# Distribution and Microplastic Pollution and Its Associated Heavy Metal Contamination from an Urban Canal: A Case Study of Saen Saeb Canal, Thailand

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Received: 14 October 2021; Revised: 8 July 2022; Accepted: 21 July 2022; Available online: 28 December 2022

**Abstract**

Microplastics are emerging as a widespread environmental contaminant in all ecological systems, including the aquatic environment. This study examined the distribution of microplastics, and heavy metals extracted from microplastics, on the surface water of Saen Saeb canal. This canal is subjected to many human activities and has a large accumulation of garbage. Samples of microplastics were collected by a modified pump. The average microplastics concentrations were 479 p/$m^3$ or 0.0856 g/$m^3$ (size of 1-0.3 mm) and 261 p/$m^3$ or 0.0415 g/$m^3$ (size of 0.3-0.1 mm). The dominant colors of these microplastics were transparent-brown and transparent. These microplastics are related to land-based sources which break into secondary microplastics. Film and fiber/line were predominantly investigated in the surface water sample. Their chemical structures were analyzed by Fourier Transformed Infrared Spectroscopy (FTIR) which were confirmed to be polymeric with polypropylene (PP) and polyethylene (PE) being the most abundant. Heavy metals (cadmium, copper, lead, chromium and zinc) were also detected in the microplastics. Since this urban canal connects two main rivers which flow into the Gulf of Thailand, many aquatic organisms in the river might have an effect on this pollution. The results of this study showed that a strong recommendation to enforce the improvement of solid waste collection to prevent pollutants from entering the environment is necessary.

**Keywords**: microplastics, Saen Saeb canal, heavy metal, plastic debris, FTIR

## Introduction

Plastic materials and plastic products are worldwide due to their properties of being light in weight, cheap, malleable, and durable. However, high usage and waste mismanagement make plastic waste a serious problem in increasing environmental pollution, particularly in the aquatic environment which includes rivers, lakes, lagoons, estuaries, and oceans (Issac & Kandasubramanian, 2021). Globally, mismanaged plastic waste results in 10% of the more than 270 million tones that are produced annually entering the oceans, especially from developing countries such as Indonesia, India, the Philippines, West African nations and Thailand (Jambeck et al., 2015). There are two forms of plastics in the environment; macroplastics and micro-nano plastics. Based on the physicochemical, mechanical and photochemical processes, retention time, and the surrounding environmental factors, result in the degradation of macroplastics and their breakdown into microplastics, known as secondary microplastics. In contrast, primary microplastics are manufactured commercially, such as microbeads, capsules, and plastic resin pellets with their original size smaller than 5 mm (Issac & Kandasubramanian, 2021; Gao et al., 2019; Jiwarungrueangkul, Phaksopa, & Sompongchaiyakul, 2021). Microplastics can be classified as large microplastics or mesoplastics (1-5 mm), small microplastics (1 mm – 0.1 μm) and nanoplastics (≤ 0.1 μm) (Lambert & Wanger, 2018). Microplastics can enter the environment from other pathways such as domestic wastewater, stormwater, industry sectors, overflow events, land runoff and the atmosphere (Horton, Walton, Spurgeon, Lahive, & Svendsen, 2017).

Currently, microplastics are one of the pressing issues of concern for the global environment. Numerous researchers have investigated microplastics contamination in surface water, landfills, sediments, wastewater, drinking water, beaches, oceans and biota (Ta & Babel, 2020; Peng et al., 2017; Kankanige & Babel, 2020; Ta, Babel, & Haarstrick, 2020; Zhang et al., 2019). Similarly, Thai researchers have also paid attention to the pollution and distribution of microplastics in the Chao Phraya River and the Chao Phraya River estuary, as well as beaches in Phuket province and Chonburi province, and on the Andaman Sea and the coastline of the Gulf of Thailand (Jiwarungruengkul et al., 2021; Ta & Babel, 2020; Kankanige & Babel, 2020; Ta et al., 2020; Zhang et al., 2019; Oo, Boontanoon, Boontanon, Tanaka, & Fujii, 2020). These microplastics in the aquatic environment are a significant form of hazardous waste and they are all anthropogenic in origin and they are causing widespread pollution. Microplastics can be directly ingested by several aquatic organisms (rock oyster, demersal fish, pelagic fish, striped barnacles, and periwinkles) and they can be transferred at different trophic levels in the food chain (Gao et al., 2019; Ta & Babel, 2020; Klangnurak & Chunniyom, 2020). Exposure to microplastics might have several hazardous effects on aquatic organisms such as reduction of predatory performance, reproduction and growth, neurotoxicity and mortality. It has been reported that, fish (e.g. *Danio rerio*), when exposed to polypropylene, show damage to the intestine and suffer higher mortality just 10 days after ingestion (Gagné, 2017). *Daphnia magna* exposed to PS with $LC_{50}$ of 87.83 mg/L for 48 hours can have serious effects such as immobilization, oxidative stress and mortality (Zhang et al., 2019). Similarly, *Dicentrarchus labrax* when exposed to PVC particles for 90 days through their diet, which constituted 0.1 % (w/w) of microplastics less than 1 mm in size, suffered ill effects (Merlin & Balasubramanian, 2021). Furthermore, microplastics can absorb the pollutants from the surrounding environment, including heavy metals, persistent organic pollutants, and pathogenic species, on the surface of the particles which can result in global distribution. Microplastics are a vector transfer for these polluted organisms which are a serious threat to aquatic organisms and human health. The sorption characteristics of heavy metals on microplastics in the laboratory are being continuously investigated (Gao et al., 2019; Brennecke, Duate, Paiva, Cacador, & Canning, 2016; Turner & Holmes, 2015). Only limited information is now available on heavy metals extracted from microplastics in the field. Moreover, microplastic contamination in surface water from urban areas or areas of high population density is still unclear in current research. Therefore, this research gap needs to be further investigated to fully understand the fate of microplastics entering the marine environment from urban rivers in the central part of Thailand.

