International Journal of Agricultural Technology 2026 Vol. 22(6):2957-2970
DOI: https://doi.org/10.63369/ijat.2026.22.6.2957-2970
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Microplastics in U-Tapao Canal water: Abundance, types, and correlations with turbidity, TDS, and TSS during rainy season

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Thammachoto, A., Lantam, A. and Pradit, S. (2026). Microplastics in U-Tapao Canal water: Abundance, types, and correlations with turbidity, TDS, and TSS during rainy season. International Journal of Agricultural Technology 22(6):2957-2970.

Abstract Microplastics (MPs) are among the most significant pollutants in the canal system, primarily originating from land waste that is associated with coastal and marine environments. The contamination of MPs in the U-Tapao Canal, Songkhla Province, Thailand was investigated by studying in terms of MPs abundance, color, shape, and polymer type. The parameters that determined the water quality were turbidity, total dissolved solids (TDS), and total suspended solids (TSS). Surface water samples were collected from seven sites along the canal during the rainy season. The determination of MPs at every site, with a mean abundance of 11.44 particles/L and fiber shapes was mostly found in blue color. Main components were composed of polyethylene terephthalate (PET), indicating that consumer packaging and synthetic textiles are the main sources of contamination. The Turbidity mean was 114.45 NTU, the TSS mean was 48.07 mg/L, and the TDS mean was 118.57 mg/L. The results showed that turbidity and TSS were elevated across sites, while TDS varied with local land use. Critically, correlation analysis revealed that turbidity, TDS, and TSS each tracked a distinct dimension of MP contamination. Turbidity was linked to MP color and shape, TDS to MP abundance and color, and TSS to MP abundance alone. This research is highlighted the importance of monitoring MPs in the canal and the comprehensive integration of water quality parameters and MPs data into systematic data collection, which assists in policy, predictive risk assessment, and long-term ecological monitoring.

Keywords: Microplastics, Polymers, Water quality, Surface water, U-Tapao Canal

Introduction

Plastic is an essential synthetic material widely used in modern society. The characteristics of plastic include light weight, durability, versatility, chemical resistance, and a low production cost. These properties have led to its extensive application in packaging, construction, transportation, medicine, industry, and daily consumer products (Thompson *et al*., 2004). Global plastic production has been continuously driven by growing economic development, population growth, and consumer demand

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(Gourmelon, 2015). However, the widespread use of plastics, particularly single-use plastics, has generated enormous amounts of plastic waste. Because plastics degrade very slowly, they accumulate in terrestrial and aquatic environments, creating a major global environmental challenge (Ziani *et al*., 2023). Worldwide, only a small proportion of plastic waste is recycled, while most is disposed of in landfills, incinerated, or released into the environment. This waste can persist for decades and adversely affect ecosystems (Pilapitiya and Ratnayake, 2024).

Plastic waste exposed to environmental conditions gradually fragments into particles smaller than 5 mm through physical, chemical, and biological processes, known as microplastics (MPs) (Wang *et al*., 2016). MPs are generally classified as primary plastics that are intentionally manufactured at microscopic sizes, and secondary MPs that originate from the breakdown of larger plastic debris (Song *et al*., 2017). MPs are widely distributed in freshwater, marine environments, sediments, soils, and the atmosphere due to their small size, low density, and persistence. In addition, they can readily pass through conventional wastewater treatment systems into natural aquatic environments (Ahmad *et al*., 2024).

MPs are recognized as evolving contaminants because they can be consumed by aquatic organisms and transferred through the food web and cause potential risks to human health (Witczak *et al.,* 2024). In addition, MPs can absorb and transport hazardous contaminants including heavy metals, pesticides, and persistent organic pollutants (POPs), and lead to higher environmental persistence and ecological toxicity (Menéndez-Pedriza and Jaumot, 2020). Monitoring the occurrence, distribution, and characteristics of MPs has therefore become an important priority for environmental protection and water quality management worldwide (Lee *et al*., 2023; Lalrinfela *et al*., 2024).

In addition to MP analysis, conventional water quality parameters include turbidity, total suspended solids (TSS), and total dissolved solids (TDS). The water quality has gained increasing attention as a practical indicator for assessing MP contamination (Eamrat *et al*., 2022). Turbidity reflects the presence of suspended particles in the water, while TSS and TDS represent particulates and dissolved materials that may be associated with the occurrence and transport of MPs. Compared with laboratory-based MP analysis, these parameters are low-cost, routine monitoring, and can provide rapid preliminary information for identifying areas at risk of MP pollution. (Sturm *et al*., 2026; Theepharaksapan *et al*., 2025, Zhou *et al*., 2021). Therefore, integrating conventional water quality monitoring with MP assessment may improve environmental investigations and support more effective water quality management and pollution control strategies.

