



Contamination of Microplastics in Surface Waters of Kapuas Kecil Estuary West Kalimantan

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ABSTRACT

Microplastics are an emerging pollutant of global concern due to their persistence and potential ecological impacts. This study assesses the types and abundance of microplastics in the surface waters of Kapuas Kecil Estuary, West Kalimantan. Sampling was conducted during low and high tides at three stations representing different levels of human activity. Microplastics were identified by morphology and categorized into fragments, fibers, films, and pellets. Results showed that microplastics were present at all stations, with abundances ranging from 62.40 to 172.80 particles/L. The highest concentrations were observed at Station III, which is influenced by ship traffic, factories, and industrial activities, while the lowest values occurred at Station I. Overall, fragments were the most dominant form, followed by fibers, while films and pellets were relatively rare. Total abundance was higher during high tide (427.20 particles/L) compared to low tide (300.96 particles/L), indicating the influence of tidal currents on microplastic distribution. These findings provide baseline information on microplastic contamination in the Kapuas Kecil Estuary and highlight the need for improved waste management in the region.

INTRODUCTION

Plastic pollution is a major global issue due to its persistence and complex management challenges (Beaumont *et al.*, 2019). Plastics dominate marine litter, and their accumulation in aquatic environments has steadily increased over the past four decades (Thompson *et al.*, 2004). Globally, 4.8-12.7 million metric tonnes of plastic enter the oceans each year (Jambeck *et al.*, 2015), with Indonesia ranked as the second-largest contributor, releasing 0.48-1.29 million metric tonnes annually (Cordova & Wahyudi, 2016; Widianarko & Hantoro, 2018). Plastic debris undergoes fragmentation into particles smaller than 5mm, known as microplastics (Masura *et al.*, 2015).

Microplastics have been identified across multiple environments, including oceans, soil, freshwater bodies, air, and within biological systems (Yona *et al.*, 2021;

Prapanchan *et al.*, 2023). The presence of microplastics in seawater, sediments, soil, and biological tissues has been widely reported, indicating their widespread occurrence (**Cole *et al.*, 2011; Da Costa *et al.*, 2016**). Microplastics have also been detected in salt, with artisanal salt having up to 29.000 particles/kg and commercial salt up to 110 particles/kg (**Ula *et al.*, 2025**). Human exposure to microplastics commonly occurs through ingestion, inhalation, and skin contact, with ingestion being the primary route (**Prata *et al.*, 2020; Li *et al.*, 2023**). Some studies have shown that microplastic may induce inflammation, oxidative stress, and tissue damage, and have also been associated with reproductive impairment in humans (**Barboza *et al.*, 2020; D'Angelo & Meccariello, 2021; Bhuyan, 2022**). In addition, other studies show that microplastics may accumulate in the body over time and lead to long-term negative effects on health, including cardiovascular disease, cancer, and autoimmune disorders (**Akhbarizadeh *et al.*, 2019; Sharma *et al.*, 2020; Amato-Lourenço *et al.*, 2021; Blackburn & Green, 2022; Ghosh *et al.*, 2023**).

Estuaries, as transitional ecosystems, often act as sinks for microplastics delivered by rivers (**Schmidt *et al.*, 2017**). Studies show that estuarine and coastal systems are hotspots of microplastic contamination, including Jakarta Bay, where ~2,900 particles have been reported (**Takarina *et al.*, 2022; Rakib *et al.*, 2023**). Kapuas River, West Kalimantan is surrounded by diverse anthropogenic activities, including aquaculture, small ports, domestic use, fish landing sites, and industries. These activities, along with estuaries acting as microplastics sinks, indicate a significant potential for microplastic pollution.

Previous study on microplastics in the Kapuas River was conducted by **Sugandi *et al.* (2021)**, who identified various microplastic types and polymers in river water, including fragments, filaments, fibers, pellets, and foam, with a total abundance of 943.3 particles/L. However, most previous studies have limited temporal coverage, often based on single or short-term sampling, which limits understanding of tidal influences on microplastic distribution. By sampling surface water during both low and high tides at the Kapuas Kecil Estuary, this study provides insight into the effects of tidal dynamics on the abundance and composition of microplastics in an understudied estuarine environment. Specifically, this study aims to: (1) identify the types of microplastics in surface waters of the estuary, (2) determine their abundance during low and high tides across different stations, and (3) identify the polymer composition of the detected microplastics. The results are expected to provide baseline information on microplastic pollution levels in the estuary and serve as an important reference for future research and decision-making regarding plastic waste management in the region.

