UDC 629
DOI: 10.15587/1729-4061.2024.313830

IDENTIFYING THE DISTRIBUTION AND SOURCE OF RIVERINE PLASTIC WASTE CONTAMINATION: CASE STUDY OF BRANTAS RIVER IN MALANG CITY

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Brantas River experiences significant pollution due to domestic and industrial wastes. This condition also causes natural disasters such as floods. Single use plastics generally made up a large portion of local wastes. However, previous studies mostly investigated plastic waste pollution and local waste management habits as separate topics. Therefore, the objects of this study are the plastic wastes in Brantas River, as microplastic particles, and the identification of its source. The assessments were based on microplastic counts, macroinvertebrate bioassessment with SIGNAL-2 index, and the quantitative data of local domestic waste management at three Stations in Malang City area. Riverine microplastic pollutant concentrations and its sources were both successfully identified and solved. The results showed that the highest riverine microplastic particles were found in Station 3. This station only had four macroinvertebrate taxa with a SIGNAL-2 score of 4.42, indicating severe degradation. Quantitative data showed that 80 % of Station 3 residents threw plastic wastes directly to Brantas River. The low macroinvertebrate counts possibly caused by ingestion of microplastic from households and small-scale enterprises which heavily utilized single use plastics to trade their goods. The first distinctive feature of this study is the comparability of the microplastic, and macroinvertebrate counts with the river degradation status. Secondly, the quantitative data can serve as complementary evidence. Practically, the obtained results can be developed into an integrated plastic waste management plan for the residents surrounding the rivers, particularly in developing countries with similar socio-cultural conditions as elaborated in this study, to maintain the ecosystem quality

Keywords: riverine microplastic, macroinvertebrate SIGNAL-2 index, waste management, domestic plastic waste, small-scale industry waste

Received date 08.08.2024
Accepted date 14.10.2024
Published date 25.10.2024

How to Cite: *Anggayasti, W. L., Sudaryanti, S., Pertiwi, M., Nurjannah, R. S. F., Sheviyandini, T. Y., Suryatama, J., Rubiyatadji, R., Koentjoro, M. P., Kurniawan, A. (2024). Identifying the distribution and source of riverine plastic waste contamination: case study of Brantas River in Malang city. Eastern-European Journal of Enterprise Technologies, 5 (10 (131)), 37–44. https://doi.org/10.15587/1729-4061.2024.313830*

1. Introduction

Environmental degradation has become a great concern within the current years, especially those related to aquatic environments. This aquatic environmental damage is also currently being studied worldwide, particularly in developing countries [1]. The increasing occurrence of natural disasters recently, such as landslides, floods, and droughts, are the indications of significant environmental damage. Such disasters are proven to be linked to the significant decrease of watershed carrying capacity [2]. River is a part of watershed which has significant relevance to the health of the aquatic environment [1]. Therefore, assessment on the quality of river water is paramount to determine the environmental health as well as to prevent disasters, especially floods.

In connection to river quality, there are growing notions of the critical role of domestic and industrial wastes in polluting the rivers and causing floods [3]. Both sources of waste often consist of a significant portion of leftover plastics [2]. As one of the most heavily contaminated rivers, Brantas River also has experienced many cases of flooding in recent years [3]. One of the possible causes of flooding is due to irresponsible plastic waste disposal from domestic and small enterprises sources. However, the severity of plastic contamination and its connection to the local waste management in some areas of the watershed, especially in Malang City area, is currently not sufficiently studied. As shown in the graphic generated from PubMed search of scientific papers with microplastic-related topics from 2014-2024 (Fig. 1), the publications themed microplastics in rivers worldwide already reached more than 200 papers in 2020. In comparison, the highest number of publications which investigated both riverine microplastics and waste management only reached 40 papers in 2022, globally (Fig. 1).

