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RESEARCH PAPER

Assessment of Microplastics Distribution and Related Water Quality in an Urban Canal, Thailand

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Abstract

Microplastics pollution has become a matter of global concern because of its effects on aquatic life and the ecosystem. This study investigated the abundance and types of microplastics found in an urban canal of Thailand. Water quality and the relationship between microplastics pollutants and the physicochemical properties of water quality were also analyzed to provide evidence for this study. The mean abundance of microplastics was 370 ± 140 particle(p)/m^3. The highest number and concentration of microplastics were found on surface water corelated with urbanization. Transparent brown and transparent colors in the form of film and fiber/lines were the predominant morphology. Polypropylene (PP) and polyethylene (PE) were the most abundant polymer type in all surface water samples. Furthermore, water quality was related with microplastic pollution. The physicochemical properties of turbidity (0.99), conductivity (0.97), total solid (0.95) and biological oxygen demand (0.84) were accounted for greatest influences on microplastics distribution. The estimated equation of microplastics was also closely corelated with water quality. These results demonstrate that microplastic pollution has progressed more in poor water quality than good water quality, indicating that the inflow process and sources of microplastics are similar to those of other pollutants. Therefore, this study is expected to encourage and enforce solid waste and wastewater management policies that prevent microplastics pollution in the environment.

Keywords: Microplastics; Water quality; Surface water; Physicochemical properties

INTRODUCTION

At present, water pollution is a serious problem worldwide. The untreated pollutants cause contamination to water bodies as a result of water pollution or poor water quality (Chandan et al., 2013). An increasing population density, human activities, industries and agriculture affect water quality. Pollutants in water bodies contain plastic, paper, glass, cloth, foam, metal, ceramics, rubber and cork. One of the most predominant pollutants in water is plastic litter, which has become a global concern (Tomoya et al., 2019). Globally, more than 270 million tons of mismanaged plastic waste is produced annually and flows from canal and rivers to estuaries and then to the ocean. An estimated 80% of plastic pollution in the sea comes from inland that enters to the river (Jenna et al., 2015; Thomas et al., 2015). The focus of this study is the urban canal named "Saen Saeb" in Thai which is located in central Thailand and which is connected to the Chao Phaya River and Bang Pakong River and flows into the Gulf of Thailand. The Saen Saeb canal is one of the important water bodies for residential area, agriculture, industries and navigation (Kirana & Sitang, 2013). The water pollutants are caused by anthropogenic activities such as domestic waste, wastewater from wastewater treatment plants, agricultural

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waste and microplastics, which all contribute to the poor water quality in this canal (Siriruk et al., 2014; Rakesh et al., 2021). The physicochemical parameters are important to test the water quality. Selection of the tested parameters is based on the purpose of using that water. Some physicochemical parameters consist of pH, temperature, turbidity color, total solid, total dissolved solid, biological oxygen demand, chemical oxygen demand, hardness, alkalinity and other (Patil, 2012). Numerous researchers have investigated the physicochemical properties for drinking, domestic, agricultural or industrial purpose (Varinthorn et al., 2015; Nidhi et al., 2017; Saroj & Chitta, 2018). Moreover, the changes in the physicochemical properties and poor water quality of the Saen Saeb canal also have been observed in previous studies (Kirana & Sitang, 2013; Sanee, 2013).

Plastic waste from inland to surface water also causes serious problems in this canal. The effects of time, physical and hydrological factors (such as photolysis, wind impact, abrasion, weathering, mechanical disintegration, wave impact, etc.), degrade plastics trash into small particles known as microplastics. Moreover, microplastics in water bodies also come from the drainage of plastic waste from land, domestic and industrial sectors, rainwater runoff, water activities, flood, wind, domestic waste, tourism and atmospheric deposition (Ali et al., 2017; Arianna et al., 2020). Microplastics pollution can affect biological interactions, estuarine ecosystems and threaten water species (Thanakorn et al., 2021). Therefore, microplastics is one of the most pressing issues in global environmental concerns. Microplastics can be classified as large microplastics or meso microplastics (1-5 mm), small microplastics (1 mm – 0.1 μm) and nanoplastics (≤ 0.1 μm) (Lambert & Wanger, 2018). Many scientific studies have focused on microplastics contamination to the environment, for example, to the atmosphere, soil, water bodies, wetlands, estuaries and oceans (Jiaxu et al., 2019; Yubo et al., 2020; Rakesh et al., 2021). They studied microplastic concentrations with respect to monitoring, morphology, the source of microplastics and distribution and characterization of microplastics (Yubo et al., 2020; Anh et al.,2020; Forero-Lopez et al., 2021), the outflow flux to the oceans (Laurent et al., 2017; Max et al., 2017), and the impacts of microplastics (Jin et al., 2018; Merlin & Kandasubramanian, 2021) and population density (Thomas et al., 2014). However, information about the effects, relation of water quality's physicochemical parameters on microplastics concentration and the correlation of microplastics on water quality from same monitoring stations is very limited.

The purpose of this study was to better understand the existence of microplastics in the Saen Saeb urban canal of Thailand and its related water quality. Moreover, the relationship between the abundance of microplastics and physicochemical parameters of water quality was also established. Our results can be used for future management to estimate microplastics from water pollution, improve water quality, and reduce microplastics in water bodies.