MATERIALS AND METHODS

Study area and sampling period

The research was conducted from February to September 2025 in the surface waters of Kapuas Kecil Estuary, West Kalimantan (Fig. 1). Water samples were collected during spring tide at two tidal phases (low and high tide). Three sampling station were

established to represent the overall Kapuas Kecil estuarine system, covering the transition from riverine to coastal environments and capturing spatial variations in hydrodynamic and anthropogenic influences. The stations were located at Station I ($0^{\circ}0'48.11''\text{N}$, $109^{\circ}15'59.59''\text{E}$), Station II ($0^{\circ}1'31.24''\text{N}$, $109^{\circ}12'10.43''\text{E}$), and Station III ($0^{\circ}2'34.72''\text{N}$, $109^{\circ}12'46.61''\text{E}$). Sample processing and abundance analysis were conducted at the Marine Science Laboratory, Faculty of Mathematics and Natural Sciences, Tanjungpura University. Polymer identification was carried out using Fourier Transform Infrared (FTIR) spectroscopy at the Chemistry Laboratory, Tanjungpura University.

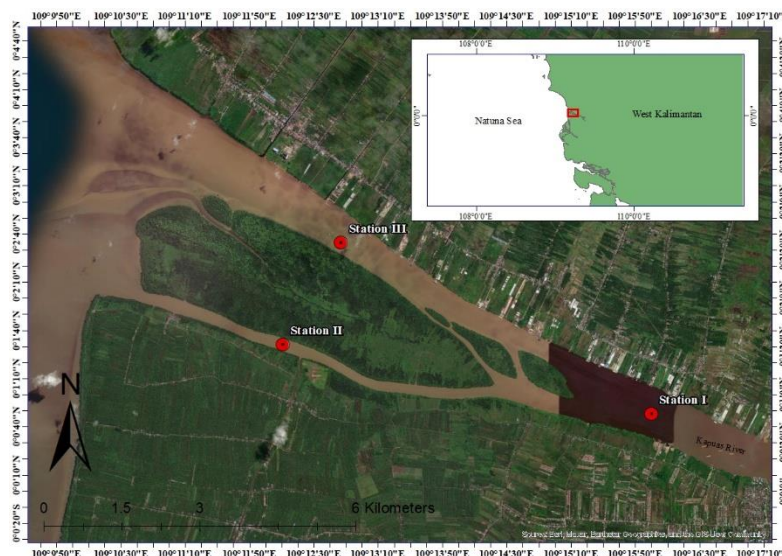


Fig. 1. Location map with three stations in Kapuas Kecil Estuary, West Kalimantan

Materials and methods

Research equipment included plankton net, stainless steel bucket, 140 mL glass bottles, container box, glass funnels, buchner funnel, beaker glasses, measuring cylinder, Global Positioning System (GPS), camera, filter paper (sheet and $0.45\mu\text{m}$ 47mm diameter), label, volumetric flask, microscope Smartcare XSZ-107BN, object glass, glass petri dish, forceps, dropping pipette, and sprayer. Chemical reagents included sulfuric acid (H_2SO_4 , 30%), hydrogen peroxide (H_2O_2 , 30%), and distilled water.

Sampling procedures followed **Harpah *et al.* (2020)** and **He *et al.* (2024)**, with modifications. Surface water samples (0-30cm depth) were collected using a stainless steel bucket, with a total volume of 40L that was then filtered through a plankton net. Samples were transferred into pre-cleaned 140mL glass bottles, marked at 50mL, labeled according to station, and transported to the laboratory for further preparation. Sample preparation referred to **Susanto *et al.* (2022)**, with modifications. Each sample was filtered through filter paper, then treated with a mixture of 30% H_2SO_4 and 30% H_2O_2 (3:1 ratio, 20mL total). The mixture was covered with aluminum foil and was left to digest for 48h. After digestion, samples were re-filtered using $0.45\mu\text{m}$, 47mm filter

papers and dried before microscopic analysis. Microplastic particles were identified under a compound microscope at 4x to 10x magnification. Classification was based on visual characteristics such as shape and color. Polymer types were identified using FTIR spectroscopy following standard procedures, by eluting retained particles from the filter into distilled water and analyzing the residue at the Chemistry Laboratory, Universitas Tanjungpura.

