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Effect of Anthropogenic Type and Depth on Microplastic Abundance in Mahakam River Water, Samarinda City

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Abstract

Mahakam is the second longest river in Indonesia and it functions as a source of raw water for drinking and other essential activities for the Samarinda people. Furthermore activities in the watershed generate solid waste such as plastic, which enters the waters and is potentially degraded into microplastics. There is a possibility that the presence of microplastics is affected by anthropogenic types along the river. Therefore, this research aims to determine the effect of anthropogenic type and river depth on the microplastic abundance in the Mahakam River. The samples were taken using an integrated approach at 3 depths, namely 0.5, 1, and 1.5 m, in 2 locations with different anthropogenic types. The sampling points include Kampung Tenun and Bukuan Villages, which represented densely populated and non-populated areas, respectively. The water collected was prepared with the following steps, which include filtration with 180 µm nylon, elimination of organic matter, density separator, and final filtration. Microplastic samples were identified based on the type, color, size, and type of polymer using a microscope and FTIR. The results show that there are 3 types of microplastics, 4 colors, and 5 size categories dominated by fiber type, black, and the smallest size, respectively. There are differences in abundance in Kampung Tenun and Bukuan Villages, namely 91 particles/L and 71 particles/L, indicating the effect of the anthropogenic type. Sampling depth also affects abundance, hence, the greater the depth, the lower the abundance value. It was also discovered that anthropogenic type and depth factors influence the identified polymer types. Nylon and nitrile polymer types were found at 2 locations and 3 sampling depths, but PVC, PETE, and PS were only found at certain locations. Furthermore, Bukuan Village, with a greater environmental factor value, has a smaller abundance than Kampung Tenun Village.

Keywords: Microplastic, Anthropogenic, Depth, Mahakam River

Introduction

Mahakam is the second longest river in Indonesia with a length and river area of 920 km and 149,277 km², respectively. This river contributes to the life of the Samarinda people as a source of raw water for Drinking Water Treatment Plants, which have more than 156,278 customers [1]. It is also used as a means of water transportation for passenger, tourist, and coal transport ships [2], as well as a floating cage fishery [3].

In the Mahakam River watershed, there are residential areas as well as commercial and industrial places such as shipyards, ports, etc. The existence of various activities along the river can produce solid waste or garbage. Indonesia is the second largest waste-producing country after China and the most waste produced is plastic. The biggest supplier is usually household, especially plastic or non-degradable or inorganic waste [4]. Generally, when plastic waste enters the waters, it decreases river water quality [5] due to continuous degradation to a very small size or microplastic, with a size of < 5 mm [6].

Microplastics are plastic waste that is fragmented into very small particles [7] of less than 5 mm [8]. The abundance and distribution are affected by environmental and anthropogenic factors. Environmental factors include wave currents, tides, cyclones, wind direction, and river hydrodynamics [9]. Meanwhile, anthropogenic factors include population density [10], which affects the presence of microplastics through the amount of plastic waste originating from human activities [11] such as tourism activities, settlements, and fishing including fishing gear and boat waste [12]. Samarinda Seberang Subdistrict ranks second with the highest population density in Samarinda City, which is 5,128 people/km², while Palaran Subdistrict has the lowest population density of 286 people/km² [13]. Annual population growth, followed by the use of plastic in domestic activities can lead to an increase in microplastics in the sea [14]. Add international standards for microplastics, if available. There are no standards related to microplastics in waters. However, several countries such as the United States and Canada have passed federal laws banning plastic microbeads, a subset of microplastics. The United States passed the Microbead-Free Waters Act of 2015 (MFWA), prohibiting the manufacture, packaging, and distribution of cosmetics containing plastic microbeads.

Therefore, this research was conducted to determine the effect of anthropogenic characteristics on the microplastic abundance in Mahakan River water. The selected anthropogenic characteristics were densely populated and non-densely populated areas in the Mahakam River watershed. The effect of depth on the microplastic abundance was also analyzed at a depth of 0.5, 1, and 1.5 m. The abundance was analyzed based on shape, size, color, and the type of polymer found.

Methods

The tools used were GPS (Global Positioning System) Define each acronym in the manuscript, water sampler, anemometer, pH meter, thermometer, flowmeter, hygrometer, vacuum pump, 180 µm nylon filter, oven, analytical balance, density separator, microscope, hotplate stirrer, FTIR (Fourier Transformer Infra Red), and glassware. The materials used were distilled water, 0.5 M Fe(II) solution, 30 % H_2O_2 solution, NaCl, and N-Hexane.

