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Presence of Microplastics in Water, Sediment, and Fish in Ancar Rivers Mataram City, West Nusa Tenggara, Indonesia

Khairunnisa, Ratih Ida Adharini, Ega Adhi Wicaksono, Eko Setyobudi*

Department of Fisheries, Faculty of Agriculture, Universitas Gadjah Mada, Indonesia
***Corresponding Author:** setyobudi_dja@ugm.ac.id

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ABSTRACT

Accumulation of microplastics can significantly impact the food chain in aquatic ecosystems due to their plankton-like shape, which often leads fish and other organisms to ingest them as food mistakenly. Environmental pollution due to microplastics in aquatic ecosystems has long been a concern of researchers. However, few studies have examined the presence of microplastics in Mataram City. This study collected water samples using a bucket and filtered with a plankton net; sediment samples were gathered with a shovel at a depth of 3–10cm (500g); and fish samples were collected from local fishermen. All samples were filtered using a vacuum pump and cellulose filter paper (20µm) and then analyzed under a stereo microscope at 45x magnification. The concentrations of microplastics ranged from 10 ± 5.00 MP/m³-30 ± 22.91 MP/m³ in water, 13.33 ± 23.09 MP/kg-180 ± 173.21 MP/kg in sediment, while in *Rastrelliger* 0.22 ± 1.04 MP/ind, 0.14 ± 0.38 MP/ind in *Sardinella*, and 0.11 ± 0.33 MP/ind in *Euthynnus* with the line containing over 80% of the results. The microplastics varied in size from 250µm to 5mm and were observed in red, blue, black, transparent, and green colors. Through the FTIR analysis, samples showed microplastic particles, particularly PP, PET, PMMA, HDPE, and PE. All sample types found microplastics, indicating significant pollution in the waters of the Ancar River. This study illustrates that the abundance in the Ancar River, Mataram City, is influenced by human activities, environmental conditions, and the characteristics of microplastics.

INTRODUCTION

Waste has long been a significant issue for human life and the environment, particularly in terrestrial and aquatic ecosystems. Among the several types of waste, plastic waste is the most prevalent. Comprising synthetic materials made of polymers, plastics contribute 60–80% of marine debris **(Daud, 2020)**. Each year, approximately 10 million tons of plastic enter marine ecosystems, where they can take 500 to 1000 years to decompose. However, even after a long time, plastics only break down into microplastics without decomposing completely. About 50-70 trillion pieces of plastic and microplastics are currently preserved in the ocean, presenting a considerable risk to marine life and disrupting the equilibrium of marine ecosystems **(Marta, 2022; Ritchie *et al*., 2023)**.

Plastic in the environment can break up into smaller pieces by physical and chemical processes such as thermal oxidation, UV exposure, and mechanical abrasion. Pieces of plastic <5mm in size are called microplastics, which, based on their origin, can be categorized into primary and secondary microplastics. Primary microplastics are intentionally made small, while secondary microplastics are plastics fragmented from synthetic polymer products **(EFSA CONTAM, 2016)**. The accumulation of microplastics in aquatic environments adversely affects ecosystems by disrupting the food chain. Fish and other aquatic organisms frequently mistake microplastics for food due to their small size and plankton-like appearance. Microplastics consumed by fish can disrupt the fish's digestive system, which in turn can interfere with growth, inhibit enzyme production, reduce steroid hormone levels, affect reproduction, and cause exposure to plastic additives to be toxic or even cause death **(Wright *et al*., 2013; Silva-Cavalcanti *et al*., 2017)**.

Cordova *et al*. (2018) have conducted a study on microplastics in Sekotong, West Lombok, but they have not yet examined the area surrounding the Ancar River in Mataram City. The Ancar River, one of the main watersheds in Mataram City, West Nusa Tenggara, Indonesia, flows throughout the year. The river length is 21km, with a watershed area of ± 63km², and the slope of the riverbed is approximately 0.05°. The river traverses residential areas inhabited by 441.147 individuals, serving various purposes such as bathing, washing, latrines, and household waste disposal **(Pemda Mataram, 2013; Efendi & Imaran, 2016; Badan Pusat Statistik Kota Mataram, 2024)**. Environmental pollution due to microplastics in aquatic ecosystems has long been a concern for researchers. The accumulation of microplastics in a body of water will impact the quality and life of aquatic biota, which will affect humans in terms of aesthetics and health. Very few studies still examine the presence of microplastics in Mataram City, especially in its aquatic ecosystems. This study aimed to figure out the distribution, type, and abundance of microplastics in water, sediment, and aquatic biota along the Ancar River in Mataram City. The obtained data on the distribution, type, and level of microplastic pollution will be the latest information source that is useful for managing the aquatic environment in Mataram City.

