Journal of Engineering and Technological Sciences

Research Paper

# Assessment of Small-Scale Microplastics Abundance and Characterization in Urban River: A Case Study in Metro River, Indonesia

**Riyanto Haribowo, Prasetyo Rubiantoro, Arriel Fadhilah*, Zefanya Alovy P. Denindya, Yunike Ayu Kristanti, Wahyu Rismiati & Muhammad Aulia Arsal**

Department of Water Resources Engineering, Faculty of Engineering, Universitas Brawijaya, Jalan MT. Haryono 167, Malang 65145, Indonesia

Corresponding author: fadhilah.arriel@gmail.com

**Abstract**

Microplastic pollution is a pressing environmental concern with detrimental effects on aquatic ecosystems and human health. This study aimed to investigate microplastic contamination in a rapidly urbanizing area along a river and to examine the spatial distribution of microplastic abundance across the study area based on land use type. Seven sampling points were selected along the study site and microplastic samples were extracted using density separation and wet peroxidation (WPO) methods. The characteristics of the microplastic particles, including size, color, shape, and abundance, were analyzed to understand their properties. The results indicated that the microplastic abundance values ranged from 28.33 to 133.00 particles/liter, with an average of 73.55 particles/liter. Small microplastic particles (SMP), with sizes ranging from 1 µm to 1 mm, along with fragment shapes, and clear colors were predominant in the study area. A generalized additive model was utilized to assess the relationship between land use and microplastic abundance. The model demonstrated a significant influence of built-up areas on the presence of microplastics ($p$-value $< 0.05$), with an $r^2$ value of 0.76. Residential areas near the river were identified as the likely primary sources of the microplastics.

**Keywords:** *abundance; characteristic; freshwater; land use; microplastic.*

## Introduction

The usage of plastics in daily life is inevitable. Their production and consumption have increased over the years. Their lightness, affordability, and multifunctionality make plastics a commonly used material for various human needs [1]. Geyer et al. [2] discovered that from 1950 to 2015, an estimated 60% of the cumulative plastic production was not appropriately managed. This may cause water pollution and potentially harms the environment [3,4].

Microplastics are small plastic pollutants with a size of 1 µm to 5 mm [5]. Their small size and light weight likely cause their spread in aquatic environments, eventually becoming a threat to biota through the food web. Several studies have discovered the presence of microplastics in the bodies of aquatic microorganisms [6-8], fish [9-12], coral reefs [13,14], and birds [15,16]. Furthermore, microplastics are also discovered in the human body, for example in the lungs [17-19] and feces [20]. Microplastics can be toxic because they can carry dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene, and other toxic materials [21]. However, the long-term effects of microplastics on human health remain uncertain [22].

Microplastics are grouped into primary and secondary size microplastics [5]. Primary microplastics are plastic products that are produced in small sizes, while secondary microplastics originate from large plastic products degraded into microplastic sizes. Most microplastics originate from land runoff and eventually end up in the ocean through rivers [23-25]. Microplastic research in freshwater has mainly focused on abundance and distribution. Several studies indicated that land use highly influences the occurrence of microplastic pollution


ISSN: 2337-5779
J. Eng. Technol. Sci. Vol. 55, No. 2, 2023, 167-176
DOI: 10.5614/j.eng.technol.sci.2023.55.2.6

[7,26], while other studies discovered that weather [28] and wastewater treatment plants [29] significantly influence the occurrence of microplastic pollution.

Indonesia, a typical rapidly developing country, has a large population and is one of the world's largest marine plastic contributors [30]. To date, microplastic evidence has been found in major rivers, such as the Citarum River [31], Surabaya River [32], Metro River [33], Brantas River [34], and Cisadane River [35]. However, most studies only focused on microplastic distribution and characteristics in large-scale watersheds without quantitatively assessing the relation with land use [32,34,35]. Therefore, information on the relation between microplastic and various human activities and freshwater pollution sources is still limited, which makes it difficult to determine proper control and prevention measures regarding microplastic issues [36].

Previous research has discovered that litter-related microplastics types (i.e., fragments, foam, and film) originate from developed and populous areas [26], while fiber-type microplastics originate from textile industrial activity [37]. According to these findings, human activities in the surroundings are likely to influence the type of microplastics present in freshwater. Understanding the relation of microplastics with land use in the surroundings is essential for future related policy formulation and microplastic pollution estimation.

This study assessed small-scale freshwater to clearly understand microplastic characteristics and distribution in relation to land use. The objectives were: (1) to evaluate the distribution and characteristics of freshwater microplastics, and (2) to assess the influence of land use within the catchment area on microplastic pollution. This is the first assessment of the relation between microplastics in small-scale freshwater and land use in the Metro River, Indonesia.

## Methods

### Study Area and Sample Collection

To ensure that the study area included a developing built-up area, we selected the Metro River as the study area. This river is a tributary of the Brantas River and runs through the densely populated urban center of Malang City in East Java, Indonesia. It is 18.2 km in length and has a catchment area of 32 km$^2$. The area has a typical tropical climate and experiences a monsoonal season, with the rainy season typically running from October to March, while the dry season lasts from April to September.

The region receives an average annual precipitation of 2,448 mm [38]. Seven observation points in the upstream, midstream, and downstream with different land use characteristics were selected (Figure 1), which meets the requirement of the sampling location having to be distributed with different land use types. The upstream areas (MT1 and MT2) were less built-up areas dominated by forest and agricultural land uses. The midstream areas (MT3, MT4, and MT 5) were dense built-up areas dominated by residential and commercial areas without agricultural activities. The downstream areas (MT6 and MT7) were dense built-up areas dominated by residential, commercial, and agricultural activities.