MATERIAL AND METHODS

The Saen Saeb urban canal in Bangkok canal was selected in the study to determine microplastic distribution and water quality. This canal is about 72 kilometers is length and it is connected to the Bang Pakong River and Chao Phaya River which flow into the Gulf of Thailand. The Saen Saeb canal flows through 21 districts which consist of residential zones, industrial and agricultural zones. The depth and width of this canal is 2.5 m and 20-35 m, respectively. Five water sampling sites were taken from upstream to downstream on June 2021 as shown in Figure 1 and the details of each site are shown in Table 1.

Microplastics particles and surface water were sampled along the Saen Saeb canal at certain sites (Figure 1). Microplastic particles were sampled by a modified stainless-steel pump with 0.3 m^3/h of water flow rate which passes through a series of stainless-steel sieves (sieve size of 5 mm – 0.1 mm) (Julie et al., 2015). The collected particles of less than 1 mm to 0.1 mm (sieve size) were rinsed with distilled water and transferred to glass bottles. The glass bottles

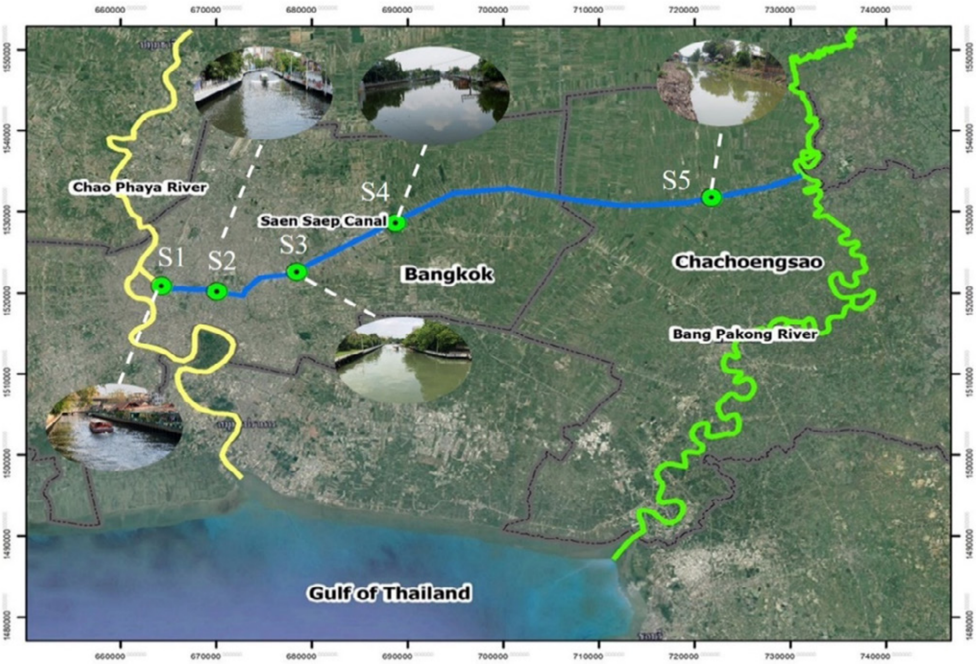

Fig 1. Sampling locations on Saen Saeb urban canal of Bangkok, Thailand

Table 1. Sampling location

Site	Latitude	Longitude	Location
S1	13.75225°	100.520415°	Inner Bangkok, Thailand (surrounding areas with urban dense area, market, school, central business district and ports)
S2	13.745741°	100.574315°	Center of Bangkok, Thailand (6 km from inner Bangkok; residence zone, small wastewater plant and ports)
S3	13.767097°	100.651242°	Center of Bangkok, Thailand (17 km from inner Bangkok; residence zone, small wastewater plant and ports)
S4	13.820965°	100.747279°	Outer Bangkok, Thailand. (30 km from inner Bangkok; peri-urban areas, floodgate between Bangkok and Chachoengsao province, Thailand)
S5	13.846912°	101.053290°	Bang Pakong river, Chachoengsao province, Thailand (70 km from inner Bangkok; residence and agriculture zones)

Note: Area definition based on Department of Public Works and Town & Country Planning of Thailand#

were kept in a sample storage cooler box and taken back to the laboratory for further analysis. Moreover, water samples were collected at the same sampling sites in 2 liter polyethylene bottles. The pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS) were measured immediately after field sampling with a multiparameter laboratory measuring instrument (HQ40D, HACH). Then the collected samples were kept in a sample storage cooler box and stored in a freezer at 4 °C before being analyzed in the laboratory for all physicochemical parameters.