The U-Tapao Canal is one of the major waterways in Songkhla Province and an important part of the Songkhla Lake Basin. The canal supports various human activities, including agriculture, aquaculture,

domestic water supply, and local economic development. Rapid urbanization, industrial expansion, and agricultural activities within the watershed have increased the risk of plastic waste and MP contamination entering the canal through wastewater and surface runoff (Srichaichana *et al*., 2019). The canal not only provides a source of raw water for the production of tap water but also supports the livelihoods of local residents; however, MP pollution could present serious threats to water quality, aquatic ecosystems, and public health (Khempheera *et al*., 2025; Kingsley and Witthayawirasak, 2020). Therefore, investigating MP contamination in the U-Tapao Canal is essential for environmental monitoring, risk assessment, and the development of effective water pollution management strategies (Paul *et al*., 2026).

The study aimed to investigate MPs contamination in the surface water of the U-Tapao Canal, Songkhla Province, Thailand and to characterize both the quantitative and qualitative properties of MPs, including their abundance, color, shape, and polymer type. In addition, it was evaluated the relationships between selected water quality parameters such as turbidity, TDS, and TSS, and MP abundance.

Materials and methods

Study area and sample collections

This study was conducted in the U-Tapao Canal (Figure 1) located in Songkhla Province. Water samples were collected from a depth of 0 to 50 cm at seven sampling sites along the canal, starting from the Sadao Reservoir to the bridge at Ban Koh Nok, Khu Tao. A suction pump was used to collect 100 L of water at each site. The sampling sites include the following locations: UT1 is Sadao Reservoir, UT2 is Prik Subdistrict Municipality Telemetry Station, UT3 is Wat Muang Kong Telemetry Station, UT4 is Wat Bang Sala Telemetry Station, UT5 is Tha Khian Canal Bridge, UT6 is Ban Hat Yai Nai Telemetry Station, and UT7 is Ban Koh Nok, Khu Tao Canal Bridge.

The analytical of MP, water quality, and relationships from surface water

Preparation and characterization of MPs

MP samples from 7 sites were digested with hydrogen peroxide (H_2O_2, 30%) and then separated by density using a saturated sodium chloride (NaCl) solution. After that, the samples were filtered through GF/C glass microfiber filters and oven-dried at 50°C for 24 h. The particles on the microfiber filter were visually examined using a stereo microscope to characterize their shape (fiber or fragment), size (<500, 500–1,000, and >1,000 μm), and color (black, blue, transparent, or others). The hot needle test was employed in ambiguous cases. Particles smaller than 500 μm were

analyzed and identified using micro-Fourier Transform Infrared Spectroscopy (μFT-IR) in attenuated total reflectance (ATR) mode from 4,000–400 cm^{-1}. Polymer types were identified by comparison with a polymer reference database, and matches with a similarity score greater than 80% were accepted (Pradit *et al*., 2024).

