Microplastics in the Water of Batang Anai Estuary, Padang Pariaman Regency, Indonesia: Assessing Effects on Riverine Plastic Load in the Marine Environment

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ABSTRACT

Microplastic (MP) is one of the most dangerous contaminants due to its ecotoxicological impact on the aquatic environment, aquatic biota, and human health. Defined as particles less than 5 mm, these contaminants originates from either primary or secondary source. Therefore, this study aimed to analyze the abundance, shape, color, size, and type of microplastic (MP) polymers. In the process, water samples were collected from 3 distinct points in the Batang Anai River, to obtain MP. Subsequently, analysis was conducted using a microscope and Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR). The results showed that the abundance of MP in the water samples ranged from 37-77 particles/L, and the most dominant shapes, colors, and sizes identified were fragments (49.44%), black (48%), and sizes >1,000 μm (33%), respectively. Characterization and interpretation of functional groups in the FTIR spectrum indicated the presence of cellulose polymer, ethylene-propylene copolymer, neoprene, and polyester. In conclusion, this report can be used as initial information to help control plastic waste pollution.

1. INTRODUCTION

Plastic waste is a global environmental pollutant, posing a threat to ecosystems (GESAMP, 2015), aquatic biodiversity (Urbina et al., 2021), air quality (Lopez-Rojo et al., 2020), and human health (Sutherland et al., 2011). The exponential growth in this material is anticipated to persist, with disposal and accumulation in landfills affecting aquatic ecosystems (Geyer et al., 2017). Currently, plastic constitutes 54% of the world's human waste by mass (Hoellein et al., 2014). This is because it can last a very long time before being degraded (Barboza et al., 2019) due to weathering which breaks down long chain polymers into smaller pieces (Rodrigues et al., 2018; Zhang et al., 2021), facilitating digestion by aquatic biota and integration into food web (Da Costa et al., 2017).

MP pollution is as a focal point of investigations into plastic waste. These minutes plastic particles are globally available in oceans, rivers, lakes, soil, and organisms (Du et al., 2021). Both densely populated cities and remote region face threat from MP pollution (Feng et al., 2021; Sekudewicz et al., 2021). While slow-flow areas, such as oceans, lakes, and reservoirs can become dumping grounds, rivers serve as conduits connecting the waste to terrestrial environment (Ho et al., 2020). The Batang Anai River spanning 54.6 km passes through 2x11 sub-districts of Anam Lingkuang, Lubuak Aluang, and Batang Anai in Padang Pariaman Regency, Indonesia (CSA, 2016). Furthermore, it originates in Tanah Datar District and empties into Muara Anai in Padang Pariaman District. This river plays a crucial role in supporting agriculture, forestry,

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fish farming, sand mining, settlement, and industrial activities. However, increased human activities, particularly deforestation and the construction of flood control canals and settlements, have negatively impacted the water quality.

No study or publication addresses the content of MP in the Batang Anai River. Therefore, it is necessary to conduct an investigation to (1) systematically examine the incidence of MP pollution in the Batang Anai River as well as (2) explain and analyze the distribution characteristics of the particles in the Batang River. The results of this investigation will contribute to the understanding of MP pollution in freshwater environments, serving as a primary reference for future studies. This can inform initiatives aimed at reducing plastic usage, improving recycling practices, and enhancing overall environmental protection.

2. METHODOLOGY

2.1 Description of the study site

The study was conducted on the Batang Anai River, Padang Pariaman Regency, West Sumatera, Indonesia, from January-February 2023. Samples of river water was collected 3 times (January 1, January 30, and February 28) from 3 different stations, namely ST 1, ST 2, and ST 3, which were upstream waters Anai Trunks, water on the Tidal Bridge, and water body at the mouth of the Batang Anai River, respectively. The selection of these stations was based on consideration of regional conditions and characteristics of the study area, aw presented in Figure 1 and Table 1.