To better understand the distribution of microplastics from the surface water of urban areas, this study investigated the Saen Saeb canal in Thailand in terms of abundance, morphology, composition and polymer types. Heavy metal extraction from microplastics was also investigated and measured in the field. Results from this research will provide valuable information about microplastic pollution and will contribute to a fuller understanding of the current status of this pollution. The current study will also encourage improvements in solid waste and wastewater management policies to prevent microplastic pollution from entering the environment in greater quantities in the future.

## Methods and Materials

**Sampling location**

Microplastics were collected from the surface water of Saen Saeb canal in June 2021 from five sampling sites, illustrated in Figure 1 (S1-S5). Saen Saeb canal is located in central Thailand, and it connects the Chao Phraya River and Bang Pakong River, which flow into the Gulf of Thailand. This canal is 72 km in length, crossing 21 districts and there are 100 smaller canals that empty into this canal. There are residential zones, wastewater treatment plants, markets, schools, temples, ports and agricultural activities along this canal.


**Figure 1** Sampling sites of microplastics from Saen Saeb canal (Note: S represent a sampling site)

Four samples were collected in the Bangkok area and one sample in Chachoengsao province. S1 represents an urban area sampling site which is located in inner Bangkok (13.75225°, 100.520415°). This is the first point of the Saen Saeb canal which is connected with the Chao Phraya River. The surrounding areas include urban-dense areas, markets, schools, the central business district, and ports. S2 and S3 are located in the center of Bangkok (13.745741°, 100.574315°), (13.767097°, 100.651242°), S2 is about 6 km from S1 and S3 is 17 km from S1. The surrounding areas comprise residential zones, a small wastewater plant and ports. S4 is located in outer Bangkok, and this sampling site is at a floodgate that connects Bangkok and Chachoengsao province (13.820965°, 100.747279°) and it is about 30 km from the urban area. S5 is located in the last section of Saen Saeb canal before its waters flow into Bang Pakong River (13.846912°, 101.053290°). This point is about 70 km from an urban area and is surrounded by mainly agricultural activities. The locations of the five sampling sites are illustrated in Figure 1.

**Laboratory analysis**

**Sample collection and preparation**

The microplastics from the surface water were sampled by a modified pump with the suction velocity of water sample flow of 0.3 $m^3$/hr (for 60 min) which passed through a series of stainless-steel sieves of 5 mm (No.4), 1 mm (No.18), 0.3 mm (No.50) and 0.1 mm (No.140) (Masura, Baker, Foster, & Arthur, 2015) so that the particles in the water samples were separated into different fractions depending on their size. This study used particles smaller than 1 mm for the analysis which can be categorized as small microplastics. The particle samples of each fraction were dried in an oven at 90°C for 24 hr and the mass of all the natural materials and all the microplastic particles were determined. Apart from microplastics, the samples also contained natural material and organic matter which were removed by using the Wet Peroxide Oxidation (WPO) method (Masura et al., 2015). An aqueous solution of 0.05 M Fe(II) was used as a catalyst with about 20 mL and 20 mL of 30% hydrogen peroxide which were added to the dried samples to digest the organic matter. A 5 M NaCl solution (1.2 g/cm$^3$) was used to separate the floating particles which were transferred from the mixed solution into a glass funnel and allowed to settle overnight. The different fractions based on density were separated and the supernatant was filtered on anopore inorganic membrane filters (Whatman, Anodic, diameter 47mm, pore size 0.2 µm) using a vacuum pump. The filtered supernatant was oven dried at 90°C and stored in the desiccator. All filtered particles were further analyzed.

**Microscope analysis and polymer identification**

The microplastic particles were counted in particles/m$^3$ (p/m$^3$). Their concentration was calculated as the ratio of the weight of the microplastic particles to the volume of filtered water (g/m$^3$). The morphology (color and shape) of the microplastics were identified using a stereomicroscope (Olympus SZ30, 40x magnification) and optical images were taken with a microscope camera (Dino Capture 2.0). The size range of the microplastic particles were between 1 mm – 0.1 mm. The natural polymer of the microplastic particles were analyzed using a Fourier transform infrared spectroscope (FTIR) operated in a single mode which analyzed 32 scans per particle with a spectral resolution of 4 cm$^{-1}$. Spectra within the wavenumbers of 600-4000 cm$^{-1}$ were used. The collected spectra were compared with a self-established plastic polymer data bank with reference spectra from common polymer types known as microplastics. A similar index of more than 70% was accepted as microplastics in this research.