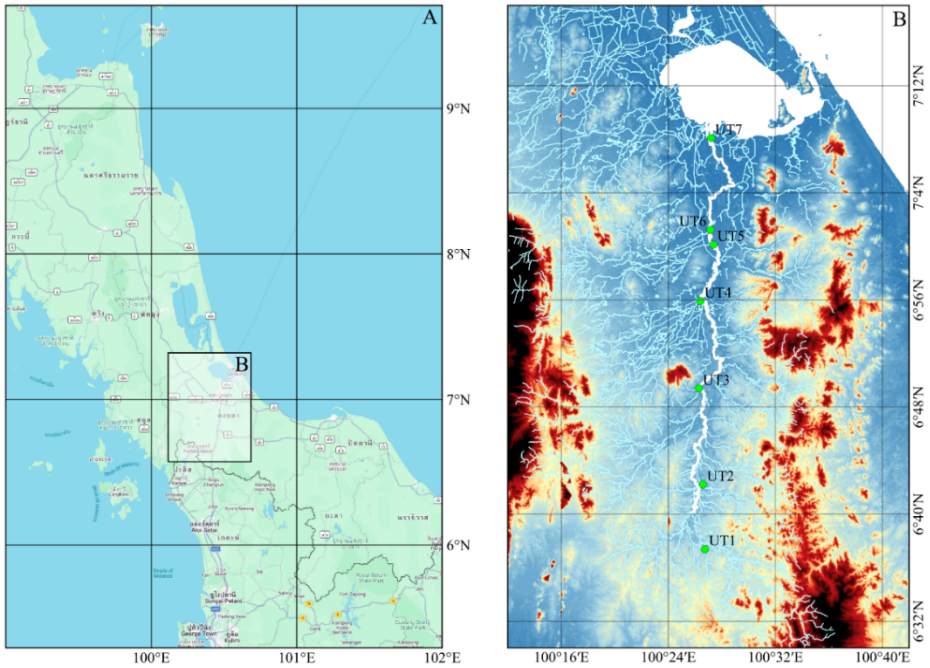


Figure 1. Study area A) the U-Tapao Canal located in the Southern Thailand B) Sampling station (solid green circles) along U-Tapao canal

Analysis of water quality

Surface water samples were analyzed for the following physical water quality parameters: turbidity, TDS, and TSS. Turbidity was determined using Standard Method Part 2130 (American Public Health Association *et al*., 2012), and TDS and TSS were determined using Standard Method Part 2540 (American Public Health Association *et al*., 1999).

Analysis of relationships between water quality parameters and MP contamination

The relationships between physical water quality parameters (turbidity, TDS, and TSS) and MP characteristics (color, shape, and polymer type) were tested using Pearson's correlation coefficient. Statistical significance was assessed at the 95% confidence level. The results were considered significant when the *p*-value was less than 0.05.

Results

MP abundance, color, shape, and polymer type

MP contamination was detected at all seven sampling sites in the U-Tapao Canal during the rainy season. The results showed an overall mean abundance of 11.44 ± 3.61 particles/L, as shown in Figure 2. The highest abundance was recorded at Ban Hat Yai Nai Telemetry Station (17.14 particles/L), while the lowest concentration was at Prik Subdistrict Municipality Telemetry Station (7.11 particles/L). This spatial variability is reflected differences in surface runoff and proximity to community activity across sites.

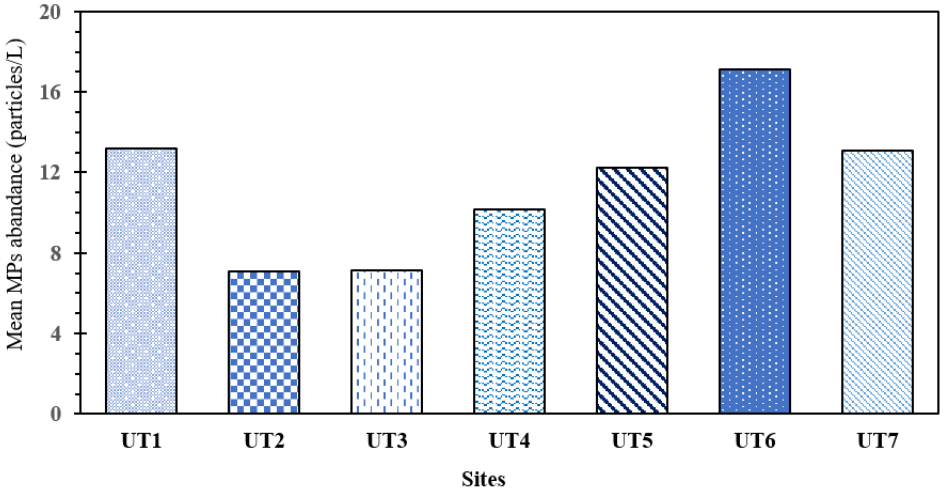


Figure 2. Abundance of MPs in the surface water of the U-Tapao Canal, Songkhla Province, during the rainy season

In the color analysis, blue MPs were found to be the most prevalent, with a concentration of 38.47 particles/L, representing 48.05% of the total. This was followed by MPs of other colors, which accounted for 26.36%. Transparent MPs accounted for 16.56%, while red MPs had the lowest abundance at 9.03%, consistently the least common across all sites, as shown in Table 1. Fiber-type MPs is strongly predominated at 53.79 particles/L (67.18%) over fragments at 32.82%, which is consistent with sources such as textile laundering, fishing gear, and rope (Figure 3).

