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RESEARCH ARTICLE

The Relationship of Microplastic Abundance, Flow Rate Discharge and Drainage Profile in Bandar Lampung City, Lampung Province, Indonesia

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Abstract The research on microplastics in urban drainage is becoming a concern. In the drainage of Bandar Lampung city, four different anthropogenic activities were investigated: road runoff, industrial activity, public place, and housing area. This study investigated the abundance, characteristics and distribution of microplastics (MPs) through drainage systems in dry weather. A total of sixteen drainage water samples were collected using grab sampling with a horizontal water sampler. Under microscope observation combined with a needle test, the average abundance of MPs was found 3.97±3.4 particles/L, with fibers as the dominant type of MPs. The order of MPs' abundance was industrial area > public area > transportation area > housing area. However, this number of MPs tends to be lower compared to other reported studies. The size of MPs mostly ranged from 500 - 1500 μm (36%). The color of MPs was amply diverse, with blue being in the dominant proportion (43%). Other studies also reported similar findings regarding the type and size range. Through Raman spectroscopy, the identification of polymer types indicated the presence of polyethylene terephthalate. From the correlation analysis, it was found that there was a positive correlation between the abundance of MPs and flow rate discharge, though with a low relationship (r=0.46). This result can be influenced by several factors such as the effects of multiple land use types and pollution sources. The significance of this research lies in its contribution to understanding the extent of microplastic pollution and its potential environmental impact on the Lampung water body.

1. Introduction

Plastic waste has become an environmental issue that continues to grow. Almost every region in the world is experiencing an increase in the amount of plastic waste. It is recorded that in 2017, global plastic production reached 384 million tons, and in 2018, it reached 359 million tons (Tuhumury and Ritonga, 2020). Indonesia is one of the major contributors to plastic waste, particularly Lampung Province, which is recorded as a producer of plastic waste in Indonesia (or the world). The problem of plastic waste is certainly inseparable from the source of the plastic itself, whether it originates from activities or the lifestyle of the community.

Moreover, the issue of microplastics is now becoming more interesting to study. Microplastics (MPs) are the result of the degradation of plastic waste into smaller sizes (< 5 mm) (Hiwari, et al., 2019). The spread of MPs can be found in the surrounding environment through various sources such as from the air (atmosphere), water bodies, oceans, rivers, and can also enter through drainage channels (Imanuel, et al., 2022). Drainage channels function as a means of carrying rainwater from an area which includes residential areas, industry, schools or supporting facilities in a city. Often these drainage channels do not function according to their intended purpose and the drainage is even full of rubbish. Through hydrological events such as precipitation, rainwater runoff, floods, it is possible to collect and transport MPs formed from degradation of the surrounding environment to drainage channels (Buwono, et al., 2021).

Proper drainage channels generally serve as a means of rainwater runoff. However, drainage channels often change their function and are even nearly filled with waste dominated by plastic waste (Oktiawan, 2012). This will certainly increase the potential for the spread of MPs. Furthermore, the runoff of rainwater sweeping microplastic particles from vehicle tire wear enters the drainage channels (Kole, 2017).

The presence of MPs in drainage channels cannot be separated from the role of water as a carrier. Surface runoff transports MPs to drainage areas (Hale, et al., 2020). Drainage that is contaminated with plastic waste, if it is passed by water flow and has a large water discharge, will give rise to the potential for the formation of MPs (Sa'diyah and Trihadiningrum, 2020). The MPs that are formed will be carried to other locations influenced by the drainage discharge (Talbot and Chang, 2022).

The abundance of MPs in drainage channels can be influenced by the flow rate and discharge of the drainage (Zhou, 2023). This study aims to identify the influence of drainage flow rates on the abundance of MPs, taking into account the surrounding activities suspected to be the source of MPs in the drainage channels. Previously, there were research about MPs abundance in the river of Way Belau in Bandar Lampung (Alam, 2023), but the input of the river from the drainage is not identified yet. With this research, it is hoped that it can be the initial step in controlling and preventing the spread of MPs in drainage channels. After knowing the abundance of microplastics in drainage channels, then knowing the effect of drainage flow rate on the abundance of microplastics, it is hoped that this research will be able to answer the issue of microplastic pollution in drainage channels, and trace drainage flows that have the potential to pollute surface water until it flows into the open ocean also policy adoption to local and international collaboration.