Mahakam River water sampling

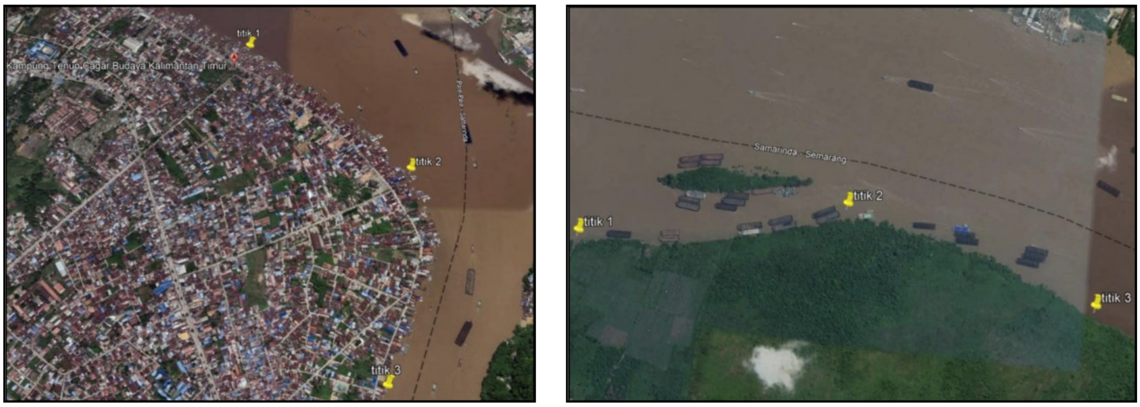
The sampling location was on the Mahakam River, namely in dense and non-populated areas. Kampung Tenun Village, Samarinda Seberang Subdistrict represented a densely populated area, while Bukuan Village, Palaran Subdistrict represented a non-densely populated area.

The sampling was carried out at 3 points for each location as shown in **Figure 1**, namely Kampung Tenun Village, Samarinda Seberang Subdistrict, and Bukuan Village, Palaran District. Coordinates were determined based on the level of population density as presented in **Table 1**. The water samples were taken at 3 depths, namely 0.5, 1, and 1.5 m at 08.00 - 10.00. There were 6 water samples taken and repeated or duplicated. Repetitions were carried out at different times, by calculating the average value of the 2 test results. The physical parameters of water were also measured to determine the value of wind speed, pH, temperature, and flow velocity before sampling. This is because these parameters play a role in the positioning of particles in the water [15].

Water sample analysis

Several stages of treatment were carried out on water samples before identifying the microplastic abundance. The treatment of water samples was carried out at the Environmental Technology Laboratory, Faculty of Engineering, Mulawarman University. The first stage was filtering using a 180 µm nylon filter with a vacuum pump on 500 mL samples from a depth of 0.5, 1, and 1.5 m. The nylon filter was put in an oven at 90 °C for 24 h to reduce the water content [16] and obtain a mixture of microplastics and contaminants. The next stage was eliminating organic substances to identify the presence of microplastics using hydrogen peroxide (H_2O_2) [17]. The sample on the nylon filter was transferred to a beaker with distilled water and 20 mL of 30 % H_2O_2 as well as 20 mL of 0.5 M Fe(II) solution were added as a catalyst. Subsequently, the mixture was allowed to stand at room temperature for 5 min [16]. A hotplate stirrer was used during this process at a temperature of 75 °C [18].

After the organic contaminants were removed, 6 g of NaCl was added per 20 mL sample and stirred using a hotplate stirrer. The mixture was heated at 75 °C until dissolved to increase the density value and allow other materials to settle [16]. The next step was to put the sample into a density separator and leave it for 24 h. The solids settled on the bottom of the tool were removed. The discarded part was the precipitated solids or other contaminants. The remaining water and microplastic samples were filtered again using a 180 µm nylon filter [18]. Microplastic observations were made on the filtering results using an Olympus CX23 microscope with a magnification of 10×10.