MATERIALS AND METHODS

This research was conducted from February 2023 to August 2023. Sampling was carried out in the Ancar River in Mataram City, West Nusa Tenggara, Indonesia, with 5 sampling points, where the points pass through residential areas to the estuary. The first sampling point is located at the Selagalas Bridge in the Sandubaya District, a region characterized by a dense population. The second point was at the Rajawali II Bridge in Karang Taliwang, strategically situated near market activities and transportation hubs. The third point, at the Karang Bedil Bridge in Punia Mataram, is a semi-urban area with potential pollution sources from various activities, including household waste and transport. The fourth sampling location is near the Universitas Mataram Bridge. While, the last point is at the mouth of the Ancar River, where the river meets the sea, which is recognized as a microplastic accumulation area before entering the marine ecosystem. The selection of these locations aimed to gather representative data on the distribution and concentration of microplastics in the Ancar River. Fig. (1) illustrates the distribution of sampling points and provides geographical context for the studied area. Sample preparation was conducted at the Department of Fisheries Laboratory, Mataram University, followed by further analysis at the Aquatic Ecology Laboratory Department of Fisheries, Universitas Gadjah Mada.

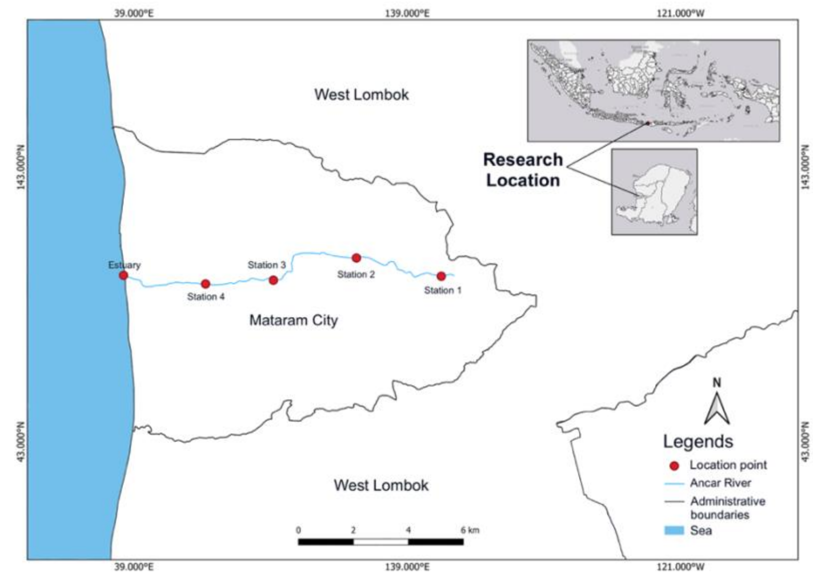

Fig. 1. Sampling location at Ancar River Mataram City, West Nusa Tenggara, Indonesia

Water samples were taken 3 times at each point using a 10-liter bucket, with each sampling repeated 10 times. Field water samples were filtered using a 150µm plankton net with a mouth opening in the shape of a circle with a diameter of 30cm and a cod-end with a volume of 200ml. The water collected in the cod-end was then transferred into sample bottles and taken to the laboratory for further analysis **(Campanale *et al*., 2020)**. The water sample was prepared by adding 30ml of 10% KOH and allowing it to settle for 24 hours. After that, filtration was carried out using filter paper with a pore size of 20µm (Whatman No. 41).

Sediment samples were taken in triplicate at each point using a scoop with a depth of 3-10cm, amounting to 500g, and placed into a zipper bag for subsequent analysis **(Dewi *et al*., 2015)**. The samples were then dried using an oven at 60°C for 24 hours. Then, 300ml of 30% NaCl was added to 100g of dry sediment and was allowed to sit for 24 hours or more until the sediment settled. After that, the supernatant was filtered using cellulose filter paper with a pore size of 20µm (Whatman No. 41).

Fish samples were obtained from fishermen around the Ancar Estuary and were then stored in a refrigerator for further analysis. The fish samples were measured for length, weight, and mouth opening. After that, the fish were dissected, and their digestive tracts were removed. Then, 10% KOH was added in an amount three times the volume of the fish sample **(Rochman *et al*., 2013)**. Next, the fish sample was oven-dried at 60°C for 24 hours **(Yona *et al*., 2021)**. After that, filtration was carried out using cellulose filter paper with a pore size of 20µm (Whatman No. 41).