2. MATERIAL AND METHODS

Research Location

The study was conducted at 4 locations in the city of Bandar Lampung, which were considered to represent various community activities. Site 1 represented the industrial area, site 2 represented the transportation area, site 3 represented the public area, and site 4 represented the residential area. More detailed information about the locations can be seen in **Figure 1.** Moreover**,** the drainage water samples were collected from four sampling sites between July to September 2023. The details of each location can be found in **Table 1**. The sampling was conducted during dry weather to track urban microplastic emission released by anthropogenic activities (Abusafia et al., 2023).

Measurement of Drainage Flow Rate

The measurement of drainage flow rate was conducted manually with the assistance of a float according to Indonesia National Standard of 8066:2015 about procedures for measuring river flow rates and open channel flow using a current meter and float. The flow velocity was determined based on the average time taken by the float to travel a certain distance. The flow rate was calculated using the equation Flow Rate (Q) = V × A. Here, Q represents the flow rate (m^3/s), V stands for the flow velocity (m/s), and A represents the cross-sectional area (m^2). An illustration of the flow rate measurement can be seen in **Figure 2**.

Collection of Drainage Water Samples

Samples were taken a total of 4 times at each location, with the specification of 3 times on working days and once on a holiday. This was done to represent the activities of the community in one week. The samples were collected using the grab sampling method with tools such as a handled dipper and a horizontal water sampler. The samples were then placed in 2-liter glass bottles (Park, 2020).

Wet Peroxide Oxidation

After the samples have dried using the MEMMERT UN110 oven, add 20 mL of 30% H_2O_2 solution. Cover the glass beaker with aluminum foil and let it sit at room temperature for 24 hours. Filter the sample and H_2O_2 solution using Whatman GF/C filter paper with a vacuum pump. Transfer the filter paper to a petri dish and let it dry (Masura et al, 2015).