Freshwater samples were collected in January 2022 to represent the rainy season in the study area. Rainfall possibly increases the microplastic transport from the surrounding area to the river. The river sampling site was grab sampled [25,39] for two repetitions from the river surface using a three-liter glass horizontal water sampler. The freshwater sample was then wet-sieved to discard the >5 mm fraction. Quality assurance was conducted beforehand by cleansing all the collected samples three times using distilled water.

### Laboratory Analyses

In brief, the separation of microplastics from the water sample was performed by wet peroxidation (WPO) and density separation [40]. WPO was performed using a hot plate stirrer (SP88857105, Thermo Scientific, USA) at 70° C and adding 20 mL of 0.05 mol/liter ferrous sulfate ($FeSO_4.7H_2O$) and 20 mL of 30% hydrogen peroxide ($H_2O_2$) to eliminate organic particles. Next, density separation was performed on the samples to obtain microplastic particles. At this stage, the microplastic samples were filtered with a Whatman filter paper number 5 (diameter 125 mm, pore size 2.5 µm, Whatman, USA) and then stored in a desiccator for identification.

DOI: 10.5614/j.eng.technol.sci.2023.55.2.6

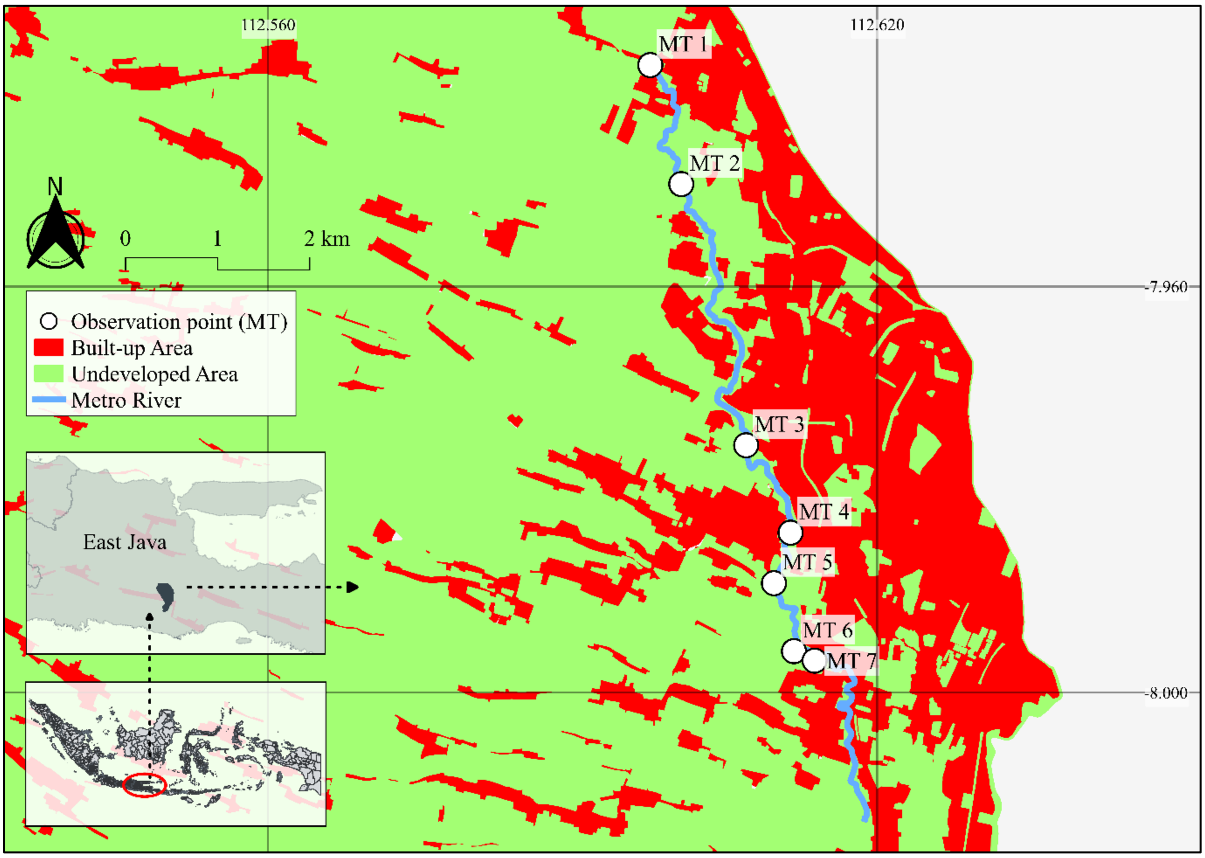



**Figure 1** Observation points in the study area, Metro watershed, Malang, East Java, Indonesia.

## Characteristics and Abundance of Microplastics

Microplastic visual observation was performed using a binocular microscope (CX23LEDRFS1, Olympus, Japan). We utilized an OptiLab device (OptiLab Viewer, Miconos, Indonesia) to capture images and observe the microplastics using the Image Raster software (Image Raster, Miconos, Indonesia). Visual observation was conducted to classify the microplastics based on color, size, and shape. Size was categorized into small microplastic particles (SMP) (1 µm to 1 mm) and large microplastic particles (LMP) (1 mm to 5 mm) [41,42], while shape was categorized into fragments, film, foam, fibers, and pellets [43,44]. The abundance of microplastics was calculated using Eq. (1), dividing the counted microplastic particles by the water sample volume in the units of particles/liter.

