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Microplastics Contamination in Water Supply Sources of Ping River, Chiang Mai Province, Thailand

Pimpawat Teeratitayangkul[1*], Surasak Nummisri[1], Chan Yodle[1],
Amnuay Wattanakornsiri[2], and Pongthipun Phuengphai[3]

[1]Department of Environmental Science, Faculty of Science and Technology,
Chiang Mai Rajabhat University, Mueang, Chiang Mai 50000, Thailand
[2]Department of Agriculture and Environment, Faculty of Science and Technology,
Surindra Rajabhat University, Surin 32000, Thailand
[3]Department of Fundamental Science, Faculty of Science and Technology,
Surindra Rajabhat University, Surin 32000, Thailand

*Corresponding author: pimpawat_tee@cmru.ac.th

Abstract

Microplastics (MPs) contamination in water supply sources is presently an important ecological problem due to they are able to move through the food chain and accumulate in living organisms, they might contain harmful contaminants on their surfaces and become a secondary source of contaminants. This study investigated the contaminated MPs in three water supply sources—Pa Ton, Pa Daet, and U-Mong water supply stations in Chiang Mai province, Thailand. Sampling and analysis referenced the National Oceanic and Atmospheric Administration (NOAA) method using plankton nets. The results showed the average number of MPs at these three sites were $3,880 \pm 1,150$, $3,810 \pm 1,355$ and $3,320 \pm 628$ pieces/m³, respectively, The MP types were polyester, polyurethane, nylon, polyethylene, polyethylene terephthalate and polypropylene observed by microscope and Fourier-transform infrared spectroscopy (FT-IR). Further, there were the positive correlation between the number of MPs and the physical water parameters (Total Suspended Solid) at the 0.05 level of probability. This is the first scientific report that investigates MP contamination in the water supply sources in Chiang Mai province. The findings are knowledgeable and fruitful for environmental concern regarding MPs contamination in water supply sources.

1. Introduction

Plastics are synthetic polymers that play a huge role in our daily lives, with increasing usages. Owing to their light weight, strength, durability, and low cost, they can be produced in a number of various forms as required (Bogusz & Oleszczuk, 2017). After utilization, they inevitably become plastic waste, which is non-biodegradable, creating serious environmental pollution (Bergmann *et al.,* 2017; Van Cauwenberghe & Janssen, 2014; Wright & Kelly, 2017; Yuan *et al.,* 2022). Plastic debris generally persists in the environment for decades or even centuries and may be transported and accumulate far away from their sources (Toussaint *et al.,* 2019). Microplastics (MPs) are generally defined as plastic debris smaller than 5 mm (Shahul Hamid *et al.,* 2018; Wang *et al.,* 2018; Wolff *et al.,* 2019; Yuan *et al.,* 2022).

Nowadays, MPs are of concerns to the biosphere because if they accumulate in organisms, they might contain heavy metals or other harmful compounds used in original plastics (Tongnunui *et al.,* 2022; Turner & Filella, 2021).

Further, if the human body regularly exposes to large amounts of contaminated MPs, they can cause allergies and interfere with the functions of internal organs and the circulatory system (Yuan *et al.,* 2022). For example, they might be able to enter a human blood vessel, cause injury and irritation to internal organs, damage the digestive system, cause stomach cancer, and, at worst, result in genetic changes since MPs are as small as bacteria or viruses (Peng *et al.,* 2018). Over the past 10 years, several studies have detected MP contamination in natural water bodies including seas, rivers, and estuaries. Some of them studied water supplies are sources for community consumption, such as Dongting Lake, China (Wang *et al.,* 2018), eight urban lakes of Changsha, China (Yin *et al.,* 2019), three Gorges Reservoir, China (Di & Wang, 2018), and even in drinking water from ground water sources (Mintenig *et al.,* 2019).

Chiang Mai is an important province both economically and socially, located in northern Thailand. The source of raw water to produce tap water for consumption is the Ping River. Currently, the Ping River flows through the city of Chiang Mai. There is a periodic problem with sewage due to contamination of plastic waste and other solid wastes. The provincial waterworks authority in Chiang Mai has six water supply stations covering the entire provincial area of Chiang Mai, namely Pa Ton water supply station receiving water from Ban Thor water supply station, Pa Daet water supply station, U-Mong water supply station, Mae Faek water supply station, Mae Kuang water supply station, and Mae Wang water supply station.

