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RESEARCH ARTICLE

Microplastics in the surface sediments from the eastern waters of Java Sea, Indonesia [version 1; peer review: 2 approved]

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Abstract

Background: This study aimed to investigate the abundance of microplastics in the eastern water of Java Sea. The study areas are well known for the high population and high industrial activities that can contribute to the plastic pollution.

Methods: Microplastics were sampled from the surface sediments at five different stations representing different local activities: fish landing area (St 1), mangrove forest (St 2), abandoned shrimp pond (St 3), river mouth (St 4) and open sea (St 5).

Results: Three types of microplastics were found; the most common was plastic fragments (54.34±6.39%) followed by fibers (41.45±4.59%) and films (4.21±3.90%). The highest abundance of microplastics was observed in the mangrove area (896.96±160.28 particles/kg), dominated with fragments and fibers. Films were found in greatest quantities in the fish landing area, but compared to the other types of microplastics, the abundance was much lower (80.73±37.62 particles/kg). Domestic wastes and fisheries activities were the main causes of the high microplastics in the study areas.

Conclusions: The results of this study showed that microplastic pollution is a serious problem that needs to be paid attention not only from the government but also from the local people. Plastics management waste is needed.

Keywords

Anthropogenic activities, Java Sea, Microplastics, Surface Sediments

Open Peer Review

Approval Status

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Introduction

The presence of microplastics in the aquatic environment has become a global concern. Microplastics are small pieces of plastic less than 5 mm in size (Barnes *et al.*, 2009; Hidalgo-Ruz *et al.*, 2012). There are two types of microplastics based on their source, the primary microplastics from manufactured plastics in microscopic sizes such as scrubbers and pellets (Isobe, 2016), or secondary microplastics which derived from the breakdown of bigger plastic products such as fragments, fibers or films (Zhu *et al.*, 2018; Zobkov & Esiukova, 2017).

Once in the aquatic environment, microplastics might float in the water column or sink to the bottom, depending on the particle density (Barnes *et al.*, 2009; Kowalski *et al.*, 2016). There have been many studies conducted to analyze the presence of microplastics in the water (Chae *et al.*, 2015; Isobe *et al.*, 2015; Iwasaki *et al.*, 2017), sediments (Alomar *et al.*, 2016; Imhof *et al.*, 2017; Wang *et al.*, 2017; Zobkov & Esiukova, 2017) or both (Frère *et al.*, 2017; Zhu *et al.*, 2018). The sinking behavior of microplastics to the bottom sediments might be the result of biofouling, which can increase its density, the size and shape of microplastics and also fluid density (Kowalski *et al.*, 2016).

Sediments have been considered to be major sinks of microplastics. With the capability of microplastics to concentrate other organic pollutants or heavy metals and also their durability and resistance to degradation, the accumulation of microplastics in sediments can bring harm to marine and human life. Thus, this study was conducted to evaluate microplastics contamination in the eastern water of Java Sea, which is busy with many human

activities. The types of microplastics and the abundances were used to investigate the influence of anthropogenic factors on the spatial distribution of microplastics in the study areas.

Methods

Sampling region

Sampling was conducted in the eastern water of Java Sea, Gresik, Indonesia. There were five sampling stations that represented different local activities. Station 1 was located in the fish landing area that is busy with fisheries activity, especially in the morning. Station 2 was located in the mangrove area that is frequently inundated during high tide. The mangrove area is vulnerable to the plastic wastes from other places that are carried away by the current and tides. Station 3 was located in the abandoned shrimp pond and was once known for shrimp culture. However, this activity had stopped and many ponds have been abandoned. Some local people discard their waste in these ponds, including plastic waste. Station 4 was located in the river mouth of Bengawan Solo River that connected to the open sea. Bengawan Solo River is the longest river in the Java Island, passing through many cities in the Central and East Java Provinces and along the way could bring domestic wastes to its end point in the Java Sea. Station 5 was located in the open sea, about 1 km from the river mouth (Figure 1).

Sampling method

Sampling was conducted in March 2018 and samples were collected in the surface sediment using an Ekman Grab soft sediment sampler. In total, three replicates were obtained and about 500 g of sediment samples from each replicate of the

Figure 1. Sampling location of microplastics in the surface sediments from the eastern waters of the Java Sea.

sampling station were stored in sealed plastic bags. Sediment samples were taken to the laboratory for further analysis. For more information about the study areas regarding the present of the plastic wastes, we also held informal discussions with the local fishermen, especially those who have concern for the mangrove ecosystem. Since this was considered low-risk personal communication, ethical approval and consent were not sought.