The analysis of the shape of MPs in the U-Tapao Canal was classified into fiber and fragment types, as shown in Fig. 3. Fiber type was found to be the most common overall at 53.79 particles/L, which is 67.18% of the total, with a mean of 7.68 ± 2.64 particles/L. In comparison, fragment-type particles were measured at 26.28 particles/L, accounting for 32.82% of the total, with a mean value of 3.75 ± 2.42 particles/L. Fiber-type particles were

the majority shape at nearly every sampling site, except for UT6, where the fragment proportion of 11.28% closely approached that of fiber at 10.13%, creating the narrowest gap between the two shapes among all sites. The high number of fibers reflected sources such as textile laundering, clothing, and fishing gear, while the comparatively higher fragment proportion at UT6 may indicate localized breakdown of larger plastic debris during the rainy season.

Table 1. Analysis of MPs color in the surface water of the U-Tapao Canal, Songkhla Province, during the rainy season

Sites	Blue		Red		Transparent		Others		Total	
	Particles/L	%	Particles/L	%	Particles/L	%	Particles/L	%	Particles/L	%
UT1	9.01	11.25	2.15	2.69	0.03	0.04	2.01	2.51	13.20	16.49
UT2	4.07	5.08	0.01	0.01	1.00	1.25	2.03	2.53	7.11	8.88
UT3	3.08	3.85	0.01	0.01	2.02	2.52	2.01	2.51	7.12	8.89
UT4	5.09	6.36	0.02	0.02	4.03	5.03	1.03	1.29	10.17	12.7
UT5	4.13	5.16	3.01	3.76	3.07	3.83	2.02	2.52	12.23	15.27
UT6	11.06	13.81	0.01	0.01	1.06	1.32	5.01	6.26	17.14	21.41
UT7	2.03	2.54	2.02	2.52	2.05	2.56	7.00	8.74	13.10	16.36
Total	38.47	48.05	7.23	9.03	13.26	16.56	21.11	26.36	80.07	100
Average	5.50		1.03		1.89		3.02		11.44	
S.D.	3.30		1.31		1.35		2.15		3.61	

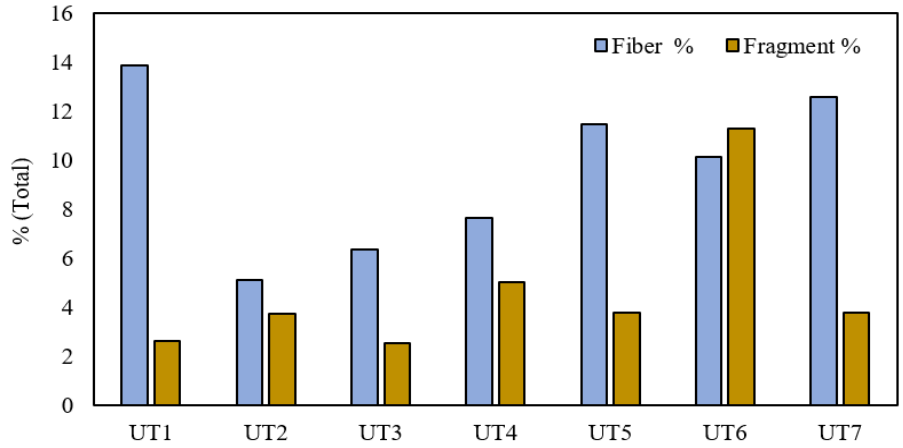


Figure 3. Percentage of fiber and fragment type MPs in the surface water of the U-Tapao Canal, Songkhla Province, during the rainy season

For the polymer type analysis, a total of 35 MP particles with 5 from each of the seven sites were examined via μFT-IR as shown in Table 2. PET was the dominant polymer with 17 samples (48.57%) of the total, followed by rayon with 9 samples (25.71%) and natural cotton with 5 samples (14.29%). Other polymers, including PA with 5.71%, PE with 2.86%, and PES with 2.86%, were detected in minor amounts, but PVC, PP, and PEI were not detected at any site. The high amount of PET is pointed to sources such as plastic packaging, drinking-water bottles, and synthetic fibers from community and industrial activities, while rayon and natural cotton reflect contamination from textiles and household laundering. The high PET proportion suggested rainfall-driven runoff plays a key role in transporting plastic debris from community areas into the canal during the rainy season.

