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RESEARCH ARTICLE

Microplastic Abundance in The Waters of The Middle Section of The Citarum River, Karawang, West Java

Indra Setiadi Hermana[a], Sigid Hariyadi[b,c], Taryono[b,c], Hidayat[a]

[a] Research Center for Limnology and Water Resources, National Research and Innovation Agency, Cibinong, 16911, Indonesia
[b] Department of Aquatic Resources Management, Graduate School, IPB University, IPB Darmaga Campus, Bogor, 16680, Indonesia
[c] Environmental Research Center, IPB University, IPB Darmaga Campus, Bogor, 16680, Indonesia

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ABSTRACT

Microplastics in the Central Citarum River, Karawang, West Java, originate from anthropogenic activities of people living around the watershed, which is an industrial, agricultural, and densely populated residential area. Microplastics are degraded plastics < 5 mm in size. This study aims to determine the abundance and size of microplastics in the Middle Citarum River, through observation with a microscope. Sampling was conducted at three locations with three observations: February, March, and April 2022. The types of microplastics found were pellets, films, fibers, and fragments. Microplastic particle size < 0.3 mm was the most common size found. The abundance of microplastics in the water of the Middle section of the Citarum River is different at each sampling location. The total number of microplastic particles in all research locations was 4,413 particles. The highest abundance of microplastics in all sampling locations was in densely populated residential areas at 239.7 ± 326.7 particles/m^3, followed by agricultural areas with an abundance of 72.5 ± 63.8 particles/m^3, then the lowest abundance was in industrial areas at 55.6 ± 57.8 particles/m^3. The average abundance of microplastics in the middle Citarum River water was 122.6 ± 209.7 particles/m^3. Statistical analysis using Kruskall Wallis with a df value of 2 > 0.05 showed no significant difference in microplastic abundance at each research location. All stations had the same potential for microplastic pollution. This study shows that high anthropogenic activities lead to high microplastic pollution in water. Therefore, proper mitigation and management of waste and plastic waste are needed.

Introduction

Microplastic (MP) pollution has been found in the global environment, both in oceans, freshwater, and also in the atmosphere. Microplastics are smaller than 5.0 mm, with the lower size limit of microplastics not specified, but they generally use a size of 333 µm or 0.33 mm. Microplastics are divided into two (2) types based on their shape and nature: (1) Primary microplastics are generated from manufactured raw materials, such as virgin pellets, microbeads, scrubbers, as well as cleaning and beauty products; (2) Secondary microplastics can be fibers or fragments from fishing nets and fishing strings, industrial raw materials and residues, plastic bags, and household appliances. Secondary microplastics derived from larger plastics (meso and macro) enter the water and degrade [1].

Plastic waste from land is carried to the sea through rivers as the main channel for transporting waste [2]. Plastic pollution in river environments has become a topic of increasing concern owing to its associated adverse effects [3]. The Citarum River is a strategic national river spanning 297 km [4]. The Citarum River is the lifeblood of the people of West Java and the capital city of Jakarta. Local government records show that 2,822 industries also have access to wastewater discharge into Citarum, which provides vital support to 18 million people living along its course [5]. The river delivers raw water for domestic needs to approximately

Corresponding Author: Indra Setiadi Hermana indra.s.hermana@gmail.com Research Center for Limnology and Water Resources, National Research and Innovation Agency, Cibinong, Indonesia.

127 million people, including the supply of clean water to the capital city. Topographically, the Citarum River is divided into three parts: the Upper Citarum, Middle Citarum, and Lower Citarum [6]. Karawang District is a densely populated industrial area and a centre of rice farming and is crossed by the middle section of the Citarum River. Around the Citarum River, many large-scale industries have effluent treatment plants, but the level of treatment is known to be low. For small industries, the availability and performance of wastewater treatment plants are poor [7]. These anthropogenic activities are closely related to the MP pollution levels in the Middle Citarum River.

The Citarum River contains an increasing amount of small-to micro-sized waste annually, and the local community continues to utilize the water from the river [8]. Microplastics are pollutants that are widely detected in aquatic environments [9]. Microplastic pollution can potentially threaten human health and aquatic organisms [10]. The entry of microplastics into rivers can be caused by many factors, including rainwater runoff and wastewater treatment plant effluents [11].