Data Analysis

Microplastic abundance in surface water was calculated following **APHA (1989)** using the formula:

$$K = (Q_1/Q_2) \times (V_r/V_o) \times (1/P) \times (1/V) \times n_i$$

Where:

K = abundance (particles/L);

Q_1 = filter paper area (1,734.95 mm²);

Q_2 = microscope field of view area (1.1279 mm²);

V_r = volume of concentrated sample (50 mL);

V_o = volume of sample observed (50 mL);

P = number of fields of view observed (81);

V = volume of filtered water (40 L);

n_i = number of counted particles.

RESULTS AND DISCUSSION

1. Types of microplastics

Four types of microplastics were identified: fragments, fibers, films, and pellets (Fig. 1). Fragments and fibers dominated across all stations and tidal conditions, while films and pellets were less common. Previous research conducted by **Sugandi *et al.* (2021)** reported similar forms in the Kapuas River, including fragments, fibers, pellets, filaments, and an additional type, foam. In contrast, foam was absent in the present study, likely due to sinking or transport offshore.

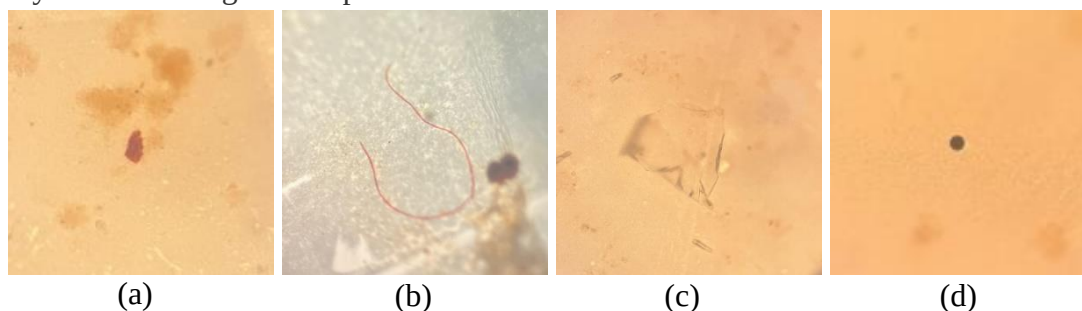


Fig. 1. Characteristics of microplastic in Kapuas Kecil Estuary, West Kalimantan: (a) Fragment (b) Fiber (c) Film (d) Pellet

Fragments result from the fragmentation of macroplastics, typically derived from anthropogenic sources such as household activities and denser plastic materials like pipes, bottle caps, and buckets (Andrady, 2011; Mauludy *et al.*, 2019). Fibers, associated with fishing gear and textiles (Browne *et al.*, 2011; Zhao *et al.*, 2018), were the second most common type. Films, derived from plastic bags and packaging, and pellets, as primary microplastics from industrial raw materials (Dewi *et al.*, 2015), were relatively rare in the study area.

The form of microplastics is strongly influenced by polymer type, which determines buoyancy in aquatic systems (Issac & Kandasubramanian, 2020). Low-density polymers such as polypropylene (PP) and polyethylene (PE) tend to float, whereas denser polymers such as polyethylene terephthalate (PET), polystyrene (PS), and cellulose acetate (CA) tend to sink (Driedger *et al.*, 2015). Floating particles may remain suspended temporarily but often sink once biofouling increases their density. Grazing on biofilm by organisms can also reduce particle density, allowing temporary resurfacing before repeated sinking cycles occur (Alimi *et al.*, 2021). Once settled on the seabed, microplastics are shielded from UV radiation, slowing degradation (Corcoran, 2015).

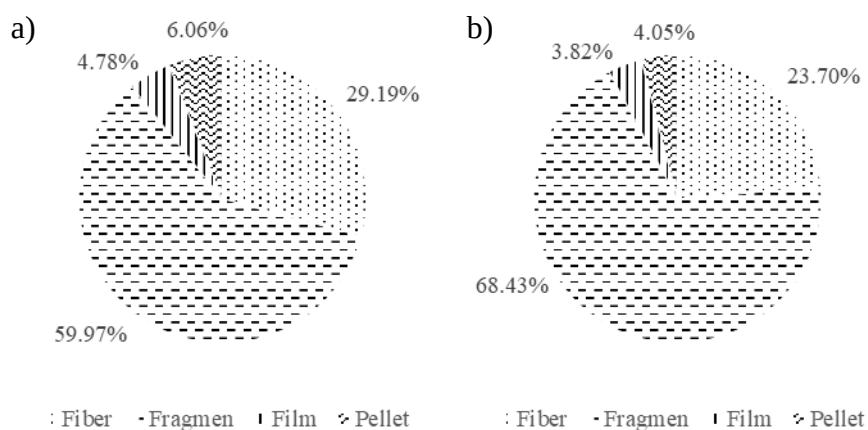


Fig. 2. Composition of microplastics types in surface water during (a) low tide and (b) high tide at Kapuas Kecil Estuary

