JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(8), 296–309
https://doi.org/10.12911/22998993/166311
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.05.17
Accepted: 2023.06.16
Published: 2023.06.28

Spatial Dynamics of Microplastic Pollution in Water and Sediments of the Ciliwung River along with Conditions of Water Quality Field Parameters and Population Density

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ABSTRACT

Microplastics are emerging contaminants that degrade from textile plastic products, petroleum, and cosmetic equipment with sizes less than 5 mm. There are more than 70,000 settlements located along the Ciliwung River in DKI Jakarta that use the river water as a source of clean water. The most common type of waste found in the Ciliwung River to date is plastic waste, which can cause flooding and other disasters. The Ciliwung River can currently be found with microplastic pollution which has an impact on exposure to living things in the river, such as in case studies in the Ciliwung River estuary area. The problem is the exposure to 75% of blue panchax fish (*Aplocheilus* sp.) as many as 1.97 particles per fish with sizes of 300 to 500 µm. This research will focus on analyzing the dynamics of microplastic quantity in water and sediment of the Ciliwung River along with the correlation between field parameters and population density around the banks of the Ciliwung River. When viewed from the seven points that represent the Ciliwung River downstream to upstream in DKI Jakarta Province, the number of microplastics is in the range of 320–741 particles/L. For the dominating form, it can be analyzed that the majority of microplastic forms are fragments (97%), followed by fibers (2.9%) and pellets (0.1%). While in the sediment, the number of microplastics in the Ciliwung River sediment is in the range of 6560–10630 particles/kg. The population density factor has the highest correlation to the number of microplastics with a value of r = 0.702. This is associated between population density and high microplastic emission loads.

Keywords: microplastic, distribution, water, sediment, population density, river, pollution.

INTRODUCTION

Indonesia is one of the countries in ASEAN that has a high per capita income and has a high waste generation, which reaches sixty-four million tons per year. The composition of the waste generation includes 60% biodegradable organic waste, 14% plastic waste, 9% paper waste, and other types of waste. The city that has the highest waste generation in Indonesia is DKI Jakarta, with the amount of waste generation reaching 7,164.53 tons per day. The source of this waste generation is mostly dominated by domestic activities (home) and followed by activities from buying and selling in the market (Fatimah et al., 2020). When compared to the Ganga River in India, 60% of domestic waste enters the water body (Indrawati & Purwaningrum, 2018). In its use, the plastic seen in the river is still in the macro category that has not been decomposed. After the plastic is not reused and disposed of, the degradation process will occur and the phenomenon of microplastic formation will occur. Biochemical conditions in the water are very influential in changing the formation of macroplastics into micro-plastics (Tokiwa et al., 2009)).

The biggest role of microplastic formation from the bio-chemical aspect is the presence of microorganisms, which can change the polymer structure contained in macro-plastics (Manzoor et al., 2021). Microplastics are emerging contaminants that are degraded from textile plastic products, petroleum, and cosmetic equipment with a size of less than 5 mm (Dong et al., 2021). The presence of microplastics in water bodies varies from almost none to millions of pieces per cubic meter, which is influenced by the sampling method, sampling location, natural conditions around the water body, and the surrounding population density (Cai et al., 2022).

Microplastics can be categorized into two types, namely: primary and secondary microplastics (Cai et al., 2022). Primary microplastics are generally found in cosmetics and facial cleansers in the form of pellets and are 2–5 mm in diameter (Cole et al., 2011). The presence of these primary microplastics can generally pollute rivers in developing areas. This is because in developing areas there is still minimal domestic wastewater treatment, so it is directly flowed into the river (Huang et al., 2019). Meanwhile, secondary microplastics are the result of biodegradation and fragmentation of macroplastics due to physical, chemical, and biological processes (de Sá et al., 2018). The process of plastic degradation into microplastics is caused by two main factors, namely: abiotic and biotic degradation. The abiotic degradation in this process is photodegradation, temperature degradation, and mechanical degradation of plastic. Meanwhile, the biotic degradation process of plastic is caused by the activity of microorganisms (Zhang et al., 2021). In general, microplastics have 6 forms, namely: fibers, films, fragments, sheets, granules, and foam (Yakushev et al., 2021). The presence of microplastics is reinforced by the replacement of non-biodegradable polymers with degradable polymers. These types of polymers can fragment with water and air into large numbers of microplastic particles (Wei et al., 2021).