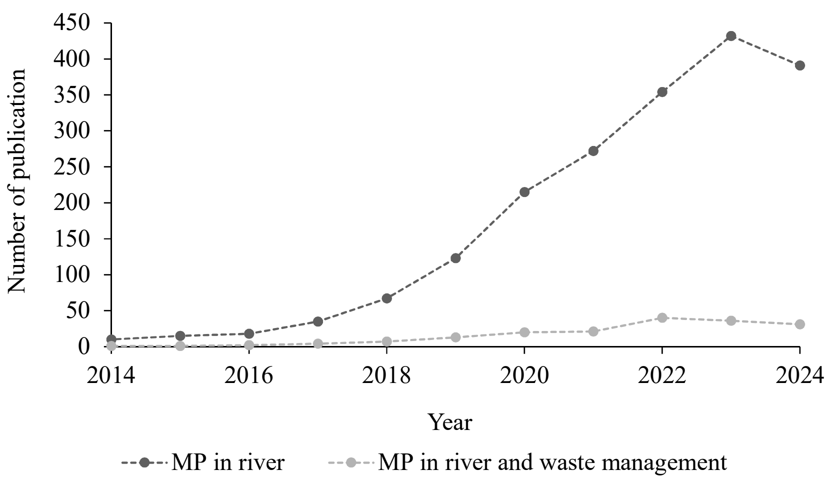


Fig. 1. Comparison of publication themes from 2014–2024 as derived from PubMed

To enrich the knowledge in this area, our study was conducted to assess the effect of plastic waste to the Brantas River in Malang City area based on the SIGNAL-2 index for total microplastic counts and macroinvertebrate bioassessment, supported by a quantitative data about local waste management in the three Stations along the river stream. The results demonstrated that the downstream river water of Station 3 was severely polluted by microplastics, as reflected by the lowest macroinvertebrate counts there. The way 80 % of the residents in Station 3 disposed their household and small-scale industry's plastic waste directly to river were closely related to the abundance of the riverine microplastics. Therefore, the studies devoted to establishing the connection between river degradation with the domestic and small-scale industry waste management along the river stream are relevant for watersheds experiencing the same problem worldwide, especially those of similar developing countries.

2. Literature review and problem statement

A watershed is a topographically defined area where water flows from the land towards its aquatic component: the river, which is characterized by a unidirectional flow from upstream to downstream [2]. Globally, river contamination by any pollutant is proven to be detrimental to the total environmental health, both for the river biota itself and the surrounding watershed inhabitants [1]. The diminishing carrying capacity of watersheds worldwide is believed to be one of the primary causes of the rising severity of the natural disasters over the years, particularly floods [2]. Each of the research above detailed the river pollution and the diminishing watershed carrying capacity. However, the potential sources of the contaminants and their contribution towards the health of the watershed was not discussed. Both the health status of a river and the exact source of pollution must be determined to predict the overall sustainability of a watershed.

There are several ways to assess the water quality of a river. One of them is by means of bioassessment, which uses the dominant riverine organisms. Macroinvertebrate is a heterotrophic organism frequently used for monitoring river water quality because they tend to remain stationary at the bottom of the water [3], have long life cycles [4], and are relatively easy to sample [5]. As some type of macroinvertebrate families can be found in harshly polluted rivers and the bioassessment was successfully being applied in other countries, it is deemed to be a suitable parameter for assessing the condition of the generally contaminated Brantas River in the East Java Province of Indonesia. It should be noted, however, that this bioassessment can only reveal the river degradation status and not necessarily the type of pollution that caused the damage. Therefore, should there be any need to investigate the precise type of contamination, an integrated study with combined methods is advisable.

Brantas River is under severe environmental stress due to various anthropogenic activities, particularly industrial and domestic waste disposal [1]. The globally rising trend of waste disposal to rivers is strongly connected to residential development [6]. This improper waste disposal by residents is also cited as the contributor to the occurrence of floods [7]. The cities along Brantas River, including Malang, often experience both riverine pollution and flooding. Floods frequently occurred in several districts of Malang City within the last five years, such as Kedungkandang, Klojen, Blimbing, and Lowokwaru [8]. In fact, more than half of the East Java province area are susceptible to flooding because of watershed damage [9]. More specifically, residents within Dinoyo ward in Malang City, as is one of the Brantas watershed areas, conveyed that their daily household waste consisted of 72 % inorganic waste which was dominated by plastics [6]. Plastic waste has become a tremendous global concern due to its role in polluting the freshwater ecosystem and toxic compounds [10]. As the degraded plastic wastes in form of microplastics currently pollute aquatic environments worldwide, it is of importance to scrutinize whether Brantas River in Malang

City area also suffers from this contamination. Currently, studies of microplastic pollution in the Brantas River area of Malang are still limited, and the intensity of such contaminations are still unresolved. In this study, the integrated methods of total microplastic counts and macroinvertebrate bioassessment were carried out to determine both the level of degradation and the severity of microplastic contaminations in the river.

Additionally, studies on microplastic pollution in rivers worldwide have been carried out frequently [11]. However, its link to the local waste management habit by the residents within the watershed area was often being overlooked. The reason for this may be that the contamination cases and poor waste disposal habits were viewed as separate entities. A way to overcome these difficulties involved side-by-side comparison between microplastic contamination data; as confirmed by macroinvertebrate assays; and the quantitative data of the local waste management practices. This approach was able to give a more thorough understanding about the connection between river pollution and poor waste management. Overall, it is recommended to conduct a study on the presence and source of riverine microplastic pollution, as it is important to prevent contamination and flood disasters.