There are three stations located in Mueang district, Chiang Mai province, namely Pa Ton water supply station receiving water from Ban Thor low-pressure pumping station, Pa Daet water supply station, and U-Mong water supply station. All three water supply stations are in densely populated urban areas. Pa Ton water supply station, Pa Daet water supply station, and U-Mong water supply station produce tap water with water supply capacities of 67,250; 67,250; and 40,700 cubic meters

per day, respectively (Provincial Waterworks Authority, 2020). Although the provincial waterworks authority of the Chiang Mai branch regularly measures water quality, the quantity and type of MPs contaminating raw water have never been monitored. The problem of MP contamination of raw water supply has become a concern among all sectors involved, especially in Thailand. MP contamination of water supply sources is unavoidably related to the quality of raw water. And, to the best of our knowledge, there have been no studies of MP contamination of water supply sources in Thailand. Therefore, it is an important challenge to investigate MP contamination of the water supply sources of the Ping River in Chiang Mai province, Thailand.

This research aims to investigate physical and chemical properties of raw water, as well as quantities of MP contamination in the water supply sources of the Ping River in Chiang Mai province, Thailand. Besides, types of MPs found in the water supply sources were studied. This research is useful for relevant organizations concerned about MPs and can serve as a database to consider surveillance or to prevent the consumption of water supply sources in Chiang Mai and other provinces of Thailand.

2. Materials and Method

2.1 Study area

This research examined MP contamination in three water supply stations located in Mueang district, Chiang Mai province, Thailand. There are three water supply stations: Pa Ton water supply station receiving water from Ban Thor low-pressure pumping station, Pa Daet water supply station, and U-Mong water supply station, as shown in Figure 1. Physical and chemical qualities of water samples were analyzed and MP contamination was detected (from both physical and chemical analyses). Six samples were collected per water source from June to September, 2020, because the rainy season in Thailand causes higher suspension of MPs in water sources compared to other seasons.
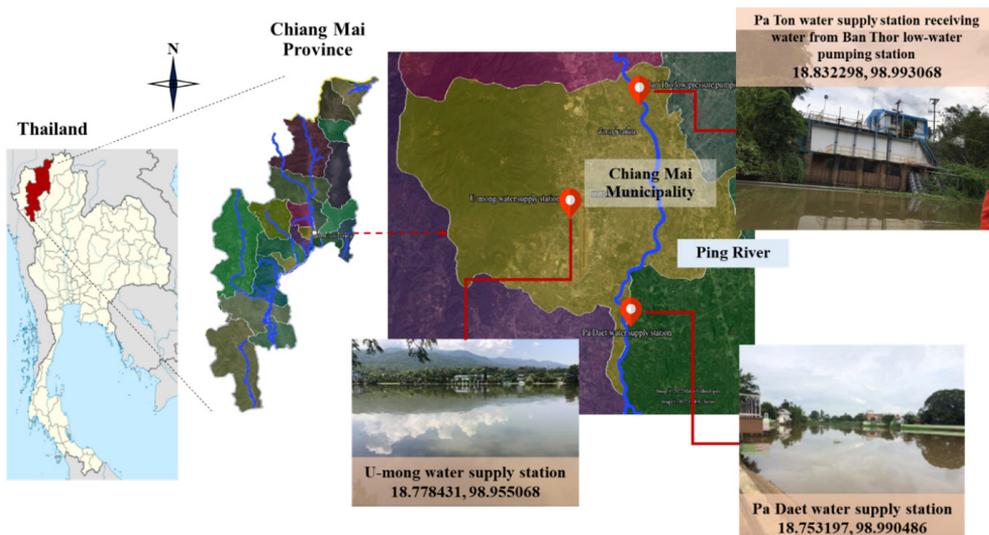
Figure 1. Three water supply stations located in Mueang district, Chiang Mai province, Thailand

2.2 Sampling and sample preparation for physical and chemical analysis

Water sampling for chemical analysis was carried out using a grab sampler (Kalkhajeh *et al.,* 2019) at the end of the water pumping pipe for water production at all three stations. Five liters of water were collected in each station with a pump. Water samples were stored in an opaque plastic sample bottle with a tight-fitting lid. Water sample analysis was performed according to the APHA method (2017) using surface water quality benchmarks. The drying method at 103 - 105 °C was used to test total suspended solids (TSS); the azide modification method was used to test dissolved oxygen (DO); the 5-day BOD test was performed to test biochemical oxygen demand (BOD); the Kjeldahl method was used to test total nitrogen (TKN); and the colorimetric method was carried out to test total phosphorus (TP).