The presence of microplastics in the river will certainly experience migration from upstream to downstream and the ocean. During the migration process, microplastics can settle in sediments, be exposed to living things, and experience the process of infiltration with groundwater (Cai et al., 2022). The quantity of microplastics in the river is certainly influenced by the surrounding conditions, this is evidenced that the quantity of microplastics in the upper reaches of the Brantas River has 133 particles/m3 and in the downstream reaches 5467 particles/m^3 (Buwono et al., 2021). The difference in the amount number of microplastics upstream and downstream indicates that the population and human activities around the river affect the presence of microplastics. In general, downstream areas have a higher population density and there are effluents from wastewater treatment and domestic wastewater discharges. In addition, the shape of microplastics also differs according to the sampling location. In general, the presence of microplastics can be found in surface water, but microplastics can be found in river sediments (Eo et al., 2019). The existence of the number of microplastics in river sediments has differences according to the depth of the sediment itself, where the number of microplastics is more common in surface sediments (0–5 cm) (He et al., 2020). The problem of microplastic pollution in water bodies is a challenge that needs to be resolved so as not to endanger the condition of the surrounding ecosystem (Cai et al., 2022). This microplastic pollution has an impact on exposure to living things in the river, such as in case studies in the Ciliwung River estuary area. The problem is the exposure to 75% of blue panchax fish (Aplocheilus sp.) as many as 1.97 particles per fish with a size of 300 to 500 µm (Cordova et al., 2020). In addition, microplastic pollution was also found in the Code River, Yogyakarta. This is evidenced by the findings of 3.14 particles/liter in the upstream section, 5.8 particles/liter in the middle section, and 5.85 particles/liter in the stream of the Code River (Syachbudi, 2020). The Brantas River, Surabaya is also one of the rivers polluted by microplastics. This is evidenced by the findings of 133 particles/m3 to 5467 particles/m3 from upstream to downstream (Buwono et al., 2021). The finding of microplastics in the three river water bodies is evidence that the condition of river water bodies in Indonesia has been polluted by microplastics. Therefore, this research will analyze the variability of microplastic quantity from upstream to downstream along with the composition of the constituent materials in the Ciliwung River. In addition, there is a need for research on the pattern of microplastic migration and transformation systems along with appropriate microplastic pollution control strategies (Cai et al., 2022). Based on the DKI Jakarta Water Agency UPK report, the amount of waste in the Ciliwung River in 2019 was 95,257.7 tons/year. The waste contained in the river certainly has a different composition, whereas, in the Pesanggrahan and Grogol Rivers, the majority is filled with plastic waste and plantations with 44% each. Whencomparatorm three countries (Indonesia, Malaysia, and India), plastic waste dominates its presence in rivers (Safira et al., 2021). The plastic waste in the sea flows through the river with the composition of polyethylene terephthalate (PET), soft polyethylene (PE), and polystyrene (PS), where the majority is PE and PP (Van Emmerik et al., 2019). The dominating waste composition in the Ciliwung River to date is plastic waste (Nizardo et al., 2021). The presence of macro-sized plastic waste in the river will certainly undergo a decomposition process and can be degraded into microplastics which are one of the emerging contaminants (Zhang et al., 2021). There are more than 70,000 settlements located along the Ciliwung River in DKI Jakarta that use the river water as a source of clean water (Dsikowitzky et al., 2018). The most common type of waste found in the Ciliwung River to date is plastic waste, which can cause flooding and other disasters (Nizardo et al., 2021). The pollutant load contained in the Ciliwung River is not only in the form of organic contaminants but also other contaminants originating from household waste and industrial waste. Other contaminants referred to here come from cosmetic waste used by the community, insect medicine waste, and pharmaceutical waste and stimulants that are disposed of into the river carelessly. In addition, in the Ciliwung River at this time, microplastic pollution can be found which has an impact on exposure to living things in the river, such as in case studies in the Ciliwung River estuary area. The problem is the exposure to 75% of blue panchax fish (Aplocheilus sp.) as many as 1.97 particles per fish with sizes of 300 to 500 μm (Cordova et al., 2020).

The Ciliwung River is a major river that has a key role for the people living around it where it is used as a source of clean water by the surrounding community (Dsikowitzky et al., 2018). The presence of microplastics in water bodies is a phenomenon that needs to be explored further (Cai et al., 2022). This research will focus on analyzing the dynamics of microplastic quantity in water and sediment of the Ciliwung River along with the correlation between field parameters and land use around the banks of the Ciliwung River.

METHODOLOGY

Water and sediment sampling locations were carried out by the monitoring points of the DKI Jakarta Environment and Forestry Agency. The sampling points are bridges in the Jalan Kebahagiaan area, Depok; bridges in the Jagakarsa area, bridges in the Balekambang area, the branching of two rivers in the Kalibata area, bridges in the Kalibata area, bridges in the Melayu Besar area, and bridges in the Slamet Riyadi area. Based on data from the Ministry of ATR/BPN, the conditions around the sampling are residential areas. Meteorological conditions at the sampling point on the first day (November 14, 2022) recorded that there was rainfall of 21.55 mm based on the recording of the rainfall station at the Faculty of Engineering, University of Indonesia. While on the second day of sampling (November 15, 2022) showed clear weather and no significant rain. The following are the coordinates of the sampling site that will be carried out (Figure 1 and Table 1).

