller plastic pieces and short fibers as a result of such degradation processes. Furthermore, because blue fishing nets and yarns blend better with water, fish may unintentionally swim into the nets or swallow the yarns. The color of MPs, on the other hand, is an important factor for freshwater and marine organism prey [34,35]. During each collection period in both the dry season (February and April) and the wet season (June and August), there were no statistically significant differences ($p > 0.05$) in terms of the shape, size, or color of the sampled MPs.

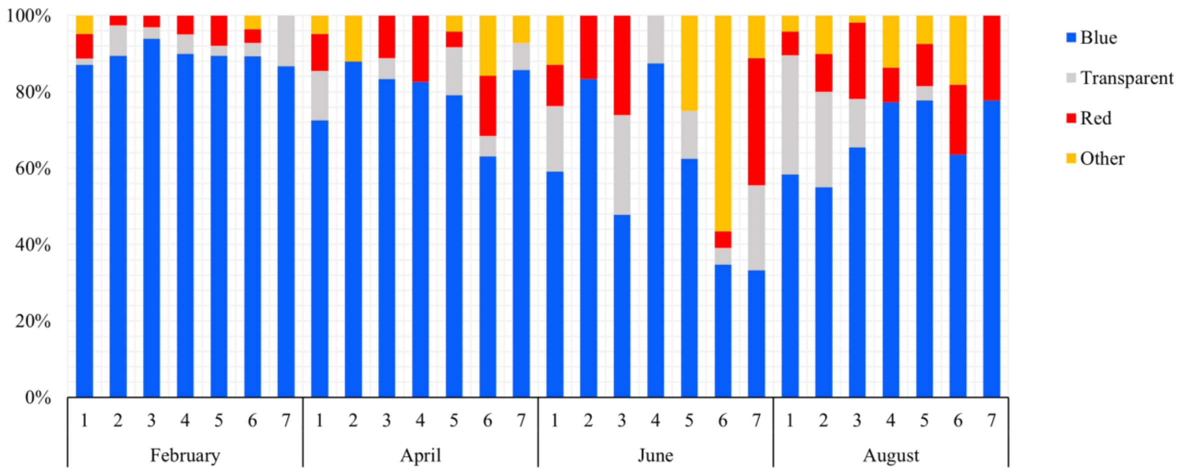

Figure 5. Colors of microplastics found in the U-Taphao River.

3.3. Polymer Types

MP samples were randomly selected and analyzed using FTIR. The results show that the polymers detected in the river water were polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), nylon, rayon, PDMS, and poly (ethylene:propylene), as shown in Figures 6 and 7, which is consistent with many studies [18,36–43]. It is noted that PE, PP, and PET were found in every sampling month (Table 2). Several broad classes of plastics are used in packaging such as PE, PP, and PET, while PET and nylons are also heavily used in fishing gear applications [44,45]. Rayon fiber is commonly used to produce artificial silk and other textiles [2,12].

Table 2. Frequency of polymers detected in the U-Taphao River.

Polymer	February	April	June	August
PE	✓	✓	✓	✓
Nylon	✓	✓	×	×
PP	✓	✓	✓	✓
PET	✓	✓	✓	✓
Rayon	✓	✓	×	×
PDMS	×	✓	×	✓
Poly (ethylene:propylene)	×	×	×	✓
Frequency	5	6	3	5

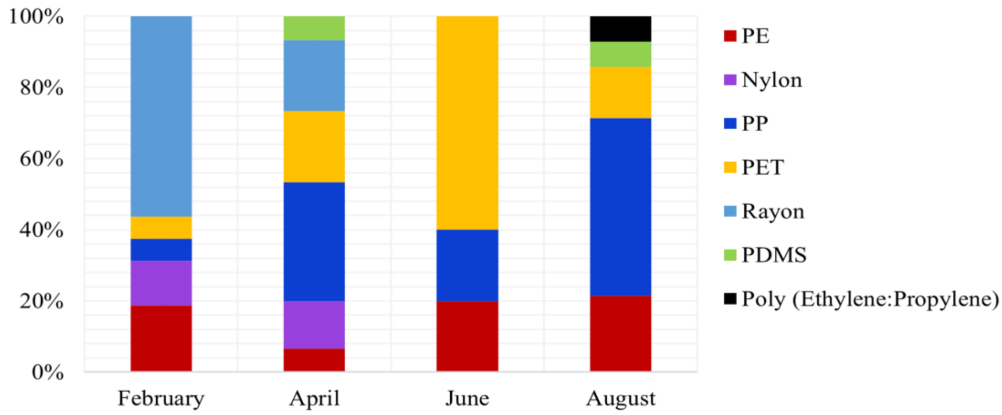

Figure 6. Polymer types found in the U-Taphao River.

