Identification of microplastic types in the Martapura River's water, sediment, and fish using FTIR (Case Study: Loktangga Village and Teluk Muara Kelayan) South Kalimantan

Nova Annisa[1,*], *Mahmud* Mahmud[1], *Anita* Fatimah[1], *Nathania* Khotidjah[1], *Rony* Riduan[1], *Rizqi Puteri* Mahyudin[1], *Indah Nirtha*[1], *Muhammad Abrar* Firdausy[1], Indro Sumantri[2], and *Hafiizh* Prasetia[3]

[1]Lambung Mangkurat University, Faculty of Engineering, Department of Environmental Engineering, 70123 Jalan A. Yani Km 37.5, Kota Banjarbaru, Kalimantan Selatan, Indonesia
[2]Diponegoro University, Faculty of Engineering, Department of Chemical Engineering, 50275 Semarang, Indonesia
[3]National Research and Innovation Agency (BRIN), Research Center for Chemistry, 15314 KST BJ. Habibie Gedung 452, Setu, Kota Tangerang Selatan, Banten, Indonesia

Abstract. Microplastics are fragments of plastic less than 5 mm in size, produced either by the breakdown of plastic waste or by using tiny pieces of plastic. The study aimed to classify the different kinds of microplastics found in the Martapura River's water, sediment, and fish. Sedgewick rafter and Fourier transform infrared spectroscopy (FTIR) were used for this study. This study's findings suggest a dissimilar distribution of microplastics between the two villages of Loktangga and Teluk Muara Kelayan. Nylon was found to be the most common type of microplastic in Lok Tangga Village. Meanwhile, polystyrene and polycarbonate were found to be the most common types of microplastics in Teluk Muara Kelayan. The dispersed nature of the microplastic pollution point to distinct regional origins or unique transport and deposition mechanisms. Knowing the specific types of microplastics found in a given area helps determine where they came from and develop effective solutions. More studies may be needed to pinpoint the precise causes and assess their effects on aquatic life and human health.

1 Introduction

The presence of microplastics in Indonesian waterways has become a significant environmental issue. The presence of minuscule plastic particles progressively permeates aquatic habitats, presenting significant hazards to the environment and human well-being. Plastic waste, encompassing plastic bags, plastic bottles, and food boxes, constitutes the predominant portion of discarded rubbish. The waste above has the ability to change in size and decomposition, resulting in the formation of microplastics. Microplastics refer to plastic particles that have a size ranging from less than 5 millimeters to 1 micrometer [1]–[4].

* Corresponding author: aiyuvasha@ulm.ac.id

Microplastics can originate from the utilization of diminutive plastic particles known as microbeads and the deterioration of macroscopic plastic materials. The utilization of microbeads in cosmetic merchandise can lead to microplastics in household refuse [5]–[7].

The river network in Indonesia, which plays a crucial role in transportation and supporting local livelihoods, has emerged as a significant area of concern due to the high prevalence of microplastic contamination [5]. Microplastics originate from various sources, including the fragmentation of larger plastic objects, discharge from industrial activities, and microbeads in personal care products. The aforementioned minuscule particles exhibit a high degree of durability and can last in the environment for extended periods, spanning several centuries. The implications of microplastic pollution have wide-ranging effects. The ingestion of microplastics can pose a threat to aquatic organisms, leading to physical harm and the disruption of ecological food webs. Moreover, it is important to note that the ingestion of microplastics by fish can result in their eventual presence in the human food chain, posing a potential risk of human exposure to hazardous compounds commonly linked with these plastic particles. Efforts to address this issue encompass heightened consciousness, more stringent legislation on the disposal of plastic trash, and the advancement of sustainable alternatives to plastic materials. It is imperative to prioritize river cleanup operations and conduct a comprehensive study on the magnitude of microplastic pollution in the rivers of Indonesia. The imperative of addressing the microplastics issue extends beyond preserving Indonesia's river health, including the well-being of its ecosystems and populace. This highlights the imperative for prompt and coordinated measures to mitigate plastic waste and safeguard the nation's irreplaceable water resources [8]–[14].