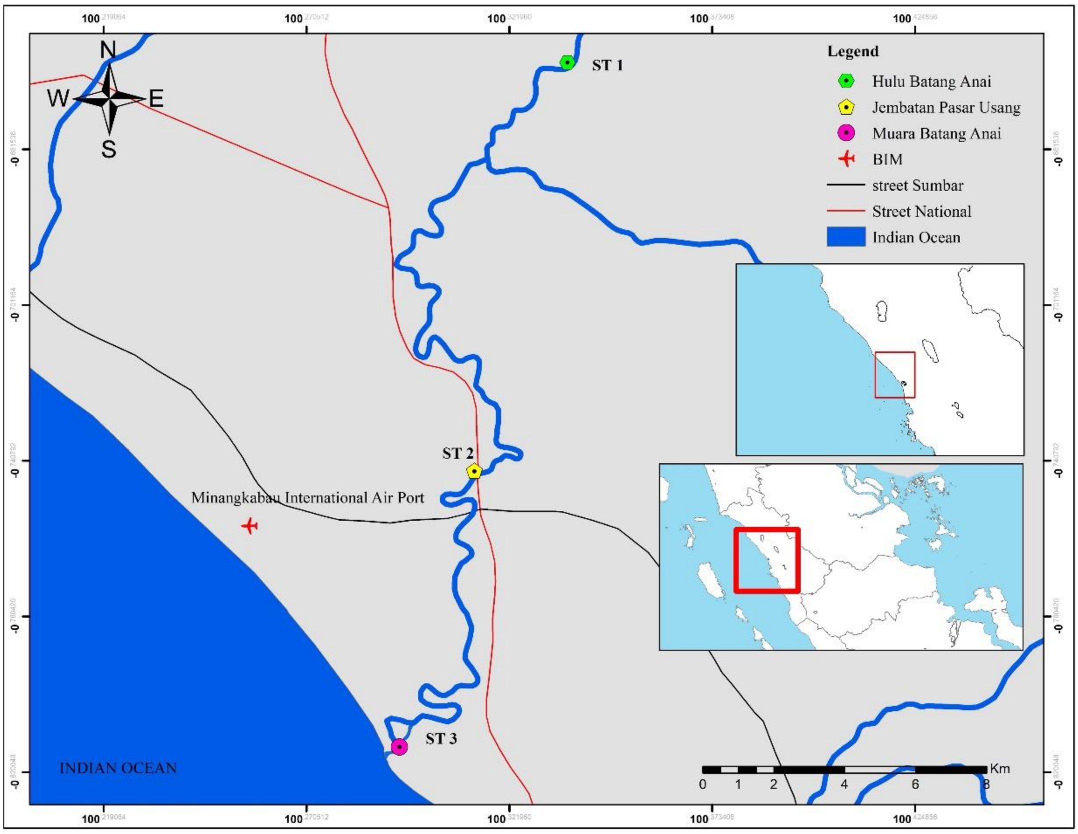

Figure 1. Batang Anai Research Locations [Source: Geospatial Agency of Special Region of Pariaman Regency (2020)]

2.2 Sampling of water

River water was collected using a 5 L bucket and filtered 20 times through a plankton net No. 25. Subsequently, the filtered samples were transferred into HDPE sample bottles to prevent particle contamination and stored in a cool box (Cordova et al., 2019; Deswati et al., 2023a; Deswati et al., 2023b).

2.3 MP extraction

Approximately 20 mL of 30% H_2O_2 was added to the water samples, and the mixture was homogenized with a magnetic stirrer for 5 min. The samples were then covered with aluminum foil to avoid environmental pollution and left undisturbed for 24 h. An extra 30% H_2O_2 was added until impurity disappeared. Furthermore, filteration was performed using Whatman filter paper no 42 with the help of a vacuum pump. The filtered particles were identified visually under a microscope, and the suspected MP was counted (Cordova et al., 2019; Deswati et al., 2023a; Deswati et al., 2023b).

Table 1. Sampling locations

Station/Coordinate	Description
Station 1 (ST 1) 0° 38' 22.03" S 100° 20' 12.24" E	This location is characterized by clear river water, large boulders, sandy bottom substrate, fast water, and no pollution. Activities in the dam: water tourism, the forest is still dense, the activity of the population is still tiny, and there are no macrobenthos.
Station 2 (ST 2) 0° 44' 36.00" S 100° 18' 47.20" E	The waters of the middle part of the Batang Anai River are characterized by high sedimentation, turbid water, slow water flow, sandy mud bottom substrate, high residential activity, community sand mining, and lots of macro-zoobenthos.
Station 3 (ST 3) 0° 48' 49.08" S 100° 17' 38.66" E	The Batang Anai estuary is characterized by high pollution, high residential activity, ship activity at the Muara Anai Fishery Port, Cooking Oil Factory, sand mining activities, sandy mud bottom substrate, turbid water, lots of macrozoobenthos, and brackish water.

2.4 MP identification

Visual inspection was conducted to obtain MP based on the characteristics. The particles were observed, photographed, and marked using a camera-equipped trinocular microscope (B-350 Optika). MP was determined using Moticplus 3.0 software, and the parameters recorded were size, shape, and color. Its forms are categorized into fibers, fragments, films, and granules. Furthermore, size categories included <100 μm, 101-300 μm, 301-500 μm, 501-1,000 μm, and >1,000 μm (Cordova et al., 2019; Deswati et al., 2023c).

2.5 MP analysis

All tagged items were confirmed using a PerkinElmer Spectrum Spotlight 400 micro-Fourier transshape infrared spectroscope (μ-FT-IR; Perkin-Elmer Inc., U.S.A.) (Ding et al., 2018). Attenuated total reflection mode (ATR) was used, and germanium (Ge) crystals in the ATR imaging attachment were in direct contact with the MP. Spectra were obtained from spectral and spatial resolution of 8/cm and 6.25 μm (the highest spatial resolution was 1.56 μm), respectively, within the spectral range of 4,000 to 750/cm with 16 Coscans for each measurement. This enabled the identification of MP diameters up to 6.25 μm. The resulting spectra were compared with the database from Sadltler to confirm polymers, with spectra matches exceeding 70% considered reliable (Su et al., 2020). Non-plastics were removed from the MP count and recalculation was conducted.