Table 2. Analysis of MP polymer types in the surface water of the U-Tapao Canal, Songkhla Province, during the rainy season

Sites	Types of plastic in rainy season									Total
	PA	PE	PES	PVC	PP	PET	PEI	Rayon	Natural cotton	
UT1	0	1	0	0	0	3	0	1	0	5
UT2	0	0	0	0	0	2	0	3	0	5
UT3	1	0	0	0	0	2	0	1	1	5
UT4	1	0	0	0	0	2	0	1	1	5
UT5	0	0	0	0	0	2	0	2	1	5
UT6	0	0	0	0	0	3	0	1	1	5
UT7	0	0	1	0	0	3	0	0	1	5
Total	2	1	1	0	0	17	0	9	5	35
%	5.71	2.86	2.86	0	0	48.57	0	25.71	14.29	100

Physical water quality

Physical water quality parameters were found to be higher during the rainy season, as shown in Table 3. This increase was occurred because rainfall washing sediment into the water. The average turbidity was 114.45 ± 0.77 NTU, ranging from a low of 3.18 NTU at the Sadao Reservoir to a high of 167.00 ± 1.41 NTU at the Tha Khian Canal Bridge. The TSS averaged 48.07 ± 2.22 mg/L, with the lowest value recorded at the Sadao Reservoir at 1.00 ± 0.00 mg/L and the highest at the Wat Muang Kong Telemetry Station, which registered 72.50 ± 4.95 mg/L. The sites with low turbidity also had the lowest TSS, indicating that the water in that location was consistently clearer. The TDS averaged 118.57 ± 3.03 mg/L, with values varying by specific site rather than following a clear pattern. The highest TDS value of 146.0 ± 4.24 mg/L was recorded at Ban Koh Nok at the Khu Tao Canal Bridge.

Table 3. Analysis of physical water quality parameters in the surface water of the U-Tapao Canal, Songkhla Province, during the rainy season

Sites	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)
	Average ± S.D.	Average ± S.D.	Average ± S.D.
UT1	3.18 ± 0.04	1.00 ± 0.00	44.00 ± 4.24
UT1	74.33 ± 0.47	40.00 ± 4.95	108.5 ± 4.95
UT3	141.33 ± 1.25	72.50 ± 4.95	131.5 ± 2.12
UT4	146.67 ± 0.47	65.50 ± 0.71	135.50 ± 3.54
UT5	167.00 ± 1.41	70.50 ± 0.71	139.50 ± 0.71
UT6	151.33 ± 0.47	48.50 ± 2.12	125.00 ± 1.41
UT6	117.33 ± 1.25	38.5 ± 2.12	146.00 ± 4.24
Mean average	114.45 ± 0.77	48.07 ± 2.22	118.57 ± 3.03

Relationships between water quality parameters and MP contamination

This section is studied the relationship between physical water quality parameters (turbidity, TDS, and TSS) and the quantitative and qualitative characteristics of MP contamination in the surface water of the U-Tapao Canal, Songkhla Province. The results were shown using Pearson's correlation coefficient. Statistical significance (Sig.) and strength of association were characterized these relationships. The results indicated that each physical water quality parameter was linked to a different aspect of MP contamination, with no consistent pattern across all parameters (Table 4).

Table 4. Relationship between turbidity, TTD and TTS and MP abundance in the surface water of the U-Tapao Canal, Songkhla Province, during the rainy season

Parameter	Variable	Quantitative characteristics	Qualitative characteristics		
		MP count	Color	Polymer type	Shape
Turbidity	r	0.067	0.521	0.474	0.537
	Sig.	0.886	0.016*	0.087	0.048*
	Strength of Relationship	No relationship	Moderate relationship	No relationship	Moderate relationship
TDS	r	0.567	0.64	0.304	0.194
	Sig.	0.034*	0.014*	0.426	0.507
	Strength of Relationship	Moderate relationship	High relationship	No relationship	No relationship
TSS	r	0.551	0.221	0.524	0.391
	Sig.	0.041*	0.259	0.148	0.167
	Strength of Relationship	Moderate relationship	No relationship	No relationship	No relationship

**Statistically significant at the 0.05 level*

Turbidity was not significant related to MP abundance during the rainy season (r = 0.067, p = 0.886). However, it was significantly associated with qualitative characteristics, specifically color (r = 0.521, p = 0.016) and shape (r = 0.537, p = 0.048). Both characteristics exhibited moderate positive relationships, with color having a more notable effect. No relationship was found between turbidity and polymer type (r = 0.474, p = 0.087). These findings suggested that water turbidity may influence the diversity of MPs accumulated in the surface water of the U-Tapao Canal, rather than their overall abundance.