3. The aim and objectives of the study

The aim of the study is to identify the distribution of plastic waste contamination in Brantas River of Malang City area in the form of microplastic particles, as well as the causes of such pollution. This will allow recognition of microplastic contaminants at each designated Station and whether it corresponds directly to the life cycles of the native macroinvertebrate and local plastic waste management.

To achieve this aim, the following objectives are accomplished:

– to determine the existence of microplastic particles at the three Stations of Brantas River using both total microplastic counts and macroinvertebrate bioassessment with SIGNAL-2 index;

– to measure the microplastic concentrations and the river degradation status based on the particle counts and the SIGNAL-2 index at each Station, and evaluate whether the results of each Station were comparable and correspond to each other;

– to collect quantitative data on local waste management practices of the nearby households and small-scale industries of each Station as an effort to identify the source of microplastic pollution.

4. Materials and methods

4. 1. Object and hypothesis of the study

The object of this study is to verify the microplastic contamination, to confirm the degradation status by macroinvertebrate bioassessment using SIGNAL-2 index, and to trace the pollution source by scrutinizing the quantitative social data. The main hypothesis of this study is that the existence of microplastic particles at certain Stations of the Brantas River would be reflected in the survival of the river's macroinvertebrate and must be related to the local waste management habit. It is assumed that, firstly, the presence of microplastic contaminants would affect the life cycle of native macroinvertebrate in the Station. Secondly, when the residents managed their plastic waste properly, there would be less microplastic particles found in the river stream, and vice versa. Simplifications adopted were the selection of sampling Stations based on land use and residents' characteristics. The choice was limited to two Stations in the upstream and one in the downstream: each with unique geographic and demographic profiles representative of the general land and society conditions along the riverbanks.

4. 2. Selection of the sampling stations and microplastic counts

The stations for sampling were determined to be the specific points at Dinoyo, Betek, and Gadang wards along the Brantas River within the Malang City area. Station 1 in Dinoyo as well as Station 2 in Betek are upstream of Brantas River, which topographically are highland and hilly areas of 400–500 m above sea level [6]. Meanwhile, Station 3 in Gadang is located further downstream of the river with lower area height. The selection of the sampling stations was also based on the land use of the area surrounding the river. The land use characteristics of the sampling stations are described in Table 1, whereas the positions of the stations within Malang City area are shown in the map of Fig. 2.

Table 1

Characteristics of the three sampling stations along Brantas River

Station	Coordinates	Land use characteristics
1	7° 56' 10,00" 112° 36' 33,786"	The land use on both sides of the riverbanks includes residential areas, with frequent use of the river for bathing, washing, and sewage
2	7° 57' 16,776" 112° 37' 19,823"	The land use on both sides of the riverbanks includes residential and commercial areas
3	8° 0' 59,155" 112° 37' 53,796"	The land use on the left side of the river facing upstream consists of vehicle traffic areas and shrubs, while that on the right side consists of shrubland. Residential area is located within 100–200 m from the riverbanks

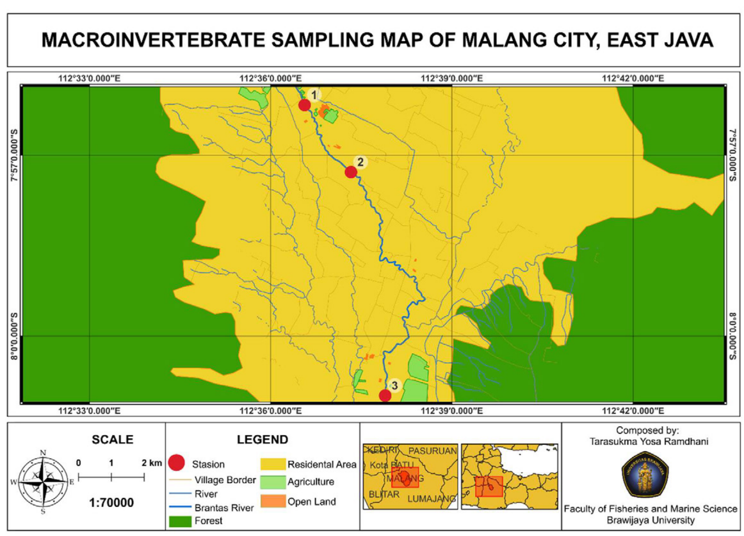


Fig. 2. Location of the sampling stations in Malang City

The total microplastic counts were done as described previously [11]. A volume of 0.3 L of water from sampling point was filtered with plankton net. All materials caught by the net were collected and set aside. The water was then filtered three times with 50-, 18-, and 4-mm mesh. The particles caught were pooled with those of the initial filtering result. A volume of 20 mL 30 % H_2O_2 and 20 mL 0.05 M Fe^{2+} were added to the filtered water. The mixture was heated at 90 °C to digest the remaining organic residues. Subsequently, the mixture was cooled and filtered with a vacuum pump. All microplastics were oven-dried at 50 °C for 1 h. The particles were examined with an Olympus BX-50 microscope (Olympus, Japan).