2.6 Quality control

To minimize contamination, MP extraction and observation procedures adhered procedures, including the use of latex gloves, 100% cotton laboratory clothing, and working in a clean and enclosed environment (Falahudin et al., 2020; Mai et al., 2018). All laboratory equipment, such as sample bottles, test tubes, tweezers, and filters, was made from non-plastic materials and was sterilized before application. Samples were kept covered when not under analysis, and double-distilled water was used during all processes (Cordova et al., 2019; Mai et al., 2018). Additionally, to control contamination from air, especially from synthetic fiber materials (Chen et al., 2020; Dris et al., 2016), a blank procedure was implemented during laboratory analysis (Falahudin et al., 2020). Post-laboratory processes, the filter paper was observed under a microscope to confirm the absence of MP, indicating no contamination throughout the procedures.

MP Abundance Calculation. MP abundance analysis in water was conducted using the following formula (Masura et al., 2015).

$$K = \frac{n}{v}$$

Where; K=abundance of MP (particle/L); n=number of MP; v=sample volume (L).

3. RESULTS AND DISCUSSION

3.1 MP abundance

The abundance of MP in Batang Anai River water samples ranged from 37-77 particles/L, and it was predominant at ST 2, followed by ST 3 and ST 1 (Figure 2).

The abundance of MP in the water at the ST 2 can be attributed to factors such as high population density, sand mining activities, elevated sedimentation, turbid water, slow water flow, and sandy mud riverbeds. This was in accordance with the study of Ding et al. (2019) who reported a high abundance of MP in water near densely populated areas with increased community activity. ST 3, as the second highest abundance location, is characterized by high pollution, intense residential activity, ship activity at the Muara Anai Fishing Harbor, cooking oil factories, sand mining activities, and sandy mud bottom substrate. In contrast, ST 1, with the lowest MP abundance, was situated in clear river water with large rocks, a Sandy river bed, fast flowing water, minimal pollution, and limited population activity.

The abundance of MP in this study was lower compared to previous investigations, such as conducted in the Estuary of the Yellow River, China (Han et al., 2019), the Dutch River, Amsterdam Canal, Netherlands, and Germany (Leslie et al., 2017), as detailed in Table 2.

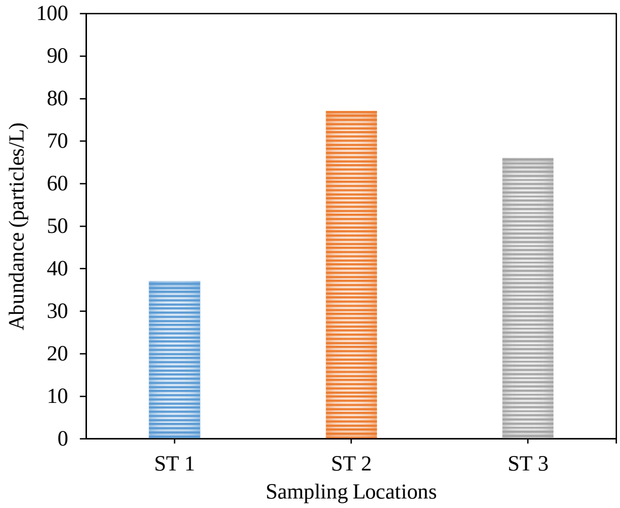

Figure 2. MP Abundance at different sampling locations of water (particles/L)

Table 2. Comparison of MP abundance in river water from several countries

Location	Sampling equipment	Abundance (particle/L)	References
Yellow River Estuary, China	Stainless-steel bucket, 5 L	930	Han et al. (2019)
Dutch River and Amsterdam Canals	Bulk, 2 L	48-187	Leslie et al. (2017)
Danube River, Austria	Net	0.32±4.66	Lechner et al. (2014)
Seine River, France	Net	0.003-0.11	Dris et al. (2015)
Ciwalengke River, Indonesia	Bulk, 1 L; 1.2 µm	5.85±3.28	Alam et al. (2019)
Pearl River, China	Net, 160 µm	0.57±0.71	Fan et al. (2019)
Batang Anai River, Indonesia	Mini manta trawl net, 300 µm, 0.35 L	37-77	This study

The high abundance of MP in river water can be attributed to 2 primary factors. Firstly, high levels of pollution play significant role. This was in line with the study by Jambeck et al. (2015) who stated that China is the largest contributor of plastic waste from land to sea. The results of investigation conducted on Batang Anai river water show higher MP content (37-77 particles/liter) compared to the report by Alam et al. (2019), where the content in Ciwalengke river water, Indonesia was 5.85±3.28 particles/L, as presented in Table 1. The difference in MP density between these locations were influenced by variations in sampling time, population activity and population density. The second factor was the sampling tool used, as shown in Table 1. Areas with high MP abundance do not use separate pumps, plankton nets, or manta nets, but instead use separate Niskin bottles, Van Dorn water sampling tools, buckets, or pails. Mesh size also determined the effectiveness of nondiscrete devices for filtering. Finer mesh sizes were generally applied in pumping methods (Cutroneo et al., 2020). Non-discrete tools allow particles smaller than the mesh size to escape during field sampling, while the discrete counterpart will collect all MP sizes and shapes (Cutroneo et al., 2020; Wu et al., 2020).