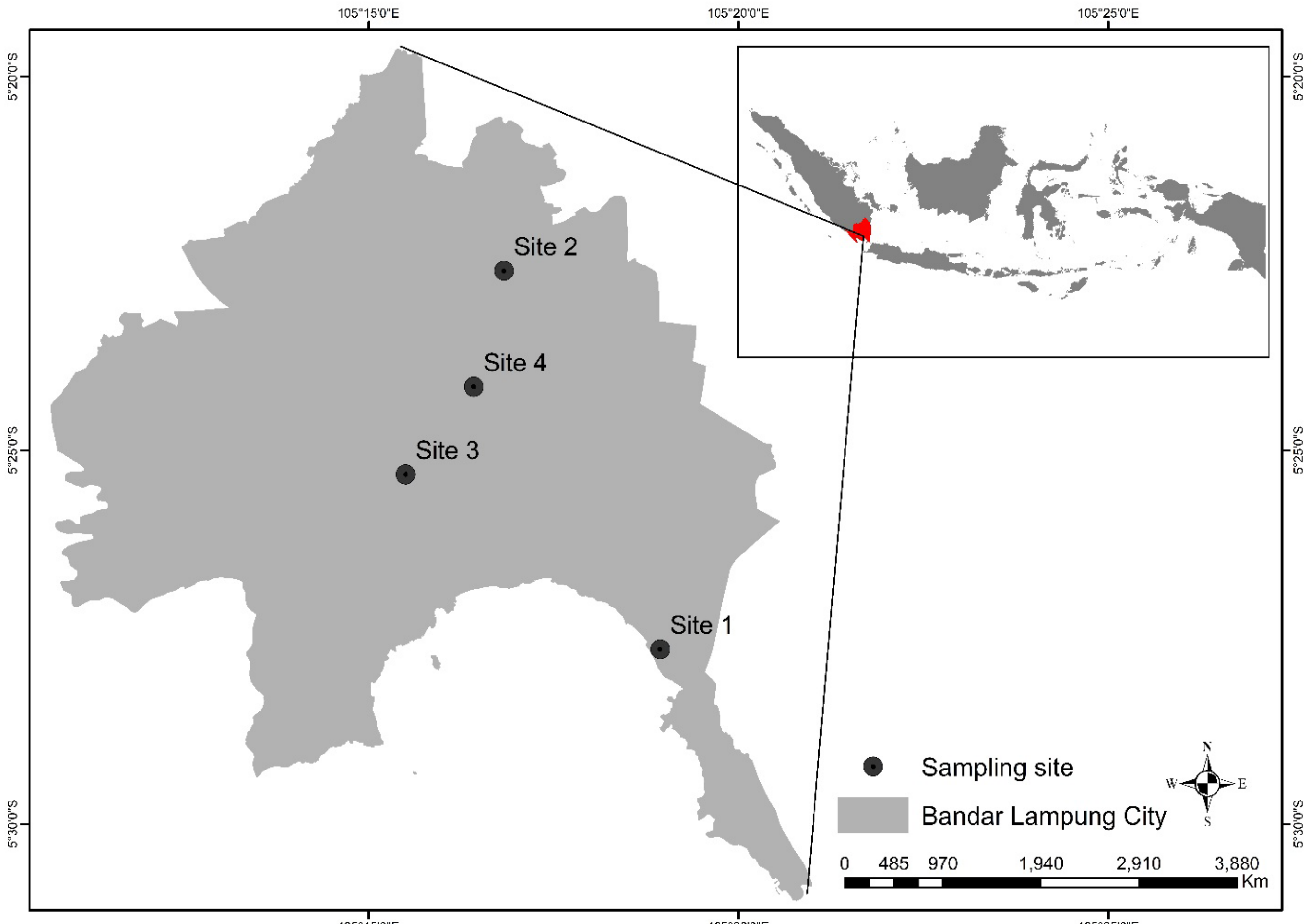

Figure 1. Study Location: Bandar Lampung City

Table 1. Sampling location

Sampling location	Coordinate		Area	Sampling condition
	Latitude	Longitude		
Location 1	5°27'40.93"S	105°18'55.80"E	Industrial area	
Location 2	5°22'37.21"S	105°16'49.98"E	Transportation area	
Location 3	5°25'19.95"S	105°15'30.83"E	Public area	
Location 4	5°24'12.05"S	105°16'30.24"E	Housing area	

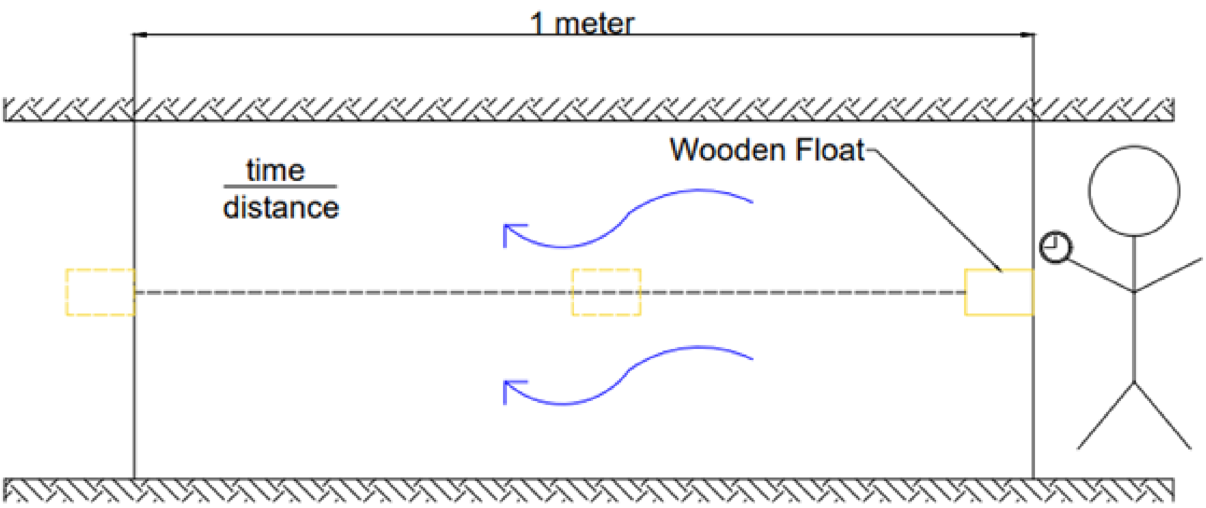

Figure 2. Illustration of measuring drainage flow discharge

Identification of Microplastic Morphology and Polymer Types

The filter paper is observed using an olympus CX23LEDRFS1 microscope at 4x and 10x magnification. Particles are identified based on their type, color, and size. The identified types of MPs include fibers, fragments, pellets, films, and foams. To ensure all suspected MPs, a needle test was also conducted (Beckingham et al. 2023). The size ranges from 20 to <250μm, 250 to <1000μm, 1 to <2 mm, and 2 to 5 mm. The size MPs can exhibit various colors such as transparent, blue, black, red, green, brown, orange, and yellow (Osorio, 2021). The size of the microplastic was determined using the ImageJ 1.54 version software. Image analysis is a technique that can quantify subtle variations in the dimensions of MPs and minimize interference from irrelevant signals (Valente et al. 2023). The identification of polymer types is conducted using Raman spectroscopy from the Physical Chemistry Laboratory, Bandung Institute of Technology. Microplastics were tested by Raman with a light shot with a wavelength of 785 nm for 30 seconds (Alam, 2023). The microplastic particles are then tested to determine the polymer from the microplastic sample.