Identifying microplastics requires several stages, namely visual observation, classification of shapes, and size determination. Visually, microplastics can be distinguished by their bright and striking colors (blue, red, green). Microplastic particles are identified visually to determine their quantity, shape, size, color, and type of polymer. After all the samples were filtered, visual identification was conducted using a stereo microscope at 45x magnification **(Masura *et al*., 2015)**. Microplastics are marked by bright and striking colors, lack cellular structure, and are shiny **(Blettler *et al*., 2017)**. Then, each particle found was recorded for its shape, color, and quantity. Documentation was carried out using a smartphone camera directed at the ocular lens. Microplastic measurement was conducted using the ImageJ software. The identified microplastics were then isolated to test their polymer types using the FTIR method **(Pungut *et al*., 2021)**. The FTIR test was performed by sending representative microplastic samples to the Integrated Research and Testing Laboratory of Universitas Gadjah Mada, and the test results were provided in the form of an absorption wavelength graph. The graph was then interpreted using the OpenSpecy website.

Contamination control was undertaken to guarantee that the study's results were valid. All equipments, including sample bottles, filters, and containers, were cleansed with aquades before use. To avoid contamination, the researchers wore lab coats and masks while observing in the laboratory. Three petri dishes containing aquades were positioned on three sides of the microscope to serve as negative controls during visual inspection. After the observation, the petri dishes were checked under a microscope to see if there are any further particles. If any other particles were discovered and suspected to be from the environment, then the particles were not included in the data and analysis. This approach is intended to minimize external contamination to the greatest extent possible.

This study conducted data analysis using ANOVA tests with Microsoft Excel and SPSS (Statistical Package for the Social Sciences) software. Descriptive analysis was also used to present an overview of data distribution.

RESULTS

1. Microplastics abundance in water samples

The concentration of microplastics in the water samples ranged from 10 ± 5.00 MP/m³ to 30 ± 22.91 MP/m³. The highest concentration was found at Station 1, with 30 ±

22.91 MP/m³, while the lowest concentration was found at Station 5, with 10 ± 5.00 MP/m³, where Station 5 is located at the river's estuary. Several factors, including proximity to pollutant sources and the hydrodynamics of the river, influence the variation in microplastic abundance among the different stations. Fig. (2) illustrates the abundance of microplastics in water across several locations in the Ancar River.

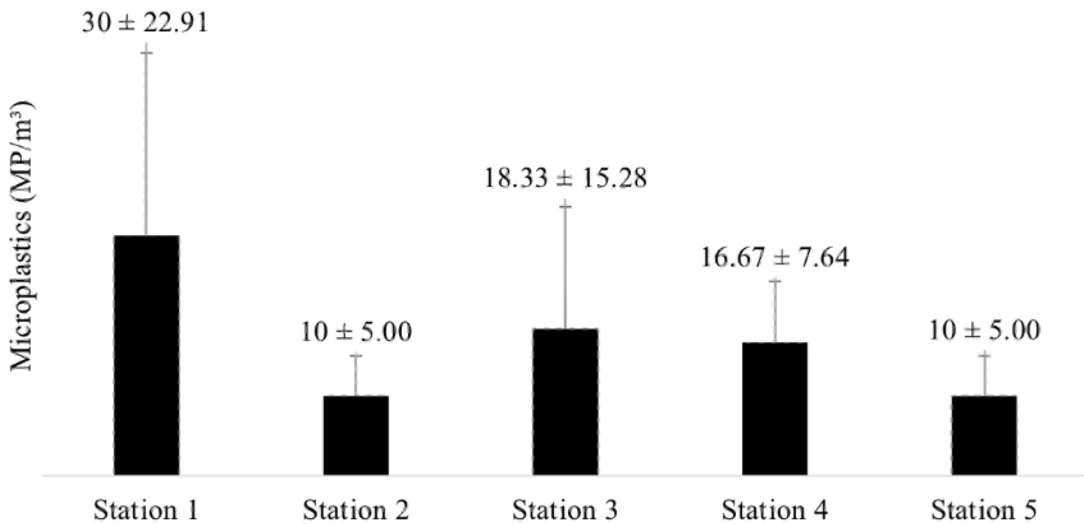

Fig. 2. Microplastics abundance found in water samples at the Ancar River, Mataram City, West Nusa Tenggara

2. Microplastics abundance in sediment samples

The concentrations of microplastics identified in the sediment samples ranged from 13.33 ± 23.09 MP/kg to 180 ± 173.21 MP/kg. The highest concentration was registered at Station 5, within 180 ± 173.21 MP/kg, while the lowest concentration was observed at Station 2, with 13.33 ± 23.09. The observed variations in microplastic abundance among the stations may attribute to several factors, including accumulation in the estuarine area, the impact of pollutant sources, and the dynamics of river water flow. Fig. (3) presents a graph depicting the abundance of microplastics in sediments at various locations within the Ancar River.