Water sampling method

Microplastic sampling was carried out using a plankton net tool with a size of 80 waste with 500 μm. The method used to take water samples is grab sampling, where the water taken is attempted to be on the surface. This is because microplastics have a small shape and light mass, making it easier to float. When the water sample has been taken, the next thing that is done is filtered into a bottle which is generally 100 ml in size using a plankton net. Based on The National Oceanic and Atmospheric Administration (NOAA) method, it is known that the container that can be used does not affect water quality, is easy to wash, and is easy to move. In general, the containers used have glass base material. Extraction of microplastics in river water using the NOAA method by adding NaCl which serves to separate microplastics from other contaminants using the principle of density differences. Then add a 30% H2O2 solution which serves to dissolve organic contaminants contained in water samples (Buwono et al., 2021). After that, the sample will be filtered using Whatmann filter paper with a pore diameter of 1 μm and observed under a microscope. In addition to taking microplastic samples, field parameter measurements (pH, temperature, dissolved oxygen, TDS, and turbidity) were also taken using a Lutron WA-2017SD multi-water LT. After the water samples were put into 100 ml

Figure 1. Sampling location

Table 1. Coordinates of water and sediment sampling points of the Ciliwung River

Site	Latitude	Longitude
Jalan Kebahagiaan, Depok	6° 20' 48.113" S	106° 50' 17.761" E
Jagakarsa	6° 18' 53.960" S	106° 51'3.956" E
Balekambang	6° 17' 33.500" S	106° 51' 12.600" E
Percabangan Anak Sungai 1	6° 15' 46.26" S	106° 51' 34.73" E
Jalan Raya Kalibata	6° 15' 29.434" S	106° 51' 37.645" E
Jalan Melayu Besar 2	6° 13' 41.329" S	106° 51' 52.636" E
Jalan Slamet Riyadi, Manggarai	6° 12' 45.554" S	106° 51'27.868" E

bottles, there was no need to use special preservation methods due to the nature of microplastics that take time to degrade. The standard used to determine water quality is local regulations, namely Appendix VI regarding National Water Quality Standards of Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management which divides into 4 classes. Class 1 indicates water that can be used for drinking water raw water; class 2 indicates water that can be used for water recreation infrastructure/facilities, freshwater fish farming, or animal husbandry; class 3 indicates water that can be used for freshwater fish farming, animal husbandry, water to irrigate crops; and class 4 indicates water that can be used to irrigate crops, and or other uses that require the same water quality as these uses.

Microplastic counting

The next thing to do is to calculate the microplastic particles using density calculations based on the NOAA method. The following is the equation used:

$$C = \frac{n}{V} \tag{1}$$

where: C – microplastic particle concentration (particles/liter), V – filtered water volume (liter), n – number of particles.

Sediment sampling method

Sampling was conducted by taking sediments found on the riverbed using a grab sampler or shovel to a depth of 5 cm (Hidalgo-ruz & Thiel, 2012). Samples taken were stored in aluminum or non-plastic containers. No preservation was necessary due to the characteristics of microplastics that degrade over time. The method used to analyze the samples refers to the research journal (Ling Ding et al. 2019). The first thing to do is to dry the samples in an oven at 75°C for 24 hours. After the sediment samples dried for 24 hours, one hundred grams of dry sediment samples were taken and put into a 500 ml beaker. Then the sample is added to 200 ml of concentrated or saturated NaCl solution to separate microplastics and sediment material based on their density. The samples were then stirred and allowed to settle for 24 hours. After 24 hours of settling, separate the supernatant and remove visible organic residues. Furthermore, the samples that have been separated are then subjected to the WPO (Wet Peroxide Oxidation) process. The WPO stage serves to destroy organic matter. After the WPO stage is complete, the sample is then filtered and observed under a microscope.

RESULT AND DISCUSSION

River water field parameters and land use around the river body

There are activities conducted when taking microplastic samples at each point, namely measuring field parameters which include: pH, oxidation-reduction potential (ORP), temperature, dissolved oxygen, salinity, dissolved solids (TDS), electrical conductivity (Cd), and turbidity. This aims to analyze the condition of the Ciliwung River water and its correlation to the number of microplastic particles obtained. Differences in field parameter data in each microplastic sampling can be caused by differences in meteorological conditions when sampling and land use around the location (Permatasari et al., 2017). Field parameter measurements were taken on two different days representing rainy and dry days at each point. This field parameter measurement will be analyzed with the number of microplastic particles at each point using correlation analysis. The following Table 2 is a tabulation of the results of field parameter measurements for both sampling days.