Based on the description above, research on microplastics is needed as supporting data for mitigating and managing water resources in the central Citarum River. This study aimed to determine the type and abundance of microplastics as information for managing Citarum Harum, following Government Regulation No. 15/2018 [12]. This regulation regulates the acceleration of pollution and damage control in the Citarum watershed through Citarum Harum activities.

Methods

Study Area

Field sampling was conducted at three stations with three replicates from February to April 2022 during the wet season. The station points, as shown in Figure 1, were used as research locations based on the following criteria: the location must be legally and easily accessible to the samplers, and the location must be representative of land use along the river, such as agricultural, industrial, or residential areas. The research site was located in Sector 19 of the Citarum Harum Task Force. Station 1 is located in Wadas, Teluk Jambe Raya, under the suspension bridge at positions S 06°19'37.41 and E 107°18'41.81. This area includes factories, industries, and warehouses. Station 2 is in Kp. Pasir Panggang, Teluk Jambe Timur, located at position S 06°18'39.71" and E 107°16'34.83". This area includes hotels, dense settlements, restaurants, warehouses, and showrooms. Station 3 is in Sumedangan, Teluk Jambe Timur, at positions S 06°16'47.63" and E 107°16'27.83". There are agricultural areas in this region. Station 1 represents industrial areas, station 2 represents densely populated settlements, and station 3 represents agricultural areas.

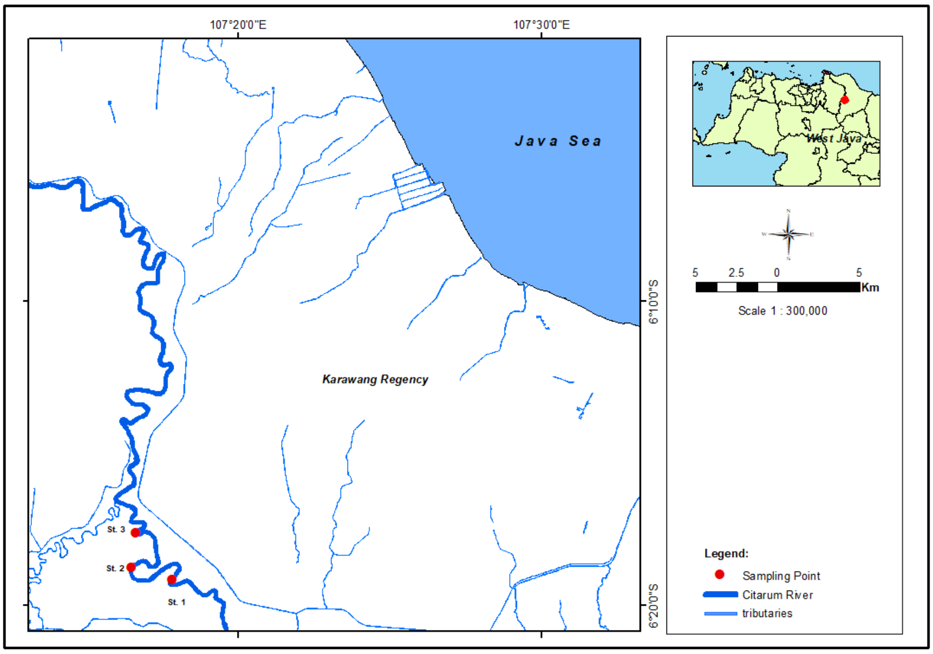


Figure 1. Map of sampling location in the middle section of the Citarum River in Karawang, West Java.

Data Collection

Microplastic sampling in water was conducted using plankton net [13,14]. The plankton net had a mouth opening with a diameter of 30 cm, mesh length of 1 m, and mesh net size of 330 µm. Microplastics are plastic particles smaller than 5.0 mm with a lower limit (size) of microplastics not specified; however, common practice is to use a mesh size of 333 µm or 0.33 mm to collect samples [15]. To streamline filtering, the plankton net was modified by placing a 5 mm filter at the mouth of the plankton net, while the net used a size of 0.3 mm to isolate debris that had the appropriate size, so that the samples obtained were filtered first with a 5 mm net and obtained samples that were less than 5 mm in size. At the end of the sample collection, a 500 ml glass jar was tied with a clamp to facilitate installation and removal. The plankton net was placed parallel to the water surface by hooking on the mooring of the boat track for 10 min using a carabiner. Sampling was performed in the middle of the river. The plankton net was lifted and rinsed until there were no remaining microplastic samples. A glass jar containing the microplastic sample was removed from the plankton net. The top of the jar was covered with aluminum foil and tightly closed with a glass jar lid to avoid contamination. Samples in glass jars were labeled and stored in a sample storage box containing ice cubes or ice gels. The samples were stored in a refrigerator until they were analyzed. Water sampling was performed in one replicate at each station. However, before water sampling was carried out, water flow measurements were first taken to calculate the volume of water filtered.

