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Occurrence of Microplastics in Kemena River and Niah River of Sarawak, Malaysia

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ABSTRACT: Microplastics in freshwater have been identified as a significant contributor to plastic pollution in marine environments. However, the effect of urbanization on the quantity and spatial dispersion of microplastics in freshwater ecosystems of Sarawak and Malaysia remains unclear. The primary objectives of this study are to investigate the quantity and distribution of microplastics in water and riverbank sediments, as well as to analyze the properties of microplastic particles in the Kemena and Niah rivers. The selection of these rivers was based on the presence of commercial, residential, and industrial areas along their lengths. A total of 24 water and soil sediment samples were collected from three different sites along the Kemena and Niah rivers. The concentration of microplastics in water samples ranged from 60 to 128 items per liter, while sediment samples ranged from 46 to 76 items per liter. The sediment samples also contained microplastics ranging from 21 to 40 and 45 to 125 items per kilogram. Microplastics were observed in various forms, including fibers, films, foam, and fragments, in both water and soil sediment samples. The majority of microplastics were between 0.1 and 1 mm in size, with blue being the most common color observed in river water and transparent in sediment samples. The ATR-FTIR spectrum analysis indicated the presence of four distinct polymers: polyethylene (PE), polystyrene (PS), polycarbonate (PC), and polyethylene terephthalate (PET). This study provides valuable information on the abundance, distribution, chemical composition, and physical properties of microplastics in the Kemena and Niah rivers.

KEYWORDS: Microplactics; Kemena River; Niah River; polyethylene; polystyrene

1. Introduction

Freshwater and marine waters and sediments have been shown to be covered in microplastics. Globally, one million tonnes of plastics are produced, which is equivalent to one thousand trucks full of plastic bottles [1]. According to previous research conducted by the University of Victoria in Canada, Americans consume between 39,000 and 52,000 microplastic particles annually, depending on their gender and age. Microplastics are defined as particles with a diameter between 0.1 µm and 5 µm in an aquatic environment [2]. Microplastics have been discovered in rivers and sediments at high concentrations (e.g., 100,000 particles per cubic metre), where they interact with animals and the environment in a variety of ways [3].

The majority of early research on microplastics focused on their prevalence in aquatic environments, with the first studies conducted in the 1970s but not published until the 1980s. Microplastic contamination has gained traction in the scientific community due to the increase in research on the pandemic-related increase in microplastic abundance. An increase in demand for food and groceries via delivery systems led to an increase in the use of plastic packaging, in accordance with WHO guidelines for COVID-19 pandemic countermeasures. Plastic products are now mass-produced due to the industrial revolution, urbanization and population growth, and the development of contemporary synthesis technologies [4, 5]. Since the pre-pandemic phase of Covid-19, the increased production of plastics has led to a 250-300 percent increase in the consumption of single-use plastics, according to a statement by the International Solid Waste Association. The WHO estimates that approximately 89 million medical-grade masks were needed globally in 2020 to combat and contain Covid-19. Using April 2020 as an example, Japan is expected to have purchased and secured orders for approximately 600 million masks per month in April 2020. This resulted in the production of more than eight million tonnes of plastic waste related to the epidemic, with more than twenty-five tonnes ending up in the world's oceans and rivers [6].

The Kemena and Niah rivers were chosen as the study sites for microplastic occurrence research due to their proximity to commercial, residential, and industrial areas, as well as their similar agricultural and industrial uses. The presence of river estuaries in these areas made them ideal for the study, as estuaries and adjacent wetlands are typically located where rivers meet the ocean, leading to heavy pollution during the era when the jetty and trade center were situated along the Niah River for the transportation of bird's nest products [7]. Additionally, these rivers are located in Sarawak, Malaysia, where little research has been conducted on the distribution and abundance of microplastics in river and sediment sampling. Therefore, this study aimed to contribute to a better understanding of microplastic pollution in Sarawak and Malaysia by examining the abundance and distribution of microplastics in the Kemena and Niah rivers..