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

where *n* is the microplastic (particles) count, *V* is the volume of the water sample (liter), and *N* is the microplastic abundance (particles/liter).

## Statistical Analysis

Statistical analysis was conducted using the RStudio software to comprehend the data. The non-parametric Kruskal Wallis test with a probability value of 0.05 was used to compare the obtained microplastic abundance among locations. The Generalized Additive Model (GAM) [45] method was used to understand the influence of land use on the microplastic abundance distribution along the river based on a model. We used built-up area as land use category, summing residential and commercial areas for the GAM predictor variable. The land use data were obtained from the database of the Indonesian Geospatial Information Agency. Each land use was sorted into a separate group according to the catchment area obtained by delineating with the QGIS 3.16.16 software.

## Results and Discussion

### Microplastic Abundance

Microplastic contamination was discovered along all of the observation points. Microplastic abundance in the study area was relatively high compared to several other locations (Table 1), such as the Brantas River [34] and the Ciwelengke River [46] but lower than the Majime River in Japan [25], the Yellow River in China [47], and the Saigon River in Vietnam [37].

**Table 1** Microplastic abundance in various freshwater worldwide.

| Study area | Abundance (particle/liter) | References |
|---|---|---|
| Metro River, Indonesia | 28.33 - 133.00 | This Study |
| Awano River, Japan | 102.00 - 146.00 | [25] |
| Ayaragi River, Japan | 86.00 - 148.00 | [25] |
| Asa River, Japan | 87.00 - 172.00 | [25] |
| Majime River, Japan | 99.00 - 1,061.00 | [25] |
| Chin-Ling Wei River, China | 2.30 - 21.05 | [24] |
| Yellow River, China | 350.00 - 1,392.00 | [47] |
| West River, China | 2.99 - 9.87 | [48] |
| Saigon River, Vietnam | 172.00 - 519.00 | [37] |
| Ciwalengke River, Indonesia | 2.57 - 9.13 | [46] |
| Brantas River, Indonesia | 0.13 - 5.47 | [34] |
| Citarum River, Indonesia (2018) | 0.00 - 350.00 | [31] |
| Citarum River, Indonesia (2020) | 0.00 - 550.00 | [31] |
| Gallatin River, USA | 0.00 - 67.50 | [39] |

The average value of the microplastic abundance in the study area was 73.55 particles/liter. The highest abundance value was found midstream (MT 5) with 133.00 particles/liter, while the lowest value was found upstream (MT 2) with 28.33 particles/liter (Figure 2). The Kruskal Wallis test results showed a significant difference between the microplastic abundance upstream, midstream, and downstream of the study area (p-value = 0.0761). This indicates that the microplastic abundance at each site was affected by the level of pollution and the source of pollution. This may be influenced by the percentage of built-up land near the observation point, making it a potential microplastic pollutant hotspot

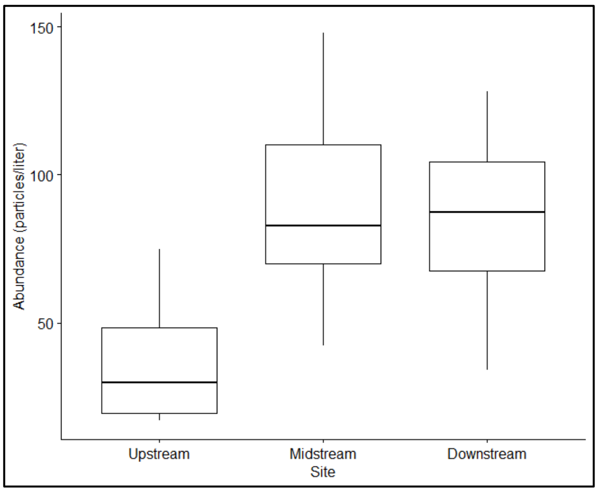



**Figure 2** Microplastic abundance in the upstream (MT 1 and MT 2), midstream (MT 3, MT 4, and MT 5), and downstream (MT 6 and MT 7) of the study area.

DOI: 10.5614/j.eng.technol.sci.2023.55.2.6

## Microplastic Characteristics

SMP is known to dominate all the study areas (>80% of the total microplastics per location) (Figure 3), while the highest value was found at MT 5 (121.83 particles/liter) and the lowest value at MT 2 (27.00 particles/liter). Meanwhile, the highest LMP value was found at MT 3 (11.67 particles/liter), and the lowest LMP value at MT 2 (1.33 particles/liter). The mean values of SMP and LMP were 66.29 particles/liter and 7.00 particles/liter, respectively. It is interesting to compare this result with previous research on the Surabaya River [49], a river with a characteristic and tributary similar to the Brantas River, as the study showed dominance of LMP. The gap in the result is most probably caused by the different sampling methods used in the study. The mesh size (> 0.3 mm) used in the other study is unable to capture smaller microplastic particles, resulting in a result gap between the studies. The discovery of SMP dominance in this study is relevant to other studies with a grab sampling approach, such as the Yellow River [47] and the Majime River [25].