The rivers in question exhibit a high degree of plastic pollution worldwide. In research conducted in 2017, The Citarum River located in West Java, was classified as one of the rivers with the highest levels of microplastic pollution globally [15]. The worrying situation is attributed to various factors, including growing urbanization, high population density, inadequate waste disposal infrastructure, and a significant dependence on single-use plastics. Microorganisms can assimilate harmful substances, thus becoming part of the ecological food web and ultimately being ingested by humans. The concentrations of microplastics in rivers in Indonesia exhibit significant variability, with quantities ranging from several hundred to several thousand particles per cubic meter. This variability is influenced by geographical location and proximity to urban areas. The extensive microplastic pollution in rivers throughout Indonesia has catalyzed many governmental and non-governmental endeavors aimed at identifying and implementing effective resolutions. Ongoing efforts to enhance waste management systems and foster behavioral modifications are being made, yet, the scale of the issue necessitates immediate, consistent, and comprehensive solutions. The case study of Indonesia's rivers is a cautionary example highlighting the enduring consequences of plastic consumption and disposal methods on freshwater ecosystems[4], [16]–[19].

Microplastics in the Martapura River, which serves as a tributary of the Barito River, cannot be overlooked. The length of this river is estimated to be approximately 25,066 meters. The river in question extends from the Banjar Regency in the upstream direction to the Banjarmasin City in the downstream direction. The river in question holds significant significance for the Banjar community residing along its banks, exerting direct and indirect influence on their lives. The engagement of community members in various activities can significantly influence the state of the local environment, particularly in terms of the degradation of river water quality[20], [21]. According to the report published, the Nusantara River Expedition (NRE) team conducted a study in 2022 and discovered the presence of microplastic particles within the gastrointestinal tracts of fish inhabiting the Martapura River [22]. The highest concentration of microplastics in water is found in sediment [13]. The research conducted by the Nusantara River Expedition team has produced noteworthy findings about microplastics, which have the potential to impact both the ecosystem and human health. Their research findings indicate that the prevalence of microplastic pollution in the rivers of Nusantara is of significant concern, providing valuable insights into the magnitude of this environmental problem within the Indonesian archipelago. An important finding of the study was the widespread occurrence of microplastics in several manifestations, such as microbeads, microfibers, and fragments, across river ecosystems. The presence of these little plastic particles in significant quantities suggests the existence of a pronounced pollution issue. Furthermore, the study revealed that some regions, such as urban and industrial areas, had heightened concentrations of microplastic pollution, underscoring the contribution of human actions in intensifying this problem. Additionally, the findings of the Nusantara River Expedition team provided evidence of the probable ecological ramifications associated with microplastic pollution. The ingestion of these particles by aquatic species, such as fish and invertebrates, has been seen posing potential risks to both individual animals and the wider food chain[22].

The study also highlighted apprehensions regarding the capacity of microplastics to carry and discharge hazardous substances, impacting the quality of water and the health of ecosystems. The findings above highlight the pressing necessity for the implementation of productive mitigation solutions, such as the enhancement of waste management practices, the reduction of plastic consumption, and the strengthening of environmental regulations. The imperative of addressing the problem of microplastics in the rivers of Nusantara cannot be overstated, as it is essential for preserving biodiversity and the sustained welfare of the local communities that rely on these ecosystems for a multitude of resources[4], [5], [7], [15], [22], [23].

The identification process will be conducted using Fourier Transform Infrared Spectroscopy (FTIR) analysis. Microplastics as small as a few micrometers can be identified in detail using FTIR. FTIR has a shorter turnaround time for processing samples than many other techniques. Appropriate for many sample types, such as water, sediment, and biota. FTIR provides unique spectral fingerprints for various polymer types by analyzing the specific infrared absorption bands, allowing for more precise identification [7], [23], [24]. This study aims to identify the various forms of microplastics present in water, sediment, and fish samples collected from the Martapura River in South Kalimantan. The specific focus of this case study will be on the Loktangga Village and Teluk Muara Kelayan areas.

2 Materials and methods

2.1 The analysis of microplastic particles in water

The analysis of microplastic particles in water samples involves the utilization of a 100 ml portion of the sample, which is subsequently treated by the addition of 10% potassium hydroxide (KOH) and a saturated sodium chloride (NaCl) solution in a 3:1 ratio [1], [25]. A saturated solution of NaCl refers to the state in which NaCl salt crystals have been completely dissolved in distilled water, resulting in a solution that is saturated with NaCl. In order to acquire a volume of 300 ml of a saturated solution of sodium chloride, it was introduced. The mixture was allowed to stand at ambient temperature for a duration of 24 hours while being covered, with the intention of facilitating the separation of microplastic particles via flotation[1], [15].