Data Analysis

Microplastic abundance from each site will be presented by number of microplastic particles (particles) / Sample volume (L). The abundance will also be presented with the shape and polymer type. The data will be described statistically with the Kruskal Wallis test to examine the differences in the mean abundance at each sampling location, and a scatter plot test was performed to assess the relationship between drainage flow rate and microplastic abundance.

3. RESULT AND DISCUSSION

Identification of Microplastic Abundance

The average abundance of MPs in drainage channels in Bandar Lampung is about 3.9 particles/L. When comparing these results to the previous research (Sugiura et al. 2021, Zhou et al. 2023, Bond and Rate, 2022), the average abundance of MPs was relatively small. Those previous studies reported averages of around 81 particles/L, 13 - 30 particles/L, 14.2 particles/L, respectively. However, when compared to study in Vietnam, the MPs abundance in Bandar Lampung was slightly higher. This research falls into the category of "small," assuming differences in discharge and channel geometry. A comprehensive comparison between different cities around the world can be found in Table 2.

According to Upadhyay et al. (2023), the lower abundance of MPs in drainage can be caused by different volumes of wastewater, MPs from effluent sources, and variations in sampling time and analysis strategy. Bandar Lampung is one of the urban areas but not as big as the other cities mentioned previously.

Table 2. Abundance of microplastics in drainage from different research

No	Research Location	Methodology	Results	References
1	Urban drainage channels, Da Nang, Vietnam	Steel bucket filtered using plankton net and GF/A glass fiber filter	1.482 particles/L	Quynh Anh Tran-Nguyen et al. 2022
2	Urban Wastewater and Estuarine Water, Japan	Water samples were taken from several points 0.6-20 L of runoff, then filtered closed with a stainless-steel filter and filter paper 5 μm diameter 90 mm	81-292 pieces/L	Sugiura et al. 2021
3	Stormwater Drains in Urban Catchments in Perth, Western Australia	Stacked filter design, continued with filter 25-100 micrometers	14.2 microplastics/L	Bond and Rate 2022.
4	Informal Urban Drainage System, India	Bucket samples	4.20 ± 1.40 particles/L	K. Upadhyay and S. Bajpai, 2023
5	Urban drainage system, China	All samples were collected 15–20 min and volume of 5 L using stainless steel bucket	between 13.6 and 30.8 items/L	Yuxuan Zhou, et al. 2023
6	Urban drainage system, Bandar Lampung, Indonesia	Bucket samples	3.9 particles/L	This research

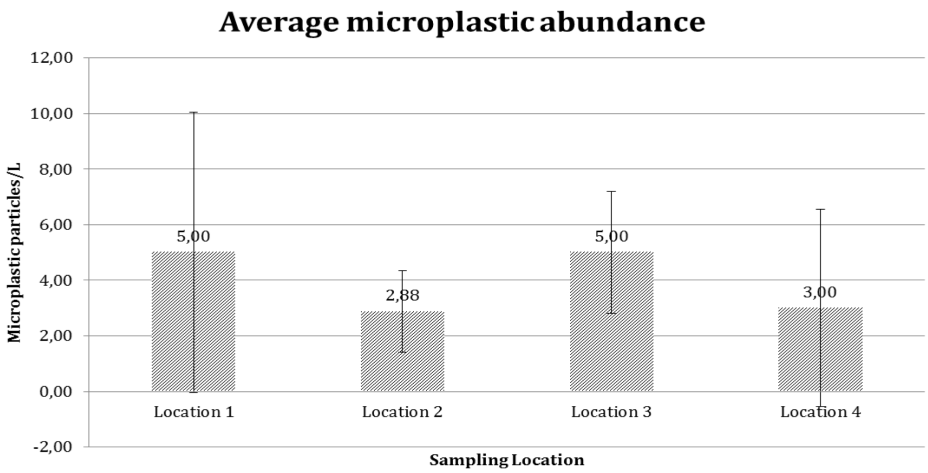

Figure 3. Average of Microplastic Abundance in each sampling location

Influence of Location to Microplastic Abundance

When comparing microplastic abundance from each location, the average microplastic abundance was obtained as shown in **Figure 3**.