2.3 Water Sampling for MPs Analysis

The method for collecting water samples for MP analysis was modified from the Environmental MP monitoring method by the National Oceanic and Atmospheric Administration (NOAA) (Masura *et al.,* 2015), by using a plankton net with a length of 10 meters and an opening of 100 microns. Before use, the net bag was rinsed with clean water to remove any residue and pat dry. The water from the surface of the water supply was pumped at a pumping rate of 10 liters per minute through the plankton net bag. Then, the blockage of the net bag was checked; the amount of water pumped through the net during the pumping time was calculated; and the MP samples were transported carefully to a laboratory.

2.4 MP analysis

The MP analysis process is shown in Figure 2. First, the plankton net was rinsed carefully with clean water to remove impurities. In this step the suspended solids were in clean water and heated slowly until the water evaporated to a volume of approximately 100 mL (Volume reduction). Next, the other natural organic compounds were removed before separating MPs using 20 mL of H_2O_2 solution with 20 mL of $FeSO_4$ at 60 - 70 °C. Density separation was performed to separate the MP samples from the rest of the material by intensifying the sample water with NaI. The addition of this solution causes the MPs, which are less dense than the NaI solution, to float into the density separators. This was used to separate MPs from other objects. The floating objects on top of the solution were separated by filtering through GF/C glass fiber filter paper with a pore size of 1.2 microns and then baked at 60-70 °C

until completely dry. Then, the dry objects attached to the filter paper were examined through a microscope (Nikon, Model H550S) to count the number of MPs and randomly collected for FT-IR (Perkin Elmer, Model Spectrum 400) analysis to identify the types of MPs.

3. Results and discussion

3.1 Physical and chemical qualities of water samples

The important parameters used to determine the physical and chemical qualities of the water samples of the three water supply stations are: suspended solids (TSS), dissolved oxygen content (DO), biochemical oxygen demand (BOD), total nitrogen (TKN), and total phosphorus (TP). The results of water quality analysis are shown in Table 1.

Table 1 shows the physical and chemical qualities of water samples from the three water supply stations. The results showed that the water qualities of all the stations were within the general standards of surface water sources. Changes in parameters at some intervals may be caused by seasonal changes and water content at the time of sampling for experimentation. The water samples from the Pa Ton and Pa Daet water supply stations, with sampling sites in the same area of the river, were compared. When considering the direction of flow, it was found that the water flow flows from the Pa Ton water supply station through the downtown area of Chiang Mai to the Pa Daet weir, which is in the area of the Pa Daet water supply station. Therefore, BOD values at the Pa Daet water supply station tend to be higher than those at the Pa Ton water supply station. It was also found that the amount of water stored at the Pa Daet water supply station was higher, but the water current was slower than that at the Pa Ton water supply station. This may affect the TSS values, which tend to decline as well. At the U-mong water supply station, the reservoir does not have a water inlet or outlet. The water utilization model is achieved by pumping water from irrigation canals. This geographical feature could have caused the lowest DO in the first sampling, which was not within the water standard (less than 3 mg/L), along with the low rate of water circulation in the reservoir. This corresponds to a lower TSS value in the non-pumped reservoir condition.