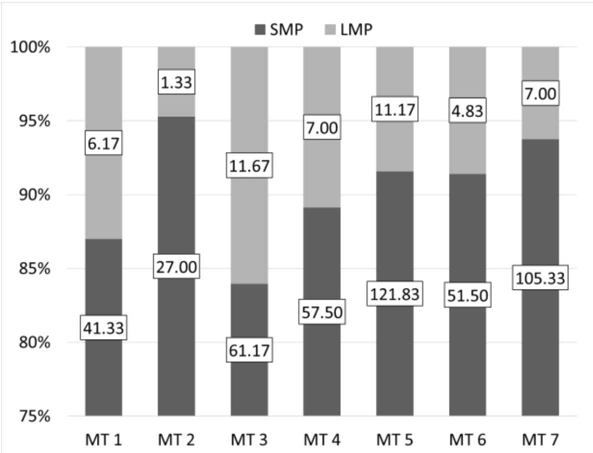
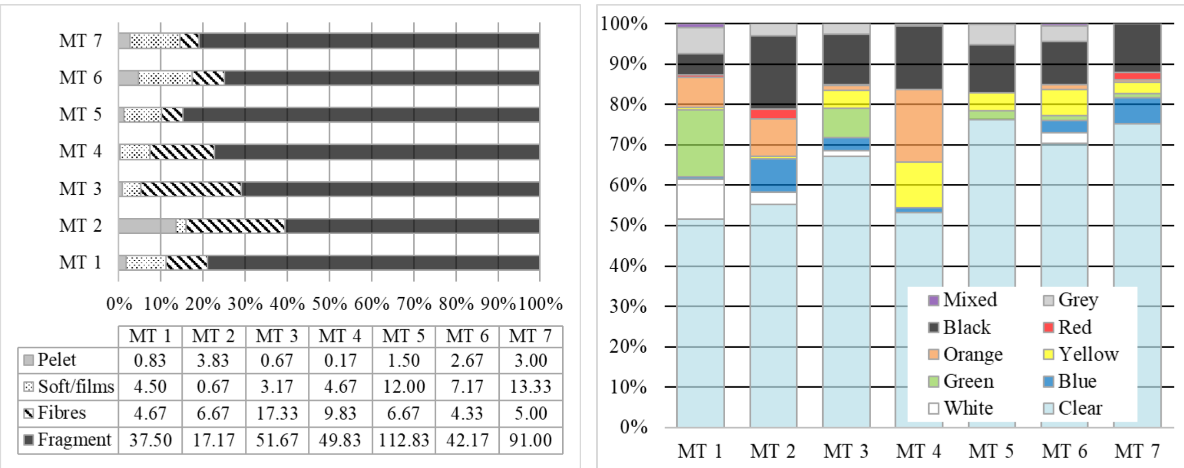



**Figure 3** Comparison of the abundance of small microplastic particles (SMP) (1 µm to 1 mm) and large microplastic particles (LMP) (1-5 mm) in the study area.

Pellets, soft/film, fibers, and fragments were found in the study area, with fragments as the typical microplastic shape in all sampling locations (78.12% of the total microplastics). Fibers (10.59%), soft/film (8.84%), and pellets (2.46%) respectively dominated the shape of the microplastics in the study area (Figure 4(a)). The dominance of fragments and soft/film indicates the high potential for anthropogenic influence in the study area, considering that fragments and soft/film are highly related to litter activities [26]. The abundance of fibers may be caused by contamination from the study area and the laboratory [50,51]. Primary microplastics from dairy products such as hygiene products, cosmetics, and textiles influence the abundance of pellets [52].




| | MT 1 | MT 2 | MT 3 | MT 4 | MT 5 | MT 6 | MT 7 |
|---|---|---|---|---|---|---|---|
| Pelet | 0.83 | 3.83 | 0.67 | 0.17 | 1.50 | 2.67 | 3.00 |
| Soft/films | 4.50 | 0.67 | 3.17 | 4.67 | 12.00 | 7.17 | 13.33 |
| Fibres | 4.67 | 6.67 | 17.33 | 9.83 | 6.67 | 4.33 | 5.00 |
| Fragment | 37.50 | 17.17 | 51.67 | 49.83 | 112.83 | 42.17 | 91.00 |

(a) (b)

**Figure 4** Microplastic characterization in the study area based on (a) shape and (b) color.

Color observations indicated that clear particles dominated the microplastic pollution (67.76%). Several other colors were also found at the sampling location, but they were not as numerous as microplastics with a clear color. Consecutively, the dominant colors found in the study area after clear were black (12.11%), yellow (4.63%), orange (3.92%), green (3.40%), blue (2.91%), gray (2.88%), white (1.59 %), red (0.58%), and mixed (0.23%) (Figure 4 (b)).

## Microplastic Relation with Land Use

We quantitatively analyzed the relationship between microplastic abundance and land use using GAM (Figure 5). The percentage of built-up area in the surrounding area of the sample sites is referred to as Absis X, while the impact of the built-up area on the amount of microplastics present is represented by the Y-axis. The model indicated that the built-up area significantly influences the microplastic abundance ($p$-value < 0.05) with an $r^2$ value of 0.76.

