Microplastic pollution in lower Cimandiri River, Indonesia: early detection on the occurrence, abundance and distribution

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Abstract. Increasing in production and use of synthetic plastic materials constantly are responsible for the global increase in plastic debris in freshwater environments especially rivers. River is believed to be one of the important way to transport microplastics from inland to the Ocean. The study was conducted to assess early detection of the occurrence, abundance and distribution of microplastics (MPs) in lower Cimandiri River, West Java, Indonesia, in which its water flows to the Indian Ocean. The water and sediment samples were collected in September 2020 from seven sampling sites in the upstream river tributaries, in the downstream segments and in the estuary. The analyses were done using a monocular stereo microscope in the laboratory. Preliminary detection showed that the abundance of microplastics was as high as 96 - 325 particles/m³ in the water and 620 - 950 particles/kg in the sediment of Lower Cimandiri River. Fibers accounted for > 70 % of the MPs types, and the size of < 300 µm was the dominant MPs found (> 60%). Predominated small size MPs could pose a threat to the eels population sustainability. High MPs detected in Lower Cimandiri River could be a potential source of MPs pollution to the Indian Ocean.

1. Introduction
Increasing in production and use of synthetic plastic materials constantly are responsible for the global increase in plastic debris in the freshwater and marine environments. A study by Jambeck [1] estimated 275 million metric tons (MT) of plastic waste generated in 192 coastal countries in 2010 with 12.7 million MT entering the ocean. Indonesia is reported to be the second largest source of plastic waste dumped into the sea worldwide [1]. It was estimated 67% of the global total of plastic emission to the ocean were from the top 20 polluting rivers, mostly located in Asia where out of 15 rivers, four were from Indonesia [2]. Rivers are regarded as sinks and pathways of plastic pollutants from terrestrial environment and/or land-based sources to various aquatic system such as lakes, reservoirs, rivers and oceans [3,4,5].

Plastic debris, once entering the environment, are subject to physical, chemical and biological weathering processes, which are broken down into smaller fragments known as microplastics (MPs). There is no clear consensus on definition of MPs based on size, however most of studies classified MPs as any synthetic solid particles or polymeric matrix with size of < 5000 µm [6,7,8]. Fragmented plastic wastes are considered as the secondary source of MPs in which fibers and fragments are the common...
dominant shapes are found in all ecosystems. The primary source of MPs is plastic which is manufactured in small size such as pellets and microbeads. However, fragmented plastic wastes have been reported as the main source of MPs pollution in the environment. The most common forms of MPs occurrence in the freshwater ecosystem were fibers>fragments>pellets or microbeads [8,9].

Despite growing issue and concern on microplastic (MPs) pollution in Indonesian freshwater and marine environment, relevant studies on those are still very limited. Fewer studies have been reported on MPs pollution in the bay area and marine environment in Indonesia [10,11,12]. Even less studies on MPs occurrence in the freshwater environment [13,14].

MPs have been found in the water and sediments of seas, beaches, lakes and rivers globally, with concentrations correlated with human population density [7]. The distribution of MPs in freshwaters has not been documented as well as that of marine ecosystems. MPs in the environment are of increasing concern because of their persistence and effects on the wildlife, and potentially, humans. Small MPs can be ingested by fish and even small organisms such as zooplankton and benthic invertebrates [15,16]. MPs has also been known to adsorb toxic metals and organic pollutants [17,18] and these metals or organic pollutants contaminated MPs could be ingested by lower trophic organism and finally to higher trophic organism including human via food chain posing threat on human’s health.

Rivers in Indonesia become a hotspot of plastic pollution and is considered to be the second largest riverine sources of plastic to the Ocean worldwide. The study has been conducted to assess the occurrence, abundance and distribution of microplastics (MPs) in downstream and estuary of Cimandiri River, West Java-Indonesia, in which its water flows to the Indian Ocean. Early detection of MPs was reported in Cimandiri upstream and the watershed tributaries [13], however there is no study reported in downstream area or the estuary area of Cimandiri River. Lower Cimandiri has been the habitat for the eels (babies) of migratory fish of freshwater eels (*Anguilla* sp.) [19]. These eels has high economic values in the region and become a hot export commodities. Microplastics pollution in this river has become concern due to the possibility of Mps ingestion by the eel elfers and threatening the eel’s health and population sustainability.

2. Materials and methods

2.1. Sample collection

The sampling locations were two (S01 and S02) in the tributaries of river upstream, two locations (S03 and S04) in the downstream and 3 locations (M01, M03, M03) in the estuary of Cimandiri River. The sampling was conducted in September 2020 which is a late hot (dry) season. The map of sampling locations is presented in figure 1.