3.2 Number and type of MPs contaminated in water supply sources

After analyzing water samples at all the three water supply stations using the procedures outlined above, the analysis was carried out by visualization under a microscope with a magnification of 4x - 40x, and samples were classified by comparison. MP samples were compared from several studies (Di & Wang, 2018; Lechner *et al.,* 2014; Wang *et al.,* 2018; Ziajahromi *et al.,* 2017), and the samples were randomized for FT-IR analysis. The results are shown in Table 2.
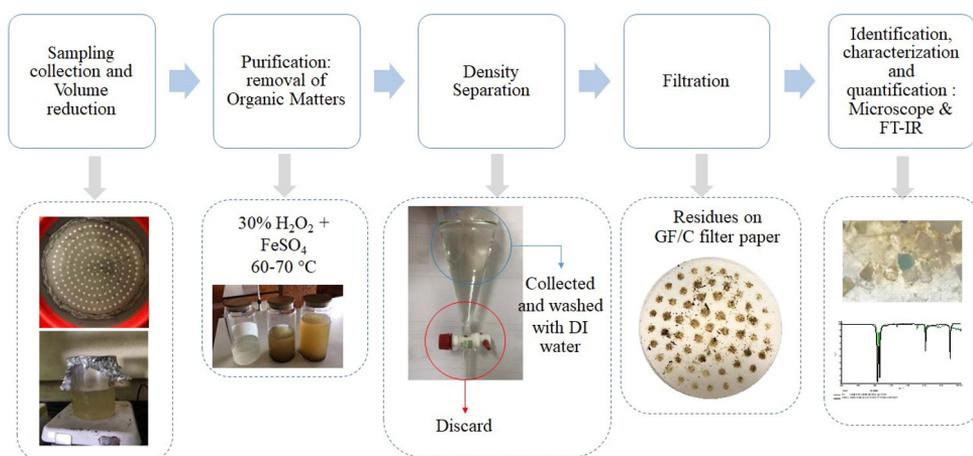

Figure 2. MPs analysis process

Table 1. Physical and chemical qualities of water samples from the three water supply stations

Parameter	TSS (mg/L)	DO (mg/L)	BOD (mg/L)	TKN (mg/L)	TP (mg/L)	Microplastics (pieces/m^3)
Pa Ton water supply station						
Standard	-	> 3 [d]	< 4 [d]	-	-	-
1st time	3.33 ± 2.30	1.54 ± 0.19	1.46 ± 0.30	N/D	0.44 ± 0.05	3,190 ± 185
2nd time	124.33 ± 8.38	3.42 ± 0.33	0.76 ± 0.25	N/D	0.76 ± 0.39	5,420 ± 692
3rd time	152.66 ± 8.38	3.85 ± 0.24	1.03 ± 0.49	N/D	0.92 ± 0.08	4,733 ± 576
4th time	84.33 ± 5.50	5.66 ± 0.55	1.70 ± 2.42	N/D	0.64 ± 0.11	4,421 ± 914
5th time	177.00 ± 2.00	6.89 ± 0.23	1.30 ± 0.17	1.68 ± 1.12	0.61 ± 0.23	2,427 ± 803
6th time	54.33 ± 12.34	6.36 ± 0.43	1.66 ± 0.20	3.00 ± 0.87	0.66 ± 0.57	3,086 ± 959
Average	99.33 ± 64.76	4.62 ± 2.04	1.32 ± 0.37	2.34 ± 0.93	0.67 ± 0.16	3,880 ± 1,150
Pa Daet water supply station						
1st time	1.12 ± 0.23	1.47 ± 0.30	3.33 ± 1.22	N/D	0.16 ± 0.01	3,058 ± 180
2nd time	4.41 ± 1.21	1.60 ± 0.70	3.25 ± 2.21	N/D	1.91 ± 0.21	2,203 ± 394
3rd time	6.86 ± 2.24	2.06 ± 1.30	3.08 ± 1.21	N/D	1.64 ± 1.02	4,023 ± 644
4th time	5.73 ± 1.40	3.70 ± 0.90	4.21 ± 1.44	N/D	0.92 ± 0.11	6,208 ± 68
5th time	6.93 ± 0.95	4.00 ± 0.00	1.83 ± 0.33	N/D	0.22 ± 0.02	3,364 ± 120
6th time	6.06 ± 0.78	2.23 ± 2.10	4.53 ± 2.14	N/D	0.14 ± 0.05	4,006 ± 471
Average	5.18 ± 2.19	2.51 ± 1.08	3.36 ± 0.95	N/D	0.83 ± 0.79	3,810 ± 1,355
U-Mong water supply station						
1st time [a]	95.00 ± 4.25	1.90 ± 0.14	4.80 ± 0.40	N/D	1.10 ± 0.32	3,820 ± 124
2nd time [b]	640.0 ± 9.21	3.90 ± 0.24	3.80 ± 0.50	N/D	2.10 ± 0.45	3,462 ± 418
3rd time [a]	409.36 ± 15.22	7.2 ± 0.50	4.30 ± 0.30	N/D	1.16 ± 1.21	4,005 ± 116
4th time [c]	45.22 ± 8.33	6.20 ± 0.50	1.70 ± 2.42	N/D	0.90 ± 0.08	3,086 ± 465
5th time [c]	93.00 ± 2.56	6.30 ± 0.23	1.10 ± 0.20	N/D	0.40 ± 0.25	2,236 ± 348
6th time [c]	27.21 ± 4.56	6.30 ± 0.33	4.00 ± 0.50	N/D	0.70 ± 0.30	3,312 ± 626
Average	122.17± 143.01	5.30 ± 2.00	3.28 ± 1.51	N/D	1.06 ± 0.58	3,320 ± 628