The microplastic particles in water were separated into 3 size ranges using stainless-steel sieves (> 5 mm; macro microplastic), 1.0 – 0.3 mm and 0.3 – 0.1 mm; small microplastics).To avoid technical errors and other limitations of the field sampling in the urban canals (with the thigh contamination of the pollutants) or the canal clean-up activities of the macroparticles in some area (especially in the inner and centre of Bangkok areas), the macro microplastics was not considered in this study, and only the small microplastics less than 1 mm was selected for analysis in this study . Microplastics from the surface water were extracted and analyzed following the laboratory methods for microplastic analysis in marine environments (Julie et al., 2015). The particle samples from each fraction were used to determine the mass of total solid and all samples of microplastic particles were dried in the oven at 90 °C for 24 h. The particle samples of less than 0.5 mm were difficult to inspect visually due to the organic matter and sediment. Therefore, Wet Peroxide Oxidation (WPO) methods were used to remove the organic matter (Julie et al., 2015). 30% of H_2O_2 and 0.5M of Fe (II) were used for digestion at 75 °C for 30 min. After that, 5 M of NaCl solution (AR. grade; 1.2 g/cm) was used for density separation to separate the floating particles via a glass funnel which were allowed to settle overnight. The different fractions based on density were separated and the supernatant was filtered through anopore inorganic membrane filters (Anodic, pore size 0.2 μm). The filters were dried at 90 °C for 24 h. The dried filters were used to determine the number of microplastic particles, morphology (shape and color) by a stereomicroscope (Olympus SZ30) connected to a microscope camera (Dino Capture 2.0). Moreover, the natural polymer of the samples was analyzed using a Fourier transform infrared spectroscope (FTIR) (Frontier, PerkinElmer). A similar index of more than 70% of established plastic polymer data banks were accepted as microplastics and below 70% was assumed as non-plastic for this study (Frias et al., 2016; Phyo et al., 2020).

To assess the physicochemical condition of the water quality in the Saen Saeb canal, 12 parameters were analyzed; namely pH, dissolved oxygen (DO), turbidity, conductivity, temperature, total solid (TS), total dissolved solid (TDS), total suspended solids (TSS), biological oxygen demand (BOD_5), ammonia (NH_4-N), nitrate (NO_3-N) and nitrite (NO_2-N). The water analysis followed the standard methods for the Examination of Water and Wastewater (APHA, 2017). The water quality values were evaluated and compared with the water quality standard from Thailand (PCD, 2022). Moreover, the relationship between the microplastics distribution and the physicochemical parameters of water quality was analyzed using Principal Component Analysis (PCA) via the XLSTAT program.

RESULTS AND DISCUSSION

Microplastics were found in all the sampling sites along the Saen Saeb urban canal with an average concentration of 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). These quantities were lower than those found in the Zhangjinwan Estuary in China (13,530 p/m^3) but higher than those in the Chao Phaya River in Thailand (48 – 104 p/m^3) (Jiaxu et al., 2019; Anh et al., 2020). Due to the above reasons of the field sampling and the procedures for microplastics analysis as mentioned in the material and methods. It should be noted that the total abundance of microplastics in this study was reported mainly on small microplastics and further investigation of the macro microplastics in the urban canal is recommended. The concentrations of the collected microplastics are shown in Figure 2. The highest number and concentrations of microplastics were found at S1 which is located in the inner part of Bangkok (1,113 ± 145.83 p/m^3 or 0.2087 ± 0.053 g/m^3 with a size range 1 – 0.3 mm and 577 ± 132.73 p/m^3 or 0.0937 ± 0.021 g/m^3 with a size range 0.3 – 0.1 mm). The lowest concentration was found at S5 which is downstream from the Saen Saeb canal and about 40 km from an urban area (307 ± 21.23 p/m^3 or 0.0363 ± 0.01 g/m^3 with a size range of 1 – 0.3 mm and 57 ± 24.63 p/m^3 or 0.0203 ± 0.01 g/m^3 with a size range of 0.3 – 0.1 mm). The plastics found in Saen Saeb come from urban activity. In this canal of Bangkok Zone (S1-S3) is located in a high-density a residential zone, with wastewater treatment, ports which are factors in the production of large quantities of microplastics. The width of this canal is 2.5 m with residence zone and high density for land use are located along the canal that carries plastics, suspended

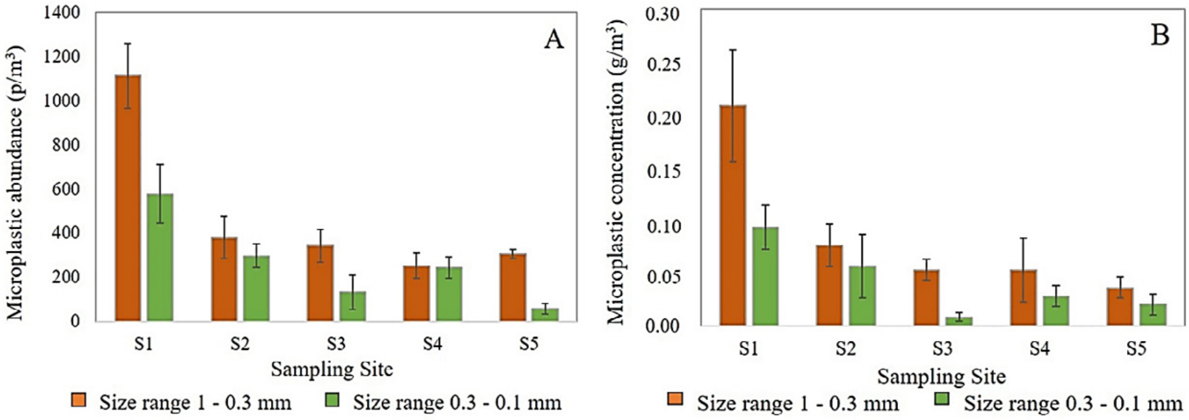

Fig 2. Abundance of microplastics at each sampling site; A) microplastic abundance (p/m^3) and B) microplastic concentration (g/m^3)