2. Materials and Methods

2.1. Sample collection

Table 1 outlines the sampling locations for the Kemena and Niah rivers, which were all publicly accessible, thus facilitating the collection of river water and sediment samples. The river water and sediment samples were obtained using a stainless steel pail and shovel, respectively. To improve the precision and accuracy of the analysis, each sample was replicated, resulting in 18 water and sediment samples. As shown in the figure below, a 5 L bucket was utilized to collect river water from three sampling locations each along the Kemena (A1RW, A2RW, A3RW) and Niah (B1RW, B2RW, B3RW) Rivers. At each location, the river water was collected in a bucket and filtered through a stainless steel mesh sieve with a pore size of 0.3 mm to 5 mm, which had been previously prepared. After filtration, the samples were washed with distilled water to eliminate any residual solids, and any sediments remaining on a 5 mm stainless steel sieve were returned to the river. The samples were then stored in glass bottles before laboratory analysis. With regard to sediment sampling, sediment samples were obtained from the same locations as the river water samples and were labeled A1S, A2S, A3S and B1S, B2S, B3S. A quantity of 400 g of sediment samples were collected using a stainless steel shovel and a refrigerated glass container before laboratory analysis [8]. To avoid plastic contamination, all equipment and glassware were cleaned three times with distilled water before use. Furthermore, to prevent plastic particles from contaminating the surrounding environment, chemical solutions were prepared under a fume hood [9].

Table 1. Sampling point condition in Niah River and Kemena River.

Sampling Point	Latitude	Longtitude	River Section	Land Use Description	pH Value	Turbidity, NTU	Temperature, °C
A1	3.14952	113.09165	Upstream	Shipyard and industries	6.83	11.80	30.20
A2	3.16099	113.05439	Middle Stream	Residential Area	6.99	13.30	30.60
A1	3.14952	113.09165	Upstream	Shipyard and industries	6.99	9.82	30.50
B1	3.73606	113.78345	Upstream	Residential Area	7.03	54.15	30.40
B2	3.80205	113.75659	Middle Stream	Commercial Area	6.93	25.70	31.60
B3	3.86498	113.72151	Downstream	Jetty	6.60	60.55	30.25

2.2. Digestion of biogenic materials and density separation.

The river water samples were transferred into a 500 mL glass beaker and oven-dried at 90 °C for twenty-four hours. Prior to adding the samples to the beakers, the mass of the beakers was measured using an electronic scale. After drying, the mass of the total solids was determined by subtracting the weight of the beaker containing the dried solids from the initial weight of the beaker containing no solids. The organic matter of the samples was then digested with 30% hydrogen peroxide, H_2O_2, for 24 hours at 60 °C [10]. Subsequently, the sediment samples were dried in an oven at 65 °C for 24 hours, using a 20 µm stainless steel mesh to capture microplastics. Microplastic particles were separated from the soil sediment by adding 300 mL of aqueous lithium metatungstate (1.62 g/cm^3), causing them to float to the surface. A second separation was conducted by adding 30% H_2O_2 to the samples to remove any existing organic substances [11,12]. Following organic digestion, density separation was carried out on water and sediment samples using sodium chloride, NaCl, to float microplastic particles from the river and sediment. Each sample was mixed with 450 mL of NaCl and stirred for 5 minutes. The salt was then dissolved in the mixture on a hotplate heated to 70 °C. Finally, the samples were filtered through a 0.3 mm stainless steel mesh sieve [8].

2.3. Identification of microplastic particles.

After the microplastics were separated from the sediment samples, a visual inspection was carried out using forceps to ensure the absence of any remaining organic substances or debris. The filtered microplastic particles were then transferred to a clean petri dish, and their characteristics such as shape, size, and color were determined using a Nikon SMZ745T stereomicroscope with a 40x magnification and high-resolution camera. To gain further insight into the microplastics' composition, Agilent-FTIR spectroscopy was employed to determine their functional groups. The FTIR spectra were recorded between 4000 and 7000 cm-1 with 20 scans per second and a resolution of 0.25 cm-1. The analysis was carried out in triplicate, and the obtained spectrum was compared with other studies that used the same methodology to ensure the reliability and validity of the results [11, 13].