(a) (b)

Figure 1 Sampling points were in (a) a Densely Populated Area in Kampung Tenun Village, Samarinda Seberang Subdistrict (b) a Non-Dense Population Area in Bukuan Village, Palaran Subdistrict Bad quality, improve the resolution of the Figure.

Table 1 Coordinates of sampling point for densely populated area coordinates of the sampling locations are not in standard format.

Point	Densely Populated Area (Kampung Tenun Village, Samarinda Seberang Subdistrict)	Non-Densely Populated Area (Bukuan Village, Palaran Subdistrict)
1)	00°30’38,64”S 117°08’54,63”E	00°34’46,29”S 117°14’127,46”E
2)	00°30’54,25”S 117°90’10,89”E	00°34’43,82”S 117°14’38,47”E
3)	00°31’13,94”S 117°09’11,23”E	00°34’42,46”S 117°14’57,15”E

Analysis of microplastic abundance based on type, size, color, and type of polymer

The type, size, and color were observed using a microscope, while the analysis of the polymer used FTIR (Fourier Transform Infa Red) analysis [12] add referance. The types of microplastics were grouped into 3 categories, namely fiber, film, and fragment. Fiber microplastics are elongated, the films are transparent, thin, and soft [19], while the fragments are hard and rigid [14].

Moreover, the type, size, and color were analyzed at the Environmental Technology Laboratory, Faculty of Engineering, and the Laboratory of Microbiology and Molecular Genetics, Faculty of Mathematics and Natural Sciences, Mulawarman University, Samarinda. The polymer type was analyzed through FTIR (Fourier Transform Infa Red) analysis at the Materials Characterization Laboratory, Sepuluh Nopember Institute of Technology, Surabaya. Fourier Transform Infa Red (FTIR) analysis produced the sample spectra, which will be compared with the spectral results of the microplastics found. Furthermore, the spectra that were close to the sample were selected and the microplastic abundance was determined by comparing the number of particles with the sample volume, as shown in Eq. (1) [6].

$$\text{Microplastic abundance (particle/m}^3\text{)} = \frac{\textit{number of microplastic particles}}{\textit{sample volume } (m^3)} \quad (1)$$

Results and discussion

Analysis of environmental factor measurement results

Samples were taken in 2 locations, namely Kampung Tenun and Bukuan Villages, representing densely and non-populated areas. The sampling technique was an integrated approach using a water sampler. Kampung Tenun Village has a low topography with land that is still affected by the river tides. In this village, sampling was carried out in a residential area above the river, and plastic, vegetable waste, wood, leaves, tree branches, as well as water hyacinth were discovered. During the process, the weather condition was sunny with the environmental physical parameters, namely air temperature 30 °C, water temperature 29 °C, water pH 7.4, water speed 0.23 km/h, wind speed 0.28 m/s, and wind direction to the south.

Sampling in Bukuan Village was carried out by boat and was far from residential activities, the weather conditions were sunny, and no waste was found. The results of the measurement of environmental physical parameters included air temperature 31 °C, water temperature 30 °C, water pH 6.6, water speed 1.2 km/h, wind speed 0.73 m/s, and the wind direction is eastward. The measurement at both locations showed almost the same results, except for water and wind speeds. There was a large difference in water speed due to waves from several fishing boats passing by. These environmental factors affect the presence of microplastics and the degradation of plastic waste in the waters.

Microplastic abundance by type

The analysis of the Mahakam River water sample obtained 3 types of microplastics, namely fiber, film, and fragments, the abundance, as shown in **Figures 2** through 5, respectively.

Figure 2 Fiber microplastic.

Figure 3 Film microplastic.

Figure 4 Fragment microplastic.

Figure 5 shows the microplastic abundance by type, dominated by fiber both in Kampung Tenun and Bukuan Villages. Fiber microplastic can come from washing waste in form of clothing fibers [20]. This is because the Mahakam River is a place for collecting domestic waste from the community, which is the estuary of the drainage channel. Domestic waste includes washing waste, from people's daily activities and textile materials from production, as well as household utensils made from cloth. Based on observations, there are 3 laundry businesses in the watershed in the village that do not manage their waste properly. This has become one of the sources of microplastics, especially for the fiber type because each washed garment can produce >1900 fibers [7].