Water samples were collected by using a plankton net (300 µm mesh size) equipped with a flow meter (Hydrobios). The sampling were done in a grab sample mode [20] especially in the upstream segment and by towing the net using a fishing boat for at least 5 to 10 min in the river segments of downstream and estuary. The volume of samples were calculated from the recorded flowmeter (initial and final), distance and the time of sampling multiply by the area of the net mouth. The MPs particles in the collected samples were investigated according to previous studies for the analysis of MPs in water and sediment samples [12, 21,22]. The water samples were sieved using stainless steel sieves with different mesh size (100, 300, 500, 1000 µm) (RETSCH quality). The Mps were rinsed using ultra-pure water from the sieves and filtered through the glass microfibre filters (GFF (Whatman), diameter of 47 mm, pore size of 1.2 µm) and or through grid cellulose nitrate filters (Sartorius, diameter of 47 mm, pore size of 0.45 µm) using glass filter apparatus with a vacuum pump. The prepared samples (filters) were dried to a dry mass at 40 °C for 24 - 48 h and stored in glass petri dishes to avoid contamination.
The extraction of MPs from sediments was performed based on density separation according to the modified method developed by Falahudin et al. [12] and Sekudewicz et al. [21]. The wet sediments are dried at 40 °C for 48 - 36 h and homogenized. A 50 grams of a dry sediment sample from each location was transferred to 250 mL glass flasks in three replicates and added with 30% H₂O₂ and heated at 40 °C for 24 hours in the water bath. Then the samples were added hypersaline solution (1.23 g/L) and stirred. The floatation process was done twice. The extraction of MPs from the supernatant followed the same procedure of water samples.

2.2. Microplastic identification
Microplastic (MPs) observation and quantification were carried out under a stereo microscope with a magnification of 20-60 x magnification (Olympus SZX10). The characteristics of MPs were observed according to number, size, shape and color. The shape for MPS was identified as lines/fibers, fragments, sheets, films, foams and microbeads [7,21,22]. Selected MPs were characterized to confirm the chemical types of MPs using Raman Spectroscopy (Horiba).

To limit contamination during sample processing, only glass bottles, beakers and filter apparatus and stainless-steel sieves were used. Hypersaline solution is pre-filtered with milli pore filter paper (0.45μm pore size, 47 mm diameter). Ultra-pure water (Merck, Milli Q water purification system) is used to rinse the sample and/or glass wares/equipment. The contamination in the laboratory was checked regularly by performing procedural dry (air pollution) and wet (sample processing pollution) blank samples.

The MPs abundance is presented as particles/m³ for water samples [21,23] and particles/kg. dw for sediment samples [12].

3. Results and Discussion
3.1. The occurrence and abundance of microplastics in the water
Diverse microplastics (MPs) were observed along the river segments of lower Cimandiri River. The occurrence and abundance of MPs according to shape and size in each sampling location from the upstream to the estuary area can be seen in figures 2a (shape) and 2b (size). The abundance of MPs ranged from 96 – 325 particle/m³ in the surface water of lower Cimandiri River in which the most abundance of MPs found was in the first segment of estuary (M03). The abundance of MPs were quite high as well in one of the tributaries of upstream river (S02). The abundance of MPs in the river water
found in this study was smaller than those in Ciwalengke River, Indonesia [14] which has been polluted by textile wastewater, Cimandiri watershed [13] or other global studies in Yangtze River, China [8] and urban lakes, China [24] but higher than those in Dongshan Bay, China [23].

Fibers were predominant MPs found with more than 70% (Figure 2c) whereas the size of MPs majorly observed was < 300 μm (30%) especially in the estuary (Figure 2d). The major MPs shape found could be regarded as an indicator of its origin. The estuary area has been harboured for fishing boats and also for capture area for the freshwater eel’s elvers (babies eel) [19]. Fragmentation of abandoned or lost fishing nets, ropes and clothing were probably major contribution of the MPs fibers found in lower Cimandiri River [23]. Fibers/line and fragments were among MPs shape observed in global freshwater even marine environment. Smaller size of MPs of < 500 accounted for significant proportion was also reported by the previous studies [8,22,23].

![Figure 2. The occurrence and abundance of microplastics in the river and estuarine waters according to shape (a) and size (b). Percentage of the microplastic occurrence according to shape (c) and size (d).](image)

3.2. The occurrence and abundance of microplastics in the sediment
The occurrence and abundance of microplastics (MPs) in the sediment of lower Cimandiri River based on the shape and size are presented in figures 3a and 3b respectively. The abundance of MPs in lower Cimandiri River ranged from 600 – 950 particles/kg. Similar results of MPs shape and size were observed in the river sediment. Fibers predominated MPs at most locations with around 67% of MPs found (Figure 3c). Small MPs particles (< 300 μm) were predominant at locations in the estuary. The abundance of MPs in the river sediments were much higher than those in the waters. Surprisingly the highest abundance of MPs found in the upstream tributary (S02). The most upstream of this tributary is the urban area which is affected by anthropogenic activities. High plastic waste from the terrestrial run off or directly dumped in the river might contribute major MPs pollution in this location. The abundance of MPs found in the river sediment of this study was comparatively higher than those found in Ciwalengke River, Indonesia [14].

