The influence of weirs on microplastic fate in the riverine environment (case study: Jeneberang River, Makassar City, Indonesia)

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Abstract. The riverine environment is known as the main pathway of microplastic entering the ocean. Recent studies show that the barricading of water flow in the riverine environment can influence the microplastic load to the ocean. The Jeneberang River, which is located in Makassar City, is prone to microplastic pollution. There are three weirs located in this river as water barricades. The aim of this study was to measure the microplastic abundance upstream and downstream of each weir flow. Microplastics in the water compartment were measured using the volume-reduce towing method and were measured in the sediment compartment using a density separator method. The results showed that microplastic abundance in the water prior to passing each weir was higher (1.43 – 3.19 item/m³) compared by the flow after each weir (1.20 – 2.10 item/m³). The same pattern was also apparent in the sediment compartment where the microplastic abundance prior to the weirs tended to be higher (28.33 – 56.67 item/kg DW) compared to the compartment after the weir (30.00 – 53.33 item/kg DW). Based on microplastic shape, there is no evidence that weirs in the Jeneberang River are blocking any specific shape of microplastic. In conclusion, weirs that are commonly found in the riverine environment could act as microplastic retention devices in the riverine environment.

1. Introduction

Rivers are one of the main routes for plastic waste to enter the marine environment. It is estimated that 5 to 12 million metric tons of plastic waste leaked into the ocean annually from more than 190 coastal countries [1]. Rivers with high plastic emission are located mostly in countries with high plastic leakage to the ocean [2]. Not only plastic waste in General, the input of microplastic (MPs) to the ocean mostly also come from the riverine area. Up to 80% of primary MPs in the ocean come from the river around the world [3]. This condition makes the river is a critical pathway for plastic, MPs in particular, to enter the ocean environment.

Microplastic is the tiny pieces of plastic (< 5mm) that come from the primary and secondary source [4,5]. Microplastic from primary source originates from the raw pellet and other virgin plastic sources. In comparison, the secondary MPs originates from the larger piece of plastic that breaks into tiny pieces due to several processes such as UV light exposure, mechanical abrasion and increment of temperature [6,7]. Microplastic with a similar appearance to the planktonic organism in the aquatic environment can be mistaken as food by the aquatic organism [8]. Microplastic can adsorb hydrophobic pollutants and transferred to the aquatic organism once MPs being ingested [9]. This makes MPs ingestion harmful
due to the physiological disruption and the potential of biomagnification in the food web. With its potential dangers, MPs pollution is a threat to environmental health.

Microplastic leakage to the ocean environment can be influenced by several factors such as the existence of dense domestic area, season, and also river condition (i.e., the presence of in-stream barrier) [10,11]. The existence of dam is known to influence the pollutant fate in the riverine environment. Microplastic fate in the river is also influenced by the existence of sizeable in-stream barriers such as dam. Microplastics are higher in the area prior to the dam in the water and biota compartment [12,13]. But, the research on the smaller in-stream barrier such as weir on MPs fate is still lacking.

Makassar City, Indonesia, is one of a growing city with up to 1.4 million residents. This city is known as a source of plastic pollution in its ocean environment, especially in its coastal area and Makassar Strait [14]. Jeneberang river is one of the rivers in Makassar City that is directly feeding the Makassar Strait. This river is one of plastic waste hotspots with the emission of plastic waste up to 200,000 kg annually [2]. This river is also known as the source of MPs pollution to the Makassar Strait [15, 16]. Jeneberang river was equipped with riverbank construction and several in-stream barriers. The Bili-bili dam was created in 1999 followed by Jenelata dam in 2019 [17], and several weirs were also built in this river. In the lower Jeneberang river, at least three weirs are present. Starting from the upper-most stream are Sungguminasa, Tamalate and Karet Weirs.

This research aims to determine the influence of weirs existence on the fate of MPs. Abundance and characteristics of MPs in the upstream part and downstream part of the weir were compared. This information can be preliminary data to help solid waste management in Makassar City, especially in term of MPs pollution.

2. Material and Methods

This study was conducted in January-August 2019. Sediment and water samples were collected from the upstream and downstream parts of Sungguminasa, Tamalate and Karet Weir in Jeneberang River, Makassar, Indonesia (Figure 1). The upstream area represents the river flow before the weir area based on river current direction. In contrast, the downstream area represents the river flow after the weir location. Samples were collected in six replications on each location.

Water samples were collected using a protocol described by Wicaksono et al. [15]. Neuston net with mouth heigh 15 cm and width 60 cm were towed to collect 350ml accrued water in the net cod-end by pulling the net in vertical to the water current direction. Water samples then keep into the 4°C to prevent algae and microbial growth until the laboratory analysis process.