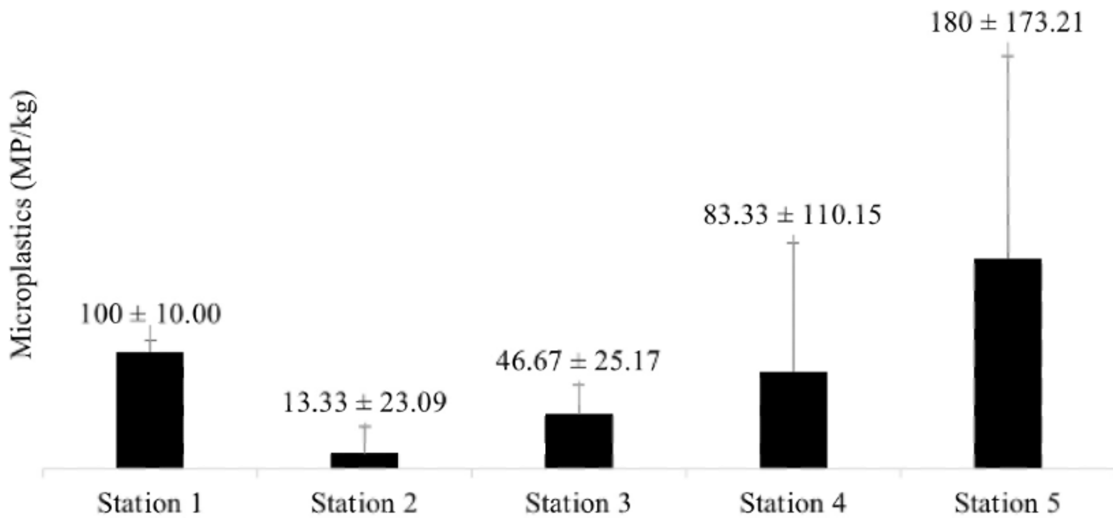

Fig. 3. Microplastics abundances found in sediment samples at the Ancar River, Mataram City, West Nusa Tenggara

3. Microplastics abundance in fish samples

The research results show that microplastics were only found in 7 samples out of 39 observed fish. Overall, the abundance of microplastics in the digestive tracts of fish was 0.14 ± 0.38 MP/individual in *Sardinella*, 0.22 ± 1.04 MP/individual in *Rastrelliger*, and 0.11 ± 0.33 MP/individual in *Euthynnus*.

Table 1. Microplastics abundance found in fish samples from the Ancar River, Mataram City, West Nusa Tenggara

Genus	Average weight (g)	Average length (cm)	Microplastics abundance (MP/ind)	Food Habit	Life mode	Total fish containing microplastics
Sardinella (n=7)	26.74	14.37	0.14	Omnivore	Pelagic	14.28%
Rastrelliger (n=23)	29.73	14.59	0.22	Omnivore	Pelagic	21.73%
Euthynnus (n=9)	112	21.04	0.11	Carnivore	Pelagic	11.11%

4. The size of microplastics

The subsequent graph illustrates the size distribution of microplastics identified in samples from the Ancar River (Fig. 4). The sizes of the microplastics varied within a range of <250 µm to 5mm. Among all samples analyzed, 1 to 2mm was the most prevalent, comprising 35% MPs in water samples, 38% in sediment samples, and 29% in fish samples.