TDS was significantly related to both the count of MPs (r = 0.567, p = 0.034, moderate) and color (r = 0.640, p = 0.014, high). However, no relationship was observed between either polymer type or shape (both p > 0.05). These results indicated that during the rainy season, TDS was associated with both the abundance and color diversity of MPs, with the strongest association found for color.

TSS was significantly correlated only with the count of MP (r = 0.551 and p = 0.041), indicating a moderate relationship. No significant relationships were found between TSS and factors such as color, polymer type, or shape of the MPs. During the rainy season, TSS was specifically associated with the overall abundance of MPs, rather than their appearance.

Discussion

The surface water of the U-Tapao Canal, Songkhla Province was significantly contaminated with MPs during the rainy season with a mean abundance of 11.44 ± 3.61 particles/L. This was found in pattern with seasonal runoff theory (Allan and Castillo, 2007). The increased rainfall enables the transport of land-based plastic debris into water systems (Lebreton *et al*., 2017). The U-Tapao Canal acts as a crucial canal transporting plastic waste from community and industrial areas into Songkhla Lake. It reinforces a pathway for terrestrial wastes to affect the transport of MPs. The sites near the community areas found higher MP concentrations that support urban and industrial wastewater combined with rainfall-driven surface runoff, which are primary contributors to MP loading in canal ecosystems (Adeel *et al*., 2024). The elevated abundance during the rainy season showed a relationship between rainfall volume and MP distribution (Jitkaew *et al*., 2023; Pradit *et al*., 2023).

The characteristics of qualitative MPs include color, shape, and type. The color was the highest evaluated as blue (48.05% of all samples). The shape of MPs was found to be fiber-shaped particles (67.18% of all samples). These results of color and shape are related to previous studies which identified textile laundering and fishing activities (Hidalgo-Ruz *et al*., 2012). The polymer type identified was PET (48.57%), confirming consumer

packaging, drinking bottles, and synthetic textiles in the local waste stream. The high amount of PET causes the rainy season to significantly transport materials from community areas into the canal system (Campanale *et al.*, 2020; Zhang *et al*., 2017).

The correlation analysis of different MPs contamination with water quality parameters showed that turbidity (mean 114.45 NTU) which significantly linked to MP color and shape, but not to abundance. This turbidity did not necessarily predict the quantity of MPs. It is reflected the transport mechanism of suspended particulate matter that physically associates with specific low-density fiber and fragment shapes (APHA, 2017; Lestari *et al*., 2025; Wagner and Lambert, 2018). In contrast, TSS (mean 48.07 mg/L) showed a significant moderate relationship ($r = 0.551$) with MP abundance. This is supported the suspended particle transport theory. MP particles are aggregated and migrated alongside suspended sediment loads during high-flow conditions (Ahmed *et al*., 2026; Eerkes-Medrano *et al*., 2015). The study of TDS (mean 118.57 mg/L) was significantly related to both MPs abundance (moderate) and color (high). This is indicated that MPs are dissolved contaminants from industrial and agricultural runoff and occur with MPs sources, providing an effective indicator for both the quantitative and qualitative diversity of MP pollution (Cole *et al*., 2011; Horton *et al*., 2017; Lestari *et al*., 2025).

These research findings showed that no single water quality parameter can fully capture the complexity of MPs contamination. Instead, water quality parameters such as turbidity, TSS, and TDS provided complementary data. Turbidity is associated with the qualitative diversity (shape/color), while TSS and TDS track the quantitative abundance of particles. This integrated approach to data collection is essential for predictive risk assessment and long-term ecological monitoring. These physical parameters can serve as low-cost proxy indicators to help prioritize sampling locations and design targeted pollution control strategies for the U-Tapao Canal watershed. Future studies would incorporate dry-season data, upstream source tracking, and expanded sampling sites would further strengthen these relationships and provide a more comprehensive baseline for environmental management.

Acknowledgements

The author would like to express sincere gratitude to Prince of Songkla University for its support throughout this research.

Conflicts of interest

The authors declare no conflict of interest.

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(Received: 8 September 2026, Revised: 17 November 2026, Accepted: 18 November 2026)