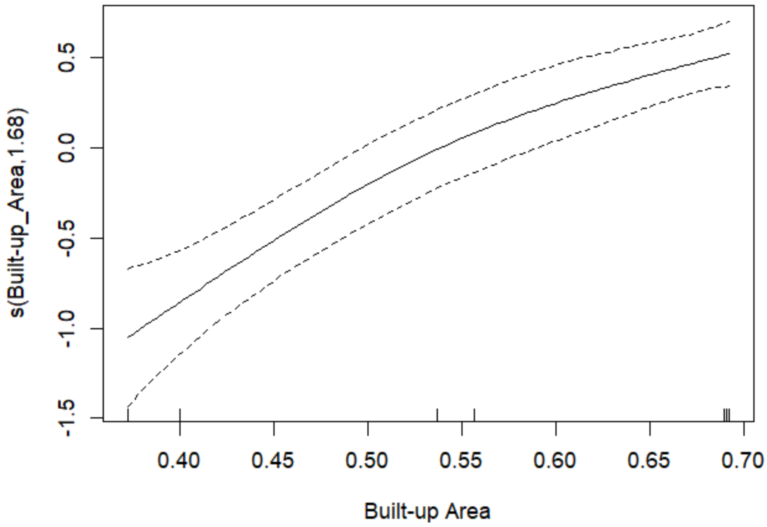



**Figure 5** GAM model between microplastic abundance and built-up area ($r^2$ = 0.76, p-value < 0.05).

According to our model, increasing the built-up area increases the microplastic abundance in the area. This discovery has implications for the study conducted in New Zealand [53], which found a correlation between residential areas and increased levels of microplastic concentration. Other studies, in Malaysia [54] and Bangkok [55], also indicated that high microplastic abundance originates from anthropogenic activities. Furthermore, the present study found that if the proportion of built-up area within the catchment area of the sampling point exceeded 68%, the concentration of microplastics was above the average level. The potential sources of microplastic pollution in the study area were linked to casual residential activities such as the illegal dumping of waste into the stream, which can potentially become litter-related microplastic point source pollution.

# Conclusion

The focus of this study was to evaluate the distribution and characteristics of microplastics in surface water across a densely populated built-up area of an urban river. In comparison to previous research, this study discovered a comparatively greater amount of microplastic abundance, with small microplastic particles (SMP) being the dominant type (>80% of total microplastics per location). Fragment-shaped microplastics (78.12% of total microplastics), and clear-colored microplastics (67.76% of total microplastics) were ubiquitous along the river. According to the GAM analysis, the presence of microplastics in the region is significantly influenced by the expansion of the built-up area ($p$-value < 0.05) with an $r^2$ value of 0.76. The microplastics found in the river area were likely the result of anthropogenic activities associated with residential areas in the vicinity. However, further investigation is necessary to determine the source of microplastic pollution in the river.

DOI: 10.5614/j.eng.technol.sci.2023.55.2.6

## Acknowledgement

We would like to express our gratitude to Argo Nugroho Prasetyo, Muchammad Ja'far Shiddik, Yurifa Auliyah Az Zahra, and Veisa Nathania (undergraduate students of the Water Resources Engineering Department, Faculty of Engineering, Universitas Brawijaya) for their exceptional help in conducting this study. We could not have achieved our research objectives without their dedication and hard work. We are also thankful to the Soil and Groundwater Laboratory, Water Resources Engineering Department, Faculty of Engineering, Universitas Brawijaya, for their essential support and provision of necessary facilities throughout the study. Their expertise and guidance were pivotal in ensuring the success of our research project.

## References

[1] MacArthur, E., *Beyond Plastic Waste*, Science, **358** (6365), pp. 843-843, Nov. 2017. doi: 10.1126/science.aao6749.

[2] Geyer, R., Jambeck, J.R. & Law, K.L., *Production, Use, and Fate of All Plastics Ever Made*, Sci. Adv., **3** (7), pp. 3-8, Jul. 2017. doi: 10.1126/sciadv.1700782.

[3] van Emmerik, T., Kieu-Le, T.-C., Loozen, M., van Oeveren, K., Strady, E., Bui, X.-T., Egger, M., Gasperi, J., Lebreton, L., Nguyen, P.-D., Schwarz, A., Slat, B. & Tassin, B., *A Methodology to Characterize Riverine Macroplastic Emission into the Ocean*, Front. Mar. Sci., **5** (372), pp. 1-11, Oct. 2018. doi: 10.3389/fmars.2018.00372.

[4] Lebreton, L.C.M., van der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A. & Reisser, J., *River Plastic Emissions to the World's Oceans*, Nat. Commun., **8** (1) pp. 1–10, 2017. doi: 10.1038/ncomms15611.

[5] Arthur, C., Baker, J. & Bamford, H.E., *Proceedings of the International Research Workshop on the Occurrence , Effects , and Fate of Microplastic Marine Debris*, Proceedings of the International Research Workshop, s.l., NOAA Technical Memorandum NOS-OR&R-30, 530, 2009.

[6] Botterell, Z.L.R., Bergmann, M., Hildebrandt, N., Krumpen, T., Steinke, M., Thompson, R.C. & Lindeque, P. K., *Microplastic Ingestion in Zooplankton from the Fram Strait in the Arctic*, Sci. Total Environ., **831** (154886), 154886, Jul. 2022. doi: 10.1016/j.scitotenv.2022.154886.

[7] Fueser, H., Mueller, M.-T. & Traunspurger, W., *Ingestion of Microplastics by Meiobenthic Communities in Small-scale Microcosm Experiments*, Sci. Total Environ., **746**, 141276, Dec. 2020. doi: 10.1016/j.scitotenv.2020.141276.