a = The volume of water was normal and water was pumped into the reservoir.
b = The volume of water was reduced and water was pumped into the reservoir.
c = The volume of water was normal and water was not pumped into the reservoir.
d = Notification of the National Environment Board No.8, B.E.2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) dated January 20, B.E.2537 (1994), which was published in the Royal Government Gazette, Vol.111, Part 16 D, dated February 24, B.E..2537 (1994)

Table 2. Numbers and types of MPs found in water supply sources at the sampling sites

Sampling site	Microplastics (pieces/m³)	Type of microplastics				
		PES	Nylon	PE	PET	PP
Pa Ton water supply station	3,880 ± 1,150	✓	✓	✓	✓	✓
Pa Daet water supply station	3,810 ± 1,355	✓	✓	✓	✓	✓
U-Mong water supply station	3,320 ± 628	✓	✓	✓	✓	✓

MPs found at the three sampling sites were approximately the same. Considering the trend of MPs per water volume at each time, it was found that, initially, MPs per volume at the Pa Ton water supply station was more than that at the Pa Daet water supply station. This may be due to the climatic conditions at the time of the sample collection, which was early in the rainy season when the tides were calmer. As a result, large and small wastes move slowly. However, the latter part of the collection was during the rainy season, resulting in an increase in river water volume and faster currents. As a result, MPs were found in upstream areas, which was different from the findings from the first period. Fewer MPs were found at the Pa Ton water supply station than at the Pa Daet water supply station. The end of this area is adjacent to the Pa Daet weir, and the flow rate of the first high tide has slowed down, resulting in a large amount of accumulated plastic waste. If they cannot be completely separated, they tend to accumulate more of these plastics, including over the distance that this river flows through the city of Chiang Mai, where some areas leak solid waste from buildings. In particular, between the waterways there is a discharge site from the Mae Kha Canal, which is a drainage canal that supports both passed and untreated household wastewater (Ziajahromi *et al.,* 2017). Under natural conditions with temperature changes, plastic waste can be mixed with general solid waste. Some of them break up into smaller plastics and/or MPs. Therefore, MPs per volume found at the Pa Daet water supply station was higher than that found at the Pa Ton water supply station.

However, considering the average number of MPs over the four-month sampling period,

at the Pa Ton and Pa Daet water supply stations were 3,880 ± 1,150 pieces/m³ and 3,810 ± 1,355 pieces/m³, respectively. The average MP contamination at the sampling sites of the Pa Ton water supply station and the Pa Daet water supply station were very similar (Table 1) to the Pearl River in China, which passes through Guangzhou and its estuary. The average MP contaminations at the Pa Ton and Pa Daet water supply stations were 19,860 and 8,902 pieces/m³, respectively. Studies have shown that the main source of MP contamination comes from wastewater from various sources. In addition, plastics smaller than 0.5 mm in size were found in the form of films, flakes, and fibers with more than 80% translucent blue in color. Yan *et al.* (2019) found that most of the MPs were identified as polyamide (26.2%) and cellophane (23.1%), and 4,137.3 ± 2,461.5 pieces/m³ of MPs were detected at the Yangtze River in China. When comparing the amounts of MPs between Asia and Europe, the average number of MPs per volume in Europe was less than in Asia. For example, Lechner *et al.* (2014) reported an average of 316.8 ± 4,664.6 pieces/1,000 m³ of MP contamination in the Black Sea by the Danube flow path, which is the second largest river in Europe.