4. 3. Macroinvertebrate bioassessment by SIGNAL-2 index

Sampling was conducted to obtain macroinvertebrate which were classified based on their families or taxa. A hand net with mesh size of 500 µm was used with kicking technique. This method is commonly used in shallow waters, covering a total of 10 meters in the riffle areas [12]. Data analysis utilized the SIGNAL-2 (Stream Invertebrate Grade Number-Average Level 2) index, which is a straightforward assessment tool for macroinvertebrates [13]. The number of macroinvertebrate family was counted, and each family was assigned a score ranging from 1 to 10. A low score indicates that the macroinvertebrate is tolerant to environmental pollutions, and vice versa [13]. The calculated SIGNAL-2 scores together with the number of macroinvertebrate taxa were plotted on a four-quadrant graph as presented in Fig. 3 and interpreted to categorize the freshwater quality [13].

In short, there are four categories of river degradation that can be determined by the chart in Fig. 3. They are based on both the taxa number counts and the SIGNAL-2 scores. The degradation status ranges from no degradation (Quadrant 1), slight degradation (Quadrant 2), moderate degradation (Quadrant 3), and severe degradation (Quadrant 4). This bioassessment method can serve as an early warning system for watershed conditions.

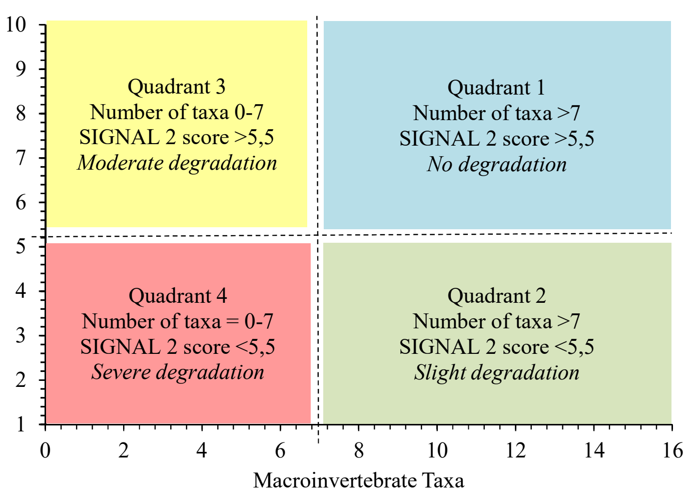


Fig. 3. SIGNAL-2 Index Quadrant

4. 4. Local plastic waste management data collection and analysis

The studied local population was grouped based on the three sampling Stations. The respondents lived within the radius of 500 m from each Station coordinates (Table 1). The group consisted of 30 respondents; 15 males and 15 females, selected with simple random sampling technique [14]. A structured questionnaire was designed to obtain information about the local plastic waste management with cross-sectional study approach to collect data at a single time point [15], while direct field observation examined waste management habits in the sampling area. The collected data were analyzed using Microsoft Excel with statistical descriptive approach [6] to describe waste management habits of the residents in the three Stations along the Brantas River.

5. Results of riverine microplastic contamination as determined by particle counts, SIGNAL-2 bioassessment data, and local waste management practices

5. 1. Determination of microplastic particles existence in three Stations with total microplastic counts

Total microplastic counts revealed that the Brantas River water at each Station possessed microplastic particles, albeit in different numbers. The lowest number of particles were found in Station 1 with 1 particles/L and followed by Station 2 with about 3 particles/L (Fig. 4). In both Stations, the proportions of fragments and films dominated the mixture of the discovered particles.

The highest amount of microplastic particles were discovered at Station 3 in Gadang ward area with almost 16 particles/L (Fig. 4). For Station 3, the largest percentages of microplastic particle types were also made up of the films and the fragments (Fig. 4). In general, the total percentages of films and fragments of each Station reach up to 80–90 %. Whereas microplastics in the form of pellets and fibers were less common in all three Stations.