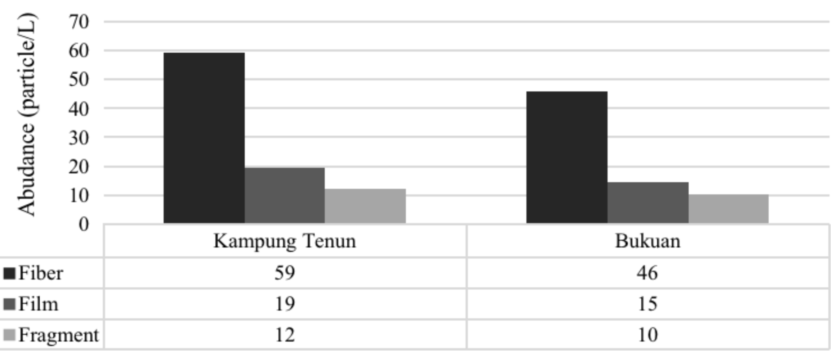


Figure 5 Microplastic abundance by type.

Film microplastic can come from plastic bags, food packaging, toiletry packaging, mulch, polybags, low or high tunnel plastic, and UV plastic. Meanwhile, fragment types come from drinking bottles, jars, buckets, mica folders, paralon pipes, irrigation pipes, and plastic pots [6].

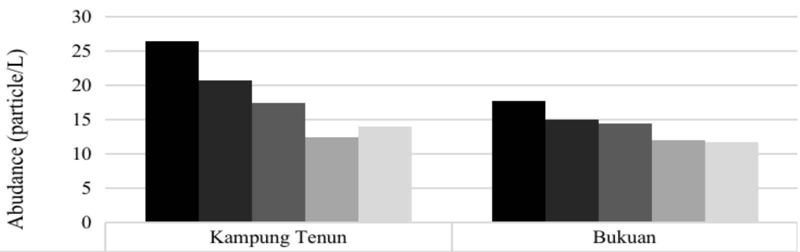
Fiber is a type of microplastic originating from primary and secondary sources associated with densely populated areas and other activities such as transportation, tourism, and fisheries [21]. **Figure 5** shows that the fiber microplastic abundance in Kampung Tenun Village is higher than in Bukuan Village. Furthermore, film and fragment types are higher compared to Bukuan Village due to ship traffic, population density, and human activities [22].

The data obtained in **Figure 5** is in line with the observations during sampling, which shows that in Kampung Tenun Village, there is still plastic waste, which is not found in Bukuan Village. This is also affected by the large population which is directly proportional to the production of plastic waste that can be degraded into microplastics in rivers.

Microplastic abundance by size

The microplastic size obtained in all samples was categorized into 5 size groups, namely 180 - 250, 250 - 500, 500 - 1000, 1000 - 2500 and 2500 - 5000 µm. This size classification is based on the findings of the size of microplastics in the sample and according to the size of microplastics, which are less than 5 mm in size. The differences in size found are influenced by environmental factors, such as temperature, water velocity, and the degradation time of plastic waste in the waters. Add sources of these type of micropollutants in the river. The trend of microplastic abundance by type for both locations was the same, namely the smaller the size of the microplastic, the higher the abundance value. From **Figure 6**, the highest abundance was found in microplastics measuring 180 - 250 µm or with the smallest sizes.

Microplastics with a size of 180 - 250 µm were mostly found on river surfaces or at a sampling depth of 0.5 m. Since smaller size produces low density, the microplastics tend to be on the water's surface [23]. The size differences identified were affected by the fragmentation process in the waters. The longer the fragmentation time, the smaller the size [24]. Large plastic pieces become brittle or age due to several other factors such as exposure to UV radiation, waves, climate change, and other abiotic factors [25].



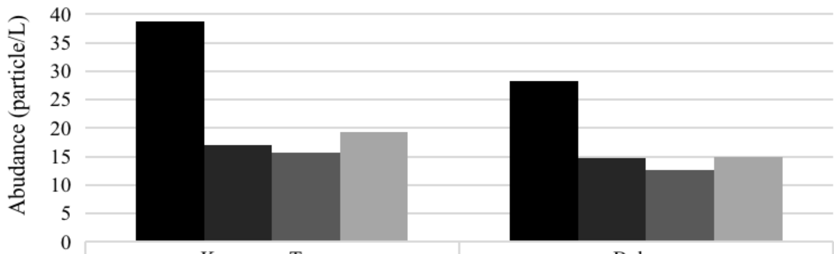
	Kampung Tenun	Bukuan
180-250 µm	26	18
250-500 µm	21	15
500-1000 µm	17	14
1000-2500 µm	12	12
2500-5000 µm	14	12

Figure 6 Microplastic abundance by size.