Microplastic analysis

Microplastics analysis was conducted by modifying the section 3.5 of the NOAA method (Masura *et al.*, 2015). In the laboratory, 150 g of sediment samples were oven-dried for 24 hours at 90°C. Density separation was performed by adding 20 ml 0.05 M Fe(II) and 20 ml 30% H₂O₂. The samples were then homogenized on a hotplate with stirrer for 30 minutes at 60°C. To remove organic materials, an additional 20 ml of 30% H₂O₂ and NaCl were added and left overnight. After one night, the floating microplastics were collected by filtration using an 0.3-mm mesh filter. Visual identification of microplastics was conducted under a microscope with three distinct rules to separate the types of microplastics. A fragment is a particle that cannot be torn apart with tweezers, with sharp and broken edges of irregular shape and size of degradational plastic; a fiber is a particle that equally thick throughout the entire length and is not tapered at the end; and film that is very thin, part of the sheets of plastic bags and similar (Dai *et al.*, 2018; Hidalgo-Ruz *et al.*, 2012; Nor & Obbard, 2014; Zobkov & Esiukova, 2017). The results of this study were compared with the results from other studies to understand more of the sources of plastic pollution.

Statistical analysis

Normality test was performed to determine the data distribution and to decide whether to use parametric or nonparametric tests for the statistical analysis. The abundance of microplastics proven

to be distributed normally, thus, one-way ANOVA was used to compare the abundance of microplastics among the sampling stations ($p < 0.01$) and the post hoc Tukey's test was run to confirm the differences of microplastics between sampling stations. Kruskal-Wallis H test was conducted to test the difference in type of microplastics found in the study areas in which the distributions were found to be nonparametric. All statistical tests were carried out using SPSS 16.0 for Windows.

Results and discussion

Location of microplastic detection

Microplastics were detected in the surface sediments of the sampling stations in the eastern waters of Java Sea. Anthropogenic activities mostly contributed to the present of microplastics in the study areas. The areas have been known to be highly populated. This is also home to many industrial activities which discharge wastewater to the eastern water of the Java Sea. Microplastics appeared in the range of 206.04–896.96 particle/kg (Figure 2). The highest abundance of microplastics was found at Station 2 in the mangrove area (896.96±160.28 particles/kg), followed by Station 1 (772±336.75 particles/kg) and Station 5 (639.51±121.58 particles/kg). Stations 3 and 4 were observed to contain rather similar amounts of microplastics, which were three times lower than the abundance in the mangrove area (206.04±84.49 particles/kg and 215.54±64.58 particles/kg, respectively). According to one-way ANOVA, there was a statistically significant different in the abundance of microplastics among sampling stations ($p < 0.01$). Tukey's post-hoc test revealed that the abundances of microplastics at Stations 1 and 2 were significantly different to the abundances at Stations 3 and 4 ($p = 0.05$). There was no statistically significant difference between the abundance of microplastics at Station 5 and the other stations. Raw data on microplastic abundance, along with all other raw data, are available on OSF (Yona, 2018).

Figure 2. The abundance of microplastics in each sampling site (n=3).

Microplastics in the mangrove ecosystems have been studied in the Singapore's coastal areas (Nor & Obbard, 2014), where there were much lower amounts compared to those found in this study. Even though the abundances were very much different between these studies, but the reasons of the occurrence of the microplastics in the mangrove ecosystems were rather similar. High occurrence of microplastics at Station 2 in the mangrove area was observed, which could be the result of root system of mangroves, which can trap many different type of rubbish including plastics. Moreover, tides that frequently inundated mangrove beds could bring more plastic wastes from the surrounding waters.

Due to their small size and ability to float in the water column, microplastics can be transported for long distance by ocean currents (Iwasaki *et al.*, 2017). Eastern water of Java Sea is the end point of a very big river, Bengawan Solo, which passes many cities in Java Island and carried plastic wastes along its way to the ocean. Therefore, microplastics found in this study might not just from the local sources, but also from faraway places. According to information from local fishermen, during west monsoon season (November-February), mangroves in the study area are filled with plastic waste from the Bengawan Solo River. Similar results were also found in the study in the Saigon River canal system crossing a megacity, Ho Chi Minh City, in which the source of the plastic pollution was from the land-based due to local habits and waste management (Lahens *et al.*, 2018).

