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Correlation of Microplastic Size Distribution and Water Quality Parameters in the Upstream Brantas River

Luthfia Ayu Dhea[1*], Andi Kurniawan[2], Siti Mariyah Ulfa[3], Karimah[4]

[1] Environmental Resource Management and Development Master Program, Brawijaya University, Malang, 65145, Indonesia.
[2] Departement of Fisheries and Marine Resources Management, Faculty of Fisheries and Marine Science, Brawijaya University, Malang, 65145, Indonesia.
[3] Departement of Chemistry, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, 65145, Indonesia.
[4] Physics Master Program, Brawijaya University, Malang, 65145, Indonesia.

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Corresponding Author:
Luthfia Ayu Dhea
luthfiaayudhea@gmail.com

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Abstract: Microplastics are contaminants resulting from plastic fragmentation with a size <5 mm. The spread of microplastics threatens the imbalance of the environment and organisms in the waters. So it is necessary to know the abundance, size distribution, and correlation between microplastic abundance and water quality parameters. This study used a quantitative descriptive method with purposive sampling. The study parameters included total microplastic abundance, microplastic abundance based on size characteristics, type of microplastic polymer, water quality parameters, and correlation between microplastic abundance and water quality. Calculating the total abundance of microplastics obtained a value range of 3311.11 – 18111.11 particles/m^3. The results of the microplastic size distribution got the highest abundance percentage value in the class with a size <50 µm, which was 84.39%. There were eight types of polymers identified, including Polyethylene (PE), Polyvinyl chloride (PVC), Polypropylene (PP), High-density polyethylene (HDPE), Low-density polyethylene (LDPE, Polyethylene terephthalate (PET), Polycarbonate (PC), and Nylon. Water quality measurements obtained temperature range of 17.37-26.63 °C, pH value range of 6.66-8.51, current velocity value range of 0.13-0.8 m/s, DO value range of 4, 32-6.103 ppm, BOD value range of 4.69-6.07 ppm and TSS value range 0.005-0.019 ppm. Correlation analysis using the Canonical Correlation Analysis (CCA) statistical method. The study showed that water quality parameters such as temperature, current velocity, and DO have a high score of 0.95, 0.83, and 0.8.

Keywords: Microplastic; Polymer; Size distribution; Water quality parameters

Introduction

The Upstream Brantas River Basin (DAS) is a river that flows through three areas, including Batu City, Malang City, and Malang Regency. Its existence, close to anthropological activities, puts pressure on the water quality. Various types of waste pollute river water bodies, so rivers have an additional role as distribution pathways for pollutant materials (Nelms et al., 2021). The main concern of pollution is plastic waste. The potential danger of plastic waste is caused by the difficulty of degradation naturally. Plastic is a product of petroleum polymerization with strong chemical bonds and is difficult to degrade.

The use of plastic has many social benefits, but fragmented plastic particles impact the environment, especially the aquatic environment. Fragmentation of plastic particles that are less than 5mm in size is generally referred to as microplastic particles (Guzzetti et al., 2018). Plastic fragmentation can undergo four processes: physical degradation, photodegradation, chemical degradation, and biodegradation (Klein et al., 2018).

Microplastics enter the waters mainly through household waste and due to runoff from residential areas (Aragaw, 2020). The distribution of microplastics in river flows is influenced by environmental factors such as current velocity, river tides, wind, and

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hydrodynamics of river water. Meanwhile, anthropogenic factors such as increasing population density affect the amount of microplastic abundance (Fitria et al., 2021). As a pollutan, microplastic have an impact on organism because their fiber can inhibit the disgetive system. Various form of microplastics can be damaging organ of organism (Laila et al., 2020). The composition of microplastic polymers and additional additives consisting of chemical compounds can be absorbed and affect the hormone system (Gunawan et al., 2021).

Microplastic is not only a pollutant in water but also a carrier for other pollutants (Yudhantari et al., 2019). The hydrophobic surface of microplastics can bind organic and inorganic matter in the waters (Purwiyanto et al., 2020). The adsorption of other contaminants by microplastics makes the level of toxicity higher. The interaction of microplastic and other contaminants allows the formation of new pollutants in the aquatic environment (Reichel et al., 2020). Microplastic acts as a pollutant and adsorbing agent for other contaminants explaining that microplastics have a high level of toxicity. The impact given can disturb the health of organisms and the aquatic environment.