MPs found at the U-Mong water supply station during the non-pumping period (the 1st - 3rd time) averaged at 3,320 ± 350 pieces/m³, whereas during the pumping period (the 4th - 6th time), the average MP content was 2,878 ± 12 pieces/m³, as shown in Table 1. It was found that there was a difference between the non-pumping period and the pumping period. When the water was pumped into the reservoir, the amount of MP was less. This may be due to the turbulence of the

current during the sampling period. In calm waters, MPs buoyancy is more likely to occur, generating different amounts. However, a comparison of the amount of MP found in surface water sources from the Three Gorges reservoir receiving water through Chongqing and Hubei provinces in China was as high as 1597 - 12,611 pieces/m^3 (Di & Wang, 2018). In another case, the Donting Lake and Hong Lake rivers, fed by the Yangzi River, found MP contaminations in surface water from 900 - 2,800 and 1,250 - 4,650 pieces/m^3, respectively (Wang *et al.,* 2018). Water sources that resemble reservoirs have the same amount of MP in water sources.

However, MPs found can be divided into five main types; namely, polyester (PES) found looks like tiny strands or thin pieces of various colors such as green, blue, translucent, etc. Polyamide or nylon, mostly found in filaments, was very tough and flexible in blue, red, clear, or slightly cloudy colors. Polyethylene (PE) was found as small, spherical, smooth, translucent, brittle granules, like blue beads. Polyethylene Terephthalate (PET) was found as smooth sheets or scales, opaque and translucent, with both opaque colors and warm tones. Polypropylene (PP) was found as small, opaque, highly flexible pieces. Polyurethane (PUR) was found as highly resilient foam, black and opaque yellow in color; this type was rare compared to the other four mentioned. Examples of all MP species found are shown in Figure 2.

In addition, a visual analysis of species through a microscope (Naked Eyes) classified the MPs by distinctive features, similarities, and differences. In this study, MPs were randomly examined using FT-IR. The results of some analysis of MP samples illustrated the spectrum lines. When comparing the spectra of MP samples, the results showed more than 90% similarity, indicating PE, PP, PET, and nylon plastics (Figure 3).