Sample Analysis

Water Sample Extraction

The sampling process used a modified bongo net with a 5 mm sieve (Figure 2). Samples in 500 ml sample bottles were filtered using a 0.3 mm sieve. The filtered sample was then transferred into a sample glass and added 0.05 M Fe(II) solution as much as 20 ml, then added back 30% hydrogen peroxide as much as 20 ml. Let stand for 5 minutes and then heated on a hot plate at 75 °C until there are hot bubbles. The sample was removed from the hot plate after the first bubble burst on the surface and cooled. When the solution has cooled slightly, the sample is reheated at 75 °C for 30 minutes. This heating can be done several times for each sample if a large amount of organic matter is obtained [16]. Rinse the sample to remove salt with distilled water using a 0.3 mm sieve. The filter results were transferred to a beaker glass and all that was filtered was moved to the beaker glass by spraying with distilled water. The final step was to filter the samples on filter paper using a vacuum pump, and the results were further analyzed using a stereo microscope.

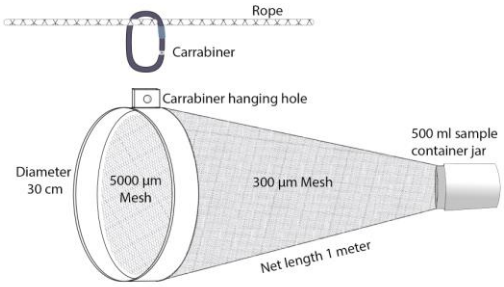
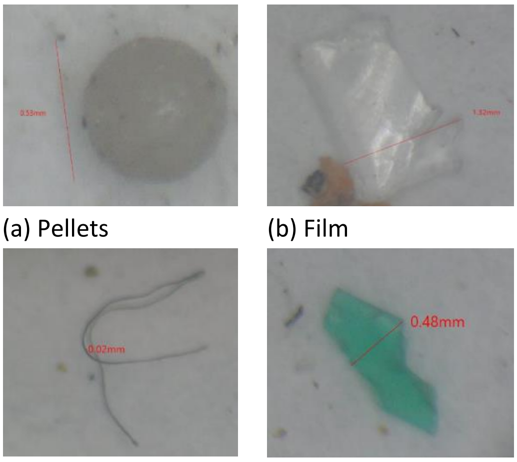


Figure 2. Plankton nets were used to sample microplastics in the water of the middle section of the Citarum River in Karawang, West Java.

Microscope Observation

The microplastics were observed and photographed under a Nikon SMZ 2 B microscope using a Koppace microscope camera and Koppace View software. The microscope with the camera was calibrated before the observations were made. Samples were observed using a microscope from left to right with a zigzag pattern. Identification and measurement of microplastic particles following the rules: particles that cannot be disturbed with tweezers, particles with different colors, and particles that have no organic structure [17]. In this study, the measured particles were <5 mm and were directly measured in length or width using the measuring line in the Koppache View Software. If a particle has a size other than that specified, it will be isolated and not analyzed. Microplastics are identified based on their type and size. Microplastics are classified as pellets, films, fibers, and fragments. Microplastics were categorized into four sizes <0.3 mm, 0.3 to <0.5 mm, 0.5 to <1 mm, and 1 to <5 mm [18]. Figure 3 shows the types and sizes of microplastics observed under a microscope.



(a) Pellets (b) Film

(c) Fiber (d) Fragments

Figure 3. Microplastics type: (a) Pellets (b) Film (c) Fiber (d) Fragments found in the Citarum River in the Center Section.