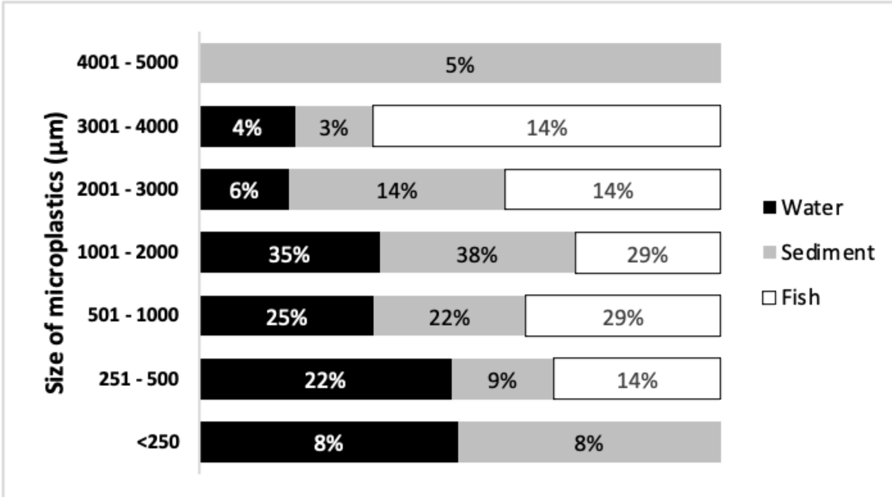

Fig. 4. The size of microplastics collected from the Ancar River, Mataram City, West Nusa Tenggara

5. The forms of microplastics

The forms of microplastics identified in water, sediment, and fish samples revealed a predominant prevalence of line forms (Fig. 5). Specifically, 90% of the microplastics exhibited line forms in the water and sediment samples, while 10% were classified as fragments. In the fish samples, 86% were characterized as line forms, with 14% identified as fragments.

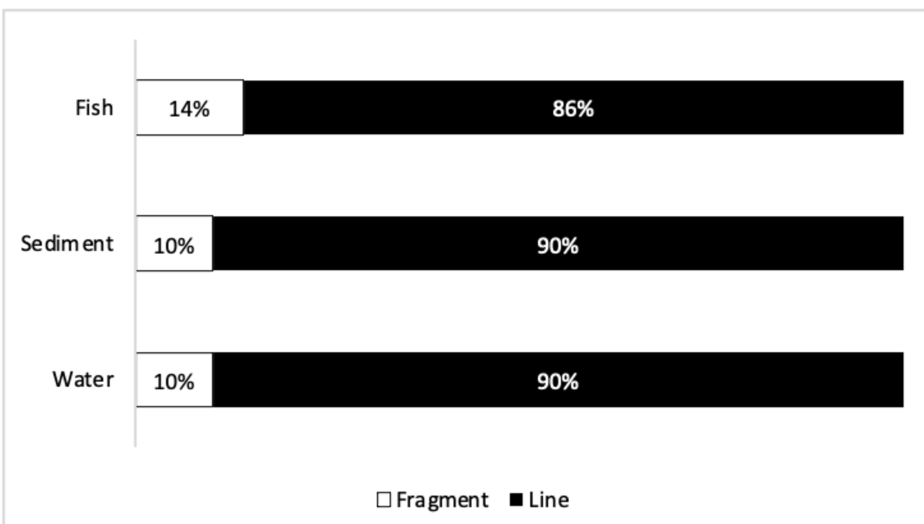

Fig. 5. The forms of microplastics found in the Ancar River, Mataram City, West Nusa Tenggara

6. Microplastics color

The color analysis of microplastics identified in water and sediment samples predominantly revealed a red hue, while fish samples predominantly exhibited a blue coloration. Furthermore, other colors observed in these samples included black, transparent, and green. A detailed summary of these findings is presented in Fig. (7).

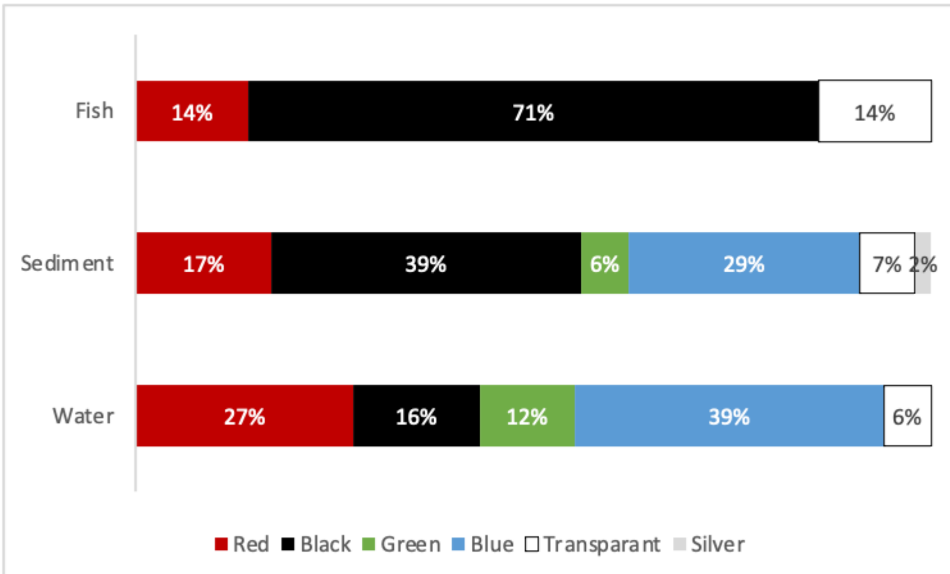

Fig. 6. The color of microplastics found in the Ancar River, Mataram City, West Nusa Tenggara