2.4. Data analysis

To express the abundance and distribution of microplastics in the Kemena and Niah rivers' water and sediment samples, the mean standard deviation was used. This method was chosen since one replicate sample was collected from each of the 24 river water and sediment samples, resulting in a sufficient number of observations to calculate the mean and standard deviation accurately. The microplastic concentration in river water and sediment samples was expressed as particles per liter (particles/L) and particles per kilogram (particles/kg), respectively. To provide a more comprehensive understanding of the microplastics, they were classified based on their type, color, and size. A detailed analysis of the microplastic polymerization properties was carried out using Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR). This method allows for the identification of the functional groups present in the microplastic polymer, which can help identify the source of the microplastics. The spectra were recorded between 4000 and 7000 cm^{-1} at 20 scans per second and 0.25 cm^{-1}. To ensure accuracy and reliability, the analysis was repeated three times, and the spectrum was compared to other studies that utilized the same methodology.

3. Results and Discussion

3.1. Abundance of microplastics in river water and sediment sample stations.

In the investigation, a total of 336 microplastic particles were discovered in ten composite samples consisting of surface water and sediment. Microplastic particles were found in all surface water and sediment samples, as demonstrated in Figures 1 and 2. The abundance and distribution of microplastics in surface water from the Kemena and Niah rivers were expressed as particles per litre (particles/l), while in sediment samples, it was expressed as particles per kilogramme (particles/kg), and the mean and standard deviation were calculated for each river. Microplastic concentrations in surface water from the Kemena and Niah rivers ranged from 60 to 128 items/l (mean 94±34) and 46 to 76 items/l (mean 56±17.32), respectively, with higher concentrations detected in river regions adjacent to urban areas. Similarly, the amount of microplastics found in sediment samples from the Kemena and Niah rivers ranged from 21 to 40 (mean 28±10.44) and 45 to 125 items/kg (mean 76.67±42.52), respectively.

The close proximity of various areas with high concentrations of microplastics to urban tributaries that flow into the river suggests that these tributaries are transporting significant amounts of microplastics into the Kemena and Niah rivers. Previous research has shown that urban tributaries and rivers are important routes for microplastics to spread. However, since the sample was taken during the rainy season, it is possible that the measured microplastics flux and geographical distribution were influenced by this factor. High water velocity and level make it more difficult for microplastics to travel away from urban areas during the rainy season. Other studies have found much higher concentrations of microplastics in both the surface waters and the sediment waters of different rivers during the rainy season, which supports this hypothesis [14, 15].

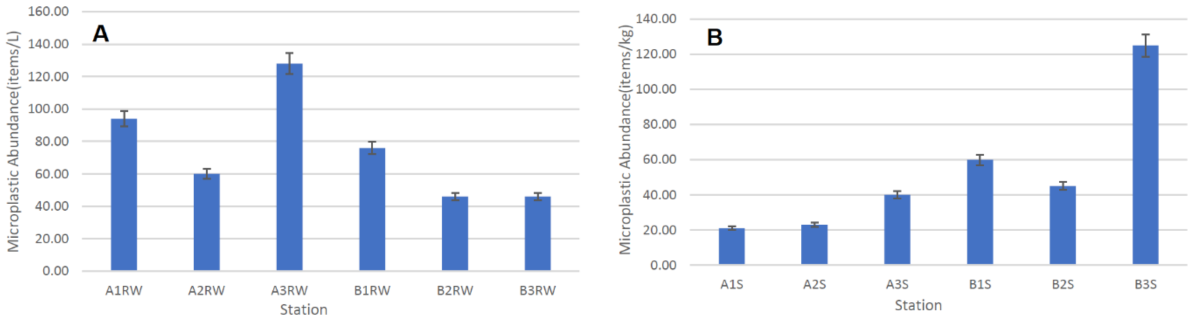

Figure 1. Microplastics abundance for river water (a) and sediment (b) from Niah and Kemena River.

Based on the results of this study, the concentration of microplastics in the surface water downstream of the Kemena River was significantly higher compared to the concentration of microplastics in surface water upstream and midstream of the river. Similarly, the concentration of microplastics in surface water upstream of the Niah River was significantly higher than the concentration in surface water downstream and midstream of the river. Interestingly, the section of the Niah River located further upstream had a significantly higher concentration of microplastic particles compared to the Kemena River sections that were further upstream, midstream, and downstream. The sedimentation process that occurs in the downstream segment of the river may cause the concentration of microplastics in the sediment sublayers to be higher than the concentration at the sediment's surface.