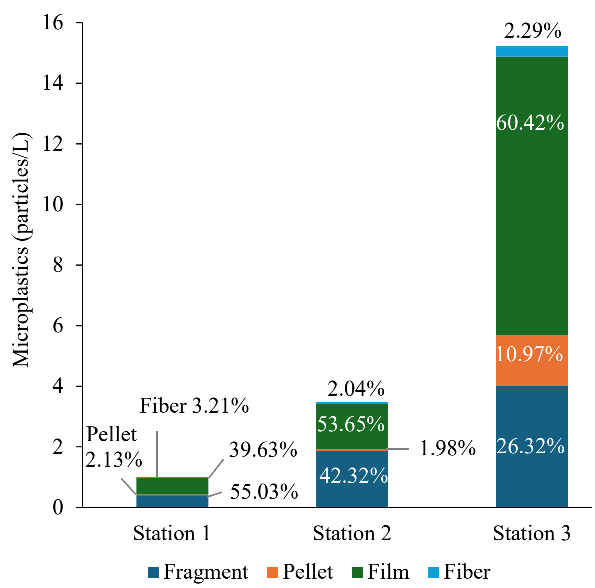


Fig. 4. The number of microplastic particles and the proportions of the forms at each Station

5. 2. Measurement and comparison of the river degradation status based on the SIGNAL-2 index at each Station

The total number of macroinvertebrate taxa found in all sampling stations of the Brantas River comprised of 22 families which belongs to 6 orders, namely Trichoptera, Diptera, Coleoptera, Ephemeroptera, Odonata, and Tricladida, and 6 classes which were Amphipoda, Gastropoda, Oligochaeta, Decapoda, Acarina, and Bivalvia. The lowest number of families was recorded at Station 3, with 4 families (Fig. 5) including Chironomidae, Hydropsychidae, Lymnaeidae, and Thiaridae. Conversely, the highest number of families was found at Station 2 (Fig. 5). Some of the 15 families found were *Chironomus thummi*, Naididae, Glossiphonidae, Psychodidae, and Richardsonianidae. Finally, 12 taxa of macroinvertebrates were found at Station 1.

The SIGNAL-2 score for Station 1 is 3.89 and, together with the discovered number of macroinvertebrate family (Fig. 5), was assigned in Quadrant 2 (Fig. 6). The macroinvertebrates in Station 1 with sensitivity score of >5.5 were Baetidae, Hydropsychidae, and Gomphidae. The macroinvertebrates with sensitivity score of <5.5 were Thiaridae, Sundathelphusidae, Nereidae, Caenidae, Haliplidae, Tipulidae, Psychodidae, and Chironomidae. The presence of macroinvertebrates tolerant to pollutants with a SIGNAL-2 sensitivity score of <5.5 and the total number of families put Station 1 in the category of slightly degraded river ecosystem (Fig. 6) [13].

Analysis of Station 2 yielded a SIGNAL-2 score of 3.30, placing it in Quadrant 2 (Fig. 6). The macroinvertebrates with score of >5.5 were Baetidae, Hydropsychidae, and Tipulidae. The macroinvertebrates with sensitivity score of <5.5 were *Chironomidae*, *Chironomus thummi*, *Gammaridae*, *Glossiphonidae*, *Hydrobiidae*, *Lumbriculidae*, *Lymnaeidae*, *Naididae*, *Psychodidae*, *Richardsonianidae*, *Sundathelphusidae*, and *Thiaridae*. Both the SIGNAL-2 score and the total taxa which was the highest among all Stations explained the categorization of Station 2 as slightly degraded [13].

For Station 3, the SIGNAL-2 index was 4.42, which was the highest of all stations. Only four Macroinvertebrate taxa were spotted here. The macroinvertebrate with score of >5.5 was Hydropsychidae. The macroinvertebrates with sensitivity score <5.5 were Chironomidae, Lymnaeidae, and Thiaridae. Based on the score and the lowest taxa number, and the fact that most of the taxa members are equipped with the ability to survive in contaminated ecosystem, Station 3 in Gadang ward was classified in Quadrant 4 as a severely degraded site of Brantas River (Fig. 6) [13].