From **Figure 3**, it can be seen that location 1 and location 3 had the greatest average abundance of microplastics around 5 microplastic particles/L. Location 1 represents an industrial area while location 3 is a location that represents a public area. A similar case was found in a study by Liu et al. (2019), which demonstrated that higher industrial land use has greater microplastic concentrations than those primarily consisting of residential land. According to Bond et al. (2022), land use intensity and population density could predict microplastic concentrations in certain areas. Even from Chen et al. (2020) research found that in descending order, the highest microplastic concentrations were found in heavy industrial > commercial/public/recreational and the lowest was residential areas. Although these findings cannot be generalized across different studies, regions, or stormwater drainage catchments. However, the Kruskal Wallis statistical test found that there were no significant differences between microplastics abundance and sampling location (p-value > 0.05).

Identification of Morphology and Polymer Types

Based on the results of microplastic abundance identification at each location, the shape, size, and color of MPs found at each sampling location can be seen in **Figure 4**.

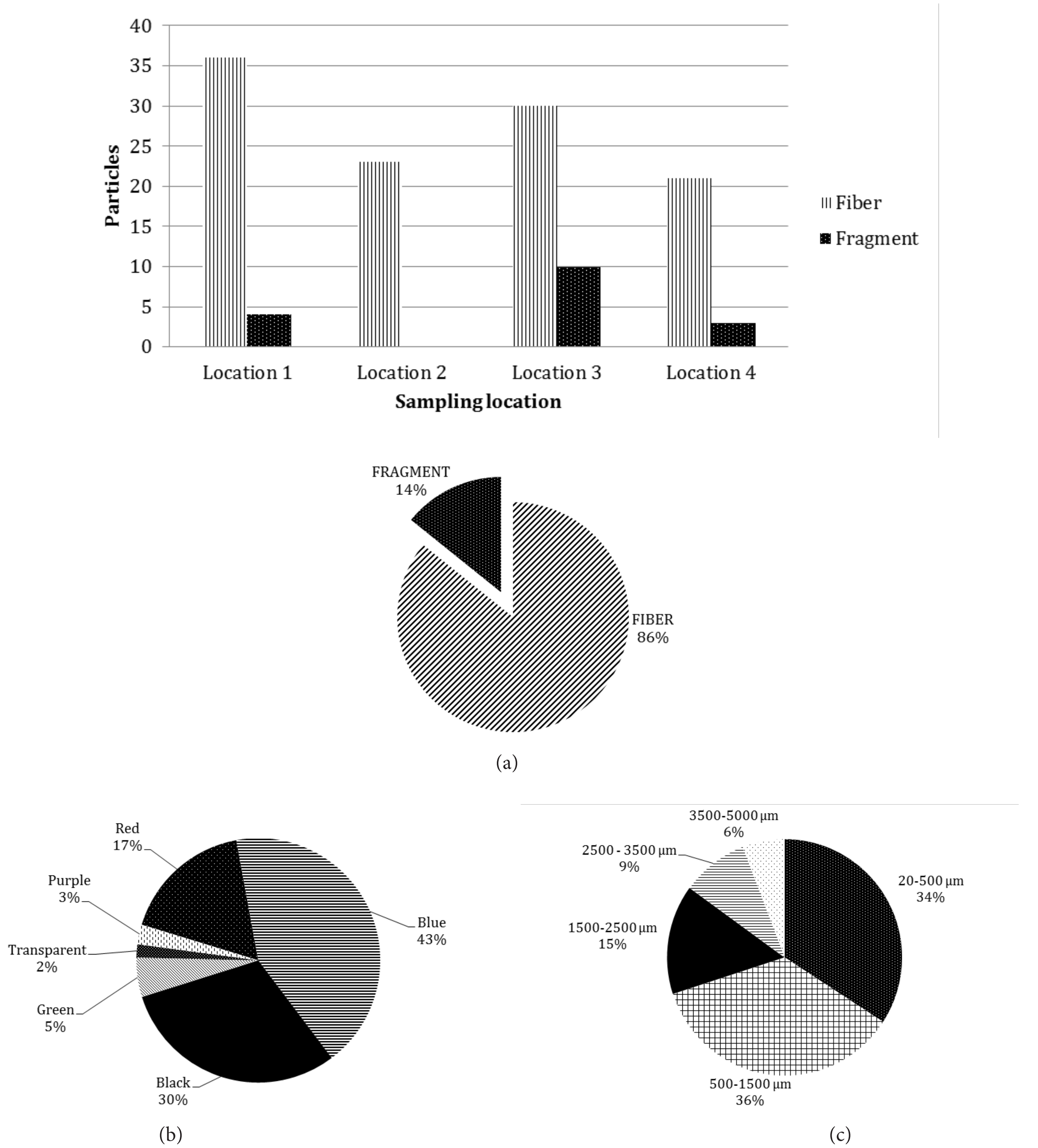

Figure 4. Microplastic morphology in each sampling location: (a) shape; (b) color; and (c) size