There was no statistically significant difference in the number of microplastics found in surface water or sediments upstream, midstream, or downstream. The results indicate that human activities such as urbanization, tourism, agriculture, and logging in the upstream, midstream, and downstream regions of the Kemena and Niah rivers increase the release of massive amounts of microplastics. The study also found significant microplastic concentrations near urban areas both upstream (Station A1RW and B1RW) and downstream (Station A3RW and B1RW), and it appears that the release of untreated domestic sewage is the most important factor in explaining microplastics concentrations in the Kemena and Niah rivers.

The findings of this study are in line with other research that has found urbanization to be the primary cause of rising levels of microplastic pollution in aquatic ecosystems [16]. The release of microplastics into waterways is a global issue that requires urgent attention and action. Understanding the sources and distribution of microplastics in aquatic ecosystems is critical for developing effective management and mitigation strategies to reduce their impact on the environment and human health.

3.2. Type of microplastics.

The results of the study indicate that the Kemena and Niah rivers contain four types of microplastics, namely fibre, fiber, foam, and fragments. Figure 2 displays the various shapes of microplastics that were identified in surface waters and sediments. Among the 336 microplastics particles analyzed, fiber was found to be the most prevalent type in both the surface water (mean = 68.4%) and sediment (mean = 48.1%) samples of the Kemena River. Similarly, fiber was also found to be the most common type in the sediment samples of the Niah River (mean = 54.7%). The most common man-made items identified were fragments, films, and foam, in that order. However, in the Niah River's surface water, film was found to be the most common shape (mean = 35.3%), while fiber was found to be the most common shape in the river's sediment (mean = 54.7%). The percentages listed above are the mean values for the different plastic categories, based on the total number of microplastic particles detected in river water and sediment samples, respectively. Figure 3 shows the percentage of different types of microplastic particles (fibre, film, foam, and fragments) in river water and sediment samples.

According to the observations made during river water sampling, it was determined that sample station A3RW, located in the downstream section of the Kemena River, had the highest concentration of fiber-type microplastic particles among all the sampling locations. On the other hand, compared to other sampling points, sample station B1RW in the upstream section of the Niah River had the highest concentration of film-type microplastic particles. Moreover, sample station B2RW in the middle stream section of the Niah River had the highest concentration of foam and fragment microplastics. Sediment samples from sampling point B3S, located in the downstream section of the Niah River, had the highest percentages of fibre-type microplastics. In contrast, the highest concentration of foam-type microplastic particles was found at sampling site A2S in the middle stream of the Kemena River, while the highest concentration of film-type microplastic particles was found downstream at sampling point A3S.

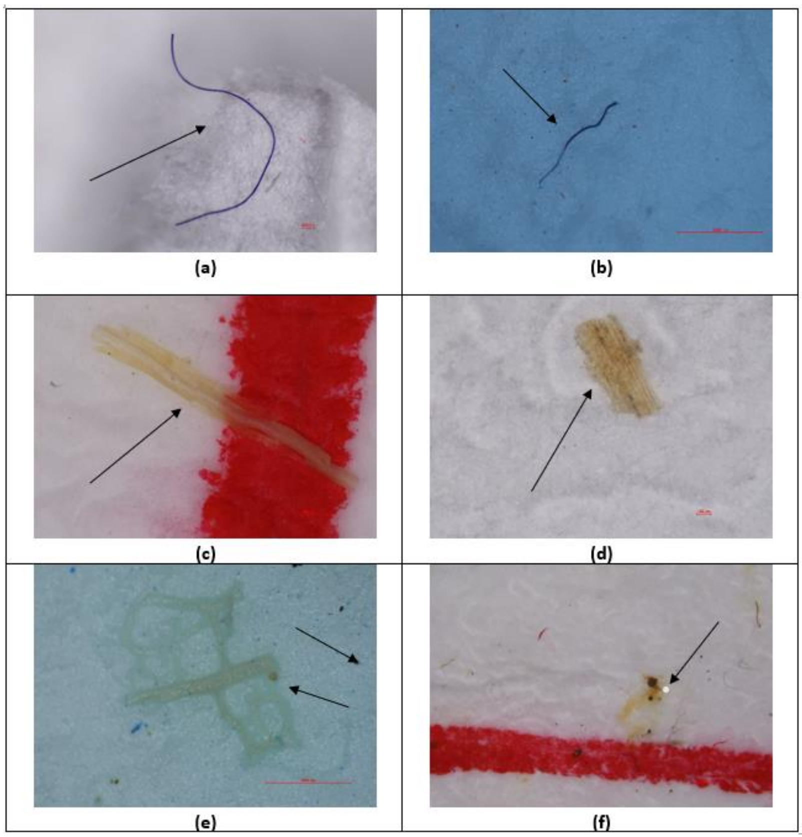

Figure 2. Microscope Image of microplastics identified along the river water and sediments of Kemena River and Niah River: Fibre (a & b); Film (c,d); Fragment (e); Foam (f).