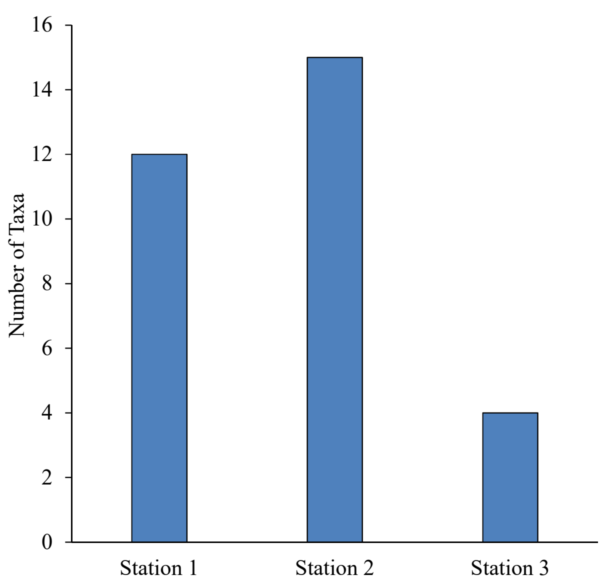


Fig. 5. The number of macroinvertebrate taxa found at each station

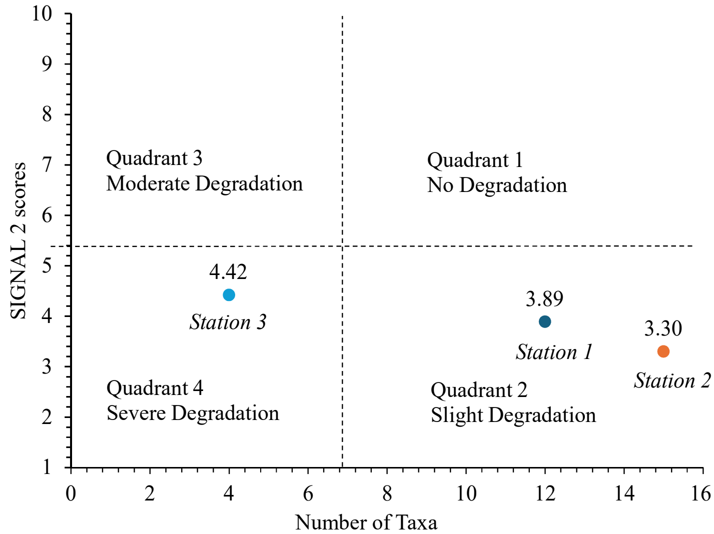


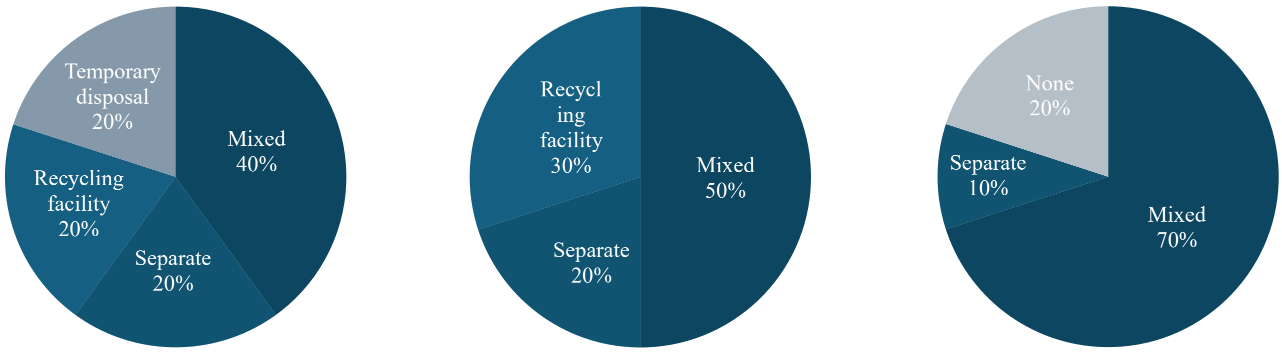
Fig. 6. The placement of each Station within the four SIGNAL-2 quadrants

5. 3. Identification of the source of microplastic pollution from the quantitative data on local waste management practices

Field observations implied that the main sources of the microplastic particles were likely to be daily domestic waste disposed by the residents. The quantitative data on local plastic waste management displayed in Fig. 7 shows that the availability of waste disposal facilities differed from one Station to the other. In general, there were more mixed waste facilities compared to separate waste facilities, signifying that most of the residents of each Station mixed their organic and inorganic garbage daily. Inorganic waste always contained single use plastics. It was also found that the average proportion of single use plastics in a single household waste was at least 50 %. Furthermore, it was of concern that 20 % of the respondents of Station 3 reported that there was no waste disposal facility near their houses. Additionally, 70 % respondents at that Station claimed that the accessible waste facilities were the mixed one. This percentage was the highest compared to the two other Stations (Fig. 7).