[8] Aytan, U., Esensoy, F.B. & Senturk, Y., *Microplastic Ingestion and Egestion by Copepods in the Black Sea*, Sci. Total Environ., **806** (150921), 150921, Feb. 2022. doi: 10.1016/j.scitotenv.2021.150921.

[9] Sainio, E., Lehtiniemi, M. & Setälä, O., *Microplastic Ingestion by Small Coastal Fish in the Northern Baltic Sea, Finland*, Mar. Pollut. Bull., **172**, 112814, Nov. 2021. doi: 10.1016/j.marpolbul.2021.112814.

[10] Tongo, I. & Erhunmwunse, N.O., *Effects of Ingestion of Polyethylene Microplastics on Survival Rate, Opercular Respiration Rate and Swimming Performance of African Catfish (Clarias gariepinus),* J. Hazard. Mater., **423**, 127237, 2022. doi: 10.1016/j.jhazmat.2021.127237.

[11] Uurasjärvi, E., Sainio, E., Setälä, O., Lehtiniemi, M. & Koistinen, A., *Validation of an Imaging FTIR Spectroscopic Method for Analyzing Microplastics Ingestion by Finnish lake fish (Perca fluviatilis and Coregonus albula),* Environ. Pollut., **288**, 117780, Nov. 2021. doi: 10.1016/j.envpol.2021.117780.

[12] Aiguo, Z., Di, S., Chong, W., Yuliang, C., Shaolin, X., Peiqin, L., Guohuan, X., Huijuan, T. & Jixing, Z., *Characteristics and Differences of Microplastics Ingestion for Farmed Fish with Different Water Depths, Feeding Habits and Diets*, J. Environ. Chem. Eng., **10** (2), 107189, 2022. doi: 10.1016/j.jece.2022.107189.

[13] Hankins, C., Raimondo, S. & Lasseigne, D., *Microplastic Ingestion by Coral as a Function of the Interaction between Calyx and Microplastic Size*, Sci. Total Environ., **810**, 152333, 2022. doi: 10.1016/j.scitotenv.2021.152333.

[14] Hankins, C., Duffy, A. & Drisco, K., *Scleractinian Coral Microplastic Ingestion: Potential Calcification Effects, Size Limits, and Retention*, Mar. Pollut. Bull., **135**, pp. 587-593, Oct. 2018. doi: 10.1016/j.marpolbul.2018.07.067.

[15] Caldwell, A., Brander, S., Wiedenmann, J., Clucas, G. & Craig, E., *Incidence of Microplastic Fiber Ingestion by Common Terns (Sterna hirundo) and Roseate Terns (S. dougallii) Breeding in the Northwestern Atlantic*, Mar. Pollut. Bull., **177**, 113560, November 2022. doi: 10.1016/j.marpolbul.2022.113560.

[16] de Souza, S.S., Freitas, Í.N., Gonçalves, S.D.O., Luz, T.M. da, Araújo, A.P. da C., Rajagopal, R., Balasubramani, G., Rahman, M.M. & Malafaia, G., *Toxicity Induced via Ingestion of Naturally-aged Polystyrene Microplastics by a Small-sized Terrestrial Bird and Its Potential Role as Vectors for the Dispersion of These Pollutants*, J. Hazard. Mater., **434**, 128814, Jul. 2022. doi: 10.1016/j.jhazmat.2022.128814.

[17] Amato-Lourenço, L.F., Carvalho-Oliveira, R., Júnior, G.R., dos Santos Galvão, L., Ando, R.A. & Mauad, T., *Presence of Airborne Microplastics in Human Lung Tissue*, J. Hazard. Mater., **416**, 126124, Aug. 2021, doi: 10.1016/j.jhazmat.2021.126124.

[18] Jenner, L.C., Rotchell, J.M., Bennett, R.T., Cowen, M., Tentzeris, V. & Sadofsky, L.R., *Detection of Microplastics in Human Lung Tissue using μFTIR Spectroscopy*, Sci. Total Environ., **831**, 154907, Jul. 2022. doi: 10.1016/J.SCITOTENV.2022.154907.

[19] Leslie, H.A., van Velzen, J.M., Brandsma, S.H., Vethaak, D.A., Garcia-Vallejo, J.J. & Lamoree, M.H., *Discovery and Quantification of Plastic Particle Pollution in Human Blood*, Environ. Int., **163**, 107199, 2022. doi: 10.1016/j.envint.2022.107199.

[20] Zhang, N., Li, Y. Bin, He, H.R., Zhang, J.F. & Ma, G.S., *You are What You Eat: Microplastics in the Feces of Young Men Living in Beijing*, Sci. Total Environ., **767**, 144345, May 2021. doi: 10.1016/j.scitotenv.2020.144345.

[21] Laskar, N. & Kumar, U., *Plastics and Microplastics: A Threat to Environment*, Environ. Technol. Innov., **14**, 100352, 2019. doi: 10.1016/j.eti.2019.100352.

[22] Leslie, H.A. & Depledge, M.H., *Where is the Evidence that Human Exposure to Microplastics is Safe?,* Environ. Int., **142**, 105807, Sep. 2020. doi: 10.1016/j.envint.2020.105807.

[23] Siegfried, M., Koelmans, A.A., Besseling, E. & Kroeze, C., *Export of Microplastics from Land to Sea. A Modelling Approach*, Water Res., **127**, pp. 249-257, 2017. doi: 10.1016/j.watres.2017.10.011.