From **Figure 4**, it can be observed that besides the prevalent fiber form, the most dominant color found in MPs is blue (43%), while the dominant size falls within the range of 500 - 1500 µm (36%). This is similar to the research conducted by Tran-Nguyen, 2022, in drainage in Da Nang City, Vietnam, where the distribution of MPs found was primarily in the form of fibers with sizes ranging from 300-2000 µm and a dominant blue color. The high abundance of blue microplastics found in the environment can be caused by the characteristics of blue plastics that cannot absorb UV light effectively, they degrade faster in the sun and make the abundance higher (Zhao et al., 2022).

Based on the results of microplastic measurements using the ImageJ software, as shown in **Figure 5**, it can be observed that fibers were the most abundant type of microplastic found. This can happen because the drainage was combined with the sewer system. So, the washing activities that mostly release microplastic fiber type that contribute to drainage microplastic abundance (Choi et al., 2021). These results were similar to the microplastics type in drainage in China, that the fiber particles were almost 70% from all types found (Zhou et al., 2023).

One of the microplastic particles found was probably PET (polyethylene terephthalate) indicated from 1573 cm-1 (phenyl) and 1702 cm-1 (C=O). It can be seen in **Figure 6**. According to Ziajahromi et al. (2017), PET fibers are more likely coming from clothing and personal care products. This PET fiber can come from different sources such as washing activities or can come from dust and mainly from anthropogenic activities (Wang et al. 2017).

The Influence of Drainage Flow Rate and Drainage Profile on Microplastic Abundance

The drainage channels in these locations received not only rainfall and stormwater, but also wastewater from households and industry. This will impact the further information regarding the source of microplastics and their behavior in transport. Based on the observations of drainage flow direction at each sampling location, the results can be seen in **Table 3.**