Following a 24-hour period, the impurities will undergo sedimentation, causing 20 ml of the uppermost layer of the liquid (referred to as the supernatant) to be extracted using a pipette. This extracted volume is then transferred to a 50 ml glass beaker and subsequently subjected to homogenization. A homogeneous water sample of 1 ml was extracted using a pipette and subsequently introduced into the Sedgewick Rafter Chamber for examination under a binocular microscope with a magnification of 40x, and observations were then recorded[1], [15]. Subsequently, a volume of 19 milliliters of the sample was subjected to filtration utilizing filter paper, facilitated by a vacuum pump. The type of microplastic present in the residue on the filter paper will be determined through the utilization of Fourier Transform Infrared (FTIR) Spectroscopy[7], [17], [23].

2.2 The analysis of microplastic particles in fish sample

Each individual's length (cm), width (cm), and weight (gr) were measured for each fish sample [26]. The digestive tract is isolated and weighed. The fish is dissected beginning with cutting the anus dorsally to the lateral line. The surgery continues anteriorly to the back of the head to the bottom of the fish's stomach so that the contents of the fish's stomach are visible and the digestive tract is isolated [1], [2], [14].

The fish specimens underwent a cleaning and drying process lasting 24 hours, during which they were subjected to a temperature of 70ºC [27]. The dried fish samples were quantified and subsequently immersed in a 10% potassium hydroxide (KOH) solution until fully submerged. During the process of digestion, alkaline solutions are responsible for the degradation of organic compounds. The proportion of 10% potassium hydroxide (KOH) solution to the digestive tract of the fish is approximately 1:3, equivalent to three times the volume of the tissue. To induce density separation, a saturated solution of NaCl was introduced, resulting in the formation of two distinct layers[26], [27].

The procedure for determining microplastic content in fish samples is analogous to that employed for water and sediment samples. A volume of 20 ml of the supernatant surface solution was carefully transferred into a 50 ml glass beaker and subsequently homogenized. One milliliter of the model was transferred to the Sedgewick Rafter Chamber for examination using a binocular microscope with a magnification 40x. The observations were then recorded. Subsequently, the residual 19 ml of homogenous solution underwent filtration utilizing filter paper in conjunction with a vacuum pump. The residue in the filter paper is later analyzed using Fourier Transform Infrared Spectroscopy (FTIR) to ascertain the microplastic particles' specific nature [7], [17], [23].

2.3 The analysis of microplastic particles in sediment

The methodology employed for detecting and quantifying microplastic content in fish samples is analogous to that used for water and sediment samples. A volume of 20 ml of the supernatant surface solution was carefully transferred into a 50 ml glass beaker and subsequently homogenized. One milliliter of the model was transferred to the Sedgewick Rafter Chamber for examination using a binocular microscope set at a magnification of 40x. The observations were then recorded. Subsequently, the residual 19 ml of homogenous solution underwent filtration utilizing filter paper in conjunction with a vacuum pump. The residue in the filter paper is later analyzed using Fourier Transform Infrared Spectroscopy (FTIR) to identify the specific type of microplastic [7], [17], [23].

A sediment sample weighing 25 grams was suspended in a beaker glass using saturated NaCl solution at a ratio of 1:5, where the weight of the sediment (in grams) was divided by the volume of NaCl (in milliliters). The suspension underwent homogenization by subjecting it to agitation on a shaker for 5 minutes at a rotational speed of 180 revolutions per minute. Subsequently, sample isolation was conducted by subjecting the sample to an incubation period of 24 hours, during which two distinct layers were observed to form [17].

 https://doi.org/10.1051/e3sconf/202450301001

3 Results and discussion

The samples exhibiting the highest concentrations of microplastics (MPs) in water, sediment, and fish will undergo Fourier-transform infrared spectroscopy (FTIR) analysis. The research utilizes Fourier Transform Infrared Spectroscopy (FTIR) as an analytical technique, yielding graphical representations and a compilation of identified compounds in the tested samples. Subsequently, a comparative analysis was conducted between the graph and the range of peak points of microplastic polymers identified in the Fourier-transform infrared spectroscopy (FTIR) test to ascertain the specific type of microplastic (MP) detected [7], [17], [23].