On the other hand, limited interaction of Station 3, which located in the shrimp pond, with the surrounding waters resulted in a low abundance of microplastics. Even so, the abundance of microplastics in the pond was not that low (206.04 particles/kg). This may be because the pond has been abandoned for quite some times and some people from local village may have discarded their rubbish inside the pond.

Types of microplastics found

There were three type of microplastics found in the study areas: plastic fragments, plastic fibers and plastic films (Figure 3). Fragments and fibers dominated most of the sampling stations, while films occurred in very low number compared to the other two types of the microplastics. In total, half of the microplastics found were plastic fragments ($54.34 \pm 6.39\%$), followed by plastic fibers ($41.45 \pm 4.59\%$) and plastic films ($4.21 \pm 3.90\%$). Kruskal-Wallis H test showed that there was a statistically difference in the type of microplastics (fragment, fiber and film) among the study sites ($p < 0.01$).

Fragments contributed the most to the composition of microplastics in the study areas. This type of microplastic is the result of fragmentation of large plastic pieces into smaller particles (Alomar *et al.*, 2016), and mostly the contribution comes from the domestic waste. Fisheries activity in the study areas might contribute to the present of fiber, as mostly local fishermen use plastic fishing nets to catch their fish. A high abundance of fibers was also observed in the North Yellow Sea as the result of constant use of plastic fishing and nets and ropes as the main fishing tools (Zhu *et al.*, 2018).

The highest abundance of plastic fragments appeared at Station 2 in the mangrove area (537.25 ± 160.28 particle/kg). The highest abundance of plastic fibers was also found at Station 2 compared to the other stations. On the other hand, plastic films were detected the highest at Station 1 in the fish landing area.

Comparison with the results of other studies

Compared to the results from the other studies (Table 1), the levels of microplastics found in this study were similar to values obtained in the Western Mediterranean Sea (Alomar *et al.*, 2016) and much higher than those in the North Yellow Sea (Zhu *et al.*, 2018). The dominant type of microplastics found among

Figure 3. The average abundance (n=3) of the type of microplastics collected from the eastern water of Java Sea.

Table 1. The abundance of microplastics in the sediment reported from this and other studies.

Location	Total abundance	Percentage (%)			Reference
		Fragment	Fiber	Film	
Beijiang River	178–544 items/kg	–	–	–	Wang et al. (2017)
The North Yellow Sea	37.1±42.7 items/kg	–	39.1±22.3	58.1±24.9	Zhu et al. (2018)
Western Mediterranean Sea	100.78–897.35 particle/kg	–	–	–	Alomar et al. (2016)
Bohai Sea, China	31.1–256.3 pieces/kg	9.0	83.7	1.1	Dai et al. (2018)
Bohai and Yellow Sea	72–171.8 items/kg	2.55	93.88	1.53	Zhao et al. (2018)
Eastern water of Java Sea	206.04–896.96 particle/kg	54.34±6.39	41.45±4.59	4.21±3.90	This study

the studies was also different. The study in the North Yellow Sea found that plastic films predominated; in the Bohai Sea the most common type was plastic fibers ([Dai et al., 2018](#)), while this study obtained the highest percentage of plastic fragments. The results revealed that microplastics found in this study are mostly from the degradation of the plastic wastes from human activities as stated by [Barnes et al. \(2009\)](#) that fragments are the result of the breakdown of a wide range of everyday plastic products. The lack of awareness from the citizen on how dangerous plastic materials are to the environment is the main reason for plastic pollution ([Derraik, 2002](#)). Efforts from the government and the community are therefore needed to combat plastic use and production.

Conclusion

Microplastics were found in all of the samples from the study area, with the highest levels found in the mangrove area. Fragments were the most common type of microplastic observed, followed by fibers and then small amount of films. The results showed that plastic contamination in the eastern waters of the Java Sea were mostly from anthropogenic activities, especially domestic waste. This plastic waste was not just from the local sources but also from the long-distance sources carried away by the Bengawan Solo River that end in the eastern water of Java Sea.

Data availability

Raw data on the microplastics at each location are given on OSF. DOI: <https://doi.org/10.17605/OSF.IO/H3ZDQ> ([Yona, 2018](#)).