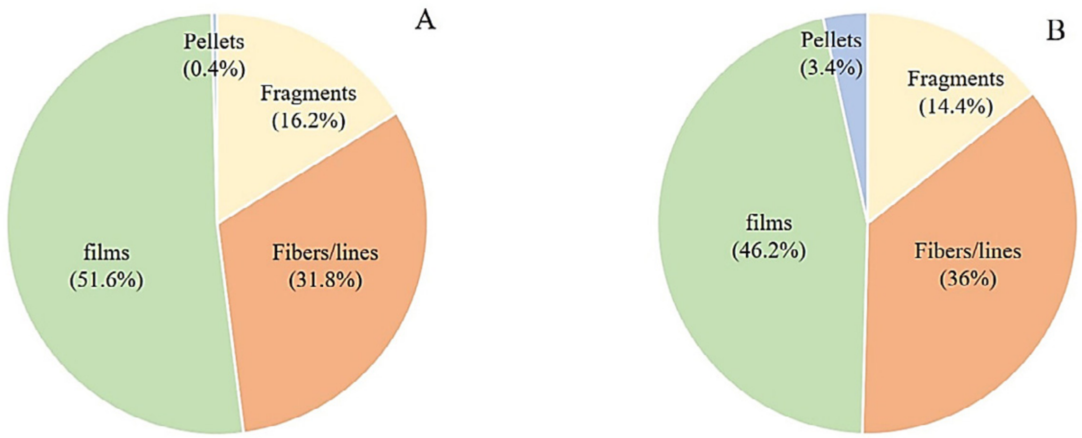

Fig 3. Shapes of microplastics; A) microplastic size range 1 – 0.3 mm and B) microplastic size range 0.3 - 0.1 mm

debris and wastewater in the canal. The high concentration of microplastics in the size range 0.3-1 mm may indicated that long time of plastics existent which can break the plastics into tiny microplastics. Song et al., 2017 found that plastic can break to small microplastics (lower than 1 mm) after 12 months with mechanical by sand and ultraviolet irradiation. Furthermore, the tide and waves from express boats can resuspend microplastics from the bottom sediment. So, a high concentration of microplastics in the size range 0.1 - 0.3 mm was found in the urban area with ports stations (S1-S2). Moreover, the abundance of microplastics decrease with distance from an urban area (Bangkok) as seen in the S5. Land use, population density, waste management and hydrological information are also related to the quantities of microplastics (Laurent et al., 2017; Thomas et al., 2014; Tomoya et al., 2019).

The morphology of microplastics takes into account both shape and color. The results show that the shapes of the collected microplastics are related to their origin as represented in Figure 3. Films, fibers and fragments were mostly found on the surface water. More than 50% of the collected microplastics consisted of films (46.2 -51.6%) and fibers (31.8 – 36%) followed by fragments (14.4 -16.2%) and pellets (0.4 – 3.4%) from microplastic sizes in the range of 1 – 0.3 mm and 0.3 – 0.1 mm. According to global research, film and fiber are the most commonly found forms in surface water.

The high relative abundance of film and fiber shaped microplastics are related to the origin

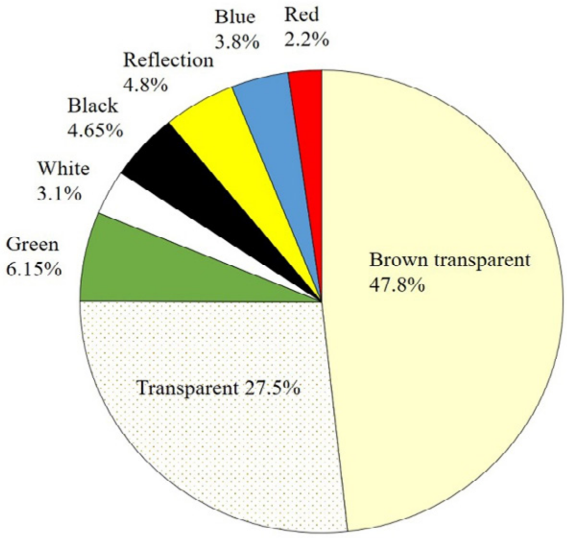

Fig 4. The relative abundance of microplastics by color

of microplastics from both primary and secondary microplastics and the density of urban activity along the canal. These microplastics which could be derived from the fragmentation of plastic waste from land. Moreover, lines shape may be generated from domestic wastewater that discharges directly or non-directly to the canal. Anh et al., 2020 also found that film is generated from plastic bags, soft bag and packaging materials (Anh et al., 2020). Fiber or lines may be generated from cloth and textile materials. Moreover, household wastewater, effluent from the treatment of domestic laundry are also sources of fibers/lines. (Chenxi et al., 2018; Anh et al., 2020).