7. Representations of microplastics

Fig. (7) visually represents the various morphologies of microplastics identified in the research samples. Panel A depicts blue line microplastics, panel B depicts red line microplastics, while panel C illustrates green line microplastics. Panel D presents green fragments of microplastics, and panels E and F depict blue fragments of microplastics.

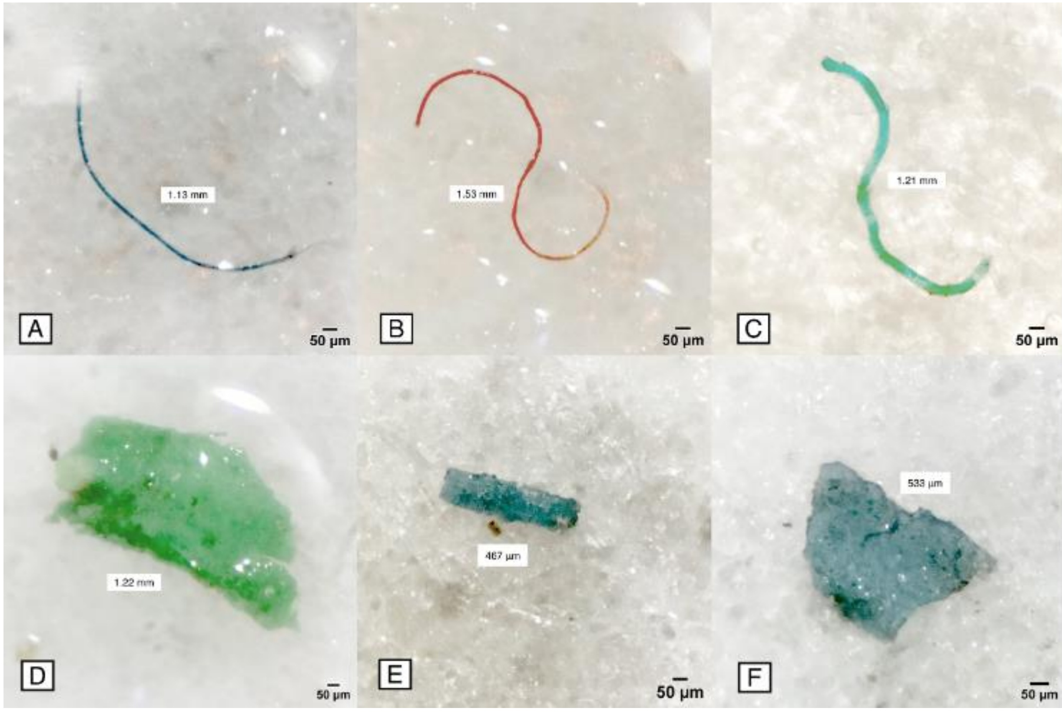

Fig. 7. (A) The representative of microplastics: blue line, **(B)** red line, **(C)** green line, **(D)** green fragment, and **(E, F)** blue fragment

8. Polymer of microplastics

Based on FTIR testing, the plastic polymers found in the samples are PP (polypropylene), PET (polyethylene terephthalate), PMMA (polymethyl methacrylate), Polyester, HPDE (high-density polyethylene), PE (polyethylene). The products made from these polymers can be seen in Table (2).