According to the data, the most prevalent types of secondary microplastics in the Kemena and Niah Rivers are those that originate from the fragmentation of large plastic goods. Domestic sewage, which includes water used for laundry, garbage disposal, personal care products, and the degradation of fishing vessel ancillary items like nets and ropes, are the primary sources of high concentrations of fibre and film in the Kemena and Niah rivers, respectively. These microplastic sources have been previously identified in both aquatic and terrestrial ecosystems, and given the increase in intestinal toxicity caused by fiber and film microplastics [17], their high proportion in the Kemena and Niah Rivers indicates a significant biological risk that warrants further investigation. Fragments and foam found in these rivers can be attributed to the degradation of larger plastic products such as plastic bottles, plastic shopping bags, plastic packaging, and more, which has occurred as a result of the expansion of the tourism and agricultural industries, as well as the discharge of untreated sewage into the water [18].

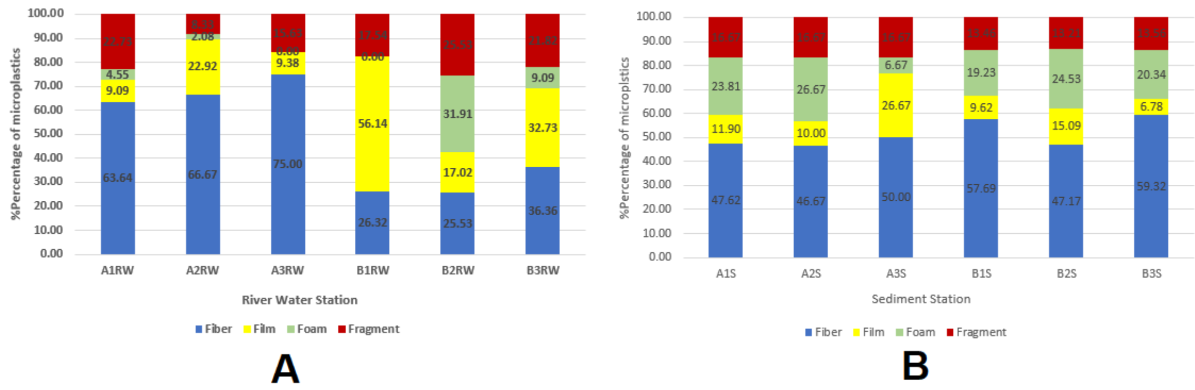

Figure 3. Percentage of microplastics based type for river water (A) and sediment (B) for the Kemena River and Niah River.

3.3. Colour of microplastics.

The data presented in Figure 5 shows that microplastics ranging from 0.1 to 5 mm and particles ranging from 0.1 to 1 mm and 1 to 2 mm were the most prevalent in surface water and sediment samples collected from the Kemena and Niah rivers, respectively. Furthermore, the frequency of smaller microplastics in Kemena and Niah River river water samples was consistently higher than in sediment samples. Previous research has indicated that plastic with a lower density than water is buoyant and thus likely to float on the surface of the water, whereas plastic with a higher density than water can settle down the river bed and sink into the sediments. As a result, the percentage of the smallest-sized microplastics was found to be higher in sediments than in surface water, as larger plastics are susceptible to flow and wind forces, causing them to float atop water, whereas smaller plastics migrate into sediments and deep water. The color composition of microplastics can provide valuable information about their sources and the human activities responsible for their release into aquatic systems. The presence of blue microplastics in river water samples, for example, may be linked to the release of synthetic textiles such as clothing, while the presence of transparent fibers could be attributed to fishing activities. Furthermore, the size distribution of microplastics in river water and sediments highlights the different processes that control their transport and fate in the environment. [21, 22].