3.2 Shape abundance

The results showed 3 shapes of MP, namely fragments, films, and fibers (Figure 3). The shape in water was dominated by fragments with the order being 89 particles/L (49.44%) > fiber 86 particles/L (47.78%) > film six particles/L (3.33%).

In the Pearl River of China, abundant types of fragments were discovered (Fan et al., 2019), while in the Yellow River, China (Han et al., 2019), Ciwalengke River, Indonesia (Alam et al., 2019), Sein River, France (Dris et al., 2015) several forms of fiber were reported. Variations in the abundance of MP forms across different locations were attributed to differences in sampling methods, processing and analysis techniques, oceanography (tides and currents), and meteorology (Abayomi et al., 2017;

Kanhai et al., 2017). The MP fragments entering rivers was thought to originate from 1) Larger plastics subjected to physical degradation over time due to exposure to sunlight, heat, and mechanical action such as crushing by waves at sea or erosion on land; 2) Synthetic clothing and textiles, such as polyester or nylon, shedding small fibers during washing; 3) Disintegration of personal care products containing small plastic particles as abrasives; 4) MP fragmentation through maintenance and painting activities, dispersing small plastic particles into the air or leaching them into the aquatic system; 5) The plastic processing industry releasing MP fragments into the environment through improperly managed industrial waste or production processes.

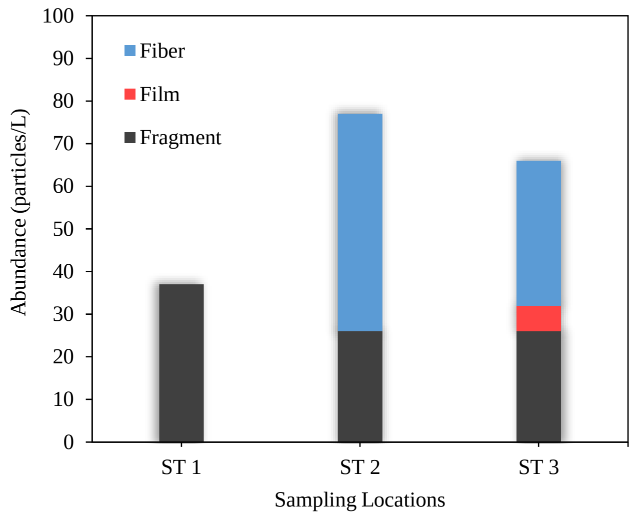

Figure 3. The abundance of MP forms in water (particles/L)

The abundance of MP in the form of fiber entering the river originates from: 1) Clothing made of synthetic fibers such as polyester, nylon, acrylic, or polyamide, releasing MP fibers during washing, reaching the environment through household wastewater or inadequately filtered sewage treatment systems; 2) Other textile products such as furniture fabrics, carpets, towels, or linen containing plastic fibers that break down into particles when used and washed; 3) Textile production processes generating plastic fiber waste that enters the environment as MP; 4) Consumer goods such as toothbrushes, makeup brushes, cleaning brushes, or other household tools made of plastic fibers can become a source of MP when damaged or disposed of improperly; 5) Industries, such as plastic processing or textile production, causing the release of MP fibers into the environment through poorly managed waste or production processes.

Plastic film is one of the most common forms of MP in water due to its high mobility, easily dispersing throughout ecosystems by water, wind, or human activities. To address the MP film problem, it is essential to reduce the usage of single-use plastic films, develope environmentally friendly substitutes, and better-managing plastic waste.

3.3 Size abundance

MP sizes identified in this study were classified into 5 categories, namely <100 µm, 101-300 µm, 301-500 µm, 501-1,000 µm, and >1,000 µm, as presented in Figure 4. The dominant size category in water was >1,000 µm (33%). This predominance may be attributed to the 300 µm sampling equipment (net) used, allowing MPs smaller than this size to eacape during water sampling (Suteja et al., 2021).