Table 2. Type of polymer found in the samples

No	Type of polymers found	Approximate source of pollution
1	PP (polypropylene)	- Bottles, food containers, toys **(Daud, 2020)** - Fish traps and cages, aquaculture ponds, and fish crates **(Lusher *et al*., 2017)**
2	PET (polyethylene terephthalate)	- Transparent bottle, cassette tape **(Daud, 2020)** - Soft drink bottles and fibers **(Shukla and Harad, 2006)** - Textiles, clothing, automotive components **(Whinfield, 1953)**
3	PMMA (polymethyl methacrylate)	Impact resistant window, skylight, canopy **(Daud, 2020)**
4	Polyester	Ship hull, car panel **(Daud, 2020)**
5	HPDE (high-density polyethtylene)	Milk bottles, wire and cable insulation, toys **(Daud, 2020)**
6	PE (polyethylene)	Packaging, pipe **(Burelo *et al*., 2023)**

DISCUSSION

The distribution of microplastics in water samples is uneven, where the highest abundance of microplastics is found at Station 1 (Selagalas Bridge), which is upstream of the Ancar River, Mataram City. Several factors, including distance from the source of pollution and the river's water flow, influence the difference in the microplastics at each station. The abundance of microplastics found was 30 ± 22.91 MP/m³, this is in line with the research of **Álvarez-Troncoso *et al*. (2024)**, where the concentration of microplastics found upstream is more than downstream. This can be caused by several factors: microplastics' hydrophobicity and specific gravity **(Kye *et al*., 2023)**. The vertical distribution of microplastics in the water column can also vary by location and particle type, depending on channel depth, flow velocity, and other factors **(Lenaker *et al*., 2019)**. In addition, microplastics can be affected by the surrounding environment and weather conditions, which can cause them to accumulate in certain areas **(Coyle *et al*., 2020; Kye *et al*., 2023)**. This disparity may also be caused by human activity in the upstream area, such as the direct deposit of domestic waste into the river and a lack of waste management facilities. Furthermore, Station 1 is located in the Sandubaya Sub-district, a densely inhabited area that may generate substantial amounts of residential garbage. Due to a lack of proper waste management facilities, single-use plastics frequently wind up in the river. Economic activities such as traditional markets, which are frequently close to this area, can also be sources of microplastics, particularly plastic wrapping debris and shopping bags carried by water flow.

Microplastics were identified in greater abundance in sediment samples from Station 5, located at the mouth of the Ancar River in Mataram City. The average abundance of microplastics detected was 180 ± 173.21 MP/kg, this is in line with the research of **Ismiyati *et al*. (2023)**, who observed a higher average abundance of microplastics in the estuary area. This can be modified by a variety of things, including river flow. River movement can transport microplastics to the estuary, where they collect before being released into the sea. Another factor is the source of pollution. Microplastic pollution in estuaries comes from various sources, including runoff, fishery operations, wastewater treatment facilities, shipping, industrial plastic manufacture, and littered single-use rubbish **(Malli *et al*., 2022; Fulfer & Walsh, 2023)**. The interactions between river flow, human activities, and surrounding environmental conditions are highly complex components that influence the accumulation of microplastics in estuaries. Although river flows transport microplastics from upstream to downstream, they accumulate in estuaries before they are released into the sea. On the other hand, estuaries are where river water and seawater often meet providing an ideal place for microplastics to settle and accumulate. In addition, this situation is exacerbated by human activities around the estuary, such as household waste, littered plastic waste, and industrial activities that produce microplastics. This suggests that estuaries can also serve as indicators of broader pollution, reflecting the adverse effects of poorly managed human activities.

Microplastics in fish were found in the least amount, namely, 7 out of 39 fish samples. Overall, the abundance of microplastics in the digestive tract of fish was 0.14 ± 0.38 MP/individual in *Sardinella*, 0.22 ± 1.04 MP/individual in *Rastrelliger*, and 0.11 ± 0.33 MP/individual in *Euthynnus*. The results showed that more microplastics were found in *Rastrelliger*. *Rastrelliger* are small pelagic fish that forage in the water column, where microplastics can be suspended more due to their floatability. In contrast, *Sardinella* tends to live in deeper waters, while *Euthynnus*, a pelagic predatory fish, has a longer food chain and is less contaminated by microplastics **(Justino, 2023)**. Another factor is the fish's ability to excrete or eliminate microplastics from its digestive system, reducing the microplastics in its tissues. The size and shape of microplastics can also affect their ingestion. Smaller microplastics are more likely to be ingested by fish, but may also be more easily eliminated from their digestive system. Environmental factors can also affect the concentration of microplastics in fish. For example, fish in areas with high levels of microplastic pollution can have higher concentrations of microplastics in their tissues **(Thiele *et al*., 2021; Alberghini *et al*., 2023; Khan *et al*., 2023)**.