**Heavy metal**

Heavy metals including cadmium, copper, lead, chromium and zinc were investigated. They were extracted from microplastic samples by aqua regia solution which is a highly corrosive mixture of HCl and $HNO_3$ in a molar ratio of 3:1 (Holmes, Turner, & Thompson, 2012). The samples were shaken in a shaker for 48 h. The extracted solution was analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES).

**Validation and quality control**

To identify the matrix effects and determine the recovery of the analyte or the selectivity of the method, the microplastic samples ranging between 1 mm – 0.1 mm were analyzed. Microplastics such as Polypropylene (PP), Polyethylene (PE), Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), High-density polyethylene (HDPE), Low-density polyethylene (LDPE), Melamine formaldehyde (MF) and Acrylonitrile butadiene styrene (ABS) were selected to be analyzed by the same procedure that was used with the collected water samples. Throughout the experimental processes, the recovery of the analyte was found to be more than 95%. Therefore, this analytical method and acid digestion are suitable to be used for examining microplastics from surface water.

Furthermore, quality controls for a sample analysis were performed to evaluate the potential contamination from the experimental procedures, laboratory materials and air. All the equipment used for the experiment was made of glass or metal and the use of any plastic material was avoided. All the glassware was rinsed using distilled water while all the equipment and samples were covered with aluminum foil to protect them from exposure to the air. Laboratory blanks of deionized water were used for the quality control of the sample by following the same analysis procedure.

## Results

**Abundance and Concentration of Microplastics**

Microplastic particles were found in all the samples obtained from the sampling sites along the Saen Saeb canal. The average size of the microplastics were 479 p/m$^3$ or 0.4051 g/m$^3$ (size of 1-0.3 mm) and 261 p/m$^3$ or 0.2415 g/m$^3$ (size of 0.3-0.1 mm). The sizes in the range of 1-0.3 mm had a higher number and a greater concentration than those in the range of 0.3 – 0.1 mm. The greatest abundance of microplastics was found in the Saen Saeb canal in the inner area of Bangkok (845 p/m$^3$ or 0.1512 g/m$^3$) (S1) and the smallest was obtained from the outer part of the canal farthest from Bangkok (181 p/m$^3$ or 0.0283 g/m$^3$) (S5). The average concentration of the microplastics collected from S2, S3 and S4 were 383.33 p/m$^3$ or 0.0667 g/m$^3$, 238.33 p/m$^3$ or 0.0308 g/m$^3$ and 248.33 p/m$^3$ or 0.0497 g/m$^3$, respectively.

**Characteristics of Microplastics**

**Morphology of Microplastics**

Morphology in this study is considered as the shape and color of the microplastics obtained from the surface water. The size of the microplastics ranged between 1 – 0.3 mm and 0.3 – 0.1 mm. The relative abundance of microplastics were categorized by shape as fragments, films, fibers and pellets as shown in Fig. 2A (size range of 1- 0.3 mm) and Fig. 2B (size range of 0.3- 0.1 mm). The proportion of the different shapes from each station number was different but similar trends were found in the relationships with the the main activities in each sampling area. The highest proportion (36-57%) of microplastics were film shapes in the range between 1 – 0.3 mm, followed by fibers (27 – 45%), fragments (12 -19%) and pellets (0-12%), as shown in Figure 2(A). Microplastics in the range between 0.3 – 0.1 mm contained film shapes which were the highest proportion of 42-60% followed by fibers (27 – 37%), fragments (5 -30%) and pellets (0-1%), as shown in Figure 2(B).

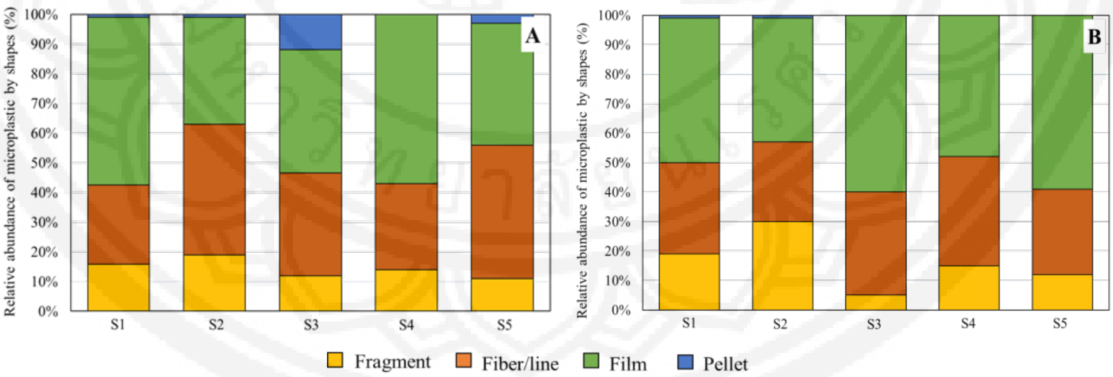


**Figure 2** Relative abundance of microplastics by shapes, A shows microplastics in the range of 1 – 0.3 mm and B shows in the range of 0.3 – 0.1 mm

Eight colors were identified among the extracted microplastics from the surface water. These were determined in order as brown-transparent, transparent, white, brown, green, black, reflection and red. Some of the colors of the microplastic particles from the Saen Saeb canal are shown in Figure 3. The relative abundance of microplastics by color is illustrated in Figure 4.