Microplastics observed during low and high tides showed consistent composition. Fragments were the dominant form, representing 59.97% at low tide and 68.43% at high tide, followed by fibers at 29.19% and 23.70%, respectively (Fig. 2). Pellets and films were low in abundance in both phases, each representing less than 10%; pellets represented 6.06% at low tide and 4.05% at high tide, while films represented 4.78% and 3.82%, respectively. Fragments were mainly composed of polyethylene terephthalate (PET, 50–60%), polypropylene (PP, 25–30%), and polyethylene (PE, 10–20%). Fibers consisted of PP (50%), PE (33%), nylon (10%), and polystyrene (PS, 5%) (Silva & Nanny, 2020). This dominance may be explained by the persistence of semi-crystalline

polymers such as PP, PE, and PET are more resistant to degradation (Issac & Kandasubramanian, 2020).

2. Abundance of microplastics

Microplastic abundances ranged from 62.40 to 172.80 particles/L (Table 1). Station III consistently recorded the highest concentrations, followed by Station II, while Station I showed the lowest. Abundance was higher during high tide (427.20 particles/L) compared to low tide (300.96 particles/L), reflecting the role of tidal currents in redistributing suspended materials (Oo *et al.*, 2021).

Table 1. Abundance of microplastics in Kapuas Kecil Estuary, West Kalimantan

Phase	Abundance (Particles/L)		
	Station I	Station II	Station III
Low Tide	62,40	100,80	137,76
High Tide	117,12	137,28	172,80

Difference in microplastic abundance across station indicate variations in environmental conditions. Station I, located near a fuel station and fishing sites but outside the main shipping lane, showed relatively low values. Station II, located on a narrower river branch within the delta, surrounded by dense riparian vegetation, close to the confluence of the Kupah and Kapuas rivers, and outside the main navigation route, showed intermediate abundance. Station III, located close to cement factories, warehouses, shipyards, and a fuel terminal, showed the highest abundance due to industrial discharges, heavy ship traffic, and inputs from tributaries.

Fragments dominated at all stations (24.00-115.20 particles/L), followed by fibers (18.24–49.92 particles/L). Films and pellets were the least common types, with films ranging from 1.92-8.16 particles/L and pellets from 1.44-8.64 particles/L (Fig. 3). The low abundance of microplastic films may result from biofouling, which increases particle density and reduces buoyancy, causing the particles to sink to the bottom of the water column. Smaller microplastic particles, such as films, are predicted to sink more rapidly because less biofilm formation is required to enhance their sinking (Fazey & Ryan, 2016; Kooi *et al.*, 2017). Pellets were rare, consistent with the absence of major plastic manufacturing activities in the study area.