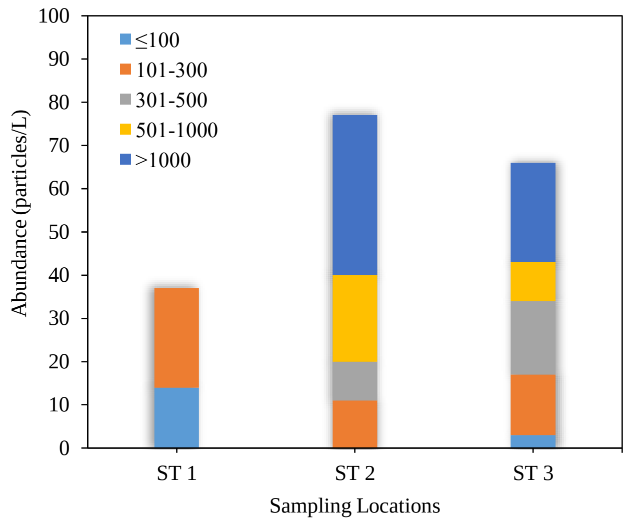

Figure 4. MP abundance based on different sizes of water sampling locations

The size of MP entering rivers can affect the environment and aquatic organisms. This influence was evident in several ways including: 1) The size affect the ability to spread and move in the environment. Smaller MP have tend to dissolve more easily in water, get moved by ocean currents or wind, and spread widely. Conversely, the sizes tend to be confined to areas closer to the source; 2) The ability of MP to enter into living organisms and move through food webs was affected. Smaller particles can easily be ingested by small organisms such as plankton, potentially accumulating and biomagnifying through the food chain; 3) The health of exposed organisms was impacted. Smaller MP had a higher ability to enter into the tissues and organs of the body, including the respiratory and digestive systems. This intrusion can lead to inflammation, oxidative stress, immune system disorders, and organ damage; 4) The size has effect on chemical interactions and potential toxicity. A larger MP surface can provide more surface area to interact with hazardous chemicals and become an absorption medium for contaminants in the environment. However, the smaller particle can precipitate more efficiently and produce a more significant toxic effect on living organisms.

3.4 Color abundance

The MP identified in this study varied from transparent, black, blue, and red to yellow. Meanwhile, the black color dominated in each river water, namely black, constituting 48% of the total, as presented in Figure 5. This prevalence of black MP is primarily attributed to the breakdown of black plastic, a material extensively used in diverse sectors such as food packaging, cooking utensils, trays, toys, household electronics, and car components. Due to lower recycling rates, more significant quantities of this color of material are likely to end up as environmental waste (Huang and Xu, 2022).

Transparent MP may come from packaging products such as disposable plastic bags, cups, and bottles. The colored forms can be derived from packaged products and other durable plastic consumer goods (Zhang et al., 2018). Blue, yellow, and red MP result from the inherent color of the plastic and from photoaging processes. Photoaging induces discoloration, providing a visual indicator of the duration of plastic particle exposure in the environment (Zhao et al., 2022).

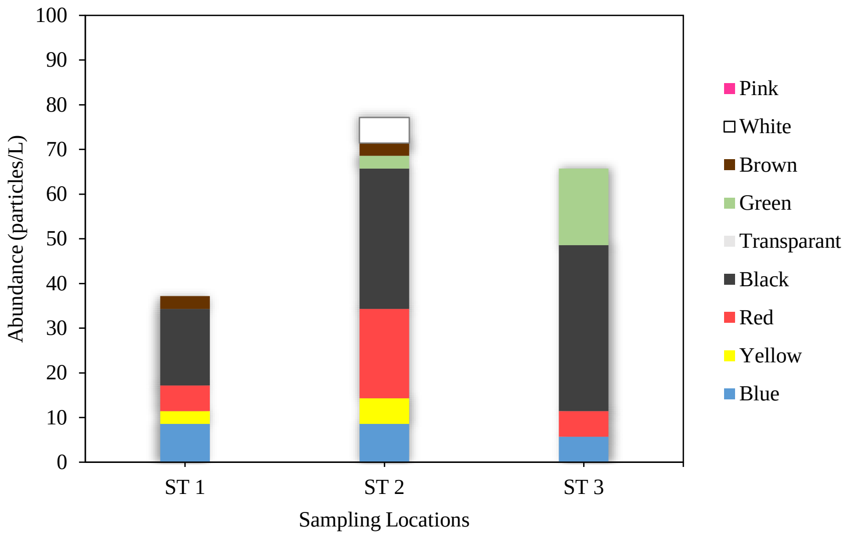

Figure 5. MP abundance based on different color water sampling locations

3.5 Identification of MP polymer types

Polymer identification was not conducted for all MP particles, but a random selection was made from the total pool of particles. Among the 63 MP particles obtained from water samples, 9.5% were randomly chosen for identification. The polymers identified in this study, confirmed through FTIR, include cellulose (Figure 6), ethylene propylene copolymer (Figure 7), neoprene (Figure 8), and polyester (Figure 9).