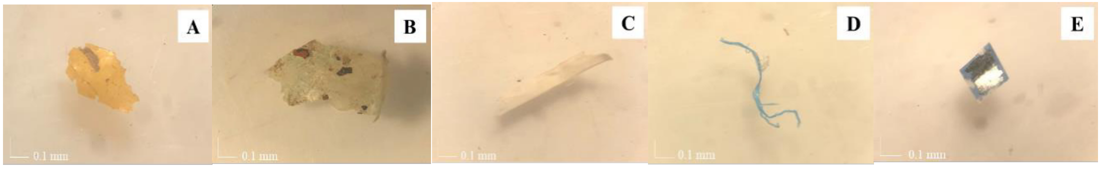


**Figure 3** The color of microplastic particles from Saen Saeb canal with A a brown transparent, B a transparent, C a white, D a blue and E a reflection color

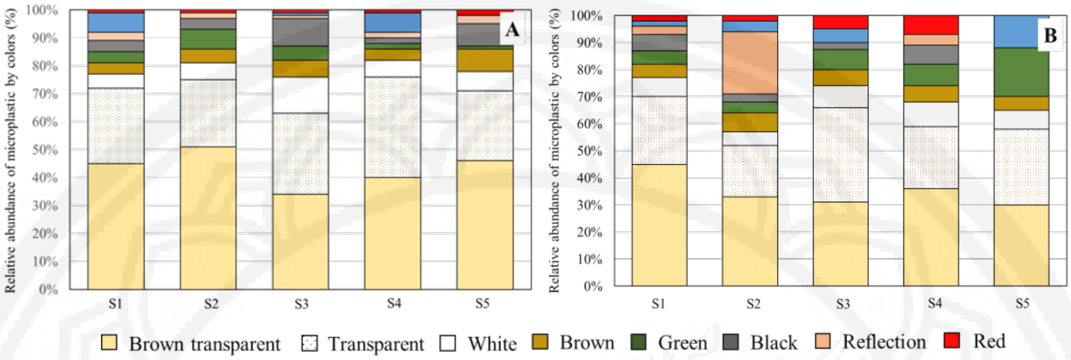


**Figure 4** The relative abundance of microplastics by color: A shows microplastics in the range of 1 – 0.3 mm and B in the range of 0.3 – 0.1 mm

The relative abundance of microplastics in the surface water was mostly brown-transparent and transparent (43.2%, 28.2% in the range of 1 – 0.3 mm and 35%, and 26% in the range of 0.3 – 0.1 mm), followed by white (7.4% in the range of 1 – 0.3 mm and 8.5 % in the range of 0.3 – 0.1 mm), green, brown and black, blue, reflection and red were found in smaller amount at 5% or less, as shown in Figure 4.

**Polymer Composition of Microplastics**

The proportion of polymer composition of microplastics from each sampling station and the average relative abundance of polymer is illustrated in Figure 5. A similar index of more than 70% of polymer types accepted the collected particle samples as microplastics. Seven polymer types were found in this examination namely PP, PE, PVS, PET, PA, PS, PVC and other polymer types (or unidentified).

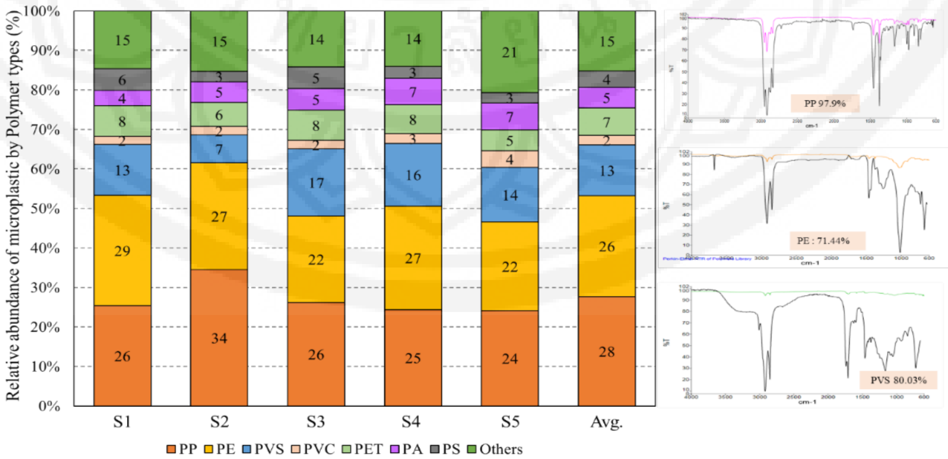


**Figure 5** Relative abundance of microplastics by polymer types

Figure 5 shows the different types of polymer found at site S1 which had 29% of PE, 26% of PP and 13% of PVS. S2 contains polymer types of PP (34%), PE (27%) and PVS (7%). Similarly, S3, S4 and S5 had polymer types of PP (26%, 25%, 24%), PE (22%, 27%, 22%) and PVS (17%, 16%, 14%), respectively. Among these compositions, the highest average abundance of polymer types was PP (26%) and PE (26%), followed by PVS (13%), PET (7%), PA (5%), PS (4%), PVC (2%) and others (15%) as shown in Figure 5.