Microplastic abundance by color

From **Figure 7**, a total of 4 colors were identified, where black has the highest abundance, followed by clear color. Meanwhile, black was found in fiber and fragment types, dominated by fiber, which is 66 % of the total abundance of black microplastics at both locations. The black color indicates that the microplastic comes from the PS (polystyrene) or PP (polypropylene) type, with the chemical content of PAHs (Polycyclic Aromatic Hydrocarbons). PS-type plastic is commonly used as a material for styrofoam dining, disposable drinking containers, and others. Furthermore, it is commonly used for food and beverage containers, medicine bottle caps, margarine tubes, other caps, straws, toys, ropes, clothes, and various kinds of bottles [26,27].

Clear-colored microplastics come from PE (polyethylene) plastic. It can come from the color of the plastic due to physical or oxidative degradation, exposure to UV and infrared rays, weather, sunlight (photodegradation), and chemical absorption. Besides PE, clear colors can also originate from LDPE (Low-Density Polyethylene) and EVA (Ethylene Vinyl Acetate) plastics. This is because LDPE is white, while EVA is clear and transparent. The color of microplastics also indicates the length of stay at sea level and the degree of weathering [26]. Meanwhile, the clear color is caused by the fragmentation that has not been exposed to sunlight for a long time, leading to changes in microplastics' color. The color of microplastics appears due to the degradation of plastics into microplastics by environmental and climatic factors. The presence of sunlight containing ultraviolet causes changes in the plastic particles which also affect the color of the microplastics



	Kampung Tenun	Bukuan
Hitam	39	28
Biru	17	15
Merah	16	13
Bening	19	15

Figure 7 Microplastic abundance by color.

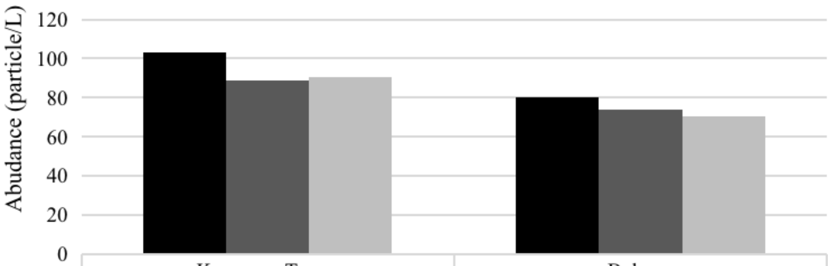
Effect of anthropogenic types on microplastic abundance

The analysis of the microplastic abundance at both locations showed differences as indicated in **Figures 5 - 7**. The microplastic abundance in Kampung Tenun Village is 91 particles/L, while 71 particles/L is obtained in Bukuan Village. This is affected by the distance between the villages, which is not extremely far, namely 12 km. However, it can be analyzed that location affects the microplastic abundance. This is because Kampung Tenun Village, as a densely populated area, is filled with various activities that produce plastic waste, a source of microplastics. The main source of waste generation in this area is domestic activities. Furtheemore, there is also a laundry business and Kampung Tenun Village is an area for producing Samarinda woven fabrics. Provide the major sources of waste generation.

Physical parameters measured at the locations also affected the distribution of microplastics such as water velocity and wind speed. These parameters in Bukuan Village tend to be greater, thereby contributing to the low microplastic abundance. Other factors such as air and water temperatures in Kampung Tenun Village tend to be lower, causing the plastic to rapidly degrade. These results show that climatic conditions such as air temperature, wind speed, and waves significantly affect the distribution of microplastics in waters [28].

Effect of depth on microplastic abundance

Figure 8 shows that the microplastic abundance in Kampung Tenun and Bukuan have the same trend, namely the greater the sampling depth, the smaller the abundance. The greatest abundance is found at a depth of 0.5 m or in the water surface area of the Mahakam River. This is due to the abundance of fiber-type microplastics compared to film and fragment types as shown in **Figure 9**. Fiber-type microplastics generally have a small density, hence, they tend to be on the surface [23].