3.3 Relationship between the physical and chemical qualities of water samples and the number of MPs contaminated

Based on the assumption that the physical and chemical qualities of water from the water supply sources to produce tap water from the Pa Ton, Pa Daet, and U-Mong water supply stations were correlated with MP contamination in those water sources, the correlation was found using a Pearson correlation (r). Significant levels of the water quality parameters measured were TSS, DO, BOD, TKN, TP, and the number of MPs from 1st to 6th water sample collection. The physical qualities, TSS of water samples from the three water supply stations, were found to be correlated, with r (6) = 0.175, p < 0.05 (weak positive correlation), r (6) = 0.361, p < 0.05 (moderate positive correlation), and r (6) = 0.569, p < 0.05 (high positive correlation) for the Pa Ton, Pa Daet, and U-Mong water supply stations, respectively. Unsurprisingly, the MP
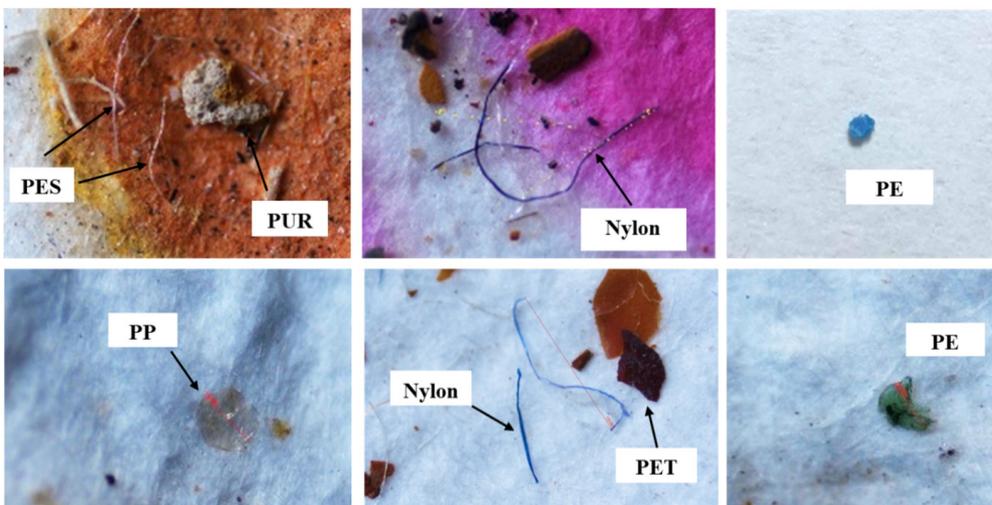
Figure 2. Types of MPs found at the sampling sites
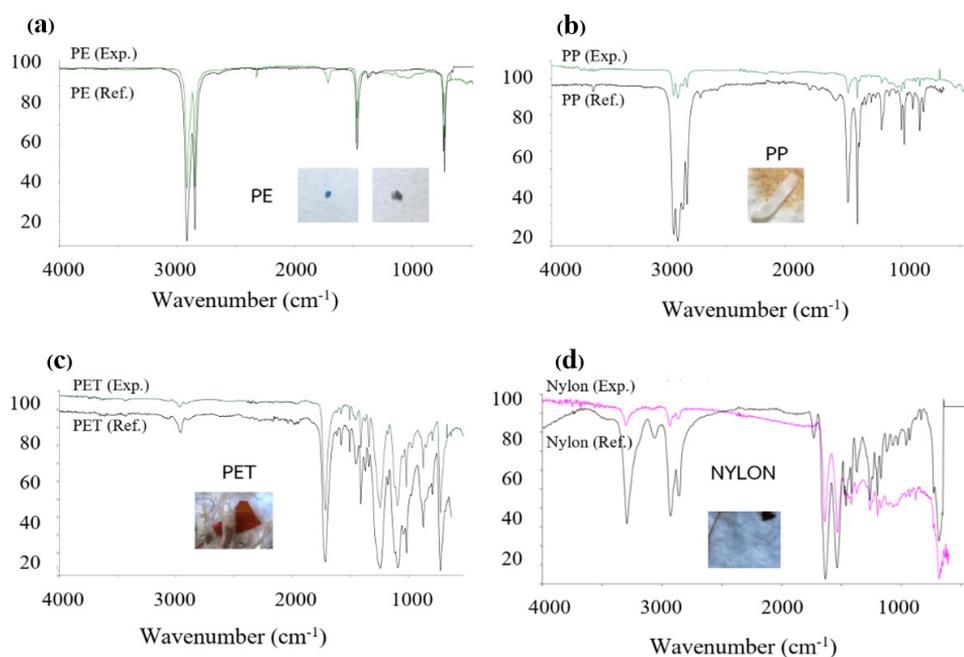
Figure 3. Spectra of (a) PE, (b) PP, (c) PET and (d) Nylon MPs

particles could be counted and related to TSS along with the location of each water supply station. The Pa Ton water supply station is in the upper stream, and TSS may contain other solid particles in a larger proportion than MPs. The Pa Daet water supply station is located downstream, 20 kilometers from the Pa Ton water supply station and near to the Pa Deat weir, demonstrating the sluggish water movement. As a result, the accumulation of MPs, which are expected to be gathered along the canal, might occur moderately with the concentration of TSS. The substantial positive association between TSS and the number of MPs at U-Mong water supply station was perhaps due the pumping-in reservoir, which is different from the other stations, causing an increase in the accumulation of MPs and raising the concentration of TSS.

4. Conclusion

This research first reported microplastic (MP) contamination in water supply sources of the Ping River, Chiang Mai province, Thailand. This research assessed and analyzed MP contamination in three water supply stations, namely, Pa Ton water supply station receiving water from Pa Ton water supply station, Pa Daet water supply station, and U-Mong water supply station, showing that the average MP contamination was $3,880 \pm 1,150$, $3,810 \pm 1,355$ and $3,320 \pm 628$ pieces/m^3, respectively. Most of the MPs detected were filamentous. This was followed by a thin scaly appearance when analyzed under an optical microscope to compare texture, color, and physical properties of specific observability. The FT-IR analysis revealed that the MPs found were PES, PUR, Nylon, PE, PET, and PP. However, the types of MPs analyzed in this study were randomized for investigation. Therefore, it is possible that, if analyzed with advanced instruments, a greater diversity of MP types could be found. The correlation between the total MP count of each of the three sampling sites and the physical and chemical qualities of TSS, DO, BOD, TKN and TP were analyzed. The results showed that all the MP amounts and TSS were positively correlated. The results of this research can serve as the basis for surveillance and raising awareness of environmental conservation in urban and sub-urban communities. It can also be a starting point for studying MP contamination in other water supply sources.

Acknowledgment

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