**Heavy Metal in Microplastics**

The concentration of heavy metals in the microplastics from Saen Saeb canal were cadmium (Cd), copper (Cu), lead (Pb), chromium (Cr) and zinc (Zn). Zn had the highest concentration from the extracted microplastics (510.67 ± 20.03 μg/g), followed by Pb of 55.83 ± 8.20 μg/g, Cr of 28.14 ± 2.49 μg/g, Cu of 22.53 ± 3.36 μg/g and Cd of 3.02 ±0.16 μg/g. A summary of the concentration of heavy metals in the microplastics from Saen Saeb canal is represented in Figure 6.

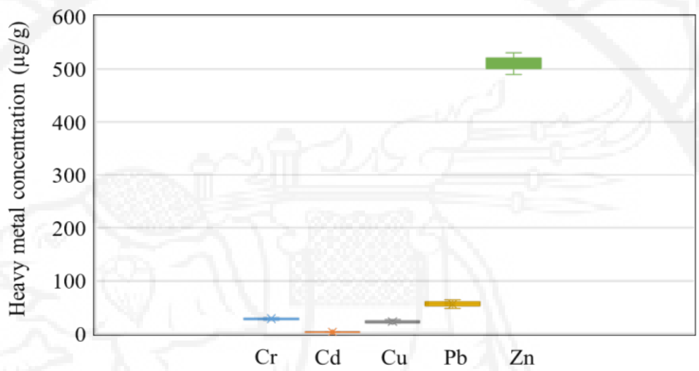


**Figure 6** Heavy metal concentrations from microplastics

## Discussion

The distribution of microplastics from the surface water of the urban area of the Saen Saeb canal was investigated in terms of abundance, morphology, composition and polymer types. A higher number and greater concentration were found in the range of 1-0.3 mm than in the range of 0.3 – 0.1 mm. The average amount of microplastics was 479 p/m$^3$ or 0.0856 g/m$^3$ (in the range of 1-0.3 mm) and 261 p/m$^3$ or 0.0415 g/m$^3$ (in the range of 0.3-0.1 mm). The abundance of microplastic particles decreased with the distance from the community area (Bangkok). A higher number and greater concentration of microplastics were found in the Saen Saeb canal, especially in the Bangkok area due to the high population density along the canal (residential zones, schools, markets, wastewater treatment plants and ports. Also, express boats cause high turbulence in water (turbulence, mechanical friction) which is one of the reasons why the plastics and microplastics break up and form sediments which are resuspended on the water surface. Furthermore, the concentration and number of microplastics found in this study were similar to those of other researchers who investigated the distribution of microplastics in other areas of the world, as summarized in Table 1. The table shows a comparison of the microplastic contamination in the surface water around the world. It was found that the average number of microplastic particles from the Saen Saeb canal was 370±180 p/m$^3$ which is lower than that of the Gulf of Guinea, Nigeria, the Zhangjinwam Estuary, China and the German Baltic Coast but higher than the concentration in the Chao Phraya River and Chao Phraya River Estuary in Thailand and the Yangtze Estuary in China. However, the standard procedures for microplastic analysis, sampling methods (Table 1), identifying methods, acid digestion and reporting units are not yet established globally. This may explain why the amounts of microplastic particles in this study area were different from other research studies.

**Table 1** Comparison of abundance and concentration of microplastics in surface water conducted by other research studies in the world

| Location | Sampling Methods | Size range (mm) | Number (particles/$m^3$) | Reference |
|---|---|---|---|---|
| Chao Phraya river Estuary, Thailand | Manta trawl | 0.3 – 0.05 | 48 | Ta & Babel (2020) |
| Chao Phraya River (Prachan area), Thailand | Manta trawl | 1 – 0.053 | 104 | Ta et al. (2020) |
| Zhangjinwam Estuary, China | Stainless steel apparatus | 1 – 0.3 | 13,530 | Zhang et al. (2019) |
| Gulf of Guinea, Nigeria | Grab sample | 1 – 0.1 | $3.03x10^5$ | Olarinmoye et al. (2020) |
| German Baltic Coast, Germany | Grab sample | 1-0.55 | 5000 | Stolte (2015) |
| Yangtze Estuary, China | pump | 1 – 0.3 | 258.9 | Li, Lu, Zheng, Wang, and Chen (2020) |
| Saen Saeb canal, Thailand | Modified pump | 1 – 0.1 | 370±180 | This study |