Eight different colors were found in this collection of microplastics which consisted of brown transparent, transparent, brown, green, white, black, refection, blue and red. The percentages of the relative amounts of microplastic colors in both size ranges were not very different as represented in Figure 4. These colors were chosen to represent the origin of plastics production and the origin of the plastic waste produced on land. Brown transparent and transparent were found to be the most dominant microplastic colors with 60 – 70% of the total collection. 20 – 25% of the microplastics were brown, white, green, and black and the remaining 10% were blue, reflection and red, respectively. Transparent colors are widely used in the plastics industry, plastics packaging, plastics resin and other colors plastic items (Cole et al., 2014). Therefore, microplastics may generated from land with high density of urban activity along the canal. These products can breakdown or fragment from large to tiny pieces of plastic (as microplastics) due to weathering, physical condition, hydrology, abrasion, ultraviolet solar radiation, mechanical disintegration and microbiological activity (Chenxi et al., 2018; Tomoya et al., 2019; Merlin & Kandasubramanian, 2021). The color of microplastics can be harmful to aquatic organisms as it can signal food for predators. Thus, the morphology of microplastics in an urban canal can impact on aquatic organisms in this and other areas through which this water flows until it reaches the Gulf of Thailand.

The FTIR results show that Polypropylene (PP), Polyethylene (PE) and Polyvinyl stearate (PVS) had the highest amounts of the average proportion of polymer types with more than 65% of the total amount of microplastics polymer. About 18% of the total microplastics polymer were Polyester or Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), Polyamide (PA) and Polystyrene (PS) and the rest were 15% of the other polymers as shown in Figure 5. PP and PE are most widely found in the plastic usage, food packaging and labelling through the world and

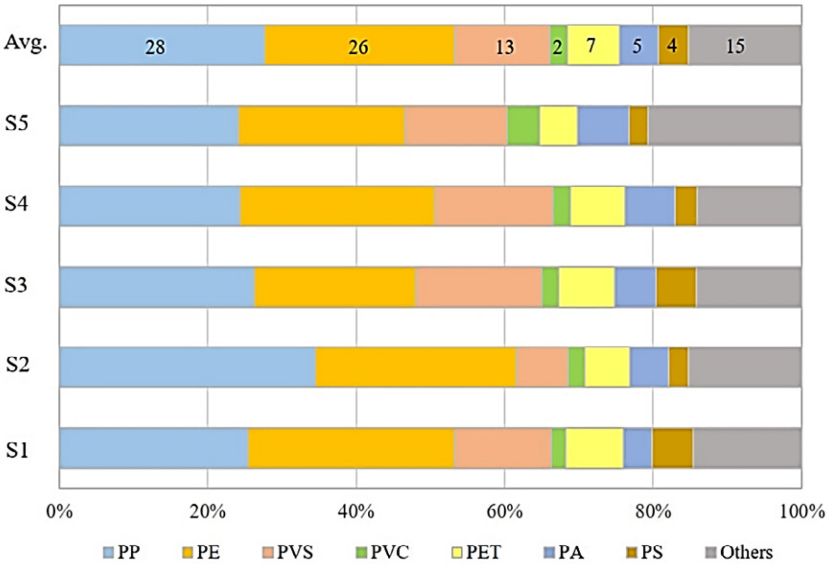

Fig 5. The relative abundance of microplastics polymers

Table 2. Water quality from the Saen Saeb canal, Bangkok, Thailand

Parameters	Unit	Sampling Site*				
		S1	S2	S3	S4	S5
Temp.	°C	30.9±0.8	31.6±0.6	32.8±0.3	33±0.6	34.2±0.7
DO	mg/L	1.84±0.21	1.76±0.07	4.79±0.26	6.79±0.24	8.33±0.15
Conductivity	ms/cm	4.42±0.17	2.31±0.14	0.67±0.03	0.83±0.01	1.28±0.004
pH	-	7.13±0.06	7.48±0.029	7.74±0.07	7.42±0.025	7.22±0.04
Turbidity	NTU	39.69±2.07	25.56±4.12	14.32±4.04	17.00±3.00	13.5±4.09
TS	mg/L	393.22±1.84	185.44±3.75	48.78±3.37	62.50±4.48	118.56±2.04
TSS	mg/L	4.35±0.35	2.83±0.55	3.13±0.23	3.47±0.42	4.85±0.51
TDS	mg/L	388.87±1.87	182.61±3.78	45.64±3.38	59.03±4.50	113.71±2.10
BOD5	mg/L	20.4±1.5	5.8±0.5	5.1±0.7	7.0±1.2	3.9±0.8
NH_4-N	mg/L	4.17±0.01	2.54±0.21	6.39±0.10	5.24±0.03	2.06±0.01
NO_3-N	mg/L	8.32±0.29	2.71±0.22	1.77±0.08	1.37±0.05	1.04±0.01
NO_2-N	mg/L	0.33±0.002	0.26±0.007	0.02±0.001	0.06±0.001	0.05±0.001

Note: *triplicate sample analysis

in Thailand especially in the packaging (Anh et al., 2020). The high relative abundance of PP and PE were secondary microplastics may generated from land by the fragmentation of plastics to tiny microplastics. In addition, PVS and PET were found from textiles, plastic bottles and plastic bags. PVS, which is used in plastic packaging, has a low density and can float on the surface of water (Dinuka & Sandhya, 2020; Suwanna et al., 2020). Therefore, these polymers are related to commercial plastic production and microplastics in this study area were mostly come from lands.