The interpretation of the FTIR spectrum (Figure 6) for the fiber extracted from water at ST 1 indicated that the fiber was a reinforced cellulose polymer. The identity of the absorption band include the broad peak at 3,331 cm^{-1} which is a function of the stretching vibration of the hydroxyl institution (-OH) in polysaccharides. The band at 2,894 cm^{-1} was related to the C-H stretching vibrations of all hydrocarbon components inside the polysaccharide. The absorption bands at 1,367-1,334 cm^{-1}, and 1,027 cm^{-1} comprise bending vibrations of $-CH_2$ and C-O bonds in cellulose (Hospodarova et al., 2018).

Based on Figure 7, the fragment and fiber indicated the presence of ethylene-propylene copolymer, which is reinforced by the advent of absorption at 1,465 cm^{-1} (CH_2 bending vibration). At 1,378 cm^{-1}, symmetrical bending of the CH_3 bond was observed. Additionally, the spectrum demonstrate absorption peaks at 1,155 cm^{-1}, corresponding to the stretching vibration of $C-C(CH_3)-C$. At 970 cm^{-1}, it was indicative of the rocking vibration of the CH_3 bond (Koenig, 1999).

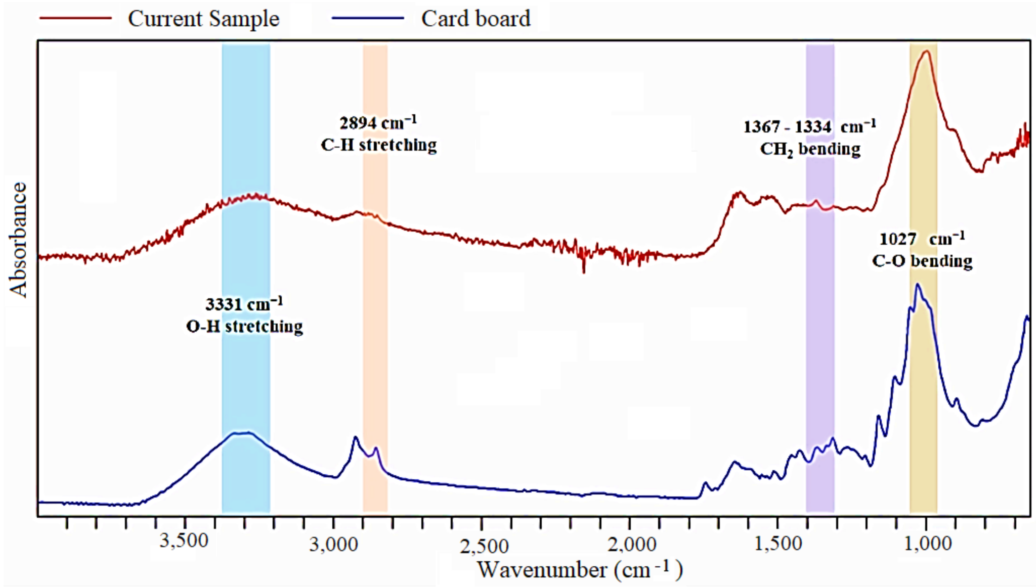

Figure 6. Fiber FTIR spectrum from water (ST 1)