The most common shapes in the distribution of extracted microplastics were films, followed by fibers and fragments. The shape of microplastics is related to the origin of the microplastics in both primary and secondary microplastics. Films shapes are soft, flat and thin, produced from packaging materials, especially single-use plastics such as plastic bags, wrappers etc. Fibers are thin and long which are produced from textile materials, domestic wastewater stream, sewage overflows and air-borne material deposition (Olarinmoye et al., 2020). Fragments are thin, flat, hard and rigid which may have been produced after the breakdown of large plastics such as plastic toys and plastic containers. Pellets are spherical, smooth and hard and are produced from microbeads or plastic resin from personal care products (Ta & Babel, 2020; Olarinmoye et al., 2020; Willis, Eriksen, Wilcox, & Hardesty, 2017). Film and fiber microplastics are the most frequently found shape in the surface water and estuaries, for example in the Changjiang Estuary (Peng et al., 2017), the Chao Phraya River estuary (Oo et al., 2020) and Bang Yai canal, Thailand (Possatto, Barletta, Costa, Ivar, & Dantas, 2011), which originate from plastic bags, plastic debris, and the washing of clothes in the densely populated urban area along Saen Saeb canal.

The microplastics in the surface water were mostly brown-transparent and transparent, followed by white, green, brown, black, blue, reflection and red color. Microplastics gain their color at the production stage of the plastic and sometimes changes and fades due to weathering. Transparent and white are widely used and found in plastics, plastic packing, plastic resin and the packing industry which indicates microplastics were caused by the fragmentation of plastic debris and the breakdown of large plastic into tiny plastic (secondary microplastics) (Issac & Kandasubramanian, 2021; Oo et al., 2020; Possatto et al., 2011). Blue, green, red and black are derived from textile materials, domestic wastewater, fishing lines and nets (Oo et al., 2020). Therefore, most of the microplastics were brown-transparent and transparent which indicated that they were produced by human activities along the Saen Saeb canal. Furthermore, the size, color and morphology of the microplastics are similar to zooplankton, meaning that the variety of these microplastics in the environment can increase the chances of fish and aquatic organisms ingesting them. The percentage of fish that ingest plastics in nature varies between 2.6% and 36.5% depending on the area and the methods used for counting and extracting the plastics from the gastrointestinal tract. This phenomenon can have a major negative effect on bioavailability and the food chain (Klangnurak & Chunniyom, 2020). Microplastics can enter the human gut through the ingestion of seafood, fish, or aquatic organisms (Issac & Kandasubramanian, 2021). Choi, Jung, Hong, Hong, and Park (2018) also demonstrated that the variety of microplastic shapes cause intestinal distention to *Cyprinodon variegatus* and *Shipshead minnows*. Therefore, the morphological variety of microplastics harms biodiversity and the ecosystem.

Polymer types of microplastics are an important parameter related to the original microplastics. Turbulent flows, tides and waves can breakdown large plastic pieces and resuspend dense microplastics from sediment. Weathering, oxidation and photodegradation can reduce the size and decrease the density of polymers. Based on the polymer types of microplastics, the amount of PP and PE were significantly higher than other polymers from extracted microplastics in the range of 1 mm – 0.1 mm. Our results showed that these two polymers were found to be similar to those found in other research studies. PP and PE are found in a large number of polymer types of microplastics in other surface waters and estuaries, for example, in the Chao Phaya River estuary (Ta&Babel, 2020; Oo et al., 2020), the Chao Phaya River (Ta et al., 2020), the estuaries in Bohai Bay (Peng et al., 2017), the Gulf of Guinea in the State of Lagos, Nigeria (Olarinmoye et al., 2020) and the river Elbe in Germany (Scherer et al., 2020). The polymer types of PP and PE are normally used to produce plastic products for packaging throughout the world and in Thailand especially in the packaging (Ta et al., 2020) and other applications and industries also produce PP and PE. The densities of these polymers (PP is 0.91 $g/cm^3$ and PE is 0.95 $g/cm^3$) are lower than water density (1 $g/cm^3$) so they can float on surface water. PP has low toxicity under normal conditions of handling and use with $LD_{50}$, oral (rat) : >5000 mg/kg while $LD_{50}$ for PE has an average molecular weight of 450, in rats is >2000 mg/kg. In addition, PS and PET are found in textiles, plastic bottles and plastic bags. PET is a nontoxic solid substance. PS, from plastic packaging, is low density and floats on the water surface. PVC is a type of polymer used for pipes and plastic film ($LD_{50}$ in fishes > 100 mg/L for 96 h) and PA or nylon are found in clothing, fishing nets and textiles etc. ($LD_{50}$ in mice > 1,100 $mg/m^3$ for 30 h) (Ta & Babel, 2020; Kankanige & Babel, 2020; Oo et al., 2020). The polymer types of the microplastics found in our study are related to the origin of plastic and commercial plastic production and are mostly derived from activities on land and the mismanagement of plastic waste in water and the environment generally.