So an analysis of the abundance and size distribution of microplastics is needed to determine the possible impacts that will be caused. This study aimed to determine the abundance of microplastics based on size characteristics and their relationship with water quality in the Upstream Brantas River.

Method

Location and Time of Research

The research was undertaken from August to October 2022. The water sample was collected from the Upstream Brantas River, which flows through three areas: Batu City, Malang City, and Malang Regency (Figure 1). Analysis and observation of samples carried out at the Hydrobiology Laboratory of the Aquatic Environment Division, Brawijaya University, Biosciences Laboratory of Brawijaya University, and Laboratory of Minerals and Advanced Materials, State University of Malang.

The research method used is a quantitative descriptive method. This method examines the data collected systematically, factually, and accurately and provides a detailed overview according to field conditions (Musfirah et al., 2022). The sampling method uses purposive sampling technique, where the characteristic sample is based on a specific subject, not a random sampling, and analysis can be according to criteria (Serra et al., 2018). The sampling site consists of five sites, with three repetitions. The characteristics of the sampling site can be seen in Table 1.

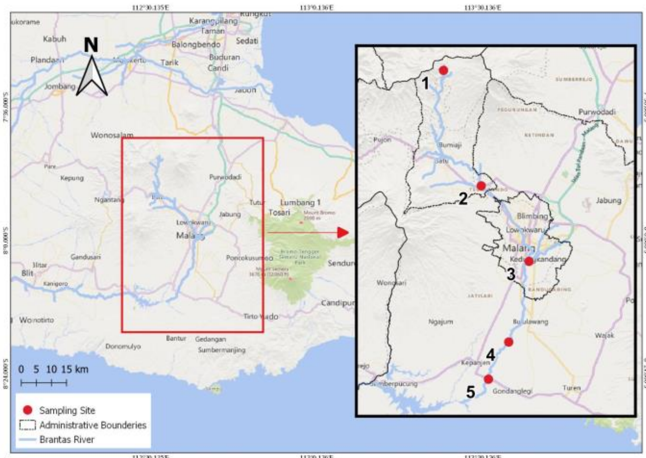

Figure 1. Sampling site location in Brantas river

Table 1. Characteristic of Sampling Site

Site	Land Use	Coordinate
1	Forest and agriculture	112º52′64.955″ E 7º75′36.72″ S
2	Residential, animal husbandry, agriculture, river sand mining	112º57′53.997″ E 7º90′29.8″ S
3	Residential, traditional market, hospital	112º63′74.525″ E 8º00′07.61″ S
4	Residential, field, industry, plantation	112º61′10.78″ E 8º10′50.73″ S
5	Agriculture, field, plantation, industry	112º58′47.973″ E 8º15′31.48″ S

Characteristic of Microplastic

In the first stage, a water sample was taken as much as 15 L and filtered using a plankton net measuring 0.25 µm. In the second stage, the water sample is re-filtered using a multilevel sieve with mesh sizes of 50, 18, and 4. The results of the multilevel sieve are rinsed using aqua steril and collected in beaker glass. Add 30% hydrogen peroxide solution of 20 mL and 20 mL of Fe^{2+} (0.05M) for degrader of organic matter and catalyst reaction. Then the sample is heated on a hotplate with a temperature of 90°C until no water bubbles form. Let it stand until it cools, and continue filtering using a vacuum pump with whatman paper no. 42. Samples in whatman were oven-dried at 50°C for 1 hour. Observations are using the LIMB-A10 Biological Microscope with a magnification of 10x.

Analysis FT-IR

Plastic particles have their constituent materials referred to as polymers. Polymer products have several functional groups (Abidin et al., 2018). Thus, the FTIR method is suitable for determining the type of polymer in microplastics. The FTIR analysis technique determines the sample characteristics (solid, liquid, and gas). The sample interaction with IR radiation affected the vibrating of molecular atoms. The results obtained are energy uptake, which can be analyzed as functional groups contained in the sample (Nandiyanto et al., 2019).

Data Analysis

The interpretation of the data in this study is a statistical analysis of the Canonical Correlation Analysis (CCA). CCA analysis can be used to determine the relationship between two groups of variables, referred to as multivariate relationships, by performing a linear combination of two random variables so that the correlation results of the two can be significant (Zhuang et al., 2020). The data variables used in this analysis consisted of microplastic abundance (Total abundance and abundance by size) and water quality parameters (Temperature, pH, Dissolved Oxygen (DO), current velocity, Biological Oxygen Demand (BOD), Total Suspended Solid (TSS)).