Heavier (higher density) MPs such as fibers and fragments may sink in to the sediment. Particle size affects the fate and retention of microplastic in the sediment along the river. Sediment of river segments with low stream could be a hotspot for deposition of microplastics due to MPs with higher density tent to be retained in the sediment as found in the urban area upstream tributary (S02) [6,8,14].
Figure 3. The occurrence and abundance of microplastics in the river and estuarine sediment according to shape (a) and size (b). Percentage of the microplastic occurrence according to shape (c) and size (d).

3.3. Characteristics of microplastics
Several microplastic (MPs) characteristics found in the water and sediment sample of lower Comandiri River (Figure 4) with distinct microplastics (MPs) shape, size and color were observed along the lower Cimandiri River. A diverse range of MPs color including green, red, blue, black/grey, white and yellow were observed in the river surface water and sediment (Figure 5). Green and red were predominant MPs color found in all location especially in the estuary. Mostly the fibers and fragments with green, red and blue color were observed and other color appeared occasionally. Diverse colored MPs may be mistaken as the food and can be ingested or swallowed by the biota especially fish [15,16,18]. The smaller size of MPs could be ingested by the freshwater eels elfers (babies) which inhabit the river estuary.

We tempted to examine the type of plastic chemical of fewer selected MPs by using Raman Spectroscopy, however we did not get a clear spectra pattern which indicated certain type of plastic chemical. Fibers found in this study looked similar to fibers found in other previous studies [14,23]. Fibers were considered the main ingredient of fishing nets, ropes and clothing [23,24].
Figure 4. Characteristics of several of microplastic shapes observed in the river water and sediment

Figure 5. The occurrence and abundance of microplastics in the river water (particle/m$^3$) (a) and sediment (particle/kg) (b) according to color of Mps.

3.4. Distribution of microplastics and possible its transport and fate from the river upstream to estuary even to the ocean?
Spatial distribution of microplastics (MPs) in lower Cimandiri River showed that the abundance of MPs did increase from river downstream to the estuary (Figure 6) indicating possible transport of MPs from the river to the ocean. Fibers, fragments and sheet were distributed along the river segment with fibers and small MPs particles (< 300 μm) were predominant in all locations in the estuary. Low abundance of MPs in the water upstream and high abundance of MPs in the upstream sediment found in this study suggest that the source of MPs in lower Cimandiri River could be impact from the anthropogenic activities. Lower Cimandiri River especially in the estuary has been harboured of fishing boats and activities. The area has been a hotspot for intensive catch fishing especially for babies eels. Human-induced hydrodynamics is considered an important factor in controlling the local MPs distribution [4,8,23].
Higher abundance of MPs in the river sediments at all locations especially at the estuary and river upstream indicated that MPs fate were deposited in the sediment. The results of this study indicated that although there is potential for MPs transport to the ocean, the fate of MPs could be deposited in the river sediments. This study was conducted at peak of dry season where river at low flow. River hydrologic regime is considered to be the main factor of MPs transport to the ocean. Rivers have become the main sources of plastic to the Ocean worldwide [4,5].

3.5. Implication of the microplastic pollution to the biota
Microplastic (MPs) pollution could have potential risk to living organisms because microplastics could be ingested and swallowed by fish, bivalve, shrimp which are commonly consumed by human [15,18]. The common forms of ingested MPs were fragments, fibers and microbeads with the size range of 50 to 200 µm and polymer types of polyethylene, polypropylene, rayon, polyester, polyamide and another copolymer [15,16,18]. MPs could finally reach to higher trophic organisms including human via food chain posing threat on human’s health. Lower Cimandiri has been the habitat for the important of migratory fish of freshwater eels elfers (babies) (Anguilla sp). These babies of eels eventually migrate to the river upstream until reaching adult’s age [19]. Predominated small size MPs of < 300 µm were found in the estuary area of Cimandiri River and with diverse color of MPs could be mistaken as food and subsequently ingested by biota including the baby of eels. Therefore, Mps pollution in this river has become concern due to the possibility of Mps ingestion by the eel elfers or even at adult’s stage and thereby threatening the eel’s health and population sustainability.

4. Conclusion
The abundance of microplastics in lower Cimandiri River is considered intermediate compared to those in other rivers. Higher abundance of microplastics found both in the water and sediment at all river segments in the estuary where high human activities such as intensive catch fishing for babies of eels and sea fishing. Fibers predominated MPs types observed and the MPs size of < 300 µm was the dominant MPs found along the river segments of lower Cimandiri River. Predominated small size MPs could potentially be ingested by the eels even at early life’s cycle. Microplastics pollution in lower Cimandiri River could pose a threat to freshwater eel population sustainability. Higher MPs detected in Lower Cimandiri River could be furthermore transported to the Indian Ocean.
5. References

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