The heavy metals extracted from the microplastic samples were also investigated by field measurements. Zn, Pb, Cr, Cu and Cd were detected from the microplastics recovered in this area. Our conclusions about the interactions between microplastics and heavy metals are similar to those of other researchers. A higher concentration of Zn was found than in other heavy metals. This is related to the location of this canal in an urban area where anthropogenic sources produce these contaminants. Ta et al. (2020) investigated the microplastic pollution by heavy metals in the Chao Phraya River estuary and they detected six heavy metals (Zn, Pb, Cr, Cu, Ni and Cd) from microplastics. However, the concentrations of heavy metals in microplastics from the Chao Phaya River estuary were found to be lower than in our study. This may be the result of a high population density, more extensive human activities and agricultural pursuits in our study area where the total area of the Saen Saeb canal is much smaller than Chao Phraya River (Ta & Babel, 2020; Oo et al., 2020). High concentrations of heavy metals such as Zn, Cu, Pb, Cd and Ni were also detected in the Benijiang river. Wang et al. (2017) also indicated that heavy metal can be responsible for sorption of the microplastics. The physicochemical properties of microplastics have high hydrophobicity, large specific surface areas and a high tendency to interact with microbes. Therefore, heavy metal from the environment can be adsorbed on microplastics (Klangnurak & Chunniyom, 2020; Fernando, Diana, Carlos, Pizarro, & Gabriel, 2021). Plastic itself also has toxic additives, such as flame retardants, dyes, antioxidants, antibacterial agents, plasticizers and UV stabilizers (Gao et al., 2019). Therefore, the sorption of heavy metals from the environment and the additives in plastic may cause this pollution in extracted microplastics. Microplastics are the vectors of heavy metals in the environmental system. All five heavy metals from microplastics in this study are toxic to aquatic organisms, human life and the ecosystem. For example, Cd can cause cancer and organ system toxicity, Cr carries a risk of lung, nasal, and sinus cancer, Cu can damage the liver, kidney, heart, and brain, Pb can harm the nervous system by directly damaging the brain and Zn can damage the pancreas and disturb protein metabolism causing arteriosclerosis (Fernando et al., 2021). Microplastics may carry these heavy metals into aquatic organisms, such as fish, oysters and plankton and subsequently affect human life. The Saen Saeb canal connects two main rivers in Thailand (Chao Phraya River and Bang Pakong River) and flows into the Gulf of Thailand, so there are many aquatic organisms in the river and ocean which might cause this pollution.

This research provides valuable information about the distribution of microplastic pollution and contributes to current knowledge on the state of pollution. Additionally, our results can inform decision-making and law enforcement to improve solid waste and wastewater management to prevent this type of pollution from entering and creating future havoc in the environment.

## Conclusion and Suggestions

The distribution of microplastic pollution on the surface water of an urban area (Saen Saeb canal, Bangkok and Chachoengsao province, Thailand) were investigated. The range in size of the microplastics of 1-0.3 mm had the higher number and concentration than 0.3 – 0.1 mm. The average amount of microplastics was 479 $p/m^3$ or 0.0856 $g/m^3$ (size of 1-0.3 mm) and 261 $p/m^3$ or 0.0415 $g/m^3$ (size of 0.3-0.1 mm). The abundance of microplastic particles decreased with the distance from dense community areas. The most frequent form of extracted microplastics was found to be films, fibers and fragments which were brown-transparent and transparent in color. PP and PE polymers were the most dominant in the samples. The characteristics of the extracted microplastics in this study are suspected to originate from the daily use of plastic products and human activities in the area of study. The heavy metals Zn, Pb, Cr, Cu and Cd were detected in microplastic pollutants in this area, cause by the sorption of the microplastics from the environment and the additives in the plastic. Further analysis of the adsorption of heavy metals into the microplastics and their effects on aquatic life as well as the pathways of the microplastics from the study area to other areas should also be studied.

The results from this research should lead to recommendations to government institutions, private companies and environmental organizations to consider the dangers of microplastic pollution and to enforce a policy of reuse or recycled plastic usage. Solid waste and wastewater management systems should also be upgraded to protect the environment from the entry of plastic debris and microplastics into canals and rivers which can permanently damage the environment.

## Acknowledgments

This study was financially supported by Ramkhamhaeng University (Project under New Normal-COVID 19, 2021). The authors also wish to extend their appreciation to Environmental Science Laboratory at Ramkhamhaeng University for providing research facilities. Many thanks to Mr. Roy I. Morien of the Naresuan University Graduate School for his efforts in editing the grammar, syntax and general English expression in this document.

## References

Brennecke, D., Duate, B., Paiva, F., Cacador, I., & Canning C. J. (2016). Microplastics as vector for heavy metal contamination from the marine environment. *Estuarine, Coastal and Shelf Science, 178*, 186-195.

Choi, J. S., Jung, Y. J., Hong, N. H., Hong, S. H., & Park, J. W. (2018). Toxicological effects of irregularly shaped and spherical microplastics in a marine teleost, the sheepshead minnow (Cyprinodon variegatus). *Marine Pollution Bulletin, 129* (1), 231-240.

Fernando, G. T., Diana, C. D. S., Carlos, I. P. O., Pizarro, & Gabriel, E. D. L. T. (2021). Sorption of chemical contaminants on degradable and non-degradable microplastics: Recent progress and research trends. *Science of the Total Environment, 757*, 143875.

Gagné, F. (2017). Toxicity and disruption of quorum sensing in Aliivibrio fisheri by environmental chemicals: Impacts of selected contaminants and microplastics. *Journal of Xenobiotics, 7*, 15-20.