Result and Discussion

Microplastic Abundance

In this study, microplastics in Upstream Brantas River were identified in 4 forms such as fragments, fibers, films, and pellets (Figure 2). Fragments are particles from the fragmentation of large plastics. The fibers are thin and long in shape like synthetic fibres. The shape of the film particles is the form of very thin and transparent plastic fragments (Ayuingtyas et al., 2019). Pellets are primary microplastics that are round shapes. The source of primary microplastics is body scrub or body wash products (Makrima et al., 2022).

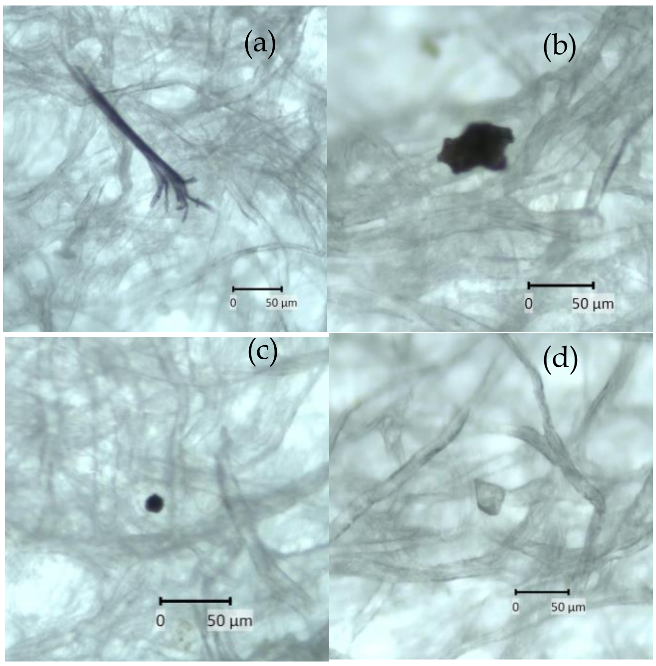

Figure 2. Microplastic identification using *biological microscope* LIMB-A10 (10x) (a) Fibers; (b) Fragment; (c) Pellet; (d) Film

Various forms of microplastics can be due to the source of microplastics. Microplastics are known to come from two sources, such as primary microplastics and secondary microplastics. Primary microplastics come from textiles, pharmaceuticals, care products (such as toothpaste, body scrubs and facial scrubs), pellets and hard materials used in the plastics industry. Secondary microplastics are formed due to the fragmentation of large plastic waste into smaller sizes through the process of phosphorylation, thermo-oxidation or erosion (Pippo et al., 2020).

The abundance of microplastics was divided into two characteristics, namely total abundance and microplastic abundance by size distribution. The total abundance of microplastics observed at the five sampling stations (Figure 3) had a range between 3311.11 – 18111.11 particles/m^3.