	Kampung Tenun	Bukuan
0,5 m	103	80
1 m	89	74
1,5 m	91	71

Figure 8 Microplastic abundance based on depth.

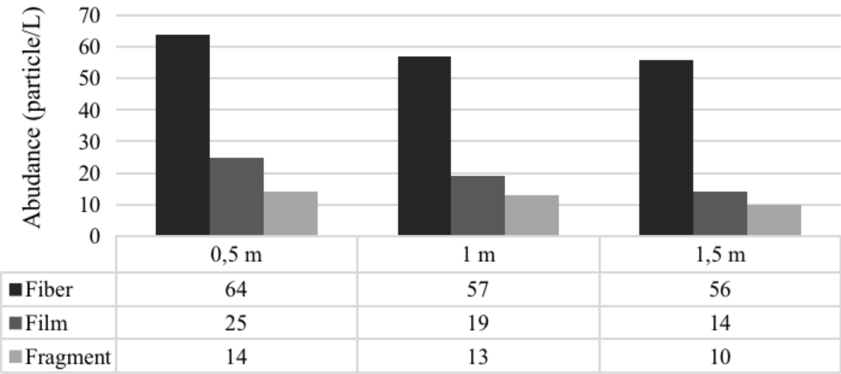


Figure 9 Microplastic abundance by type and depth in Kampung Tenun Village improve the resolution of the Figure. Use attractive colors in the graphs.

Types of microplastic polymers in Mahakam River Water

The polymer type was analyzed by identifying the wave crests found in the FTIR analysis as shown in **Figure 10**. Based on the results, the type of chemical bond was identified and adjusted to make up the plastic polymer. In Kampung Tenun Village, polymer nylon, nitrile, PVC (polyvinyl chloride), and PETE (polyethylene terephthalate) were found, while in Bukuan Village, polymer nylon, nitrile, and PS (polystyrene) were discovered. More detailed identification is shown in **Figure 10** and **Table 2**.

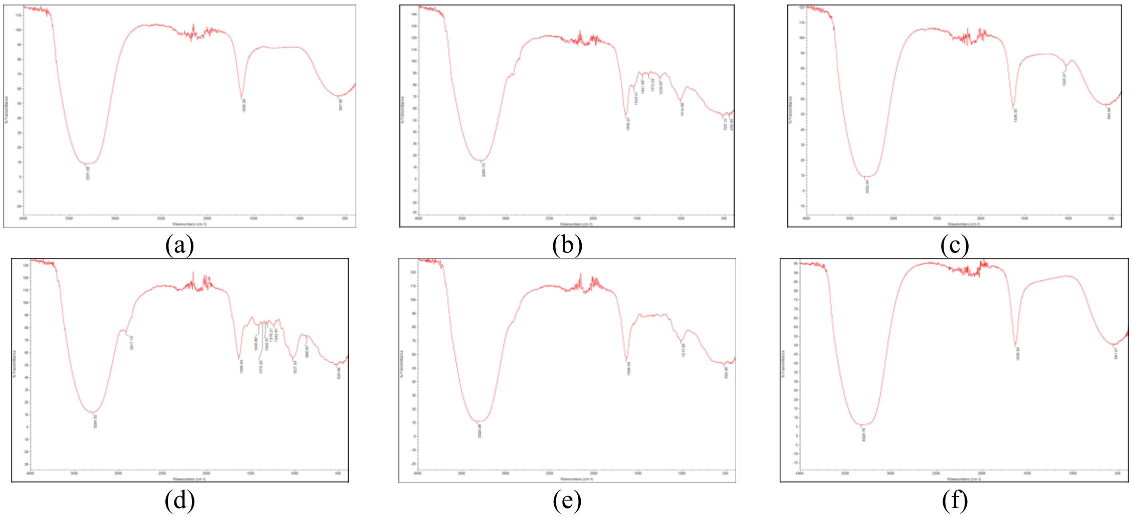


Figure 10 The results of the FTIR of Kampung Weaving Village at a depth of (a) 0.5 m, (b) 1 m, (c) 1.5 m; Bukuan Village at a Depth (d) 0.5 m, (e) 1 m, and (f) 1.5 m.

Table 2 Identification of the type of polymer in the sample.