Based on the results of field parameter measurements on the first day (November 14, 2022), the pH value is in the range of 7.05 to 7.97. The pH value in the Ciliwung River still meets the river water quality standards for classes 1 to 4, where being in the range of 6 to 9 can be said to be safe for aquatic life in it (Buwono et al., 2021). When compared with previous research, the pH value in the Ciliwung River is in the range of 6.92 to 8.25 (Aisyah et al., 2022). The condition of the insignificant difference in pH value can be caused by the similarity of the characteristics of the surrounding discharges, which come from residential land use areas. The temperature at the seven sampling points was in the range of 26 °C to 28.2 °C, which is still in the safe category for aquatic life in it (Buwono et al., 2021). When compared to the first day, the pH value on the second day has no difference by having a range of 7.03–7.86. This indicates that the Ciliwung River water on the second day still meets the quality standards and is classified as safe for aquatic life in it.

DO on the first day was in the range of 1.2 mg/L to 3.3 mg/L, which is classified as class 3 (minimum 3 mg/L) and 4 (minimum 1 mg/L) water bodies, which cannot be used as a source of clean water for the surrounding community. The low value of dissolved oxygen in a water body

Table 2. Field parameters and weather data

Parameters	Weather	Mean	Median	Standard deviation
pH	Wet	7.43	7.18	0.40
	Dry	7.51	7.74	0.38
Suhu	Wet	27.10	27.10	0.64
	Dry	27.10	26.90	0.44
DO	Wet	2.53	2.60	0.72
	Dry	2.40	2.50	1.03
Turbidity	Wet	93.21	49.72	91.04
	Dry	53.73	45.28	20.02
TDS	Wet	133.37	119.30	59.97
	Dry	170.84	119.70	113.30

indicates the presence of organic pollutants in it (Buwono et al., 2021). The dissolved solids parameter is in the range of 89.4 mg/L to 262 mg/L which still meets the quality standards for classes 1 to 4 with a maximum limit of 1000 mg/L to 2000 mg/L. There is a significant difference in the dissolved oxygen parameter at point two which reaches 0.9 mg/L which indicates that at this point the condition is anaerobic and this value does not meet the quality standards of classes 1 to 4. The value of the dissolved solids parameter is in the range of 93.3 mg/L to 397 mg/L, which still meets the quality standards of classes 1 to 4. There is a difference in the value of dissolved solids on the first and second days which can be caused by rainfall on the second day of 21.55 mm, where there is a correlation between river water discharge caused by rainfall and the concentration of dissolved solids in water bodies (Sinyukovich, 2001).

Turbidity parameters at all seven sampling points ranged from 44.7 NTU to 279 NTU, with the third point having the highest value. As for the second day of measurement, the turbidity parameter was in the range of 29.88 to 92 NTU. This level of turbidity can reflect the condition of waters containing solids, organic and inorganic substances, and other organisms. When viewed from the sampling location, it can be analyzed that the Ciliwung River is located on the border between South Jakarta and East Jakarta which is filled with residential areas. There are differences in population density from the first sampling point to the seventh, where the beginning has a lower density and will increase until the seventh point. This population density can be associated with the pollutant load that enters the river body. The following is the population density in the sampling point area (Table 3).

Microplastic abundant in each segment of river water

Based on the results of sampling on November 14 and 15, 2022, it can be analyzed that there are three forms of microplastics found, namely: fragments, fibers, and pellets. The shape of microplastics can be divided into three major parts, namely: flat, fibrous, and round (Rosal, 2021). The three shapes can be used as a reference to analyze the number of microplastic particles in an object (Lorenzo-Navarro et al., 2021). When viewed from the seven points that represent the downstream to upstream Ciliwung River in DKI Jakarta Province, it can be analyzed that the majority of microplastic shapes are fragments (97%), followed by fibers (2.9%) and pellets (0.1%).

Microplastic fragments can be formed due to abiotic and biotic degradation of macroplastics, whereas plastics with lower quality can be easily degraded into fragments (Zhang et al., 2021). The number of microplastics in the form of fragments on the first day was in the range of 303 to 651 particles per liter, where the highest was at point six. Whereas on the second day, it was in the range of 420 to 721 particles per liter, where the highest was at point two. This difference can occur partly due to differences in rainfall between the first and second days (Figure 2 and 3). Most of the color of these fragment-shaped microplastics is black, which is formed due to the fragmentation process of black plastic or comes from the fragmentation of car tires that run off into water bodies (Ziajahromi et al., 2020). The next form of microplastics found in Ciliwung River water is fiber, which comes from acrylic, nylon yarn, and rayon which comes from degraded textile objects (Cai et al., 2022). Based on the quantification results, the number of fiber-shaped microplastics on the first day was in the range of 0 to 21 particles per liter, and on the second day was in the range of 0 to 31 particles per liter. The highest number of fiber-shaped microplastics was found at points 4 and 5, where at these two points several people conducted fishing activities on both the first and second days. Based on the results of a brief interview with the community, this fishing activity is quite routine. This proves that fiber-shaped microplastics come from fiber threads used as fishing gear (Lorenzo-Navarro et al., 2021). Pellet-shaped microplastics are the least ordinary form encountered in this study. The pellet shape is characterized by a round shape with a certain diameter size (Rosal, 2021). This shape comes from primary microplastics contained in the cosmetic equipment used (Lorenzo-Navarro et al., 2021).