The water quality in the Saen Saeb canal was analyzed based on physicochemical parameters. Twelve water quality variables consisting of temperature, DO, conductivity, pH, turbidity, TS, TSS, TDS, BOD_5, NH_4-N, NO_3-N and NO_2-N were analyzed and the results are shown in Table 2. In general, water sampling was conducted at the same location with observation of microplastics distribution. The temperature of the Saen Saeb canal was between 30.9 – 34.2 °C. Water temperature is related to the seasonal and ambient temperature and the average temperature was found to be 32.5 ºC. The pH values from S1 to S5 were found to be in the range of 7.13±0.06 to 7.74±0.07. These pH values are within the standard levels of quality for aquatic life at 5.0 – 9.0 (Nanik et al., 2021). Conductivity values varied from 0.67±0.03 ms/cm to 4.42±0.17 ms/cm at all locations. TS, TSS and TDS values were obtained from 48.78±3.37 mg/L to 393.22±1.84 mg/L, 2.83±0.55 mg/L to 4.85±0.51 mg/L and 45.64 mg/L to 388.87 mg/L, respectively. The turbidity of this urban canal was found to be from 13.5±4.09 to 39.69±2.07 NTU. The turbidity and TS at S1 and S2 were found to be high when compared with other sampling sites due to the tide and wave from express boats which can cause the resuspension of total solids from the sediment at the bottom of the canal. Moreover, the high values at S1 and S2 may have been due to the increase of municipal waste, septic waste and dissolved salts. Also, the values at S5 were found to be rather high due to riverbank erosion and increased levels of livestock waste and fertilizers. Moreover, the concentration of solids and turbidity levels revealed a positive relationship with the concentration of microplastics (Tomoya K et al., 2019; Nanik R.B. et al., 2021). The DO values were one of the water quality indicators which showed significant differences from those at S1 to S5. Low DO values were found at S1, S2 and S3 due to the fact that these parts of the canal are located in urban areas with a high population density, residential zones along the canal, small wastewater treatment plants, market and embarkation points for express boats.

Furthermore, DO concentration and BOD_5 were positively related and they varied from 1.76±0.07 mg/L to 8.33±0.15 mg/L and 3.9±0.8 mg/L to 20.4±1.5 mg/L, respectively. The highest concentration of BOD_5 was found at S1 (20.4±1.5 mg/L), which suggests that a large amount of organic matter was contaminated in this part of the canal which was related to DO concentration lower than 2 mg/L. Moreover, the average concentration of nitrogen (NH_4-N, NO_3-N and NO_2-N) was found to be 3.68 mg-N/L, 1.24 mg-N/L and 0.14 mg-N/L, respectively. A high concentration of nitrogen was found at S1. A high nitrogen concentration is the result of domestic effluent discharge that is contaminated with detergents and chemical cleaning (Ali et al., 2018). On the basis of these results and compared with the water quality standard of Thailand, Saen Saeb canal is classified as Class 5 (DO < 2 mg/L; BOD5 > 4 mg/L; NO3-N. 5 mg/L and NH4-N > 0.5 mg/L) (PCD, 2022). Consequently, this canal is now only suitable for navigation purposes, but cannot be used for drinking water or water supplies as it is highly polluted.

The relationship between microplastics morphology (films, fibers, fragments and pellets) and physicochemical parameters (Temperature, Conductivity, DO, Turbidity, TS, BOD_5, NH_4-N, NO_3-N and NO_2-N) in the Saen Saeb canal at 5 sampling stations is shown in Figure 6 using Principal Component Analysis (PCA) analysis. The results show that high concentrations of microplastics were detected in highly polluted water with high total solids, conductivity, turbidity, BOD_5, NO_3-N and NO_2-N, but moderate NH_4-N and low DO, pH and Temperature. Films were most frequently found in this surface water, followed by fibers, fragment and pellets. Films were detected at high TS, conductivity, turbidity, BOD_5, NO_3-N and NO_2-N, but moderate NH_4-N and low DO and pH. The highest concentrations of films were detected at S1 (urban area) but they were not significantly different from those at the other stations. Moreover, fragments were predominantly located at S1 and S2 which are related to the same physicochemical parameters as films. Film and fragments were detected with high pollutants due to the increase of municipal waste, septic waste and dissolved salts into the canal. Mismanagement of plastic from land also source of this microplastics type in the canal. Moreover, the resuspension of total solids from the sediment at the bottom of the canal caused this microplastics type to be represented with high TS, conductivity turbidity and BOD_5. Fibers and pellets were found in the samples with high DO, pH, temperature with medium NH_4-N and low TS, conductivity, turbidity, BOD_5, NO_3-N and NO_2-N levels. Fiber may be generated from domestic wastewater direct or indirect discharge to canal. Most represented in downstream (S4 and S5) with far from urban area.