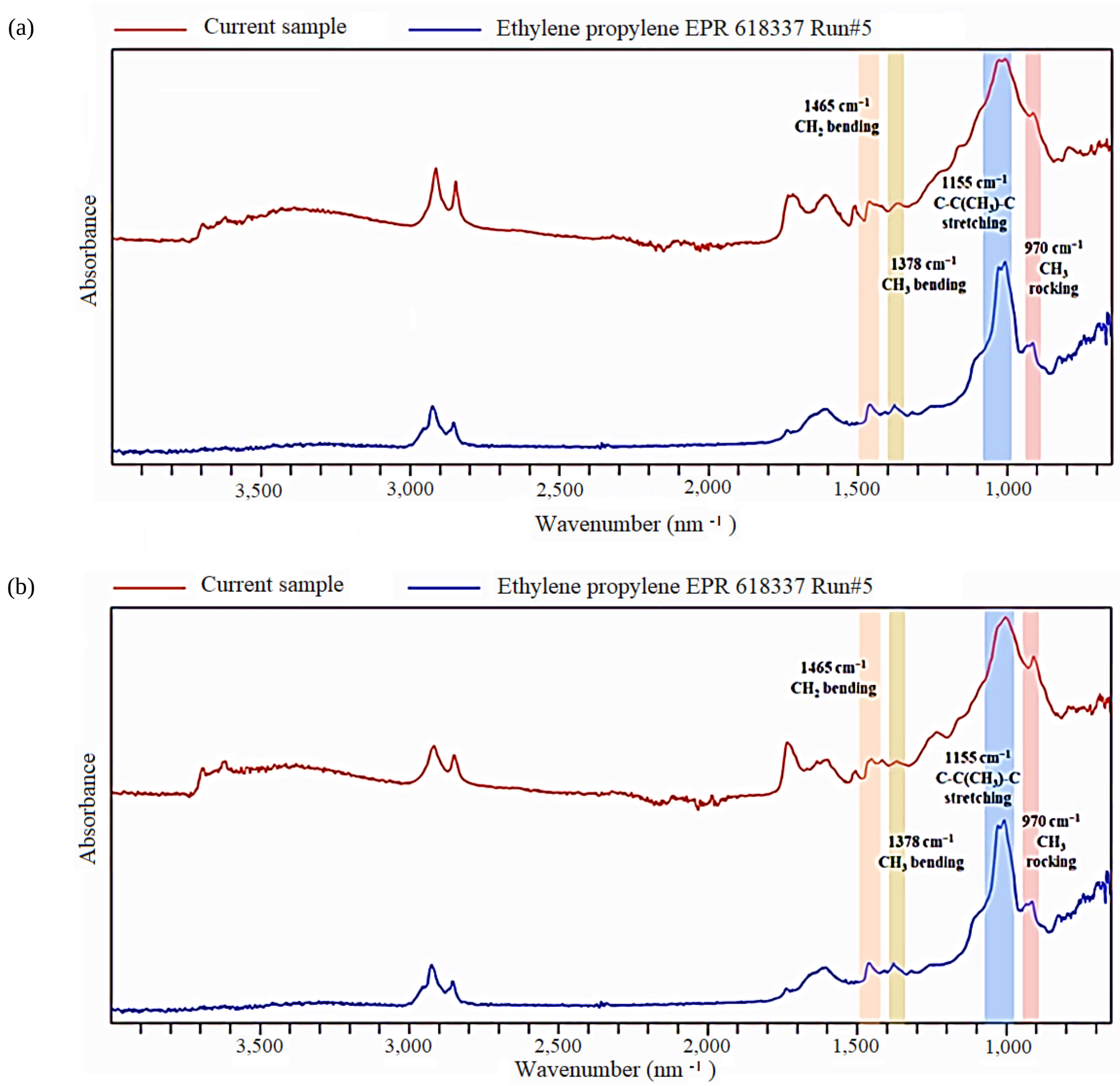

Figure 7. FTIR spectrum (a) Fragment from water ST 1 and (b) Fiber from water ST 2