Data Analysis

The total abundance of microplastics is the number of particles divided by the total volume of filtered water (1). The number of microplastics found at each station was averaged and the standard deviation of each station location was calculated. Microplastic abundance was calculated using the following formula [19,20]:

$$N = \frac{c}{v} \quad (1)$$

Where:

N = microplastic abundance (particles/m3)

c = number of microplastics

v = volume of filtered water

The total volume of filtered water (2) is given by the formula [21]:

$$Vtsr = l \times t \times v \quad (2)$$

Where:

Vtsr = total filtered water volume

l = sieve mouth opening area

t = sampling time

v = water current speed

Statistical Analysis

Abundance analysis was conducted using Microsoft Excel, while statistical analysis used IBM SPSS Statistics Version 25. The first step was a normality test, followed by a further test using the Kruskal-Wallis test as a non-parametric test to verify whether there was a significant difference in microplastic abundance between stations.

Results and Discussion

A total of nine samples from three stations with three repetitions obtained 4,676 MP particles of four microplastic types: pellets, films, fibers, and fragments. The percentage of microplastic types from the largest to the smallest at each station is as follows (Figure 4): Station 1 comprised 51% fiber, 24% fragments, 23% pellets, and 2% film. Station 2 comprised 44% fragments, 33% pellets, 18% fiber, and 5% film. On the other hand, Station 3 comprised 43% fiber, 35% fragments, 16% pellets, and 6% film, respectively. There was a difference in the highest percentage between stations, where stations 1 and 3 had the highest percentage dominated by fiber, while station 2 occupied the highest percentage by fragments. The film type had the lowest percentage at the three stations.

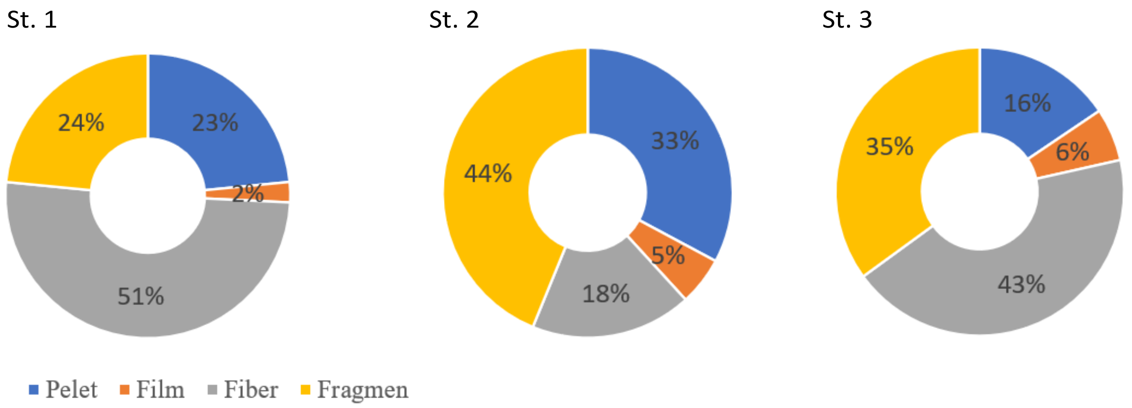


Figure 4. Composition of microplastic types at each station.

Three samples were collected from Station 1 in Wadas, East Teluk, and Jambe. Based on microplastic types, a total of 473 MP particles were observed with an average total concentration of 55.64 ± 57.85 particles/m^3, with consist of an average of each type as follows: pellet concentration of 52.20 ± 16.82 particles/m^3 followed by film concentration of 5.12 ± 3.38 particles/m^3, fiber concentration of 113.04 ± 86.49 particles/m^3 and fragment concentration of 52.21 ± 51.58 particles/m^3, respectively (Figure 5). The weather at the sampling time was sunny with an average water velocity of 1.57 m/s and an average river width of 35.77 m.

Similar to Station 1, three samples were collected at Station 2 in Pasir Panggang, East Teluk, Jambe. Based on microplastic type, a total of 3,362 MP particles were observed with an average total concentration of 239.66 ± 326.69 particles/m^3, with averages for each type as follows: 314.58 ± 357.31 particles/m^3 pellet concentration, 51.65 ± 33.64 particles/m^3 film concentration, 172.34 ± 126.88 particles/m^3 fiber concentration and 420.06 ± 593.06 particles/m^3 fragment concentration (Figure 5). Station 2 had an average river width of 34.70 m with an estimated average water velocity of 3.93 m/s. The weather at the time of sampling was rainy, namely in March sampling, which affected the high waste samples obtained, so that when averaged, the total microplastics obtained were 958.60 ± 987.24 particles/m^3 much greater than stations 1 and 3, which were sampled during sunny weather.