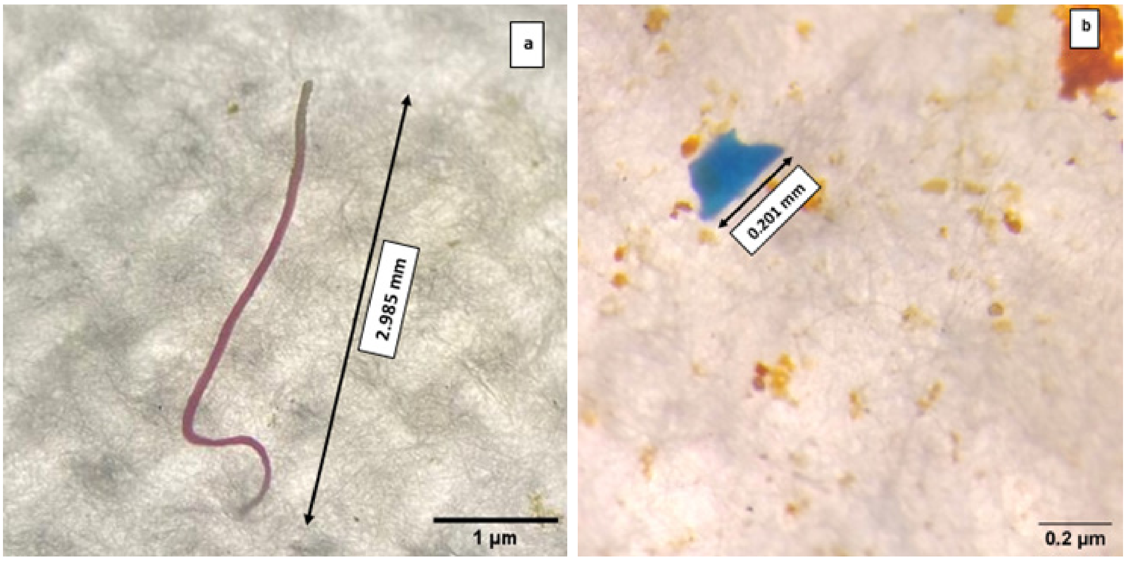

Figure 5. (a) Fiber Type (b) Fragment Type

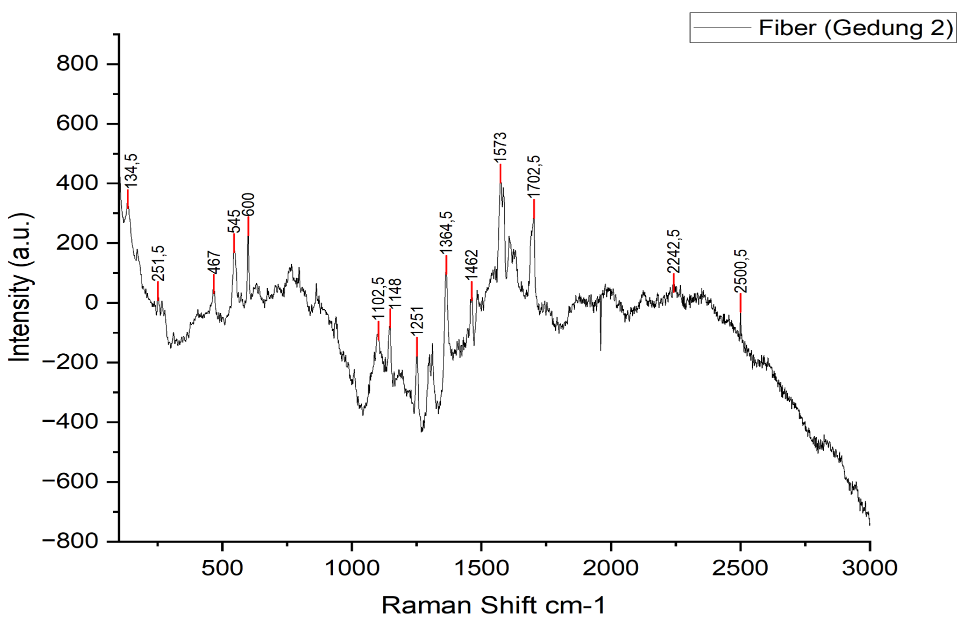

Figure 6. Raman spectra for fiber microplastic

Table 3. Drainage Flow

Sampling Location	Area	Drainage Flow Discharge
Location 1	Industrial area	
Location 2	Transportation area	
Location 3	Public place	
Location 4	Housing area	

The direction of drainage flow is thought to have a role in the transport of MPs. This can happen if there are not many obstacles such as sediment that can hold back the rate of MPs in the drainage channel (Tien, et al. 2020). In this research, the relationship between discharge and the abundance of MPs are discussed. The discharge data and drainage channel geometry can be seen in **Table 4**.

Drainage discharge is related to cross-sectional area and flow velocity. The cross-sectional area can be determined based on the width of the channel and the water level in the channel. Different cross-sectional shapes will produce different velocities and discharges (Widiatmoko, 2021). According to Table 3, locations 1, 2 and 3 have the same cross-sectional shape, namely a rectangle, while location 4 has a trapezoidal cross-sectional shape. The channel width at each point is different. This can be caused by the contour of the land and the capacity of the flow received. The shape and size of a drainage basin can influence how microplastics are transported and deposited. Basins with more convoluted shapes or those with numerous tributaries can potentially trap more microplastics in sediments and along riverbanks, whereas more streamlined basins may facilitate quicker transport of microplastics downstream and into larger water bodies (Nkosi et al 2023).

The channel with the largest width is at location 1, which is 602 cm. This is because location 1 accommodates flows from industry, so a larger channel is needed. This situation can also be seen at location 4 which represents a residential area with a channel width of 202 cm assuming it accommodates waste from housing. Location 1 and location 4 have the highest microplastics abundance, 5 particles/L and 5,05 particles/L respectively. However, if it compared to the discharge flow rate it did not show any specific pattern. The plot of MPs abundance at each point with the flow rate in the channel can be seen in **Figure 7**.

Table 4. Discharge data and drainage channel geometry

Location	Width (cm)	Water level (cm)			Cross-sectional Shape	Cross-sectional Area (m^2)	Water Velocity (m/s)	Discharge (m^3/s)
		Left	Middle Point	Right				
Location 1	602	60	60	60	rectangular	3.61	0.1333	0.4815
	602	43	43	43	rectangular	2.59	0.1333	0.3451
	602	13	13	13	rectangular	0.47	2.1487	0.2166
	602	12.5	12.5	12.5	rectangular	0.45	2.2346	0.2003
Location 2	100	18	18	18	rectangular	0.18	10.97	0.0164
	100	18	18	18	rectangular	0,18	11	0.0164
	100	15	15	15	rectangular	0,16	11.39	0.0141
	100	16	16,5	14	rectangular	0.17	10.77	0.0159
Location 3	72	8	8.5	8.5	rectangular	0.07	14.56	0.0051
	72	9	10,5	10.5	rectangular	0.08	17.02	0.0049
	72	6,5	8.5	8.5	rectangular	0.06	6.17	0.0098
	72	2	2	2	rectangular	0.02	4.59	0.0041
Location 4	202	22	25	10	trapezoid	0.35	6.54	0.0531
	202	20	18	24	trapezoid	0.32	8.88	0.0356
	202	19.5	15	14	trapezoid	0.31	7.12	0.0433
	202	15.5	20	15	trapezoid	0.24	4.02	0.0609