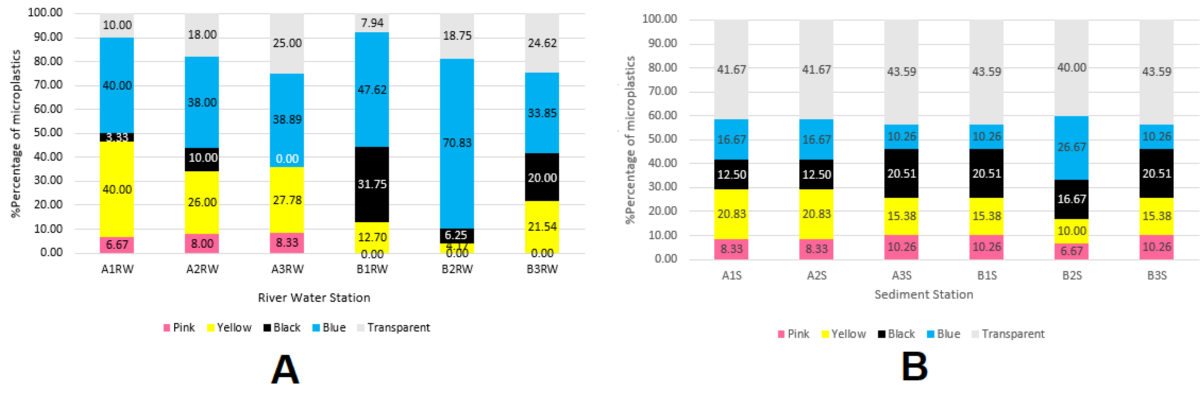

Figure 4. Percentage of microplastics based on colour for river water station (A) and sediment station (B) for Kemena River and Niah River.

3.4. Size of microplastics.

The results presented in Figure 5 show that microplastics ranging from 0.1 to 5 mm in size were the most prevalent in surface water and sediment samples collected from the Kemena and Niah rivers, respectively. Among these, particles ranging from 0.1 to 1 mm and 1 to 2 mm were the most commonly detected in sediment samples. Interestingly, the frequency of smaller microplastics in river water samples from both the Kemena and Niah rivers was consistently higher than in sediment samples. This observation is consistent with previous research, which suggested that buoyant plastic particles with a lower density than water can remain suspended in the water column, while denser particles can settle down onto the river bed and eventually sink into the sediments [21, 22]. The higher percentage of the smallest microplastics detected in the sediment samples of the Kemena and Niah rivers highlights the fact that smaller plastic particles are more prone to migrate into sediments and deep water. In contrast, larger plastics are more susceptible to flow and wind forces, which causes them to float atop water. Therefore, the fact that smaller microplastics were found more frequently in sediments suggests that they are more likely to accumulate over time and remain in the environment for a longer period.

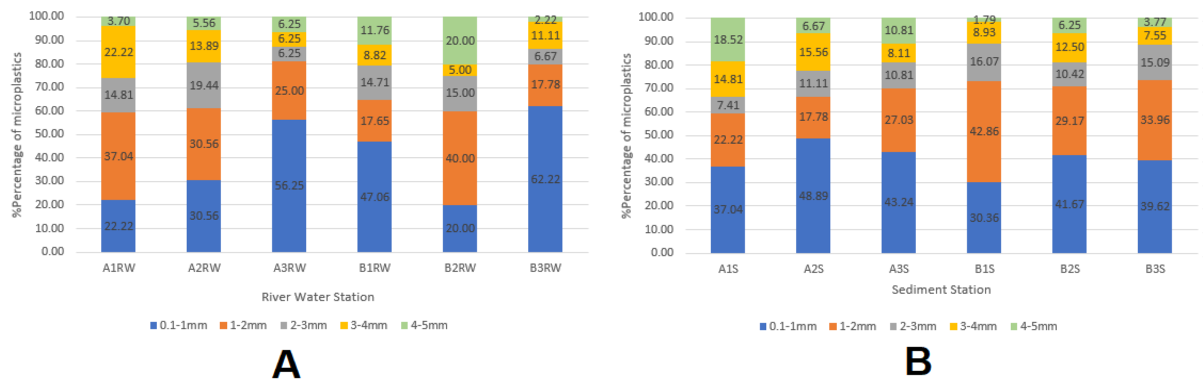

Figure 5. Percentage of microplastics based on size for river water station (A) and sediment station (B) for Kemena River and Niah River.