Three samples were collected at Station 3 in Sumedangan, East Teluk, Jambe. Based on microplastic types, a total of 841 microplastic particles were observed with an average total concentration of 72.48 ± 63.79 particles/m^3, with consist of an average of each type as follows: pellet concentration of 45.08 ± 34.08 particles/m^3, film concentration of 17.20 ± 12.50 particles/m^3, fiber concentration of 126.09 ± 103.17 particles/m^3 and fragment concentration of 101.55 ± 12.09 particles/m^3, respectively (Figure 5). The weather at the time of sampling at this station was sunny, with an average river width of 40.37 m and an average water velocity of 1.76 m/s. Comparing the three study sites based on the type of microplastics, Station 2 had the highest mean value of total microplastic concentration at 958.60 ± 987.24 particles/m^3, followed by Station 3, and the lowest was found at Station 1. Station 1 had the lowest total concentration. The microplastic concentration values according to type are shown in Figure 5.

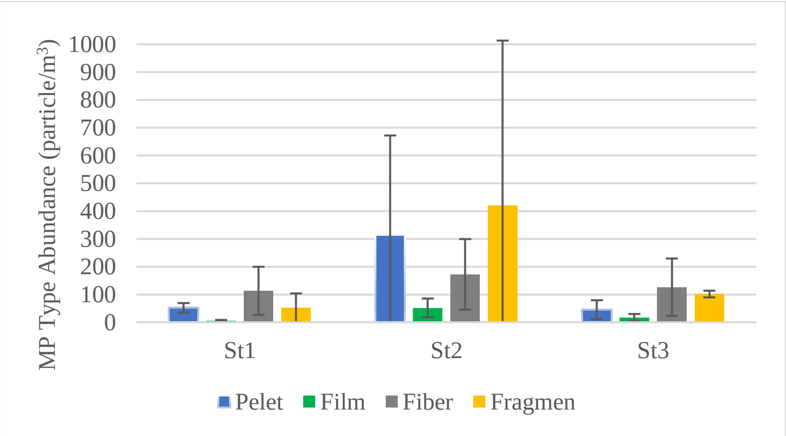


Figure 5. Abundance of the type of microplastic at each station.

Differences in microplastic concentrations among sampling sites may be due to differences in anthropogenic impacts and sources of microplastic inputs from natural factors such as water currents, wind, river flow [22], and rain [23]. In the wet season, extreme currents can exacerbate microplastic pollution in rivers and re-suspend particles previously trapped in sediments [24]. Microplastics are thought to enter rivers through runoff and drainage systems [11]. Weather conditions, including rainfall and water velocity, influence the distribution of microplastics [24]. Sampling at station 2 was conducted during rainy weather conditions, while sampling at stations 1 and 3 was conducted during sunny weather conditions. Daily and monthly average rainfall data are shown in Table 1. According to earlier studies, microplastics are found more frequently in the rainy season than in the dry season. Where research conducted in the rainy season in August with 37.4 ± 37.0 particles/m^3 compared to the dry season in April of 28.2 ± 22.2 particles/m^3 [10].

Table 1. Monthly and daily average rainfall data in the rainy season Feb to April 2022, Karawang, West Java [25].

Month	Number of precipitation (mm)	Number of rainy (day)
February	678.6	26
March	187.4	21
April	358.2	23

Based on Figure 5, the middle Citarum River had a microplastic concentration of 122.59 ± 209.69 particles/m^3. This indicated that the middle Citarum River had a higher MP concentration when compared to previous research in the downstream Citarum, with a microplastic concentration of 0.086 ± 0.004 particles/m^3, but lower than milkfish ponds located in the lower reaches of the Citarum River, which had a concentration of 3,000 ± 2,645 particles/m^3 [5]. The microplastic concentration of the middle section of the Citarum River when compared to the total microplastic abundance studies in several locations, including the Cherating River, Kalimas Surabaya River, Banyuurip Waters, and Han River with microplastic concentrations of 0.0042 particles/m^3, 0.07 particles/m^3, 57.11 x 10^2 particles/m^3, and 31.4 ±28.5 particles/m^3 respectively, as shown in Table 2.