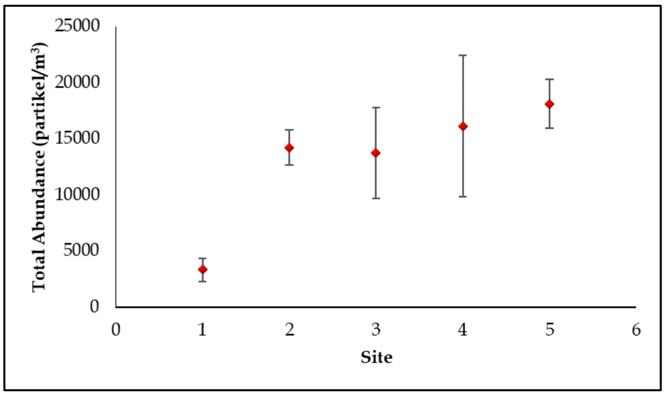

Figure 3. Total Microplastic Abundance

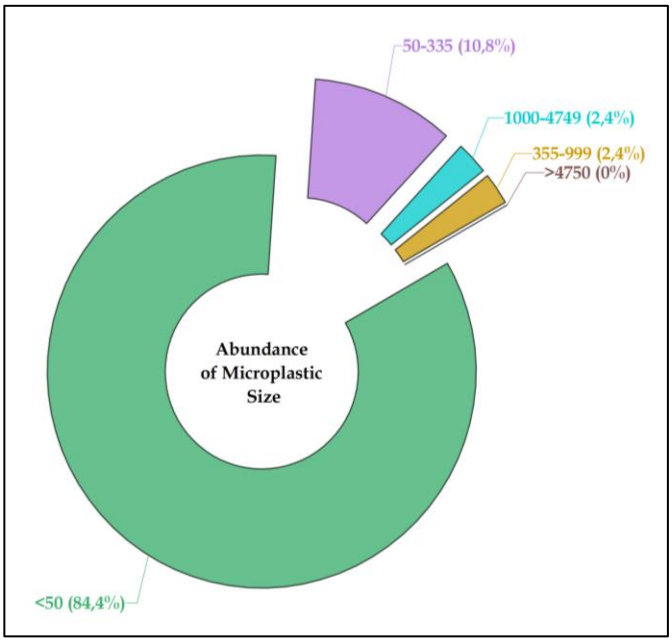

Figure 4. Percentage of abundance by microplastic size

The results showed that obtained the lowest abundance at station 1, a category of natural stations.

The land use around site 1 is forest and agricultural areas. The highest abundance is found at site 5, located at the final point in the river's flow. The movement of water flow occurs vertically and horizontally from the upstream to the downstream river to the mouth of the river and estuary (Pohan et al., 2016). It allows for accumulating microplastic particles from several previous site at site 5. Along the Upstream Brantas River flow, anthropogenic activities such as forests, agriculture, fields, residential, markets, industries, and hospitals are increasingly diverse. Microplastic pollution has a variety of sources, including anthropogenic activity. Increasingly high anthropogenic activity positively correlates to the possibility of an increase in microplastic abundance (Sulistyowati et al., 2022). Buwono et al. (2021) mentioned that the abundance of microplastics at the end of the Brantas river flow has greater abundance than at the previous site.

Microplastic abundance by size (Figure 4) is grouped into five classes, including <50 µm (Song et al., 2015); 50-355 µm; 355-999 µm; 1000-4749 µm; and >4749 µm (Eriksen et al., 2013). The results showed that the percentage of abundance based on microplastic size was dominated by the <50 µm class, which was 84.39%. The distribution of microplastics that have a size below 250 µm is microplastics derived from products used in everyday life. It is assumed that the source of microplastics under 250 µm is primary microplastics. Meanwhile, microplastics that have a size of more than 250 µm are the result of microplastic fragmentation from larger plastics (secondary microplastics) (Estahbanati et al., 2016). As mentioned by Fitriyah et al. (2022), the microplastic size dominated river waters is the small microplastic (<1 mm) group, which is 65%. It is because larger microplastics have a high density, so they tend to cause these microplastics to sink. Microplastic dominated by sizes less than 1mm in waters inadvertently allow ingestion by aquatic organisms and can accumulate through the food chain (Zhang et al., 2017).

Microplastic Polymer Analysis

FTIR test results obtained several types of polymers based on the analyzed functional groups, including Polyethylene (PE) with peak characteristics of 2902.87 cm^{-1}, Polyvinyl chloride (PVC) with peak characteristics of 630.72 cm^{-1}, Polypropylene (PP) with peak characteristics of 1375.25 cm^{-1}, High-density polyethylene (HDPE) with peak characteristics of 3448 cm^{-1}, Low-density polyethylene (LDPE) with peak characteristics of 2916.37 cm^{-1}, Polyethylene terephthalate (PET) with peak characteristics 1741.72 cm^{-1}, Polycarbonate (PC) with peak characteristics of 1180.44 cm^{-1}, and Nylon with peak characteristics of 3304.06 cm^{-1}.

Water Quality Parameters Analysis

Water quality parameters are environmental factors related to microplastic pollution in river waters. This study measures six water quality parameters, including temperature, pH, current velocity, DO, BOD and TSS (Table 2).

Table 2. Result of Water Quality Parameters Measurement.

Parameters	Site				
	1	2	3	4	5
Temp (°C)	17.37 ± 0.4	25.67 ± 0.5	24.83 ± 0.2	25.03 ± 0.8	26.63 ± 0.0
pH	6.84 ± 0.3	8.51 ± 0.0	6.66 ± 0.6	7.95 ± 0.0	7.42 ± 0.0
Current Velocity (m/s)	0.13 ± 0.1	0.8 ± 0.4	0.4 ± 0.1	0.23 ± 0.2	0.6 ± 0.1
DO (ppm)	4.32 ± 0.3	5.95 ± 0.1	4.9 ± 0.2	5.84 ± 0.1	6.103 ± 0.2
BOD (ppm)	5.02 ± 1.4	5.95 ± 0.2	4.69 ± 0.2	5.82 ± 0.1	6.07 ± 0.2
TSS (ppm)	0.009 ± 0.0	0.019 ± 0.0	0.014 ± 0.0	0.016 ± 0.0	0.005 ± 0.0