3.5. Microplastics chemical characteristics.

The identification of microplastics' polymerization types in sediment and water samples from the Kemena and Niah rivers can be achieved using ATR-FTIR spectroscopy. Validation of the analysis was conducted on 100 particles selected from surface water and sediment samples, with 90% of these particles being confirmed as microplastics. The remaining 10 particles could not be confirmed as microplastics due to insufficient spectrum intensity, despite having a spectrum matching score of less than 70%. Nevertheless, none of these particles were identified as natural organic components, suggesting that they were likely microplastics, but the equipment's limitations prevented a conclusive determination. Four distinct polymers, namely polyethylene (PE), polystyrene (PS), polycarbonate (PC), and polyethylene terephthalate or polyester (PET), were distinguishable among microplastics using ATR-FTIR (Figure 6). PE was the most common polymer, followed by PS, PC, and PET, respectively. In Figure 6A, PE was determined to have the principal absorption band, with absorption bands occurring at 2917 cm^{-1} (C-H asymmetrical stretching), 2849 cm^{-1} (C-H asymmetrical stretching), 1462 cm^{-1} (CH_2 bending), and 719 – 729 cm^{-1} (CH_2 bending) (CH Rocking deformation). In Figure 6B, the principal absorption band of PS was identified at band 3025 cm^{-1} (C-H asymmetrical stretching), band 2918 cm^{-1} (C-H asymmetrical stretching), band 1601 cm^{-1} (Aromatic ring stretch), band 1491 cm^{-1} (aromatic ring stretch), band 1452 cm^{-1} (CH_2 stretch), band 1027 cm^{-1} (aromatic CH bend), band 753 cm^{-1} (aromatic CH out-of-plane bend), and 695 cm^{-1} (aromatic ring out-of-plane bend). Figure 6C was associated with PC, given that the main absorption band occurred at band 2963 cm^{-1} (CH stretch), 1767 cm^{-1} (C=O stretch), 1500 cm^{-1} (Aromatic ring stretch), 1407 cm^{-1} (Aromatic ring stretch), 1362 cm^{-1} (CH_3 bend), 1185 cm^{-1} (C-O stretch), 1155 cm^{-1} (C-O stretch), 1012 cm^{-1} (Aromatic C-H in-plane bend), and 827 cm^{-1} (Aromatic C-H out-of-plane bend). Finally, Figure 6D identified PET as the main absorption band, occurring at band 2158 cm^{-1} (C=O stretching), 1711 cm^{-1} (C=O stretching), 1506 cm^{-1} (Vibrations of aromatic ring), 1407 cm^{-1} (vibrations of aromatic ring, 1338 cm^{-1} (CH_2 Wagging vibration of trans conformation), 1237 cm^{-1} (C(=O)-O stretching), 1016 cm^{-1} (vibrations of aromatic ring), 870 cm^{-1} (vibrations of aromatic ring), 790 cm^{-1} (ring CH out-of-plane bending), and 721 cm^{-1} (ring CH out-of-plane bending).

The research found PS polymers in residential and commercial areas upstream and midstream of the river, which can be attributed to illegal garbage dumping into the river and an open dumpsite that infiltrates the river water system via surface runoff. PC-type polymers have been found in the Kemena and Niah rivers' river water and sediments, respectively. PC polymers are another type of polymer that is commonly used in the production of a wide range of goods, such as plastic lenses for eyewear, water bottles, protective gear, and digital discs. It is also possible that the residents of that area have been improperly disposing of garbage. In the case of PET polymers, these polymers are widely used in the textile industry, where they eventually end up in river water systems as a result of the wear and tear caused by repeated washing of polyester clothes in river water [27]. The presence of PET polymers in this study is influenced by the sampling location's proximity to a residential neighborhood. Given that plastic product consumption in Malaysia is still at an all-time high, it is highly likely that the majority of Malaysian rivers are already polluted with various microplastic polymer types. This pollution affects not only the Kemena and Niah rivers, but also the majority of Malaysia's other rivers. This can be attributed to a lack of public awareness about the contamination caused by microplastics, as well as poor waste management.