[24] Bian, P., Liu, Y., Zhao, K., Hu, Y., Zhang, J., Kang, L. & Shen, W., *Spatial Variability of Microplastic Pollution on Surface of Rivers in a Mountain-plain Transitional Area: A Case Study in the Chin Ling-Wei River Plain, China*, Ecotoxicol. Environ. Saf., **232**, 113298, Mar. 2022. doi: 10.1016/j.ecoenv.2022.113298.

[25] Kabir, A.H.M.E., Sekine, M., Imai, T., Yamamoto, K., Kanno, A. & Higuchi, T., *Assessing Small-scale Freshwater Microplastics Pollution, Land-use, Source-to-sink Conduits, and Pollution Risks: Perspectives from Japanese Rivers Polluted with Microplastics*, Sci. Total Environ., **768**, 144655, 2021. doi: 10.1016/j.scitotenv.2020.144655.

[26] Baldwin, A.K., Corsi, S.R. & Mason, S.A., *Plastic Debris in 29 Great Lakes Tributaries: Relations to Watershed Attributes and Hydrology*, Environ. Sci. Technol., **50** (19), pp. 10377-10385, Oct. 2016. doi: 10.1021/acs.est.6b02917.

[27] Zhang, Y., Peng, Y., Xu, S., Zhang, S., Zhou, G., Yang, J., Li, H. & Zhang, J., *Distribution Characteristics of Microplastics in Urban Rivers in Chengdu City: The Influence of Land-use Type and Population and Related suggestions*, Sci. Total Environ., **846**, 157411, Nov. 2022. doi: 10.1016/j.scitotenv.2022.157411.

[28] Campanale, C., Massarelli, C., Bagnuolo, G., Savino, I. & Uricchio, V.F., *The Problem of Microplastics and Regulatory Strategies in Italy*, Handb. Environ. Chem., **112**, pp. 255-276, 2022. doi: 10.1007/698_2019_419.

[29] Suzuki, G., Uchida, N., Tuyen, L.H., Tanaka, K., Matsukami, H., Kunisue, T., Takahashi, S., Viet, P.H., Kuramochi, H. & Osako, M., *Mechanical Recycling of Plastic Waste as a Point Source of Microplastic Pollution*, Environ. Pollut., **303**, 119114, Jun. 2022. doi: 10.1016/j.envpol.2022.119114.

[30] Meijer, L.J.J., van Emmerik, T., van der Ent, R., Schmidt, C. & Lebreton, L., *More than 1000 Rivers Account for 80% of Global Riverine Plastic Emissions into the Ocean*, Sci. Adv., **7** (18), pp. 1-14, 2021. doi: 10.1126/sciadv.aaz5803.

[31] Jeong, H., Novirsa, R., Nugraha, W. C., Addai-arhin, S., Dinh, Q. P., Fukushima, S., Fujita, E., Bambang, W., Kameda, Y., Ishibashi, Y. & Arizono, K., *The distributions of microplastics (MPs) in the Citarum River Basin, West Java, Indonesia*, J. Environ. Saf., **12** (2), pp. 33-43, 2021. doi: 10.11162/daikankyo.E21RP0102.

[32] Lestari, P., Trihadiningrum, Y., Wijaya, B.A., Yunus, K.A. & Firdaus, M., *Distribution of Microplastics in Surabaya River, Indonesia*, Sci. Total Environ., **726**, 138560, 2020. doi: 10.1016/j.scitotenv.2020.138560.

[33] Haji, A.T.S., Rahadi, B. & Firdausi, N.T., *Analysis of Abundance Microplastic in Surface Water in Metro River , Malang*, J. Sumberd. Alam dan Lingkung., **8** (2), pp. 74-84, 2021. (Text in Indonesian and Abstract in English)

DOI: 10.5614/j.eng.technol.sci.2023.55.2.6


[34] Buwono, N.R., Risjani, Y. & Soegianto, A., *Distribution of Microplastic in Relation to Water Quality Parameters in the Brantas River, East Java, Indonesia*, Environ. Technol. Innov., **24**, 101915, Nov. 2021.doi: 10.1016/j.eti.2021.101915.

[35] Sulistyowati, L., Nurhasanah, Riani, E. & Cordova, M.R., *The Occurrence and Abundance of Microplastics in Surface Water of the Midstream and Downstream of the Cisadane River, Indonesia*, Chemosphere, **291** (P3), 133071, 2022. doi: 10.1016/j.chemosphere.2021.133071.

[36] Xu, Y., Chan, F.K.S., Johnson, M., Stanton, T., He, J., Jia, T., Wang, J., Wang, Z., Yao, Y., Yang, J., Liu, D., Xu, Y. & Yu, X., *Microplastic Pollution in Chinese Urban Rivers: The Influence of Urban Factors*, Resour. Conserv. Recycl., **173**, 105686, 2021. doi: 10.1016/j.resconrec.2021.105686.

[37] Lahens, L., Strady, E., Kieu-Le, T.-C., Dris, R., Boukerma, K., Rinnert, E., Gasperi, J. & Tassin, B., *Macroplastic and Microplastic Contamination Assessment of a Tropical River (Saigon River, Vietnam) Transversed by a Developing Megacity*, Environ. Pollut., **236**, pp. 661-671, May 2018. doi: 10.1016/j.envpol.2018.02.005.