Table 2. comparison of literature studies of microplastic content in rivers and waters.

Sl. no.	Location of study	Average microplastics concentration /range	Sample types	Detection techniques	Shape of microplastics	Sampling techniques	Extraction techniques	Heated	References
1	The Cherating river, Malaysia	0.0042 ± 0.0033 particle/m^3	Surface water	Microscope	Line Fragment Film Foam Pellet	Plankton net	20% alcohol solution	Not detected	[13]
2.	Kalimas River, Surabaya, East Java	0.07 item/m^3	Water	Microscope	Fragmen, filamen and fiber	Plankton net	Fe (II) 0.05 M solution, H_2O_2 30%, NaCl (NOAA)	60 °C	[22]
3.	Banyuurip Waters, Gresik, East Java	57.11 × 10^2 partikel/m^3.	Surface water	Microscope	Fragment, fiber, and film	Plankton net	0.05 M Fe, 20 ml H_2O_2, 6 gr NaCl every 20 ml NOAA)	90 °C	[20]
4.	Han River, Korea	31.4 ± 28.5 particles /m^3	Water	FTIR	Fragment	100 µm pore size manta net	30% H_2O_2,	62.5 °C	[10]

The concentration of microplastics by size (Figure 6) at Station 1 - Wadas, East Teluk Jambe was as follows: size <0.3 mm: with a concentration of 120.33 ± 54.07 particles/m^3 obtained by 76%; size 0.3 to <0.5 mm: with an average concentration of 22.00 ± 12.68 particles/m^3 by 14%; size 0.5 to 1 mm: with an average concentration of 13.67 ± 7.45 particles/m^3 by 9%; size 1 to 5 mm, with an average concentration of 22.00 ± 7.45 particles/m^3 of 1%. Microplastic concentration by size (Figure 6), at Station 2 - Pasir Panggang, East Teluk Jambe was obtained: size <0.3 mm: with a concentration of 357 ± 397.04 particles/m3 obtained 32%; size 0.3 to <0.5 mm: with a concentration of 313.67 ± 394.79 particles/m^3 obtained 28%; size 0.5 to <1 mm: with a concentration of 332.67 ± 438.14 particles/m^3 by 30%; Size 1 to 5 mm: with a concentration of 117.33 ± 169.40 particles/m^3 at 10%.

Microplastic concentration by size (Figure 6), at Station 3 - Sumedangan, East Teluk Jambe obtained microplastic particles size <0.3 mm: with a concentration of 127 ± 28.69 particles/m^3 by 59%; size 0.3 to <0.5 mm: with a concentration of 41.67 ± 40.74 particles/m3 by 20%; 0.5 to <1 mm: with a concentration of 40.33 ± 41.97 particles/m^3 at 19%; Size 1 to 5 mm: with a concentration of 4.67 ± 5.75 particles/m^3 at 2%.

The types of microplastics found can be used to identify their sources. A previous study reported that fiber-type microplastic sources were used as basic materials in the manufacture of clothing, clothing fibers, fishing nets, and household appliances [26]. Film-type microplastics are in the form of plastic sheets or flakes, which are generally used for making plastic bags, packaging, or wrapping food or drinks. However, microplastic fragments are thought to come from broken plastic bottles, bottle caps, or jars [27]. Microplastics of the pellet type come from raw materials left over from industrial activities, toiletries, soaps, and facial cleansers [28].

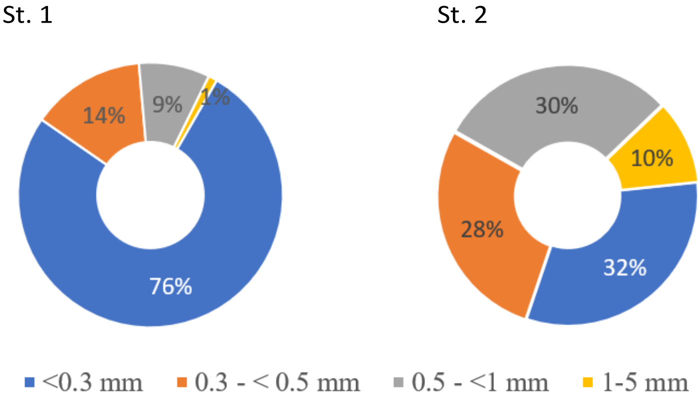


Figure 6. Particle size distribution of microplastics at each station.