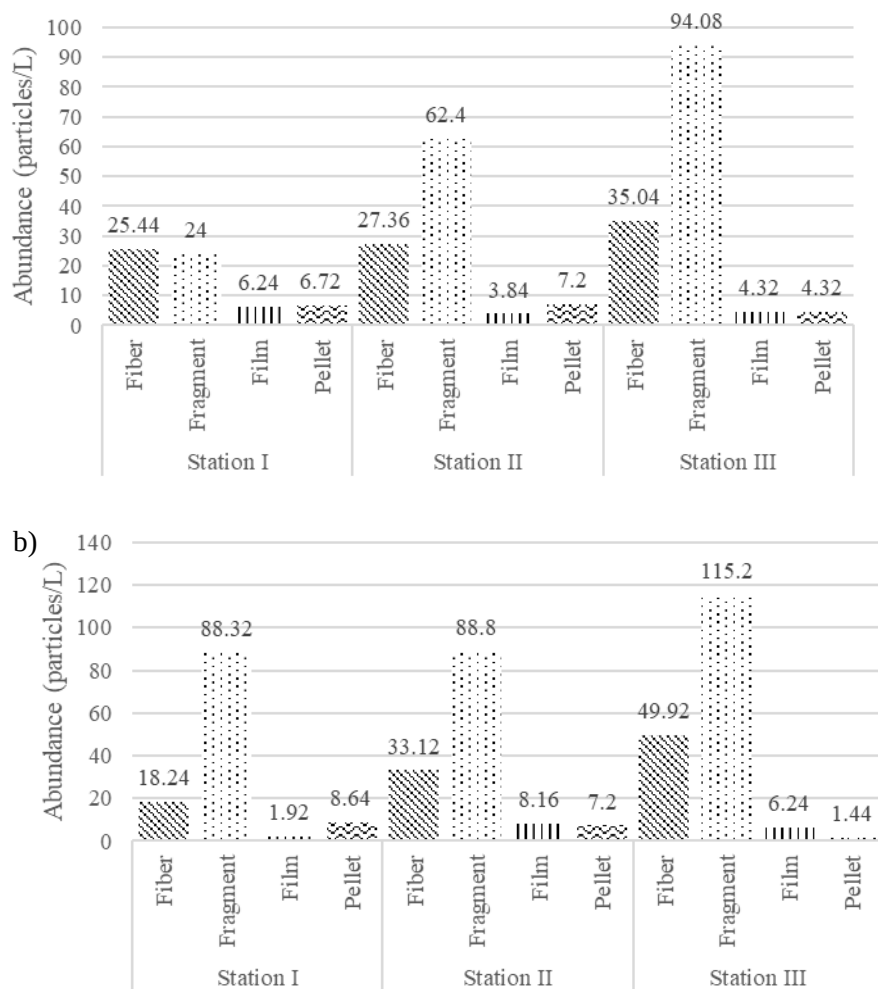


Fig. 3. Abundance of microplastics at each station: a) Low tide and b) High tide

During low tide, the total abundance of microplastics reached 300.96 particles/L, with station values ranging from 3.84 to 94.08 particles/L (Fig. 3a). Station I showed abundances between 6.24 and 25.44 particles/L. Fibers were most abundant at this station (25.44 particles/L; 40.77%), followed by fragments (24 particles/L; 38.46%), pellets (6.72 particles/L; 10.77%), and films (6.24 particles/L; 10%). Station II recorded abundances from 3.84 to 62.40 particles/L, dominated by fragments (62.40 particles/L; 61.9%), followed by fibers (27.36 particles/L; 27.15%), pellets (7.20 particles/L; 7.15%), and films (3.84 particles/L; 3.8%). At Station III, abundances ranged from 4.23 to 94.08 particles/L, with fragments being dominant (94.08 particles/L; 68.29%) and fibers second (35.04 particles/L; 25.43%). Films and pellets were least abundant (4.32 particles/L; 3.14%).

During high tide, the total microplastic abundance increased to 427.20 particles/L, with station values ranging from 1.44 to 115.20 particles/L (Fig. 3b). Station I recorded abundances of 1.92–25.44 particles/L, dominated by fragments (88.32 particles/L;

75.41%), followed by fibers (18.24 particles/L; 15.57%), pellets (8.64 particles/L; 7.38%), and films (1.92 particles/L; 1.64%). Station II ranged from 7.20 to 88.80 particles/L, with fragments again dominant (88.80 particles/L; 64.69%), followed by fibers (33.12 particles/L; 24.13%), films (8.12 particles/L; 5.94%), and pellets (7.20 particles/L; 5.24%). Station III recorded the highest values (1.44–115.20 particles/L), with fragments dominant (115.20 particles/L; 66.67%) and fibers second (49.92 particles/L; 28.89%). Films (6.24 particles/L; 3.61%) and pellets (1.44 particles/L; 0.83%) remained the least common types.

Differences in microplastic abundance among stations are also influenced by tidal dynamics and water mass circulation. Sampling in this study was conducted during spring tide (Fig. 4), a phase characterized by the highest high tide and lowest low tide, which typically occurs during new and full moons and generates strong currents. In contrast, neap tide, which occurs when the moon is positioned at 90° from the sun, produces weaker currents (**Kisnarti & Prasita, 2019**). Tidal motion in rivers, estuaries, and bays produces bidirectional flows: during flood tide, seawater levels exceed those of the estuary, causing water to flow landward, while during ebb tide, estuarine levels exceed seawater levels, producing seaward flows (**Kisnarti & Prasita, 2019**). These dynamics affect suspended matter retention and transport, explaining why microplastic abundance during high tide was higher than during low tide at all stations (**Oo *et al.*, 2021**). Tidal currents strongly influence circulation, distribution, and residence time of suspended materials in semi-enclosed waters such as estuaries (**Putu, 2019**). Pollutants, including microplastics, can thus be mixed throughout the water column (**Mustiawan *et al.*, 2014**; **Sadri & Thompson, 2014**). Near-bottom tidal currents maintain microplastics in resuspension, while turbulence at the seabed surface prevents settling (**Lemckert *et al.*, 2004**; **Bagaev *et al.*, 2017**). This resuspension process may reintroduce microplastics into the water column (**Zhou *et al.*, 2021**).