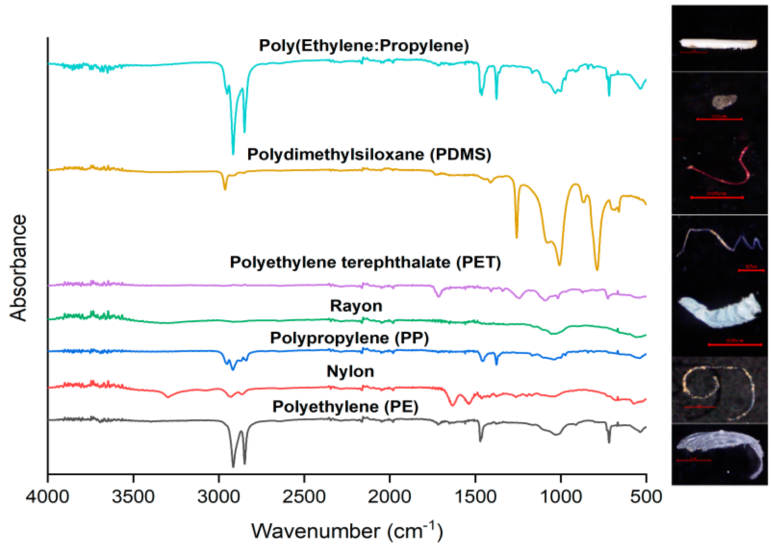

Figure 7. The spectrum of polymer types.

3.4. Comparison of Abundance of MPs Worldwide

When the abundance of MPs found in this study was compared to that of others rivers around the world (Table 3), it was discovered that it was lower than that of studies in the rivers close to urban areas [36–39,46,47] but similar to those in the Tapi-Phumduang River in Thailand [18], the Hudson River in the USA [48], and the Karnafull River in Bangladesh [39]. MPs were found in the surface water of the Chao Phraya River in Bangkok, Thailand, at 21 ± 16 items/m^3 and 104 items/m^3, respectively, according to reports by Ounjain et al. [37] and Tuan et al. [38]. The Ounjain et al. [37] study lagged behind the Tuan et al. [38] study. The sampling sites for the two studies were different: the Tuan et al. [38] sampling zone was adjacent to the area around Bangkok's high-density population, whereas the Ounjain et al. [37] sampling sites were in the urban lower river, which may be related to the distinct geology of the sampling locations (lower population density). Presently, the situation is extremely critical due to the death statistics of the Irrawaddy dolphins in the Songkhla Lagoon. As mentioned previously, Songkhla Lake is a habitat for Irrawaddy dolphins, an endangered species. Several serious problems for the Irrawaddy dolphins in the Songkhla Lagoon include the amounts of water and sediment that are contaminated with chemicals and toxic metals, which may affect newly born and juvenile dolphins. Therefore, the increased number of MPs in the river itself is likely harmful to them and the other living organisms in the lagoon.

Table 3. Abundance of microplastics found in river waters around the world.

Location	Abundance	Shape of MPs	Reference
Tapi-Phumduang River, Thailand	0.68–2.81 particles/5 L	Fibers	[18]
Saen Saeb Canal, Thailand	370 ± 140 particles/m^3	Films, fibers	[36]
Chao Phraya River, Thailand	21 ± 16 particles/m^3	Fragments or sheets/films	[37]
Chao Phraya River, Thailand	104 particles/m^3	Fragments	[38]
Karnafull River, Bangladesh	0.57 ± 0.07 to 6.63 ± 0.52 particles/L	Fibers	[39]
Rivers in Sungai Dungun, Malaysia	22.8–300.8 particles/m^3	Fibers	[40]
Rivers in Nwangele, Nigeria	440–1556 particles/L	Fragments	[41]
Wei River, China	3.67–10.7 particles/L	Fibers	[42]
Nakdong River, South Korea	293 ± 83 particles/m3 and 4760 ± 5242 particles/m^3	Fragments and fibers	[43]
Ganga River, India	380–684 particles/1000 m^3 and 143–340 particles/1000 m^3	Films	[46]
Fengshan River, Taiwan	334–1058 particles/m^3	Fibers	[47]
Hudson River, USA	0.98 particles/L	Fibers	[48]
Yangtze River, China	0.9 particles/m^3	Sheets and fragments	[49]
Rivers in Tibet Plateau, China	483–967 particles/m^3	Fibers	[50]
Mississippi River, USA	14–83 particles/L	Fragments	[51]
Ciwalengke River, Indonesia	5.85 ± 3.28 particles/L	Fibers	[52]
Taltow Canal, Germany	0.01–95.8 particles/2.2 L	Fragments	[53]
Chishui River, China	1.77–14.33 particles/L	Fibers	[54]
U-Taphao River, Thailand	0.24 ± 0.11 to 0.41 ± 0.08 particles/L	Fibers and fragments	This study

4. Conclusions

This study uses samples taken at seven locations from the upstream, middle stream, and downstream areas of the U-Taphao River in Southern Thailand to examine the seasonality, spatial variation, and features (such as form, size, color, and type) of microplastics (MPs). The results showed that MPs have a diminishing trend in terms of their average abundance from upstream to downstream, that fibers make up the majority of them, that their predominant size ranges between 500 µm and 1 mm, and that their predominant color is blue. Future research should concentrate on the probable sources of these MPs and the effects of additional chemicals on the environment and biota.

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