Their size influences the mobility and transport of microplastics within aquatic ecosystems. Research by **Shamskhany *et al*. (2021)** and **Almeida *et al*. (2023)** indicates that larger microplastics are more likely to sink and accumulate in sediments than smaller ones. Furthermore, the size and forms of microplastics can affect their interactions with marine organisms, as small predators more readily ingest smaller microplastics **(Auta *et al*., 2017)**. Environmental factors, including river flow, tidal cycles, turbulence, and bioturbation, significantly impact the transportation of microplastics. The transport and mobility of microplastics in aquatic environments are significantly influenced by their density and forms, as demonstrated by several studies **(Shamskhany *et al*., 2021; Malli *et al*., 2022; Almeida *et al*., 2023)**. It is important to note that the distribution of microplastics in the environment is highly dependent on their density, which can vary depending on the type of plastic, with densities ranging from 0.33 to 1.5g/ cm^3. Ethanol, ultrapure water, saturated NaI, and ZnCl2 are density gradient solutions that can accurately determine microplastics' density and buoyancy **(Li *et al*., 2018)**. Microplastics with a density less than water can float and travel long distances on wind and water currents, affecting their mobility and transportation in aquatic environments **(Shamskhany *et al*., 2021)**.

The most common forms of microplastics are lines and fragments. These microplastics can result from various sources, including fragmentation of larger plastics, abrasion of synthetic textiles, and degradation of plastic products over time. In addition, environmental factors such as wind, waves, and sunlight can contribute to the breakdown of larger plastics into smaller fragments and fibers, leading to the prevalence of these forms in the environment **(Daud, 2020)**. The color of microplastics in the environment significantly impacts their interaction with aquatic organisms and the environment. Furthermore, it affects how aquatic organisms perceive them, as they may mistake tiny microplastics for plankton **(Corinaldesi *et al*., 2021)**. The color of microplastics also influences the absorption of solar energy. **Podbielska *et al*. (2023)** assert that dark-colored polystyrene microplastics can absorb more solar energy and may be more toxic to marine organisms than lighter-colored microplastics. FTIR tests confirmed the presence of microplastics in 70% of the representative samples, with various polymers, including PP, PET, PMMA, polyester, HDPE, and PE. As per the literature, PE, PP, and PS are the most prevalent polymers in water and sediment. Polymers have varying densities. However, PE (0.92-0.97 g/cm^3) and PP (0.90-0.91 g/cm^3) are less dense than seawater, which makes them float. On the other hand, polymers like PS, PVC, PES, and PA have higher densities than seawater, causing them to sink **(Daud, 2020)**.

Results from this study show that microplastics may pose a risk to seafood safety, as fish species commonly consumed in Indonesia were found to contain microplastics at variable levels. These contaminants can biomagnify within the food chain and may pose health risks to humans who depend on seafood as a significant source of protein. Upon addressing these findings, this study serves as critical evidence to address Indonesia's National Action Plan to Combat Plastic Pollution. This research provides, for the first time in this region, localized data on microplastic pollution within an aquatic environment and its uptakes in marine organisms that could support targeted interventions and policy formulation in mitigating plastic pollution, protecting marine biodiversity, and ensuring seafood safety for public consumption.

CONCLUSION

The results of this research indicate that microplastics in water samples from the Ancar River ranged from 10 ± 5.00 MP/m^3 to 30 ± 22.91 MP/m^3, while the concentrations of microplastics found in sediment samples between 13.33 ± 23.09 MP/kg to 180 ± 173.21 MP/kg. Moreover, the abundance of microplastics in the digestive tracts of fish is 0.14 ± 0.38 MP/individual in *Sardinella*, 0.22 ± 1.04 MP/individual in *Rastrelliger*, and 0.11 ± 0.33 MP/individual in *Euthynnus*. The disparity of the microplastic number can be ascribed to the following factors: hydrophobicity, river flow dynamics, types of fish, and their food habits. The most frequently reported microplastics were lines and fragments accompanied by red, blue, black, green, and transparent colors. Furthermore, Fourier Transform Infrared Spectroscopy (FTIR) analysis results proved that the samples were microplastics with various polymers, including Polypropylene (PP), Polyethylene Terephthalate (PET), Poly Methyl Methacrylate (PMMA), Polyester, High-Density Polyethylene (HDPE), and Polyethylene (PE). This study illustrates that the abundance in the Ancar River, Mataram City, is influenced by human activities, environmental conditions, and the characteristics of microplastics. The results of this study highlight the importance of plastic waste management in reducing microplastic pollution. Yet, more research is suggested to check out the things causing the spreading and characteristics of microplastics, plus the effects on ecosystems and human health. Since this study is just a survey, the study can be a convenient source for other, more in-depth research covering microplastics in water, sediment, and fish.

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