3. Polymer types of microplastics

FTIR spectral analysis of surface water samples during low and high tides revealed several similarities in functional groups across sampling stations. At Station I during low tide, absorption peaks at 2,923.74 cm⁻¹ (asymmetric CH₂ stretching), 2,856.04 cm⁻¹ (symmetric CH₂ stretching), and 1,744.94 cm⁻¹ (C=O stretching) indicated the presence of polyethylene (PE), while a peak at 1,087.41 cm⁻¹ (C–C stretching) suggested high density polyethylene (HDPE). Station II showed peaks at 2,925.24 cm⁻¹ (asymmetric CH₂ stretching), 2,857.36 cm⁻¹ (symmetric CH₂ stretching), 1,743.80 cm⁻¹ (C=O stretching), and 1,461.57 cm⁻¹ (–CH₂ scissoring), confirming PE, whereas a peak at 574.60 cm⁻¹ (C–Cl stretching) indicated polyvinyl chloride (PVC). At Station III, peaks at 3,322.34 cm⁻¹, 3,230.08 cm⁻¹, and 3,186.86 cm⁻¹ corresponding to N–H stretching suggested nylon, with C–Cl stretching at 695.13 cm⁻¹ and 637.46 cm⁻¹ indicating PVC.

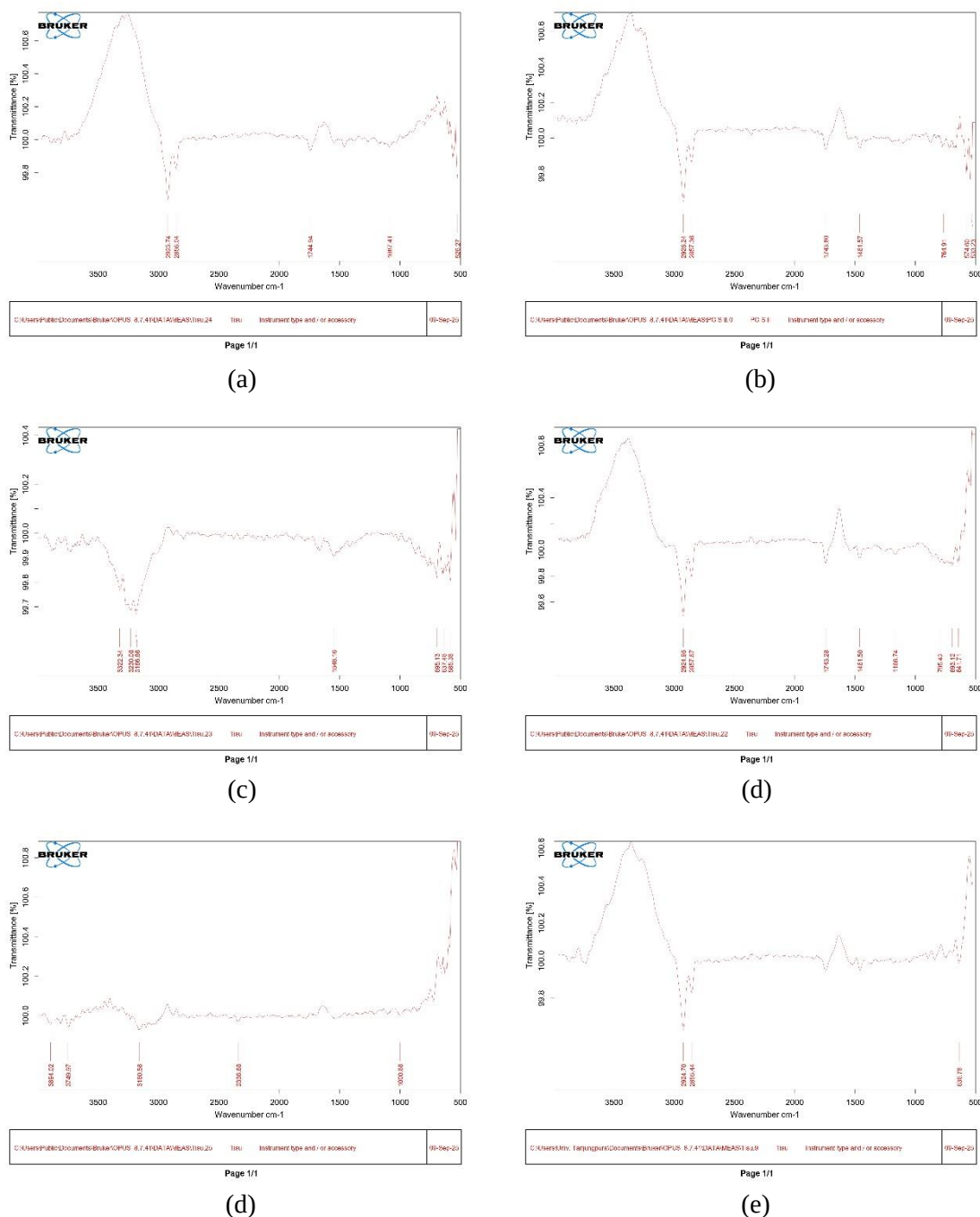


Fig. 4. FTIR spectra of microplastic samples, during low tide: (a) Station I (b) Station II (c) Station III, during high tide: (a) Station I (b) Station II (c) Station III

During high tide, Station I exhibited peaks at 2,924.95 cm⁻¹ (asymmetric CH₂ stretching), 2,857.67 cm⁻¹ (symmetric CH₂ stretching), 1,743.28 cm⁻¹ (C=O stretching), and 1,461.50 cm⁻¹ (-CH₂ scissoring), confirming PE, while C-Cl stretching at 641.71 cm⁻¹ indicated PVC. Station II showed N-H stretching at 3,894.02 cm⁻¹, 3,749.97 cm⁻¹,

and $3,160.58\text{ cm}^{-1}$, indicating nylon. Station III displayed a C–Cl stretching peak at 636.78 cm^{-1} , confirming PVC.

Overall, the polymers identified in surface water from the Kapuas Kecil Estuary were PE, HDPE, PVC, and nylon. Similar polymers, along with PP, PS, and PTFE, have been reported in the Kapuas River (**Sugandi *et al.*, 2021**). PE and PP, with densities lower than water ($0.83\text{--}0.85\text{ g/mL}$), are widely distributed in Asia and tend to float at the water surface (**Driedger *et al.