Gao, F., Li, J., Sun, C., Zhang, L., Jiang, F., Cao, W., & Zheng, L. (2019). Study on the capability and characteristics of heavy metals enriched on microplastics in marine environment. *Marine Pollution Bulletin, 144*, 61-67.

Holmes, L. A., Turner, A., & Thompson, R. C. (2012). Adsorption of trace metals to plastic resin pellets in the Marine environment. *Environmental Pollution, 160*, 42-48.

Horton, A. A., Walton, A., Spurgeon, D. J., Lahive, E., & Svendsen, C. (2017). Microplastic in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of the Total Environment, 586*, 127-141.

Issac, M. N., & Kandasubramanian, B. (2021). Effect of microplastics in water and aquatic systems. *Environmental Science and Pollution Research, 28*, 19544-19562.

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science, 347*, 768-771.

Jiwarungrueangkul, T., Phaksopa, J., & Sompongchaiyakul, P. (2021). Seasonal microplastic variations in estuarine sediments from urban canal on the west coast of Thailand: a case study in Phuket province. *Marine Pollution Bulletin, 168*, 112452.

Kankanige, D., & Babel, S. (2020). Identification of micro-plastic (MPs) in conventional tap water sourced from Thailand. *Journal of Engineering and Technological Sciences, 52*(1), 95-107.

Klangnurak, W., & Chunniyom, S. (2020). Screening for microplastics in marine fish of Thailand: the accumulation of microplastics in the gastrointestinal tract of different foraging preferences. *Environmental Science and Pollution Research, 27*, 27161 – 27168.

Lambert, S., & Wanger, M. (2018). Microplastics are contaminants of emerging concern in freshwater environments: an overview, in: S. Lambert, M. Wanger (Eds.), Freshwater microplastics, Springer, Cham, 1-23.

Li, Y., Lu, Z., Zheng, H. Y., Wang, J., & Chen, C. (2020). Microplastics in surface water and sediments of Chongming Island in Yangtze Estuary, China. *Environmental Sciences Europe, 32* (15), 1-12.

Masura, J., Baker, J., Foster, G., & Arthur, C. (2015). *Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying particles in waters and sediments*. USA: NOAA Technical Memorandom NOS-OR&R-48.

Merlin, N. I., & Balasubramanian, K. (2021). Effect of microplastics in water and aquatic systems. *Environmental Science and Pollution Research, 28*, 19544-19562.

Olarinmoye, O. M., Stock, F., Scherf, N., Whenu, O., Asenime, C., & Ganzallo, S. (2020). Microplastic Presence in Sedimen and Water of a Lagoon Bordering the Urban Agglomeration of Lagos, Southwest Nigeria. *Geosci, 10*, 494.

Oo, P. Z., Boontanoon, S. K., Boontanon, N., Tanaka, S., & Fujii, S. (2020). Abundance and distribution of suspended microplastics in the surface water of Chao Phraya River Estuary. *Thai Environmental Engineering Journal, 34* (2), 57-66.

Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., & Li, D. (2017). Microplastics in sediments of the Changjiang Estuary, China. *Environ. Pollut, 225*, 283-290.

Possatto, F. E., Barletta, M., Costa, M. F., Ivar, J. A., & Dantas, D. V. (2011). Plastic debris ingestion by marine catfish: An unexpected fisheries impact. *Marine Pollution Bulletin, 62*(5), 1098-1102.

Scherer, C., Weber, A., Stock, F., Vurusic, S., Egerci, H., Kochleus, C., Reifferscheid, G. (2020). Comparative assessment of microplastics in water and sediment of large European river. *Science of the Total Environment, 738*, 139866.

Stolte, A. (2015). Microplastic concentrations in beach sediments along the German Baltic coast. *Marine Pollution Bulletin, 99*(1-2), 216-229.

Ta, A. T., & Babel, S. (2020). Microplastics pollution with heavy metals in the aquaculture zone of the Chao Phraya River Estuary, Thailand. *Marine Pollution Bulletin, 161*, 111747.

Ta, A. T., Babel, S., & Haarstrick, A. (2020). Microplastics contamination in a high population density area of the Chao Phraya River, Bangkok. *Journal of Engineering and Technological Sciences, 52*(4), 534 – 545.

Turner, A., & Holmes, L. A. (2015). Adsorption of trace metals by microplastic pellets in fresh water. *Environmental Chemistry, 12*, 600-610.

Wang, J., Peng, J., Tan, Z., Gao, Y., Zhang, Z., Chen, Q., & Cai, L. (2017). Microplastics in the surface sediments from the Beijiang river littoral zone: composition, abundance, surface textures and interaction with heavy metal. *Chemosphere, 171*, 248-258.

Willis, K. A., Eriksen, R., Wilcox, C., & Hardesty, B. D. (2017). Microplastic distribution at different sediment depths in an Urban Estuary. *Frontiers in Marine Science*, *419*, 4.

Zhang, J., Zhang, C., Deng, Y., Wang, R., Ma, E., Wang, J., Zhou, Y. (2019). Microplastics in the surface water of small-scale estuaries in Shanghai. *Marine Pollution Bulletin*, *149*, 110569.