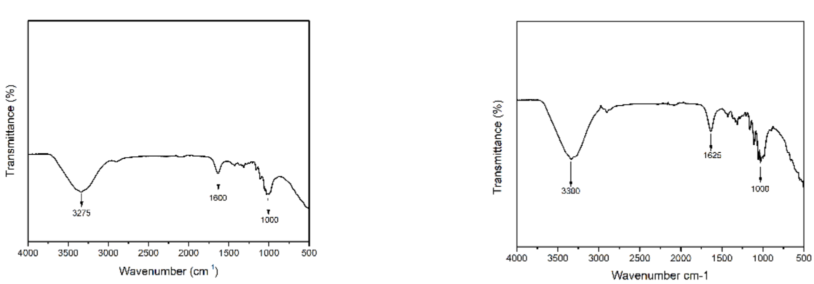
Table 1. The present study investigates the wavelengths associated with microplastic polymers identified through Fourier Transform Infrared (FTIR) analysis of the provided test samples.

No.	Polymer	Wavelengths (cm^{-1})	Information
1	*Polystyrene* (PS)	3024	C-H aromatic stretching
		2847	C-H stretching
		1601	Aromatic stretching ring
		1492	Aromatic stretching ring
		1451	CH_2 bending
		1027	CH aromatic bending
		694	CH Aromatic exhibits out-of-plane bending.
		537	Aromatic rings exhibit out-of-plane bending.
2	Nylon (All Polyamide)	3298	N-H stretching
		2932	CH stretching
		2858	CH stretching
3	*Polycarbonate* (PC)	2966	CH stretching
		1768	C=O stretching
		1503	Aromatic rings stretching
		1409	Aromatic rings stretching
		1364	CH_3 bending
		1186	C-O stretching
		1158	C-O stretching
		1013	CH aromatic in the bending plane
		828	CH Aromatic exhibit out-of-plane bending

Sources: [4], [15], [17], [25], [27], [28]

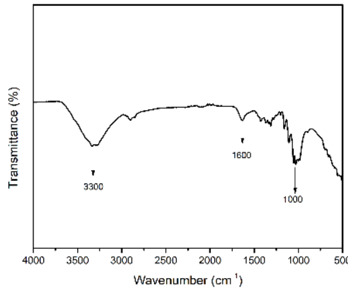
3.1 The Varieties of Microplastics in the Martapura River of Loktangga Village

The subsequent data pertains to the Fourier-transform infrared spectroscopy (FTIR) measurements conducted at designated sampling sites where the highest levels of microplastics were detected (Fig. 1).



(a) (b)

 https://doi.org/10.1051/e3sconf/202450301001



(c)

Fig. 1. The Fourier Transform Infrared (FTIR) test results about the microplastic samples collected from the Martapura River of Loktangga village, Banjar district of South Kalimantan, are as follows: (a) microplastic particles in water, (b) microplastic particles in sediment, (c) microplastic particles in fish sample.

This particular variant of Nylon is frequently observed in the Martapura River due to the prevalence of floating net cages in the Loktangga village vicinity. The degradation of nylon nets can be attributed to various environmental factors, including temperature, light intensity, and the presence of moss on the net. Additionally, the feeding behavior of fish that consume the attached phytoplankton and moss can also contribute to the decay of the net. The issue of controlling microplastic pollution upstream can also extend to the materials utilized as floating net materials. The fish species cultivated by the community residing in the vicinity of Loktangga village is known as pomfret (*Colossoma macropomum*). This fish exhibits omnivorous characteristics, consuming a wide range of food sources, including the moss that adheres to buoyant nets.

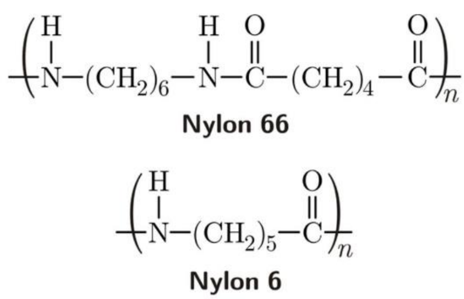


Fig. 2. Molecule of Nylon Material (source: https://europlas.com.vn/en-US/blog-1/nylon-6-definition-properties-and-common-uses)