Significant physicochemical parameters are necessary to score the loading variable from

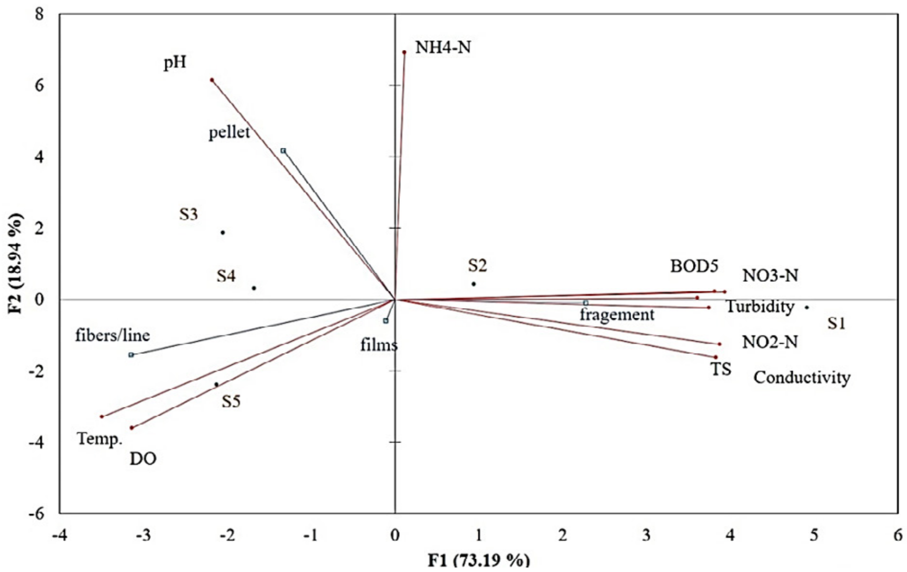

Fig 6. The relationship between the distribution of microplastics and water quality by PCA

PCA. Turbidity (0.99), Conductivity (0.97), TS (0.95) and BOD_5 (0.84) were found to have a significant effect on the abundance of microplastics. These results indicate that microplastic pollution is related to the water quality, especially with respect to fragments and film. Due to urbanization and high population density, the poor water quality is related to the polluted water by microplastics. Microplastics in surface water can be produced on land or come from the sources of pollutants (point sources and non-point sources) which reach the aquatic environment through similar pathways of other pollutants (Tomoya et al., 2019). Film and fragments are formed by large pieces of plastic decomposing, such as plastic bags, plastic debris, mulching film and cleaning products, which originated in the canal (Babalola et al., 2020).

Based on the considerable effects of physicochemical parameters on microplastic pollution, this study investigated the correlation between the various factors and predicted the number and concentration of microplastics with regard to turbidity, TS, conductivity and BOD_5 shown in Figure 7 (A-D). This study may be the first to correlate the amount and concentrations of microplastics with respect to water quality parameters at the same monitoring site on a horizontal axis with canal basin; but no comparable data is available. All of this equation developed from the surface water quality that has high positive affect to concentration and number of microplastics. This equation can by apply and predict only microplastics in contaminated surface water. Figure 7 (A-D) shows a significant positive correlation between the number of microplastics with turbidity (R^2 = 9.93), total solids (R^2 = 0.90), Conductivity (R^2 = 0.91) and BOD_5 (R^2 = 0.69). It is interesting to note that the physicochemical parameters of water quality at different locations were positively related to the amount of microplastics found there. Therefore, the prediction equation based on this relationship can be modified and expressed as in Table 3.

Total solids, turbidity and conductivity parameters are indicators of water quality which show a positive relationship. TS like organic or inorganic substances, mud, sand, plastics debris, microplastics and other substances are the sources of turbidity (Nanik et al., 2021). As a result of the Saen Saeb canal structure, channel morphology and physical damage from human activities, plastics can break into fragments from being compressed by transportation activities, such as the passage of express boats. Moreover, microplastics from the canal sediments can be resuspended on water surfaces due to the hydrological characteristics of physical force (tides and waves from the express boats). Moreover, high total solids, turbidity, and conductivity indicate