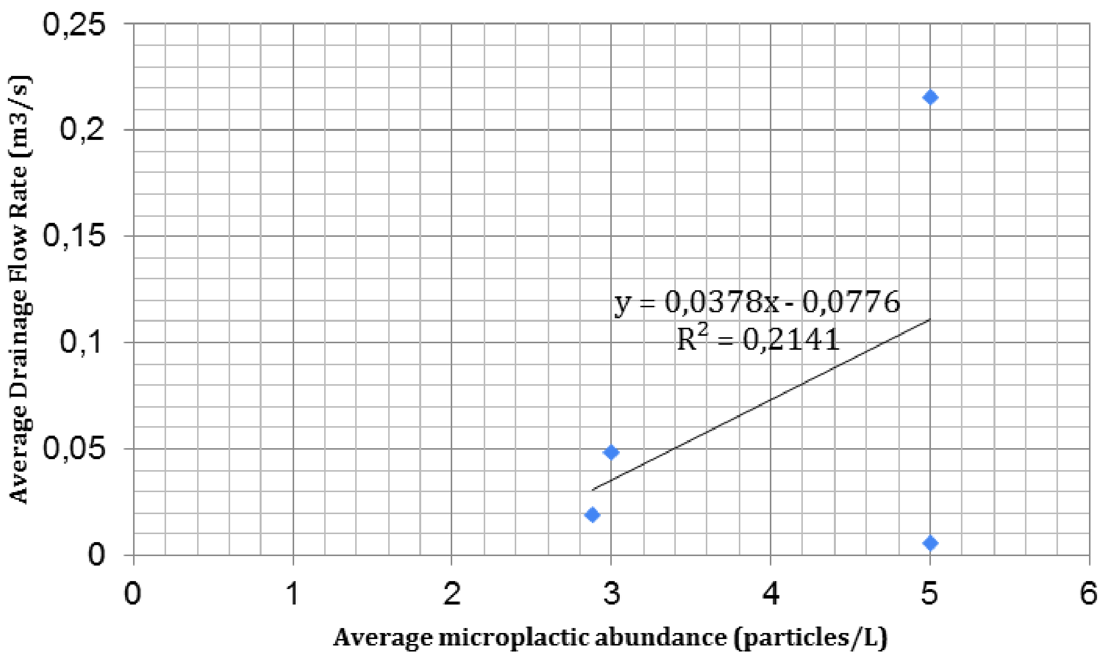

Figure 7. Correlation of microplastic abundance with drainage flow rate

From the graph, it can be seen that the average microplastic abundance and drainage flow rate have a positive correlation but with a low relationship (r= 0,46). This is similar to the research of Sun et al (2023) which mentions a significant relationship between urban surface runoff and the abundance of MPs. However, the low relationship can be caused by different factors, Watkins et al. (2018) mentioned that higher flows will result in greater turbidity. This will allow for less evenly distributed microplastic particles and probably uneven resuspension of particles in the water. Other than that, the presence of the sediment can be the place of MPs to settle. The low flow discharge in drainage can cause the tendency of MPs to settle rather than float like the case in Najafgarh drainage, India (Vaid et al, 2024). It can make the variability of the MPs' abundance still need further analysis especially with continuous flow rate data.

Conclusion

Microplastics abundance in drainage of Bandar Lampung City were relatively small compared to other cities in the world. This can be attributed to the fact that the population of each city is different and MPs were influenced by surface runoff from anthropogenic sources. However, from the study it was found that the drainage flow rate has a low relationship to the microplastic abundance although it has positive correlation. The correlation between the shape of drainage basins and the abundance of microplastics has been low, because it can be caused by various influencing factors such as land use, proximity to urban areas, and other hydrological characteristics of drainage basins. This research can be the baseline for further microplastic exploration in urban drainage ecosystems with more multiple factors identified.

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