*, 2015**; **Hamid *et al.*, 2018**; **Ramadhan & Sembiring, 2020**). HDPE is produced under high pressure and temperature from petroleum and exhibits greater strength and durability than PET (**Karuniatuti, 2013**; **Widiyatmoko *et al.*, 2015**). PVC, a chlorine-containing plastic, is difficult to recycle and used in cables, pipes, and containers, releasing toxic compounds when burned (**Widiyatmoko *et al.*, 2015**; **GESAMP, 2021**; **Nurito *et al.*, 2022**). PE is commonly used in bags and containers, while nylon is applied in fishing nets and ropes (**GESAMP, 2021**).

CONCLUSION

This study confirms the presence of microplastic contamination in the surface waters of the Kapuas Kecil Estuary, West Kalimantan. Four types of microplastics were identified—fragments, fibers, films, and pellets—with fragments and fibers being dominant. Abundance ranged from 62.40 to 172.80 particles/L, with the highest values observed at Station III and the lowest at Station I. Although the stations were selected as representative sites, differences in their surroundings, such as proximity to settlements, shipping lanes, and industrial zones, may partly explain the variation. Abundance was also higher during high tide (427.20 particles/L) than low tide (300.96 particles/L), indicating the influence of tidal currents on microplastic redistribution. These results provide important baseline data on microplastic pollution in an estuarine system shaped by both natural processes and human activities.

For future research, broader temporal and spatial coverage is needed, including sediments, vertical water profiles, and biota to evaluate ecological impacts. Advanced analytical techniques should be applied for more precise polymer identification and source tracking, while hydrodynamic modeling combined with socio-environmental assessments would strengthen understanding of transport mechanisms and support effective mitigation strategies.

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