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

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Microplastics in the surface sediments from the eastern waters of Java Sea, Indonesia
Defri Yona, Syarifah Hikmah Julinda Sari, Feni Iranawati, Syamsul Bachri, Wulan Cahya Ayuningtyas

This paper uses coastal sediment samples from sites in the east Java Sea to examine abundance and composition of microplastics. The article is generally well written although I note below a few places where the language could be improved. The work really constitutes a report rather than a scientific article as while it provides useful baseline information, it does not provide any mechanistic advance, or specific policy advice. I would suggest this article is sound subject to minor revisions.

Abstract:

- "that needs to be paid attention" > "that needs greater attention".
- "Plastics management waste is needed." > "Plastics waste management is needed."

Page 3:

Paragraph 1:

- "the primary microplastics from manufactured plastics". All plastics are manufactured, do you mean "used in the manufacture of plastic products"? Suggested edit: "There are two types of microplastic: primary microplastics including pellets and scrubbers that are used in the manufacture of products and secondary microplastics which are..."

Paragraph 2:

- "and also fluid density" > "and also by fluid density".

Paragraph 3:

- "Sediments have been considered to be major sinks of microplastics." Reference needed.
- "With the capability of microplastics to concentrate other organic pollutants or heavy metals and also their durability and resistance to degradation, the accumulation of microplastics in sediments can bring harm to marine and human life." Reference needed or rephrase e.g. "could potentially cause harm...".
- "Thus, this study was conducted to evaluate microplastics contamination in the eastern water of Java Sea, which is busy with many human..." > "Thus, this study was conducted to evaluate microplastics contamination in the eastern water of the Java Sea, which is subject to intensive human..."

Paragraph 4:

- "that are carried away by the current and tides" > "that are carried by the currents and tides".
- "shrimp pond and was once" > "shrimp pond that was once".
- "this activity had stopped" > "this activity has stopped".
- "in the Central and East Java Provinces and along the way could bring domestic wastes to its end point in the Java Sea." > "in Central and East Java Provinces and along its path could accumulate domestic wastes that ultimately is transported to the Java Sea."
- It would be useful to give a brief introduction to the local oceanography, as this would help to understand the distribution of microplastics: what does the circulation look like? How important are tides and tidal currents?

Paragraph 5:

- "In total, three replicates were obtained and about 500 g of sediment samples from each replicate of the sampling station were stored" > "In total, three replicates were obtained at each site comprising of about 500 g of sediment per replicate. Samples were stored..."
- "the present of the plastic wastes" > "the presence of plastic waste..."

Figure 1:

- I've looked at a number of other maps of this region (to try and orient myself) and the coastline looks quite different to the one shown here (e.g. see google map satellite). The inset map isn't very helpful, the red square doesn't have the correct size. It would be also be more helpful to zoom out to show east Java and Madura island. What is the yellow area in the inset map?

Page 4:

Paragraph 4:

- "Anthropogenic activities mostly contributed to..." But aren't all plastics related to anthropogenic activity?

- “activities mostly contributed to the present of” > “activities mostly contributed to the presence of”.
- “The areas have been known to” > “The areas are to”.
- “206.04–896.96 particle/kg”. You don’t need so many significant figures. The nearest gramme would be more than adequate given the huge range. Can you explain the units? Is this no. of particles per kg of water? I know this has been commonly used but I’m not clear as to the relevance of using particles as a measure. Are 10 small particles considered the same as 10 large particles?
- “mangrove area (896.96Å}160.28 particles/kg)”. Above the upper limit for the range was 896.96. Here you have 896+/-160 so the total range is higher than stated above. Needs to be clearer what you mean by ‘range’.
- “three times lower”. $200 \times 3 = 600$. Its more than 4 times.

Figure 2: what are the error bars? The total range? Presumably they should go in both directions. Makes more sense to show the actual values of the 3 replicates.

Page 5:

Paragraph 1:

- “in the Singapore`s coastal areas” > “in Singapore`s coastal areas”.
- “these studies, but the reasons” > “these studies, the reasons”.
- “Even though the abundances were very much different between these studies, but the reasons of the occurrence of the microplastics in the mangrove ecosystems were rather similar.”
- How do you know this? Either you have evidence for this or it is just a guess, in which case you need to use more careful language, e.g. “In both cases we suspect that the high abundance relates to large tidally driven transport of water through the mangroves and the capture of particles by the complex root systems.” NB you haven’t provided any information about the tidal circulation.