The results showed that obtained temperature measurements in the range of values of 17.37-26.63 °C. It obtained the highest temperature value at site 5 due to the lack of cover in the watershed. Following the explanation of Arsad et al. (2021), the temperature value of the Brantas River is between 25 °C. Water temperature with high value is caused by the intensity of sunlight entering the waters and the location of the sampling station is an open area (Marlina et al., 2017). The pH range value is obtained from 6.66-8.51. The temperature has a role in optimizing the process of microplastic degradation in the aquatic environment. Not only temperature but the pH value with a range of 8 also influence microorganisms in the degradation process (Lin et al., 2022).

Measurement of current velocity obtained a range of values of 0.13-0.8 m/s. The current velocity affects the distribution of microplastics in the water column. Microplastic with high density will tend to settle, while low-density microplastics will remain suspended in the water (Kumar et al., 2021). Measurements of DO parameters obtained a range of values of 4.32-6.103 ppm. DO sources from the diffusion of oxygen in the atmosphere (35 %) and photosynthetic activity by aquatic plants and phytoplankton (Sugianti et al., 2018). At the same time, the BOD value range is 4.69-6.07 ppm. The presence of dissolved oxygen concentrations in waters helps the interaction of microplastics with the organic matter until the formation of biofilms. The biofilm formation can contribute to microplastic degradation (Pan et al., 2023). Meanwhile, BOD describes the amount of oxygen microorganisms use in the degradation process (Aji et al., 2016).

The range of TSS values obtained is 0.005-0.019 ppm. TSS affects the presence of microplastic abundance. TSS is related to microplastic and suspended particle aggregation (Besseling et al., 2017). Microplastic particles have a smaller density than water, allowing particles to float in the water column. These microplastic properties cause microplastics to become part of suspended particles (Kooi et al., 2018).

Correlation of Microplastic Abundance and Water Quality Parameters

Correlation analysis between microplastic abundance and quality parameters using Canonical Correlation Analysis (CCA) analysis. The dependent variable group of microplastic abundances used is size microplastic abundance consisting of <50 µm, 50-355 µm, 355-999 µm, 1000-4749 µm, and >4750 µm. While independent variables are water quality parameters, including temperature, pH, current velocity, DO, BOD and TSS.

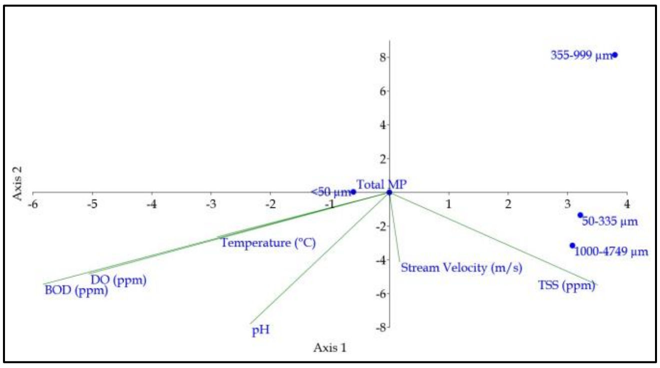

Figure 5. Result of canonical correlation analysis triplot

The results of the correlation analysis stated that the abundance of microplastics with a size of <50 µm had a high correlation with temperature, DO, BOD, and pH. The abundance of microplastics with sizes of 50-335 µm and 1000-4749 µm strongly correlates with TSS and current velocity. The abundance of microplastics with size 355-999 µm has a moderate correlation with the entire parameter. The high correlation between the parameters and the abundance of microplastics shows that the parameters affect the abundance of each microplastic size. The score value of the results of the correspondent of several variables shows that the parameters of temperature, current velocity, and DO have a high significance value of 0.95, 0.83 and 0.8. A significantly high score explains that the abundance of microplastics correlates highly with water quality parameters.

Conclusion

The results showed that microplastic pollution was found in the Upstream Brantas River, with the highest abundance at the end of the site. The class of <50 µm dominated the size of the microplastics, and various constituent polymers were found. The results of the correlation analysis found that the parameters of temperature, current velocity and DO were the parameters that most significantly affected the abundance of microplastics.

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