Table 3. Population density data

Site	Population density (capita/km^2)
1	12810
2	16285.5
3	15591.5
4	21399.5
5	21399.5
6	27063
7	27063

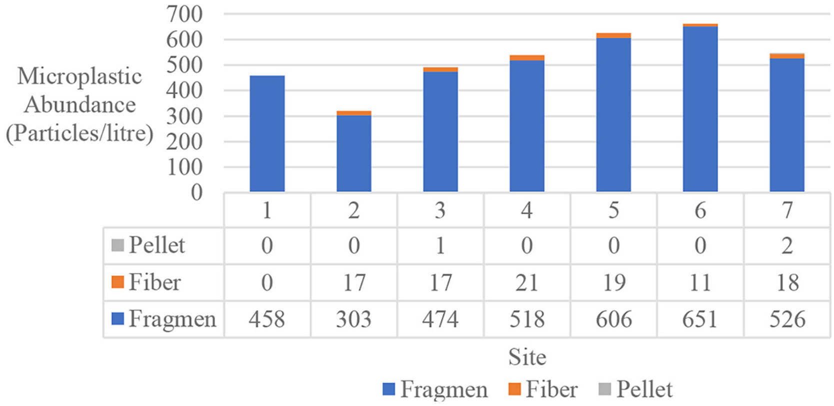

Figure 2. Microplastic abundance in Ciliwung River water wet day

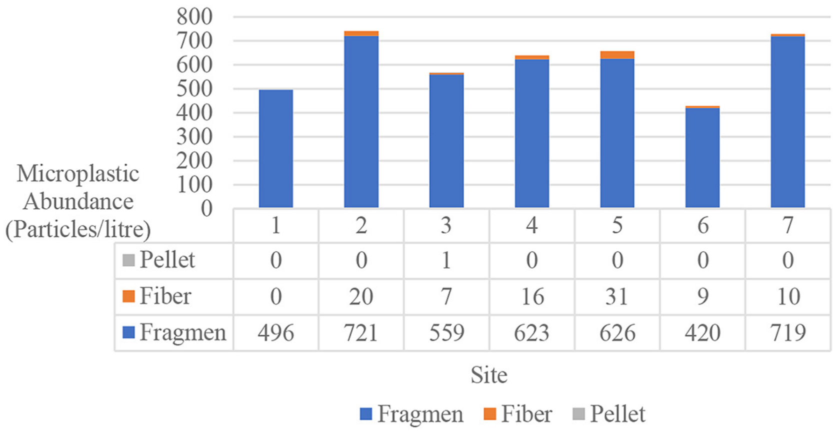

Figure 3. Microplastic abundance in Ciliwung River water dry day

On the first day, pellet-shaped microplastics were obtained with a range of 0 to 2 particles per liter. Meanwhile, on the second day, a range of 0 to 1 particle per liter was obtained. These particles were found at the third point, where the surrounding conditions are residential areas.

In general, the trend that occurred on the first day was an increase from point two to point five which illustrates the fluctuations from upstream to downstream of the Ciliwung River water. Whereas on the second day, there is a difference in trend with the first day, where there is an increase from point one to point two and an increase from point three to point five. The difference in the number of microplastic particles is one of the causes of the difference in rainfall on the two days (Figure 4). The difference in the number of microplastics can be visualized in the following boxplot (Figure 5).

When compared to various rivers in Indonesia, the Ciliwung River is categorized as moderately polluted with microplastics with a range of 320–741 particles/L, while one of the causes of the presence of microplastics is the degradation process of plastic waste which is most of the waste in the Ciliwung River (Lestari & Trihadiningrum, 2019). This is evidenced by the Banyuurip River which reaches 7.78×10^3 particles/L, and the Surabaya River conditions have a microplastic pollution range of $3.45–63.38 \times 10^3$ particles/L (Sari et al., 2021). Microplastic pollution conditions in the Ciliwung River are like the Yellow River but not as high as during the dry season, where it reaches a range of 623–1392 particles/L (Han et al., 2020). Table 4 is a tabulation of microplastic data polluting river water bodies in several countries.