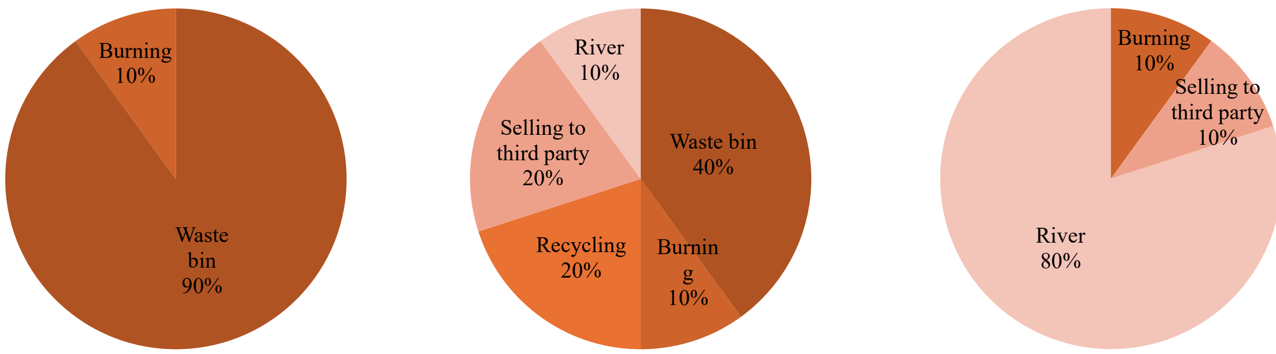
Fig. 8 further elaborated how the residents disposed of their waste, including plastics. Residents in Station 1 appeared to rely on using waste bins which were managed by their local government apparatus. However, 10 % of the residents resorted to burn their wastes, especially the plastic ones. Conversely, the residents in Station 2 seemed to put more effort into their waste management, which was shown as 20 % recycling and 20 % selling activities, especially regarding plastic bottles or containers (Fig. 8). It must be noted, however, that 10 % of the residents admitted throwing their domestic waste into the river. In addition to that, 10 % of the residents also claimed to use open burning for their plastic waste.

Finally, the percentage of residents involved in plastic littering to Brantas River drastically increased in Station 3. As many as 80 % respondents conveyed, they threw their wastes directly to the river, and an additional 10 % committed open burning for plastic wastes. The results tie closely the highest microplastic content of Station 3 (Fig. 4). Additional data showed that more than half of the respondents were involved in small-scale industries on food and beverages or groceries, which mostly relied on the utilization of single use plastics.



a *b* *c*

Fig. 7. The waste disposal facility types at: *a* – Station1; *b* – Station 2; *c* – Station 3



a *b* *c*

Fig. 8. The waste disposal activities at: *a* – Station1; *b* – Station 2; *c* – Station 3

6. Discussion of the close correlation of Brantas River microplastic contamination with macroinvertebrate bioassessments and the poor waste management practices

The results can be interpreted and explained as follows. All three Stations were confirmed to contain microplastic particles and Station 3 had an exceptionally high number of particles (Fig. 4). The dominant forms of microplastics in all Stations were films and fragments (Fig. 4). The flexible films mainly resulted from degraded plastic bags or wrappings [16]. Meanwhile, fragments usually have irregular shapes and are sturdier than films. They are brought along the streams in various colors and generally are the byproducts of degraded plastic bottles or food containers [17]. The use of plastic bags, wrappings, bottles, or containers are very common in households, groceries-related activities, and both small and large-scales food and beverage businesses.

The macroinvertebrate taxa found at each Station (Fig. 5) can be interpreted as the description of the local aquatic environment condition (Fig. 6). Psychodidae larvae of Station 1 are usually found at the edges of slow-moving sandy contaminated rivers [18], and feed on detritus [19]. *Chironomus thummi* [20] and Naididae thrived in muddy rivers [21] like in Station 2. They adapt by having gills resembling feathers at the back of their bodies. The gills are usually enclosed in a gill chamber and allow survival in water with low dissolved oxygen [22]. Lumbriculidae of Station 2 can be found in typically polluted soft sediment pockets of rocky habitats [23]. In contrast, the substrate condition of Station 3 was harsher, as reflected on the *in-situ* macroinvertebrate taxa (Fig. 5, 6). The life of Thiaridae and Lymnaeidae are sustained due to their adaptation mechanism with a pouch or sac to survive [24]. Some of them fill the mantle sac with water and use it as a secondary gill [25]. The presence of the secondary gill indicated that the substrate of Station 3 was highly polluted.

The likely explanation for the gradually increasing microplastic particles from Station 1 to the downstream Station 3 (Fig. 4) and the suggested severe degradation status of Station 3 (Fig. 6) can be found in the quantitative results of the residents' waste management. The rising proportion of residents in Station 2 and Station 3 who threw plastic waste directly to the river, in combination with open burning (Fig. 8) contributed to the river pollution. Open burning the plastic wastes is quite common globally and is confirmed to pollute the air and the land. The residual microplastic debris can be carried by winds and deposited in water [26], which may explain the existence of 1.011 particles/L microplastic in Station 1, although no resident claimed to throw their plastic wastes to the river. These results agreed with the previous study that domestic waste management by residents played a paramount role in keeping the cleanliness and health status of the river nearby the residential area [10].