[38] BPS-Statistic Indonesia, *Malang City in Numbers,* Statistics Indonesia, 2022. (Text in Indonesian)

[39] Barrows, A.P.W., Christiansen, K.S., Bode, E.T. & Hoellein, T.J., *A Watershed-scale, Citizen Science Approach to Quantifying Microplastic Concentration in a Mixed Land-use River*, Water Res., **147**, pp. 382-392, Dec. 2018. doi: 10.1016/j.watres.2018.10.013.

[40] Masura, J., Baker, J., Foster, G. & Arthur, C., *Laboratory Methods for the Analysis of Microplastics in the Marine Environment*, National Oceanic and Atmospheric Administration, 2015.

[41] Naji, A., Nuri, M., Amiri, P. & Niyogi, S., *Small microplastic particles (S-MPPs) in Sediments of Mangrove Ecosystem on the Northern Coast of the Persian Gulf*, Mar. Pollut. Bull., **146**, pp. 305-311, 2019, doi: 10.1016/j.marpolbul.2019.06.033.

[42] Kabir, A.H.M.E., Sekine, M., Imai, T., Yamamoto, K., Kanno, A. & Higuchi, T., *Microplastics in the Sediments of Small-scale Japanese Rivers: Abundance and Distribution, Characterization, Sources-to-sink, and Ecological Risks*, Sci. Total Environ., **812**, 152590, 2022. doi: 10.1016/j.scitotenv.2021.152590.

[43] Wu, C., Zhang, K., & Xiong, X., *Microplastic Pollution in Inland Waters Focusing on Asia*, in Water research, **137**, 2018, pp. 85–99.

[44] Free, C.M., Jensen, O.P., Mason, S.A., Eriksen, M., Williamson, N.J. & Boldgiv, B., *High-levels of Microplastic Pollution in a Large, Remote, Mountain Lake*, Mar. Pollut. Bull., **85**(1), pp. 156-163, Aug. 2014. doi: 10.1016/j.marpolbul.2014.06.001.

[45] Wood, S.N., *Generalized additive models: An Introduction with R*, Second edition, 2017.

[46] Alam, F.C., Sembiring, E., Muntalif, B.S. & Suendo, V., *Microplastic Distribution in Surface Water and sediment river around slum and industrial area (case study: Ciwalengke River, Majalaya District, Indonesia*), Chemosphere, **224**, pp. 637–645, Jun. 2019. doi: 10.1016/j.chemosphere.2019.02.188.

[47] Han, M., Niu, X., Tang, M., Zhang, B.T., Wang, G., Yue, W., Kong, X. & Zhu, J., *Distribution of Microplastics in Surface Water of the Lower Yellow River Near Estuary*, Sci. Total Environ., **707**, 2020. doi: 10.1016/j.scitotenv.2019.135601.

[48] Huang, D., Li, X., Ouyang, Z., Zhao, X., Wu, R., Zhang, C., Lin, C., Li, Y. & Guo, X., *The Occurrence and Abundance of Microplastics in Surface Water and Sediment of the West River Downstream, in the South of China*, Sci. Total Environ., **756**, 143857, 2021. doi: 10.1016/j.scitotenv.2020.143857.

[49] Wijaya, B.A. & Trihadiningrum, Y., *Meso- and Microplastics pollution in Surabaya River on Driyorejo to Karang Pilang Segment*, J. Tek. ITS, **8** (2), pp. 211-216, 2019. (Text in Indonesian and Abstract in English)

[50] Woodall, L.C., Gwinnett, C., Packer, M., Thompson, R.C., Robinson, L.F. & Paterson, G.L.J., *Using a Forensic Science Approach to Minimize Environmental Contamination and to Identify Microfibres in Marine Sediments*, Mar. Pollut. Bull., **95**, (1), pp. 40-46, 2015. doi: 10.1016/j.marpolbul.2015.04.044.

[51] Foekema, E.M., De Gruijter, C., Mergia, M.T., Van Franeker, J.A., Murk, A.J. & Koelmans, A.A., *Plastic in North Sea Fish*, Environ. Sci. Technol., **47** (15), pp. 8818–8824, 2013, doi: 10.1021/es400931b.

[52] McCormick, A., Hoellein, T.J., Mason, S.A., Schluep, J. & Kelly, J.J., *Microplastic is an Abundant and Distinct Microbial Habitat in an Urban River*, Environ. Sci. Technol., **48** (20), pp. 11863–11871, Oct. 2014. doi: 10.1021/es503610r.

[53] Dikareva, N. & Simon, K.S., *Microplastic Pollution in Streams Spanning an Urbanisation Gradient*, Environ. Pollut., **250**, pp. 292-299, Jul. 2019. doi: 10.1016/j.envpol.2019.03.105.

[54] Pariatamby, A., Hamid, F.S., Bhatti, M.S., Anuar, N. & Anuar, N., *Status of Microplastic Pollution in Aquatic Ecosystem with a Case Study on Cherating River, Malaysia*, J. Eng. Technol. Sci., **52** (2), pp. 222-241, 2020, doi: 10.5614/j.eng.technol.sci.2020.52.2.7.

[55] Ta, A.T., Babel, S. & Haarstrick, A., *Microplastics Contamination in a High Population Density Area of the Chao Phraya River, Bangkok*, J. Eng. Technol. Sci., **52** (4), pp. 534-545, 2020. doi: 10.5614/j.eng.technol.sci.2020.52.4.6.

Manuscript Received: 11 October 2022
Revised Manuscript Received: 20 April 2023
Accepted Manuscript: 2 May 2023