The presence of microplastics derived from nylon materials (Fig. 2) presents a multitude of substantial risks to both the natural environment and the well-being of human populations. Nylon, a synthetic polymer, finds extensive application in textiles, fishing equipment, and other consumer goods. However, the degradation of nylon into microplastics exacerbates the global issue of microplastic pollution. To begin with, it is essential to note that nylon microplastics have a high level of persistence throughout the environment. The complete degradation of these substances can span several centuries, resulting in their accumulation within aquatic habitats and ecosystems. The buildup of these particles can have detrimental effects on marine creatures, such as fish, as they frequently consume these minuscule particles. This ingestion can result in bodily impairment, diminished reproductive capacities, and potentially fatal consequences. In addition, it has been observed that nylon microplastics can absorb hazardous substances from their immediate environment. When marine organisms digest microplastics, they have the potential to serve as vehicles for dangerous pollutants. This can result in the transfer of these poisons along the food chain, ultimately posing dangers to human health if individuals consume contaminated seafood. Furthermore, the presence of nylon microplastics has the potential to exert detrimental effects on water quality. Plastic waste harms water treatment facilities by causing clogging, escalating the expenses associated with water purification, and impeding the provision of potable water [4], [6], [13], [14], [27]–[30].

3.2 The Varieties of Microplastics in the Martapura River of Muara Kelayan

To ensure accuracy in the identification process, an FTIR test is employed to mitigate potential errors in identification[31]. The identification of different types of microplastics is discussed by Veerasingam et al.[32], who have categorized the peak point ranges of microplastic polymers using Fourier-transform infrared (FTIR) testing. The Fourier Transform Infrared (FTIR) analysis was born on the samples that exhibited the highest concentration of microplastics. The polymers that were identified in the study were polystyrene and polycarbonate. Polystyrene is commonly regarded as a polymer that exists in the form of a film, while polycarbonate is widely regarded as a polymer that exists in the form of microplastic fragments.

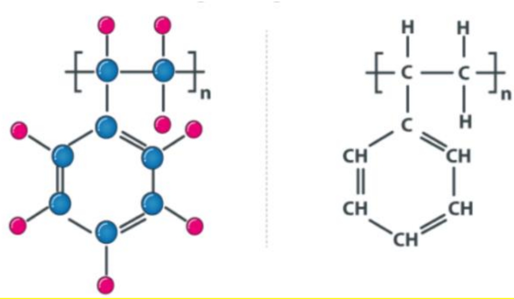
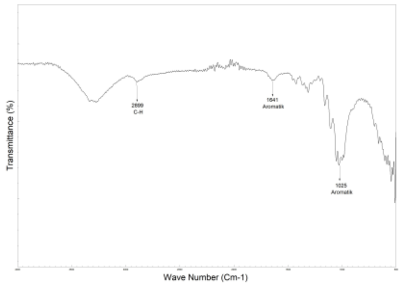
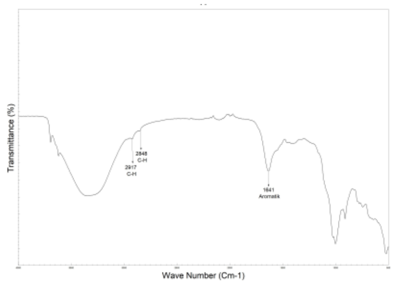


Fig. 3. Properties of Polystyrene (source: https://europlas.com.vn/en-US/blog-1/everything-you-need-to-know-about-polystyrene)

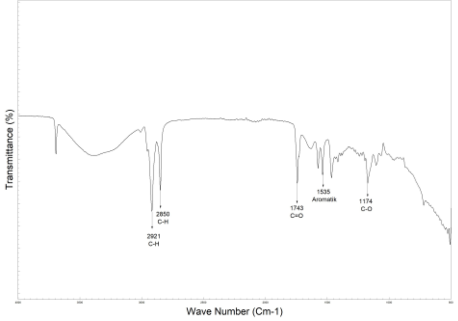
The microplastic variant detected in both water and sediment samples is polystyrene (Fig. 3), as evidenced by the presence of a distinct peak within the 2900 - 2800 wavelength range, which signifies the existence of the C-H functional group (Fig. 2). A peak is observed at a wavelength of 1600, suggesting the presence of an aromatic moiety. The groups above are responsible for forming the Polystyrene (PS) polymer. Polystyrene (PS) is a plastic polymer for food packaging and household appliances. According to the research conducted by Kooi and Koelmans [33], it has been observed that the settling rate of polystyrene particles can be enhanced by 81% when they are subjected to fouling.



(a)



(b)



(c)

Fig. 4. The Fourier Transform Infrared (FTIR) test results about the microplastic samples collected from the Martapura River of Muara Kelayan, Banjar district of South Kalimantan, are as follows:: (a) microplastic particles in water, (b) microplastic particles in sediment, (c) microplastic particles in fish sample.