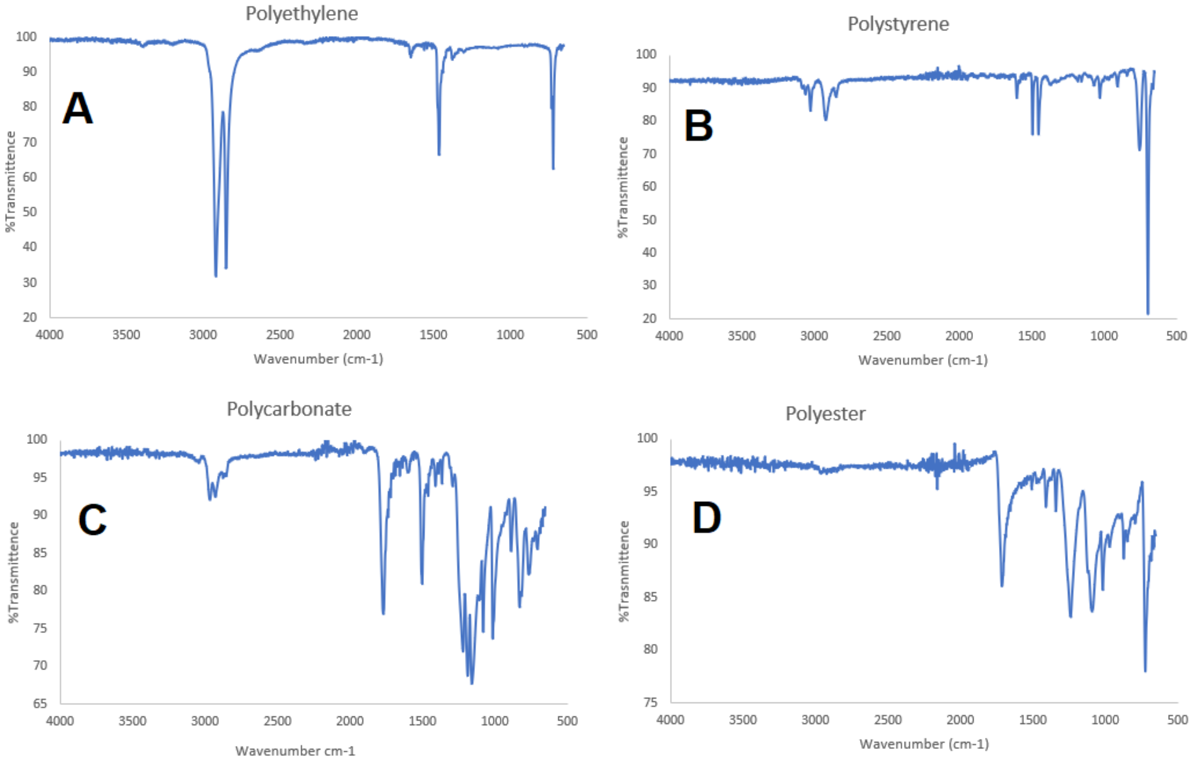

Figure 6. Spectra produced from plastic consumer goods labled with resin codes of polyethylene (A), polystyrene (B), polycarbonate (C) and polyester (D) using ATR FT-IR

4. Conclusions

In summary, the purpose of this study was to determine the abundance, distribution, and types of microplastics present in the Kemena and Niah rivers and to assess their environmental impact. The study was successful in achieving both objectives, with microplastics being found in both sediments and the water column, emphasizing the importance of sediment location. Duplicate water and sediment samples were taken from each habitat to ensure accuracy. The study revealed a substantial amount of microplastics in the sediments of the Kemena River and the water of the Niah River. Twelve river water and twelve riverbank sediment samples were collected from each river, and the results showed that fiber microplastics were the dominant type in both the river water and sediments. Fragment microplastics were the second most common type in the river water, followed by foam. In the sediments of both rivers, foam microplastics were second only to fragments and films. The Kemena and Niah River water samples had the most blue-colored microplastic particles, while the majority of sediment samples from both rivers contained transparent microplastics. Four polymers - PC, PS, PC, and PET - were found in water and sediment samples from both rivers. This is the second study conducted on microplastics in Sarawak's freshwater ecosystem. Microplastics are not yet considered a significant pollutant in Malaysia compared to crude oil and agriculture, leading to a limited number of studies. It is crucial to understand how urbanization increases microplastics in Sarawak and Malaysia's freshwater ecosystems since Malaysia is still developing. This research will provide a better understanding of the impact of urbanization on microplastics pollution, thereby contributing to the conservation of Malaysia's environmental ecosystem.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

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