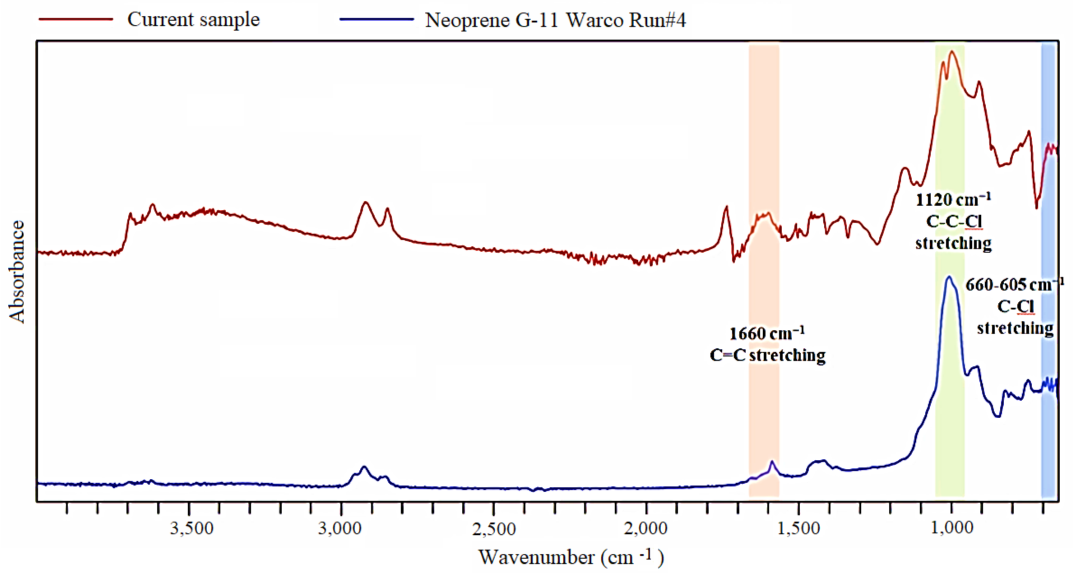

Figure 8. Fragment FTIR spectrum from water ST 2

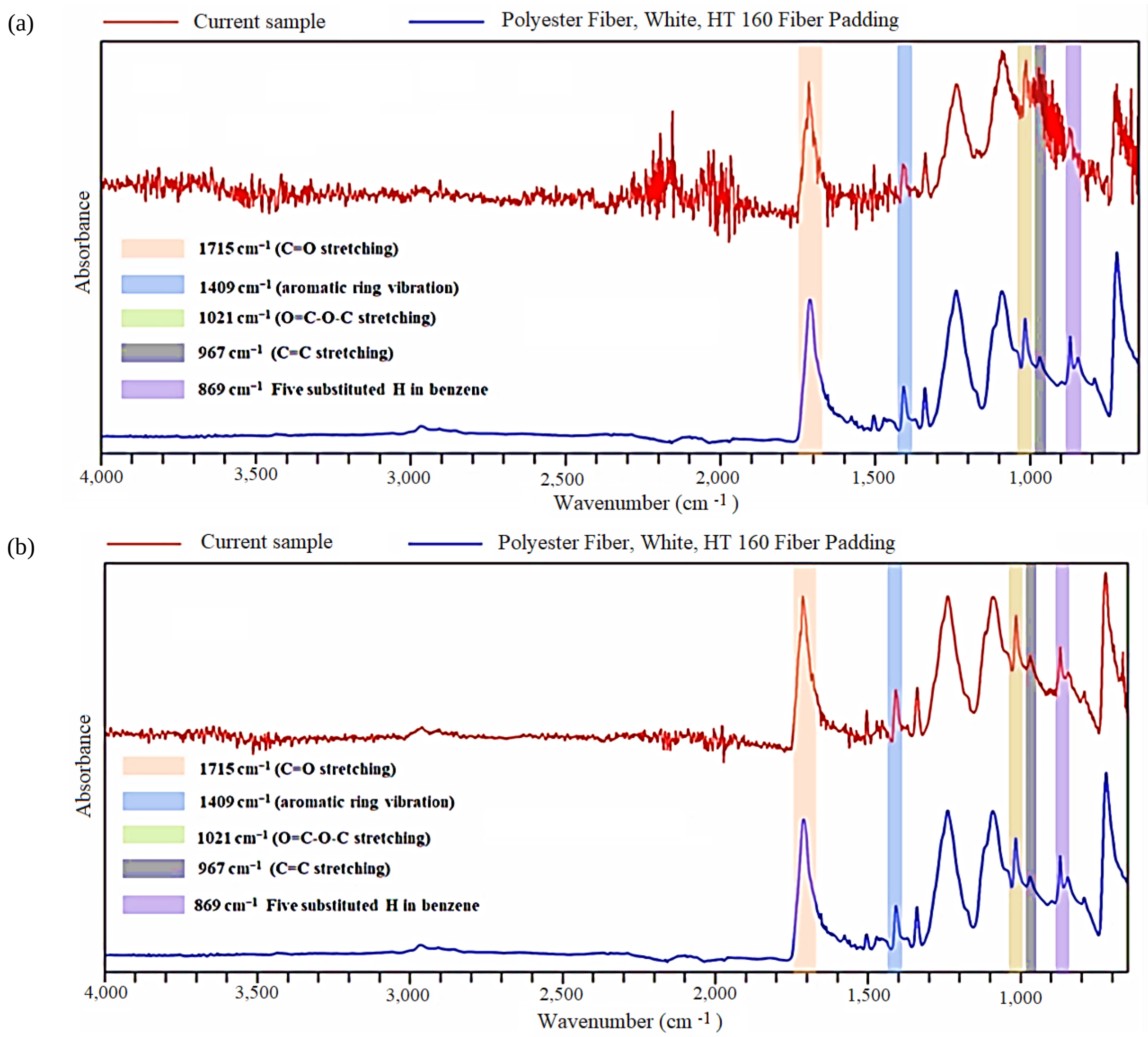

Figure 9. The two-fiber FTIR spectrum of Water ST 3

Based on Figure 8, the fragment extracted from ST 2 water indicated the presence of neoprene polymer, which is reinforced through the appearance of absorption at 1,660 cm^{-1}, 1,120 cm^{-1}, and 660-605 cm^{-1}, namely C=C stretching vibrations, C-C stretching at C-C-Cl, and C-Cl stretching vibration (Koenig, 1999).

The results of the translation of the FTIR spectrum on 2 fibers extracted from ST 3 water were polyester polymers, bolstered through the appearance of absorption at 1,715 cm^{-1}, 1,409 cm^{-1}, 1,021 cm^{-1}, 967 cm^{-1}, and top 869 cm^{-1}, indicating C=O stretching vibrations, aromatic ring vibrations, O=C-O-C stretching, C=C stretching, and 5 H substituted in benzene, respectively (Bhattacharya, 2014).

4. CONCLUSION

In conclusion, the utilization of plastic materials in everyday led to the introduction of MP into the waters of Batang Anai River, attracting considerable attention for its impact on humans and organisms that absorb organic contaminants and pathogens from the surrounding media. This study was in accordance with the aim of analyzing the abundance of microplastics (MP), shape, color, size and characteristics of polymers. The abundance in Batang Anai River water samples ranged from 37-77 particles/L, with the dominant form being fractional. Furthermore, MP in water were dominated by sizes >1,000 µm (33%), while the most appeared color was black. Based on the identification of polymer using the FTIR test, it was suspected that the detected types were cellulose, ethylene-propylene copolymer, neoprene, and polyester. Therefore, it was hoped that the results of this study can be a reference to better understand of MP pollution in Batang Anai river water.

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