The presence of microplastics originating from polystyrene poses (Fig. 5) a substantial risk to both the environment and human health. Polystyrene is a commonly utilized synthetic polymer renowned for its advantageous characteristics of being lightweight and possessing excellent insulation capabilities. It is predominantly employed in manufacturing disposable items such as foam cups, food containers, and packaging materials. The persistence of microplastics formed from polystyrene is a significant concern about environmental hazards. The degradation process of these minuscule plastic particles can span several centuries, leading to their accumulation within both terrestrial and aquatic ecosystems. This accumulation significantly threatens wildlife and marine animals, resulting in adverse effects. These microplastics have the potential to be consumed by a variety of organisms, resulting in detrimental effects such as bodily harm, compromised nutritional intake, and diminished reproductive capabilities. Polystyrene microplastics can adsorb and facilitate the transportation of harmful substances, such as persistent organic pollutants (POPs) and heavy metals. When consumed by marine organisms, these poisons have the potential to be transferred through the food chain, ultimately reaching people through the consumption of seafood, hence presenting health hazards [27], [28], [31]–[33].

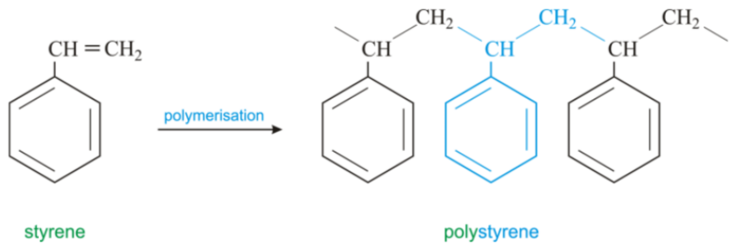


Fig. 5. Process of Polystyrene made (source: https://europlas.com.vn/en-US/blog-1/everything-you-need-to-know-about-polystyrene)

The microplastic variety detected in water and sediment samples is polystyrene, as evidenced by the presence of a peak within the 2900 - 2800 wavelength range, indicative of the C-H functional group (Fig. 4). A distinct peak is observed at a wavelength of 1600, suggesting the existence of an aromatic moiety. The groups above are the constituent groups responsible for forming the Polystyrene (PS) polymer. Polystyrene (PS) is commonly employed as a plastic polymer in food packaging and household appliances. According to the findings of Kooi and Koelmans[33], the settling rate of polystyrene particles can be enhanced by 81% when subjected to fouling. The increasing apprehension regarding the hazards linked to microplastics originating from polycarbonate is primarily driven by the extensive utilization of this artificial polymer in diverse consumer goods. Notably, polycarbonate plastics, frequently employed in manufacturing water bottles, food containers, and eyeglass lenses, are of particular concern. There are many dangers associated with microplastics derived from polycarbonate materials. Firstly, these particles can disintegrate into minuscule components that endure in the environment for prolonged durations, resulting in their accumulation within terrestrial and aquatic ecosystems. The buildup of these particles can result in the ingestion of such particles by animals and marine organisms, leading to physical injury, digestive complications, and, in certain instances, mortality. Moreover, the presence of polycarbonate microplastics has the potential to result in the release of bisphenol A (BPA), a chemical commonly employed in their manufacturing process, into the surrounding ecosystem. Bisphenol A (BPA) is recognized for its capacity to alter the endocrine system potentially, and has been linked to a range of health concerns in the human population[1], [2], [32].

4 Conclusion

Based on the findings of the research, it can be inferred that the predominant type of microplastic identified in Loktangga village (upstream) is nylon, whereas in Muara Kelayan (downstream), it is predominantly composed of polystyrene and polycarbonate. The diversity of microplastic types detected in the downstream area of Muara Kelayan surpasses that observed in the upstream region of Loktangga village. The observed phenomenon can be attributed to the increased diversity of plastic sources entering the river, which includes a collection of upstream debris. Ongoing monitoring and investigation of the origins of these microplastics can yield valuable insights for environmental conservation and the development of policies.

Acknowledgments

We express our utmost appreciation to all the teams involved in this endeavor.

References

[1] Andreas *et al.*, "Microplastic contamination in the Skipjack Tuna (Euthynnus affinis) collected from Southern Coast of Java, Indonesia," *Chemosphere*, vol. 276, 2021, doi: 10.1016/j.chemosphere.2021.130185.

[2] M. Smith, D. C. Love, C. M. Rochman, and R. A. Neff, "Microplastics in Seafood and the Implications for Human Health," *Curr. Environ. Heal. reports*, vol. 5, no. 3, pp. 375–386, 2018, doi: 10.1007/s40572-018-0206-z.