Sediment samples were collected from the sampling point using a sediment core with a 5 cm diameter. Wet sediment samples (about 400g wet weight) then put in the zip lock bag and transported to the laboratory under low temperature (4°C). in the laboratory, the sediment then dried at 60°C for two days to remove the water content from the samples. About 100g of dried sediment then subjected to 300ml of NaCl solution (ρ = 1.2 g/cm³) for density separation [19, 20]. The samples then agitated using a magnetic stirrer for 2 minutes, followed by a density separation method until the supernatant was created.

Preserved water samples and sediment supernatant were filtered to the cellulose filter to separate the solid material and the liquid. Microplastic in the filter was then identified and counted using Stereomicroscope (Euromex Stereoblue). Microplastic shape determination was following the guide published by GESAMP (2019) [20]. Microplastic abundance was presented in item/m³ and item/kg dry weight for water and sediment samples, respectively.
3. Results and Discussion

All water samples (n=36) collected from the study sites contain MPs with abundance ranging from 1.20 – 3.19 item/m$^3$ (Figure 2). In general, MPs abundance in the downstream part of the weirs were lower (1.20-2.10 item/m$^3$) compared to the upstream part (1.43 – 3.19 item/m$^3$) of the weir. This pattern indicates the tendency of MPs retention in the upstream part of the weir. High MPs abundance behind the in-stream barrier in river environment has also been reported in several locations. Watkins et al. [21] reported a high abundance of MPs in the upstream part of six dams in New York, USA. The upstream part of the dam in the Qing River, China, was also reported to have about 80% higher MPs abundance on water compared to the downstream part [13]. The existence of manmade infrastructure in a lotic environment (i.e., weir, dam, bridge pier) can substantially decrease the water velocity due to reduced water momentum [22]. Low water velocity in the aquatic environment can increase the retention time of MPs, lead to the higher abundance of MPs in the upstream part of the weir.

Figure 1. Sampling sites on Sungguminasa, Tamalate and Karet weir, Jeneberang River, Makassar, Indonesia.
Figure 2. Microplastic abundance on the water samples (n=6, each bar).

Microplastic abundance in sediment samples shows a similar trend with the water samples. Microplastic abundance on sediment in the upstream part of the weir are generally higher (28.33 – 56.67 item/kg DW) compared to sediment in the downstream (30 – 53.33 item/kg DW) (Figure 3). Only MPs abundance in Karet Weir show different patterns where MPs abundance in the downstream part is higher than in the upstream part of the weir. These results were indicating the sinking process of MPs in the upstream part of the weir. In low water velocity, the high-density polymer of MPs tends to sink caused by the physical process.

Microplastic with a higher density than water (1 g/cm³) will be sink because of gravity force. Microplastic with low density also can be shrouded by biofilm and lead to the increment of its density [24, 25]. That sinking process can transport the MPs item from water to the sediment compartment. The difference pattern of MPs abundance in Karet Weir might be because of its location. Karet Weir is the closest weir to the estuary environment that makes this weir affected by the tidal variation. In the high tide condition, the river current is affected by the water mass from the ocean and creates the backflow of the river current. This condition makes the downstream part of the Karet Weir get MPs intake from the sea. With the low water velocity, MPs can be transported to the sediment compartment and increase the MPs abundance on the sediment in the downstream part of Karet Weir.

Figure 3. Microplastic abundance in sediment samples (n=6, each bar).
Microplastic items at all locations were dominated by fragment and Line shape (17.95 – 79.49%) (Figure 4). The only small number of film and foam shapes (1.06 – 16.67%) and there is no pellet MPs found on the study area. Fragment and Line are the common MPs shape to be found in the aquatic environment. Most line MPs originate from synthetic textiles [3]. Single washing machines with less than 10 kg washing load of fabric can release more than 700,000 line items per wash [25]. Leakage of those fibres into the aquatic environment will lead to a higher proportion of line MPs. There is no evidence of weir to block any specific shape of MPs in all three weirs observed in this research. Most dominant MPs shape in the upstream part of the weir also exists almost in the same proportion in the downstream part of the weir.

To this date, this is the first research that compares the MPs abundance and shape between weir’s upstream and downstream parts. This research provides information on how the existence of weir can affect the MPs fate in the riverine environment. Based on the results, we suggest that using in-stream barriers in the riverine environment (i.e., Trash trap and weir) could be a useful device to prevent solid waste from leaking to the ocean. That barrier can decrease the water velocity and trap the solid waste (macro- and microplastic) to be more collectible and easier to handle.

4. Conclusion

In conclusion, MPs abundance in the upstream part of the weir is higher in the water and sediment compartment. The results show the retention process of MPs by the weir. It is suggested to use the in-
stream barrier devices (i.e., weir, trash trap, dam) as an alternative to prevent solid waste entering the ocean.

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