Location	Wavelength	Absorption Tape[29]	Identified Polymer Type
Kampung Tenun village, depth of 0.5 m	3331.98	3298	Nylon
	1636.39	1605	Nitrile
	587.85	616	Polyvinyl chloride (PVC)
Kampung Tenun village, depth of 1 m	3286.74	3298	Nylon
	1636.27	1605	Nitrile
	1239.05	1241	Polyethylene terephthalate (PETE)
Kampung Tenun village, depth of 1.5 m	3332.64	3298	Nylon
	1636.35	1605	Nitrile
	564.88	616	Polyvinyl chloride (PVC)

Location	Wavelength	Absorption Tape[29]	Identified Polymer Type
Bukuan village, depth of 0.5 m	3294.52	3298	Nylon
	2917.15	2917	Nitrile
Bukuan village, depth of 1 m	3328.98	3298	Nylon
Bukuan village, depth of 1.5 m	3328.76	3298	Nylon
	561.47	537	Polystyrene (PS)

Table 2 shows that the types of polymers found at the 2 research sites were nylon and nitrile. Nylon is a polymer compound that has an amide group on each repeat unit, hence, it is called a polyamide compound. It also has N−H, CH, CH2, C=O, and C−N bonds in the polymer [29] and is widely used in the textile and plastics industry. Nitrile is a polymer that can be used in latex and medical gloves, as an alternative to allergenic gloves [30]. It has =C−H, CN, C=C, and CH_2 bonds in the polymer [29]. Meanwhile, nylon was found in the samples because its membranes are resistant to high pH and temperature, have a small pore size distribution, and tend to float on the water surface [31].

In Kampung Tenun Village, PVC and PETE polymers were also found. Polyvinyl chloride (PVC) is one of the synthetic polymers that is widely used as the main material in plastics formation for packaging food and beverages. Its pure state is a rigid material [32] and has C=C, C−H, and CH_2 bonds in the polymer [29]. Polyethylene terephthalate (PETE) is a type of plastic derived from processing crude oil derivatives, namely terephthalic acid (TPA) and ethylene glycol (EG). It is often used as disposable bottles or in form of films, but mostly as fiber [33]. It has C=C and C-O bonds in the polymer [29] and comes from plastic waste in form of food as well as beverage packaging at the sampling location. PVC and PETE were found in Kampung Tenun Village because this area is a densely populated which affects the generation of plastic waste in the form of food packaging and disposable drinks which degrade into microplastics. This is in line with the conditions during sampling as shown in the **Figure 11**.

(a) (b)

Figure 11 Conditions during sampling in (a) Kampung Tenun Village and (b) Bukuan Village.

Polystyrene (PS) was found in Bukuan village, which is a thermoplastic polymer made by the chemical industry and used in various applications, including plastic bags, food containers, and tires. This plastic is more heat resistant, hard, flexible, and impermeable to light. It can pass through chain degradation when exposed to ultraviolet radiation from sunlight [34]. PS has O−H and C−H bonds in the polymer [29].

Conclusions

Kampung Tenun Village, which represented a densely populated area has an abundance of 91 particles/L, while Bukuan Village, as a representation of a non-populated area, has an abundance of 71 particles/L. The difference in anthropogenic types and depth of sampling affects the abundance value. The analysis shows that the greater the depth, the lower the abundance. Based on the results, a depth of 0.5 m has the highest abundance.

Microplastics were found in Mahakam River in 2 locations, namely Kampung Tenun and Bukuan Villages. The 3 microplastic types found, were fiber, film, and fragments, dominated by fiber. The microplastics were divided into 5 size groups, namely 180 - 250, 250 - 500, 500 - 1000, 1000 - 2500 and 2500 - 5000 µm, dominated by the smallest size. Furthermore, a total of 4 colors were identified, which include black (dominant), red, blue, and clear. In this condition, 66 % of the black color was dominated by the fiber type. This conclusion doesn't summarize the main results presented and discussed in this paper. Should be rewritten.

Anthropogenic type and depth factors also affect the identified polymer types. Based on the observation, nylon and nitrile polymer types were found at 2 locations and 3 sampling depths. However, PVC and PETE were only discovered at Kampung Tenun Village, and PS was only found in Bukuan Village at a depth of 1.5 m. Environmental factors such as water speed, wind speed, air temperature, and water temperature affect the abundance value. The value of these environmental factors in the Bukuan Village is greater, hence the abundance value tends to be smaller than in Kampung Tenun Village.

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