Microplastic abundant in each segment of river sediment

Based on the results of sediment sampling in the Ciliwung River on November 14 and 15, 2022, it can be analyzed that there are two major forms of microplastics found, namely: fragments and fibers. This is different from the shape of microplastics found in water bodies, where there

Figure 4. Microplastic in Ciliwung River water

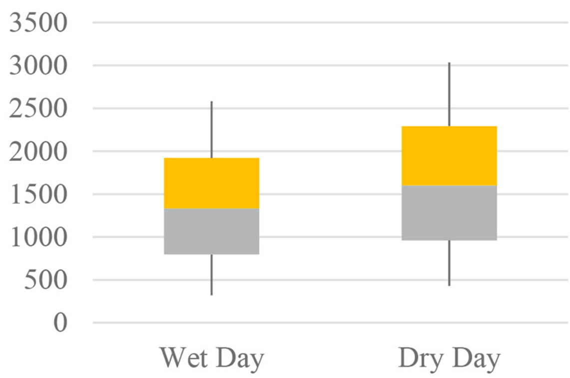

Figure 5. Boxplot of difference between microplastic in wet and dry day

are pellet-shaped microplastics although in small quantities. The shape of microplastics can be divided into three major parts, namely: flat, fibrous, and round (Rosal, 2021), wherein the observation of sediment samples only flat and fibrous microplastics (fragments and fibers) were found. When viewed from the seven points that illustrate the Ciliwung River downstream to upstream in DKI Jakarta Province, it can be analyzed that the majority of microplastic shapes are fragments followed by fiber. The following is an illustration of microplastic fluctuations in the Ciliwung River sediment (Figure 6 and 7).

Naturally, microplastics in river water bodies can be precipitated into sediments or sucked in by living things in these waters (Cai et al., 2022). The presence of microplastics in the sediment can also be caused by the photodegradation process under conditions of low temperature, oxygen, and degradation rate (Zhang et al., 2021). The amount of microplastics in sediments has a significant difference when compared to microplastics in river water. This is due to the process of transporting microplastics from water bodies to sediments, rainwater runoff, and due to differences in the density

Table 4. Comparation of microplastic in several rivers water around the world

Location	Country	Concentration	Unit	Reference
Wei River	China	3.67–10.7	items/L	(Wang et al., 2021)
Yellow River	China	380–582 (wet)	items/L	(Han et al., 2020)
		623–1392 (dry)	items/L	
Los Angeles River	USA	13.7	items/L	(Moore et al., 2011)
Gulf St Vincent freshwater	Australia	6.4 ± 5.5	items/L	(Leterme et al., 2023)
Saigon River	Vietnam	172–519	items/L	(Lahens et al., 2018)
Klang River estuary	Malaysia	0.5–4.5	items/L	(Zaki et al., 2021)
Citarum River	Indonesia	210 ± 130 (2018)	items/L	(Jeong et al., 2021)
		140 ± 275 (2020)	items/L	
Ciwalengke River	Indonesia	5.85+–3.28	items/L	(Jeong et al., 2021)
Banyuurip Waters	Indonesia	7.78 x 10^3	items/L	(Sari et al., 2021)
Surabaya River, Surabaya City	Indonesia	7.14–32380 (2019)	items/L	(Sari et al., 2021)
		3.45–63380 (2020)	items/L	
DKI Jakarta River–Estuaries (Tiram, Ciliwung, Sunda Kelapa, Baru, Karang, Angke, Cengkareng)	Indonesia	90–110	items/L	(Sari et al., 2021)
Ciliwung River	Indonesia	320–741	items/L	this research

of microplastics (Liong et al., 2021). The form of microplastics that is the majority in the Ciliwung River sediment is black-colored fragments (Figure 8). When viewed, the number of microplastics in the Ciliwung River sediment is in the range of 6560–10630 particles/kg, with the condition of point seven being the location that contains the highest microplastics when compared to other points. The general trend on the first day was an increase, but there was a decrease from point one