Paragraph 2:

- “...can be transported for long distance by ocean currents (Iwasaki *et al.*, 2017). Eastern water of Java Sea is the end point of a very big river, Bengawan Solo...” I don’t follow the link. In the first sentence you are talking about ocean currents. In the second you are referring to estuarine flow.
- “and carried plastic wastes” > “and carries plastic wastes”.
- “might not just from” > “might not just come from”.
- “but also from faraway places” > “but may have been transported considerable distances”.

- “during west monsoon” > “during the west monsoon”.
- “Similar results were also found in the study in the Saigon River canal” > “The importance of estuarine contamination was also found in a study of the Saigon River canal”.
- “pollution was from the land-based” > “pollution was land-based”.

Paragraph 3:

- “which located” > “which is located”.
- “resulted in a low abundance of microplastics” > “resulted in a low abundance of microplastics relative to the other sites.”
- “and some people from local village may have discarded their rubbish inside the pond.” > “and dumping of waste from the local village into the pond may have occurred.”

Paragraph 4:

- “while films occurred in very low number compared to the other two types of the microplastics.” > “while films occurred in very low numbers in comparison.”

Paragraph 5:

- “Fragments contributed the most to the composition of microplastics in the study areas”.
You just said this, no need to repeat.
- “and mostly the contribution comes from the domestic waste.” > “with the largest contribution coming from domestic waste.”
- “to the present of fiber, as mostly local fishermen use” > “to the presence of fiber, as local fishermen primarily use”.
- “fishing and nets” > “fishing nets”.

Paragraph 6:

- “were detected the highest at Station 1” > “were most common at Station 1”.

Page 6:

- Table 1: What’s the difference between an item and a particle?
- “...North Yellow Sea ... in the Bohai Sea...”. Describe where these are and the local setting.
- Fibres seem to be overwhelming in Bohai - did the authors explain what the source was? Would be nice to mention here. Also what are the source of films in the north Yellow Sea? Would be interesting to offer some explanation as to why the sources are different in different areas.

Paragraph 1:

- “The lack of awareness from the citizen on how dangerous plastic materials are...”. So what are the dangers?

Paragraph 2:

- “...mostly from anthropogenic activities...” What plastic isn’t related to anthropogenic activity?
- “carried away by” > “carried by”.

There seems to be a lot of speculation. Why does station 4 have so much less plastic than station 5, if the primary source is from the estuary?

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Physical Oceanography, Climate Science

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 06 February 2019

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This is a well-written paper on microplastic abundance in the bottom sediment east of the Java Sea. I have only trivial points to be improved.

- P. 3, "Methods": Please add "Bengawan Solo River" into Figure 1.
- P. 4, "Microplastic analysis": What was the maximal size of microplastics in your analysis? I recognized that the minimal sizes was 0.3 mm according to the mesh filter. The maximal size was however not specified.
- P.4, "Microplastic analysis": How did you avoid the contamination of fibers floating in the air in both the field and laboratory? We sometimes set a "blank" to monitor air-borne microfibers during the experiment. If you did not conduct the monitoring, please add the sentence: the abundance of microfibers detected in this study might be overestimated by the contamination due to air-born microfibers.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: transport and fate of oceanic microplastics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 11 Feb 2019

Syarifah Sari

We would like to say thank you to Prof. Atsuhiko Isobe for the comments and suggestions. Our responses to his concerns on making the improvements to our paper are presented below:

- P. 3, "Methods": Please add "Bengawan Solo River" into Figure 1.
 - We will add the Bengawan Solo River into Figure 1 in our next revised version of the manuscript.
- P. 4, "Microplastic analysis": What was the maximal size of microplastics in your analysis? I recognized that the minimal sizes was 0.3 mm according to the mesh filter. The maximal size was however not specified
 - The maximal size was 5 mm. We conducted filtration using stacked arrangement of sieves in the size of 5 mm and 0.3 mm to collect microplastic samples.
- P.4, "Microplastic analysis": How did you avoid the contamination of fibers floating in the air in both the field and laboratory? We sometimes set a "blank" to monitor air-borne microfibers during the experiment. If you did not conduct the monitoring, please add the sentence: the abundance of microfibers detected in this study might be overestimated by the contamination due to air-born microfibers.
 - We did not conduct the monitoring of air-born microfibers, therefore, we will add your suggestion to the revised manuscript.

Competing Interests: No competing interests were disclosed.

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