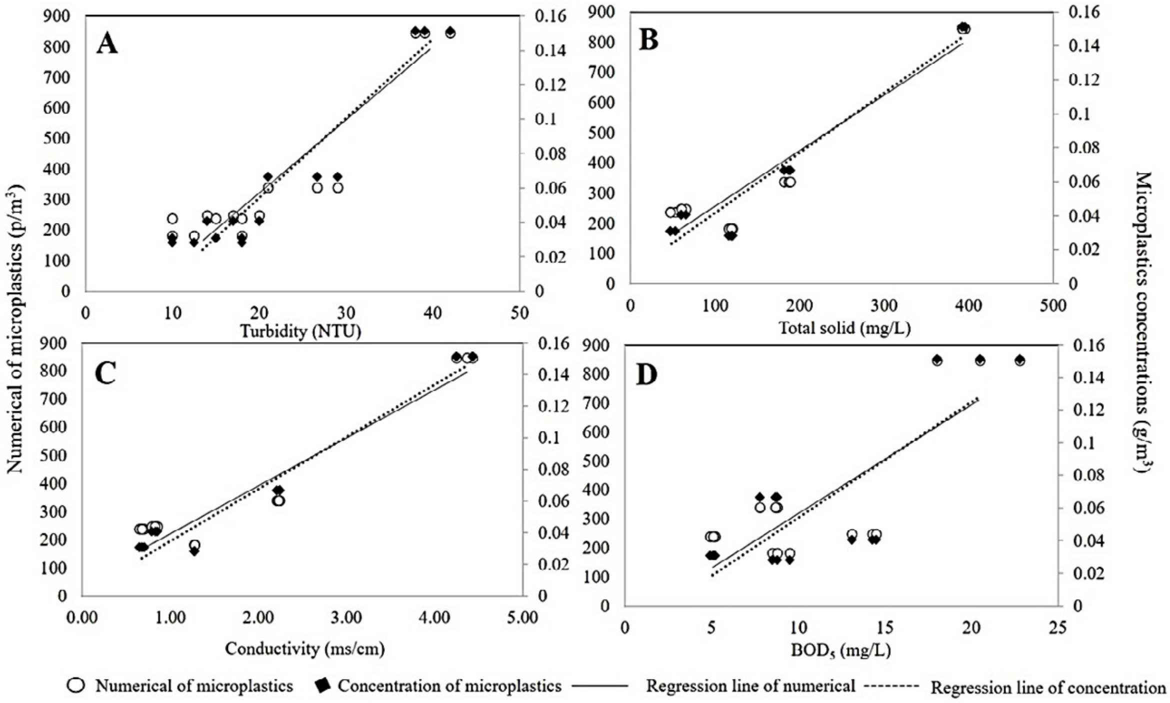

Fig 7. Correlation of the number and concentration of microplastics with four water quality parameters: A) Turbidity, B) Total solid (TS), C) Conductivity and D) Biological oxygen demand (BOD_5)

Table 3. Prediction equation of the number and concentration of microplastics based on the four water quality parameters.

Parameters	Equations	R^2
Turbidity (NTU)	$Numb.MCs_{(p/m^3)} = 23.893 Turb._{(NTU)} - 155.71$	0.93
	$MCs_{(g/m^3)} = 0.0046 Turb._{(NTU)} - 0.0382$	0.98
Total solid (mg/L)	$Numb.MCs_{(p/m^3)} = 1.836 TS_{(mg/L)} + 73.418$	0.90
	$MCs_{(g/m^3)} = 0.0004 TS_{(mg/L)} + 0.0063$	0.93
Conductivity (ms/cm)	$Numb.MCs_{(p/m^3)} = 169.98 Conduct_{(ms/cm)} + 51.681$	0.91
	$MCs_{(g/m^3)} = 0.0329 Conduct_{(ms/cm)} + 0.0019$	0.95
BOD_5 (mg/L)	$Numb.MCs_{(p/m^3)} = 37.512 BOD_{5(mg/L)} - 56.084$	0.68
	$MCs_{(g/m^3)} = 0.0071 BOD_{5(mg/L)} - 0.0172$	0.69

Note: MCs is microplastics, Numb. is number of microplastics, Turb. is turbidity

that high pollution from microplastics is likely to be present because microplastics can attract solid particles. Therefore, the correlation of TS, turbidity and conductivity with microplastic concentrations and the number of microplastics can be expressed as in the equation in Table 3. Furthermore, BOD_5 is one of the important water quality indicators that shows that dissolved oxygen in bacteria is a necessary part of the degradation process. High BOD_5 indicates that water is highly polluted which results in low amount of dissolved oxygen in water. This phenomenon can reduce the plastic degradation of bacteria, which significantly impacts microplastics distribution (Luisa et al., 2018). BOD_5 positively correlates with concentration and number of microplastics as represented in the equation in Table 3. Microplastics are released into the aquatic environment in the same way as other pollutants from various sources (point source and non-point source). Rivers with poor water quality in which there are high concentrations of BOD_5, DO, T-N and T-P also result in several pollutants and microplastics (Nanik et al., 2021; Tomoya et al., 2019).

The findings of this study reveal that microplastics pollution is related to water quality. TS, turbidity, conductivity and BOD_5 were the greatest influence on the number and concentration of microplastics. The prediction of microplastics pollution can be defined and expressed in prediction equations. However, the influence of hydrodynamic conditions and channel morphology should be further examined to complete the prediction equation.

CONCLUSIONS

The findings of this research revealed that the abundance of microplastics decreased with distance from urban areas. As a result of urbanization and high population density, the poor water quality has related to the polluted water by microplastics. The dominant color of microplastics were brown transparent and transparent in the shape of film and fiber/lines. PP and PE polymers predominated in the samples. This is the result of the original source of plastic production, sources of plastic waste and human activities along the canal. Microplastics on surface water can be produced on land or come from various other sources of pollutants which reach the aquatic environment through similar pathways to those of other pollutants. Moreover, microplastics pollution is related to the physicochemical properties of water quality. Microplastics concentrations were more often detected in the area of highly polluted water rather than those of good water quality. Additionally, total solids, turbidity, conductivity and biological oxygen demand parameters were found to have the greatest influence on the quantities of microplastics. The estimation of number and concentration of microplastics can be defined and expressed in prediction equations. This is useful for estimating the concentrations of microplastics in contaminated surface water under urban area, but it is important that hydrodynamic conditions should be analyzed the future in order to fully complete the equation. Therefore, this study will be useful to encourage and enforce improvements in solid waste and wastewater management policies which should prevent microplastics pollution in the environment.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of the manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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