[3] M. Revel, A. Châtel, and C. Mouneyrac, "Micro(nano)plastics: a threat to human health?," *Curr. Opin. Environ. Sci. Heal.*, vol. 1, pp. 17–23, 2018, doi: https://doi.org/10.1016/j.coesh. 2017.10.003.

[4] M. R. Cordova, A. I. S. Purwiyanto, and Y. Suteja, "Abundance and characteristics of microplastics in the northern coastal waters of Surabaya, Indonesia," *Mar. Pollut. Bull.*, vol. 142, no. October 2018, pp. 183–188, 2019, doi: 10.1016/j.marpolbul.2019.03.040.

[5] N. P. Purba *et al.*, "Marine debris in Indonesia: A review of research and status," *Mar. Pollut. Bull.*, vol. 146, no. March, pp. 134–144, 2019, doi: 10.1016/j.marpolbul.2019.05.057.

[6] A. A. Horton, A. Walton, D. J. Spurgeon, E. Lahive, and C. Svendsen, "Microplastics in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities.," *Sci. Total Env.*, vol. 586, pp. 127–141, 2017, doi: https://doi.org/10.1016/j.scitotenv.2017.01.190.

[7] A. D. Syakti *et al.*, "Simultaneous grading of microplastic size sampling in the Small Islands of Bintan water, Indonesia," *Mar. Pollut. Bull.*, vol. 137, no. October, pp. 593–600, 2018, doi: 10.1016/j.marpolbul.2018.11.005.

[8] R. C. Thompson, C. J. Moore, F. S. V. Saal, and S. H. Swan, "Plastics, the environment and human health: current consensus and future trends.," *Philos. Trans. R. Soc. B Biol. Sci*, vol. 364, no. 1526, pp. 2153–2166, 2009, doi: https://doi.org/10.1098/rstb.2009.0053.

[9] B. Jovanović, "Ingestion of microplastics by fish and its potential consequences from a physical perspective," *Integr. Environ. Assess. Manag.*, vol. 13, no. 3, pp. 510–515, 2017, doi: 10.1002/ieam.1913.

[10] W. C. Li, *The Occurrence, Fate, and Effects of Microplastics in the Marine Environment*. Elsevier Inc., 2018. doi: 10.1016/b978-0-12-813747-5.00005-9.

[11] C. M. Rochman *et al.*, "Anthropogenic debris in seafood: plastic debris and fibers from textiles in fish and bivalves sold for human consumption.," *Sci. Rep.*, vol. 5, p. 14340, 2015, doi: https://doi.org/10.1038/srep14340.

[12] P. G. Ryan, "A simple technique for counting marine debris at sea reveals steep litter gradients between the Strait of Malacca and Bay of Bengal," *Mar. Pollut. Bull*, vol. 69, pp. 128–136, 2013.

[13] D. Peixoto, C. Pinheiro, J. Amorim, L. Oliva-Teles, L. Guilhermino, and M. N. Vieira, "Microplastic pollution in commercial salt for human consumption: A review," *Estuar. Coast. Shelf Sci.*, vol. 219, no. February, pp. 161–168, 2019, doi: 10.1016/j.ecss.2019.02.018.

[14] S. Abbasi, N. Soltani, B. Keshavarzi, F. Moore, A. Turner, and M. Hassanaghaei, "Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf," *Chemosphere*, vol. 205, pp. 80–87, 2018, doi:

10.1016/j.chemosphere.2018.04.076.
[15] M. R. Cordova, I. S. Nurhati, A. Shiomoto, K. Hatanaka, R. Saville, and E. Riani, "Spatiotemporal macro debris and microplastic variations linked to domestic waste and textile industry in the supercritical Citarum River, Indonesia," *Mar. Pollut. Bull.*, vol. 175, p. 113338, 2022, doi: https://doi.org/10.1016/j.marpolbul.2022.113338.
[16] P. Sathishkumar, R. A. A. Meena, T. Palanisami, V. Ashokkumar, T. Palvannan, and F. L. Gu, "Occurrence, interactive effects and ecological risk of diclofenac in environmental compartments and biota - a review," *Sci. Total Environ.*, vol. 698, p. 134057, 2020, doi: 10.1016/j.scitotenv.2019.134057.
[17] J. Li, C. Green, A. Reynolds, H. Shi, and J. M. Rotchell, "Microplastics in mussels sampled from coastal waters and supermarkets in the United Kingdom," *Environ. Pollut.*, vol. 241, pp. 35–44, 2018, doi: 10.1016/j.envpol.2018.05.038.
[18] S. M. Harmon, *The Effects of Microplastic Pollution on Aquatic Organisms*. Elsevier Inc., 2018. doi: 10.1016/b978-0-12-813747-5.00008-4.
[19] J. Li *et al.*, "Using mussel as a global bioindicator of coastal microplastic pollution," *Environ. Pollut.*, pp. 522–533, 2019, doi: 10.1016/j.envpol.2018.10.032.
[20] Badan Pusat Statistik, *Banjarmasin dalam angka 2023*. Banjarmasin: BPS Provinsi Kalimantan Selatan, 2023.
[21] E. R. Normasari, *Model Pengendalian Pencemaran Sungai Martapura di Kota Banjarmasin*. Surakarta: UNS-Pascasarjana Prog. Studi Doktor Ilmu Lingkungan, 2016.
[22] Rafika Aprilianti, *Rekam Jejak Mikroplastik*. Gresik, Jawa Timur: Yayasan Kajian Ekologi dan Konservasi Lahan Basah, 2023.
[23] A. D. Syakti *et al.*, "Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia," *Mar. Pollut. Bull.*, vol. 122, no. 1–2, pp. 217–225, 2017, doi: 10.1016/j.marpolbul.2017.06.046.
[24] V. Hidalgo-Ruz, L. Gutow, R. C. Thompson, and M. Thiel, "Microplastics in the marine environment: a review of the methods used for identification and quantification.," *Environ. Sci. Technol.*, vol. 46, pp. 3060–3075, 2012.
[25] A. Deriano, E. Nurdin, and M. P. Patria, "Analisis Kelimpahan Mikroplastik pada Ikan Sapu-Sapu Pterygoplichthys Pardalis (Castelnau, 1855), Air, dan Sedimen di Dua Daerah Ciliwung, Jakarta Selatan," *J. Kelaut. dan Perikan. Terap.*, vol. 4, no. 2, p. 95, 2022, doi: 10.15578/jkpt.v4i2.10563.
[26] S. J. B. Lumban Tobing, I. G. Hendrawan, and E. Faiqoh, "Karakteristik Mikroplastik Pada Ikan Laut Konsumsi Yang Didaratkan Di Bali," *J. Mar. Res. Technol.*, vol. 3, no. 2, p. 102, 2020, doi: 10.24843/jmrt.2020.v03.i02.p07.
[27] C. Wu, K. Zhang, and X. Xiong, "Microplastic Pollution in Inland Waters Focusing on Asia," p. 302, 2018, doi: 10.1007/978-3-319-61615-5.
[28] M. R. Jung *et al.*, "Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms," *Mar. Pollut. Bull.*, vol. 127, no. January 2018, pp. 704–716, 2018, doi: 10.1016/j.marpolbul.2017.12.061.
[29] C. M. Rochman, R. L. Lewison, M. Eriksen, H. Allen, A. M. Cook, and S. J. Teh, "Polybrominated diphenyl ethers (PBDEs) in fish tissue may be an indicator of plastic contamination in marine habitats," *Sci. Total Environ.*, vol. 476–477, pp. 622–633, 2014, doi: 10.1016/j.scitotenv.2014.01.058.
[30] J. Li, D. Yang, L. Li, K. Jabeen, and H. Shi, "Microplastics in commercial bivalves from China," *Environ. Pollut*, vol. 207, pp. 190–195, 2015.
[31] O. Konechnaya, S. Lüchtrath, L. Dsikowitzky, and J. Schwarzbauer, "Optimized microplastic analysis based on size fractionation, density separation and μ-FTIR," *Water Sci. Technol.*, vol. 81, no. 4, pp. 834–844, 2020, doi: 10.2166/wst.2020.173.
[32] S. Veerasingam *et al.*, "Microplastics in different environmental compartments in

India: Analytical methods, distribution, associated contaminants and research needs," *TrAC - Trends Anal. Chem.*, vol. 133, p. 116071, 2020, doi: 10.1016/j.trac.2020.116071.

[33] M. Kooi, S. Primpke, S. M. Mintenig, C. Lorenz, G. Gerdts, and A. A. Koelmans, "Characterizing the multidimensionality of microplastics across environmental compartments," *Water Res.*, vol. 202, no. April, p. 117429, 2021, doi: 10.1016/j.watres.2021.117429.