Station 1 contained the highest concentration of fibers, followed by pellets and fragments, which were most likely generated from industries around the area. In addition, there is a high possibility that microplastics are transported by upstream water flow. Based on the types of microplastics found at Station 2, fragments were dominant, followed by pellets and fibers. This is possible because Station 2 is a densely populated area with all life activities that can have an impact on the surrounding environment. Microplastics found at station 2 originate from discarded plastic bottles, bottle caps, or plastic waste that is burned, discarded, or carried by water runoff into the river. Likewise, pellets can come from leftover personal care products. As an area with a high population density along the river, it is likely to produce large amounts of microplastic fibers, such as from clothes washing waste [22], where water is discharged through the sewer and into the river. At the time of sampling at station 2, it was raining; therefore, it is suspected that there was water runoff from the land into the river. The carrying of microplastics downstream can also be the cause of the higher microplastic concentrations at station 2 compared to station 1. At station 3, the types of microplastics were dominated by fibers, followed by fragments. Fragments, filaments, and fibers are common forms of MP in agricultural soils. It is likely that these MPs came from plastic food wrappers or agricultural product wrappers, such as fertilizers that are disposed of carelessly, which can cause high MPs in this research location [29]. It is likely that these types of MP enter the irrigation system or are exposed to rainwater runoff before entering the river.

High anthropogenic activities from settlements, plantations, fishing industry, aquaculture, and tourism sectors provide inputs of pollutants, especially plastics, due to low awareness of waste management [30]. Primary microplastics come from industrial plastic particles, then enter the environment from sewage treatment plants into rivers; pellets used in cosmetics and detergents; and leakage from smaller product factories [31]. Degradable plastic products, which are sourced from plastics used for packaging, agricultural plastics, automotive products, and domestic plastics. When deemed to be defective, many plastic products are discarded into the environment by not being recycled. Fragments produced by degradation and decomposition are larger than domestic plastic products. Plastic packaging that has reached the end of its life and is discarded into the environment will produce large amounts of film-type microplastics. Rubber particles produced by tire wear during use on asphalt roads are also considered a source of microplastics. The polyester, cotton and nylon detected came from the remnants of damaged fabrics and fibers released during the washing process, which provides strong evidence for a fiber-type source of microplastics.

Statistical analysis to determine the abundance of microplastics in the middle Citarum River used the Shapiro-Wilk normality test. Stations 1 and 3 had df values >0.05, while Station 2 had df values <0.05. This means that the abundance of microplastics is not normally distributed, so it is necessary to conduct further tests using the Kruskal-Wallis non-parametric test. This test obtained a df value of 2 > 0.05. This indicates that the microplastic abundance at stations 1, 2, and 3 are not significantly different. All stations have the same potential for microplastic pollution. In other words, there is no significant difference in microplastic pollution between observation stations, where Station 1 represents industry, Station 2 represents densely populated settlements, and Station 3 represents agricultural areas.

Conclusion

A microplastic study was conducted in the middle section of the Citarum River. Microplastics from the three sampling stations were categorized into four types: pellets, films, fibers, and fragments. There was a different dominance of microplastic types between stations, where stations 1 and 3 were dominated by fibers, while Station 2 was dominated by fragments. The highest MP particle size in the 3 research locations was dominated by <0.3 mm in size.

The high microplastics concentration found in the Central Citarum River indicates the need for better waste management by industries, households, and agriculture through wastewater treatment plants. Industrial waste disposal should be better managed by integrated monitoring of wastewater treatment plants. Household waste is not directly channeled into the river, but by providing septic tanks in each household. In addition, plastic materials can be replaced with environmentally friendly materials without carelessly burning plastic waste. Socialization of the dangers of plastic, its management, and law enforcement are needed to reduce the adverse effects of plastic on the environment.

The occurrence of microplastic pollution in the middle section of the Citarum River may provide information to the government, industrial sector, and community on the importance of proper and integrated waste management and disposal. Further research on the impact of MP on the health of communities affected by the Citarum River is needed.

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