Unlike the topics of previous studies which specifically examined microplastic contaminations in rivers worldwide like in Sidoarjo [11] and Kahayan [27] and those which dealt with local waste management as a different object altogether like in Indonesia [6] and Nigeria [7], the result of this study which compared the high particle counts (Fig. 4) and the poorest local habit of plastic littering to the river in Station 3 (Fig. 8) allows the establishment of the link between the two research objects. Although the suggestion of the interconnection of both topics was made in a recent paper [10], this study made it possible by side-by-side comparison of the *in-situ* and qualitative data.

As a response to the problems posed in this study, the results suggest that the existence and life cycles of macroinvertebrates are affected by microplastic pollution in rivers by direct ingestion. Microplastics are commonly found in both water and sediment of a contaminated river [27]. Some surviving taxa with low SIGNAL-2 scores might encounter microplastic pollutants in muddy sediments of each Station. Microplastic particles were ingested by 50 % of the taxa found in South Wales riverine, including Baetidae [28] which was also identified in Station 1 and Station 2 in this study. The order of Ephemeroptera, in which some taxa found in this study belonged to, also absorbed microplastic particles [29]. In particular, the macroinvertebrate with high SIGNAL-2 score were significantly decreasing in Station 3, as the highly sensitive taxa are most likely to be affected by microplastic pollution [30]. In summary, the high concentration of microplastic particles in Station 3 (Fig. 4) can be linked to the low number of macroinvertebrate taxa found in that site (Fig. 5). Littering and open burning practices (Fig. 7) further confirm the source of microplastic contamination, therefore providing answers to the research problems.

It should be noted that these results were limited in the scope of sampling time. The microplastic sampling was only being carried out at a specific time during the day. Future study should consider doing sampling in different time points to ensure the consistency of the particle count results. The second limitation is that the study was only being carried out in three stations of Malang City area, as shown in Fig. 2 and Table 1, to be the representatives of upstream and downstream watershed areas. However, despite the latter limitation, it is confirmed that that the local waste management habits in Malang City are similar with the other developing countries. For example, open burning plastic wastes in watersheds exists and even encouraged not only in Indonesia, but also in India, Zambia, and the Philippines [26]. The habit of littering is also akin to the inhabitants in the watersheds of Nigerian river [7]. Considering the resemblance of the socio-cultural structures of these countries, a simultaneous effort in identifying both the microplastic pollution as well as its source at the same time using the integrated methods of this research is very promising.

The shortcomings of this study were because the findings were at the initial stage of tracing the source of microplastic pollution in the water body. The more holistic solution should involve the ways to prevent plastic waste littering to the Brantas River, especially considering the claim of the residents in Station 3 that there was no waste disposal facility (Fig. 7). As the world is currently dominated by the proportion of developing countries, this study is relevant and can be developed in the future to be an integrated domestic waste management plan to prevent plastic waste contamination to the river by the residents of the developing nations. Therefore, the application of this management plan may be an education and informative model for the watershed areas experiencing the same problem globally, thus aiding to maintain the aquatic ecosystem quality and preventing natural disasters especially floods.

7. Conclusions

1. Station 3 of downstream Brantas River in Malang City recorded almost 16 particles/L of microplastics, as well as severe degradation status based on SIGNAL-2 index of macroinvertebrate bioassessment. Other Stations upstream were categorized as only slightly degraded with lower number of microplastics.

2. Specific macroinvertebrate taxa found in Station 3 had high survival rates in polluted, muddy substrates due to their anatomy. It is also known that some families are susceptible to ingesting microplastics, such as Baetidae which lived in Stations 1 and 2 but could not be found in Station 3. It is therefore likely that the high microplastic content of Station 3 hampered the survival of the sensitive macroinvertebrates, as only four families were found there.

3. The poor habit of the residents surrounding Station 3, whereby 80 % of the respondents threw their plastic wastes directly to Brantas River concluded the dominant source of microplastic pollution in that area.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise that could affect the research, and its results presented in this paper.

Financing

This research was funded by Hibah Penelitian Kelompok Kajian 2024 or Research Group Funding 2024 (grant number: 00374/UN10.F4001/B/PT.01.03/2024) from the Graduate School of Brawijaya University.

Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

Acknowledgements

The authors are deeply grateful for the support and generous knowledge sharing by the experts in Aquatic Resources Management Study Program, Faculty of Fisheries and Marine Sciences of Brawijaya University.

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