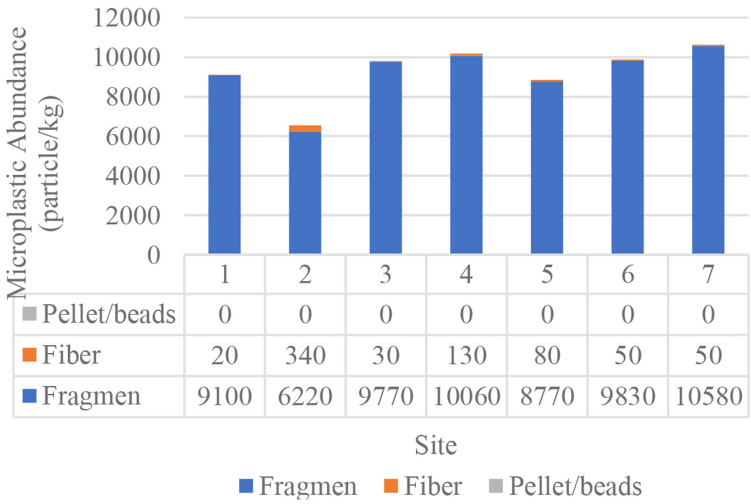

Figure 6. Microplastic abundance in Ciliwung River sediment wet day

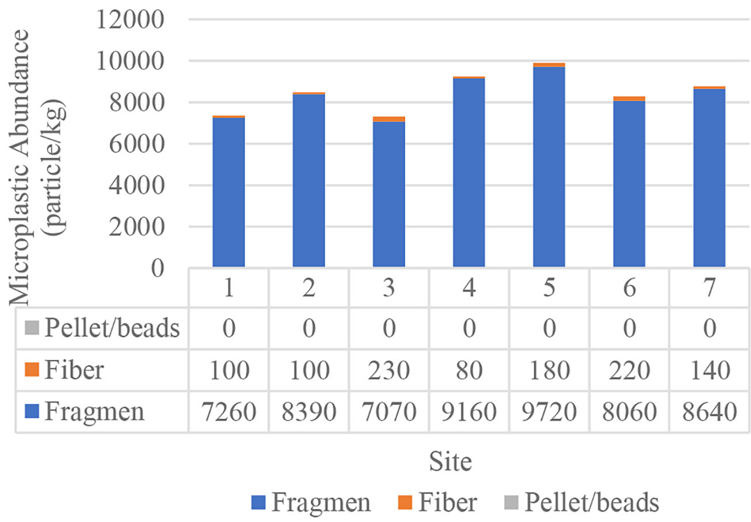

Figure 7. Microplastic abundance in Ciliwung River sediment dry day

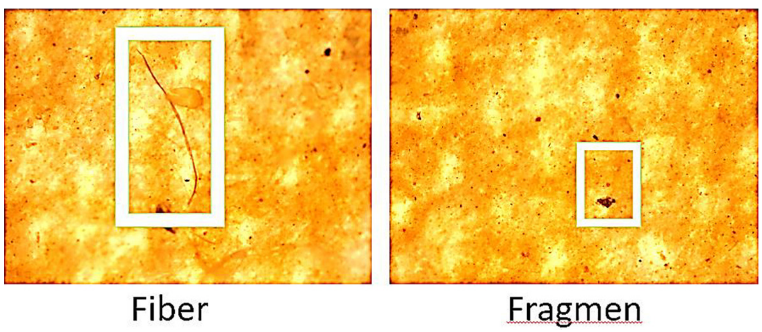

Figure 8. Microplastic in Ciliwung river sediment

to point two which resembled the trend of changes in microplastics in river water. There is also a decrease from points 4 and 5, where point four is close to the tributary, so it gets pollutant load from two sources. Whereas on the second day, the spatial trend from upstream to downstream was not observed, which could be due to the rainfall on the second day of 21.55 mm. This is due to the influence between rainfall and the condition of dissolved solids, in this case including sediment (Sinyukovich, 2001). Based on observations in this study, the majority of microplastic forms on the first and second days were fragmented with a range of 6220–10580 particles/kg. The presence of fragment-shaped microplastics is very often found in river sediments and is the majority form that is contained in sediments (Han et al., 2020). The highest number of fragment-shaped microplastics was found at point seven on the first day, where point seven is an area with the highest community density when compared to other points. This is one of the causes of high microplastics in sediments, where the closer the sampling point to the population density, the higher the number of microplastics obtained (Wen et al., 2018). The next form of microplastics is fiber with a range of 20 to 340 particles/kg. This has similarities with the conditions of microplastic pollution in the sediments of the Miri River, Kalimantan. The similarity is that the fiber form is the second most microplastic form after fragments (Liong et al., 2021). The following Table 5 is a comparison of the number of microplastics in sediments in several rivers in the world.

Correlation analysis of field parameter and population density

Fluctuations in microplastic pollution in river water can be caused by anthropogenic factors or human activities and environmental factors (Shahul Hamid et al., 2018). Anthropogenic conditions discussed in this study are population density and environmental factors are field parameters (pH, temperature, DO, Turbidity, and TDS). The method used to analyze the correlation between the number of microplastics and field parameters along with population density is correlation analysis. Based on the location of the sampling points, it can be analyzed that each point has a different population density. The trend that occurs is an increase from the first to the seventh point, with a value of $r^2 = 0.93$. This happens because the residential area at the fourth to seventh sampling points has entered the more densely populated area of DKI Jakarta.

Based on the results of the analysis conducted, the population density factor has the highest correlation with the number of microplastics with a value of $r = 0.702$. This is associated between population density and high microplastic emission loads (Zhou et al., 2021). The presence of microplastics in rivers influenced by anthropogenic human activities is influenced by the disposal of degraded plastic waste, laundry wastewater, and domestic wastewater which contains microplastics (Auta et al., 2017). The locations of the fourth to seventh sampling points have entered urban settlements, which have a higher impact on the

Table 5. Comparation of microplastic in several rivers sediment around the world

Location	Country	Concentration	Unit	Reference
Wei River	China	360–1320	items/kg	Ding et al., 2019
Antua River	Portugal	18–629	items/kg	Rodrigues et al., 2018
Rhine-Main	Netherland	228–3763	items/kg	Moore et al., 2011
Chai River Valley	China	7100–42960	items/kg	Zhang and Liu., 2018
Beijiang River Littoran Zone	China	178–544	items/kg	Wang et al., 2018
Atoyac Rivers Basin	Mexico	4500 ± 702.23	items/kg	Shruti et al., 2018
Chao Phraya	Thailand	2290	items/kg	Ta et al., 2020
Brisbane River	Australia	10–520	items/kg	He et al., 2020
Rhine and Meuse Rivers	Germany	1400–4900	items/kg	Leslie et al., 2017
Tapi-Phumduang River	Thailand	55–160	items/kg	Chinfak et al., 2021
Miri River	Malaysia	283.7–456	items/kg	Liong etal., 2021
Deli River	Indonesia	360	items/kg	Sari et al., 2021
Badak River	Indonesia	190	items/kg	Sari et al., 2021
Ciliwung River	Indonesia	6560–10630	items/kg	This Study

Table 6. Correlation between microplastic and field parameter in Ciliwung River

Parameter	Day	pH	Suhu	DO	Turbidity	TDS	Kepadatan Penduduk	Total MP
pH	Hujan	1.000						
	Kering	1.000						
Suhu	Hujan	-0.007	1.000					
	Kering	-0.205	1.000					
DO	Hujan	0.802	-0.482	1.000				
	Kering	0.414	-0.300	1.000				
Turbidity	Hujan	-0.192	0.076	-0.088	1.000			
	Kering	0.448	-0.290	0.813	1.000			
TDS	Hujan	0.480	0.234	0.188	0.095	1.000		
	Kering	0.100	0.399	-0.777	-0.564	1.000		
Kepadatan Penduduk	Hujan	0.749	0.235	0.348	-0.161	0.688	1.000	
	Kering	0.525	0.309	0.509	0.483	-0.221	1.000	
Total MP	Hujan	0.778*	0.526	0.411	-0.084	0.284	0.702*	1.000
	Kering	0.339	0.486	-0.080	-0.146	0.607*	0.049	1.000

Note: * The highest *r* values.

number of microplastics when compared to the three previous sampling points. This is evidenced by the comparative analysis of microplastics in water bodies in urban and rural residential areas, where urban areas have higher microplastic deposits when compared to rural areas (Chen et al., 2020). The other parameters that correlate with the number of microplastic particles are TDS and pH. River water that has high TDS and TSS values contains high pollution, where contaminants and including microplastics can be reviewed based on the value of these parameters (Buwono et al., 2021). The pH parameter correlates with the concentration of microplastics due to the influence of the surrounding waste leachate, including plastic waste. This is because the pH parameter has the greatest influence on plastic materials (Mortula et al., 2021). The following Table 6 is a correlation analysis of pH, temperature, DO, turbidity, TDS, and population density parameters.

CONCLUSION

Based on the findings in the Ciliwung River, in general, the level of microplastic pollution in water has an upward trend spatially from upstream to downstream. The most ordinary form of microplastics found in Ciliwung River water is black fragments, followed by fibers and pellets. This correlates with the level of population density in the area around the sampling which also increased from the first point to the seventh point. Rainfall conditions also influence the amount of microplastics, where there are differences between dry and rainy days. The field parameters that correlate with the presence of microplastics are pH and TDS with $r = 0.702$ and 0.607. Microplastic pollution in the Ciliwung River sediment has a different trend from water, where there is a fluctuating trend with the most microplastic form being black fragments. In general, microplastic pollution in the water and sediment of the Ciliwung River is in the high category when compared to several other countries. This is because developing countries have higher microplastic contaminants when compared to developed countries (Chen et al., 2020).

Acknowledgements

The his research was funded by Professor Grant 2022 (grant number: NKB-1959/UN2.F4.D/PPM.00.00/2022) from Faculty of Engineering University of Indonesia and provided by the Environmental Quality Laboratory Universitas Islam Indonesia, Yogyakarta Province

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