Preliminary study on microplastic pollution in surface-water at Tallo and Jeneberang Estuary, Makassar, Indonesia

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Abstract. Microplastic is anthropogenic-based pollution that becomes a global problem, threatening the ecosystem and food security. Microplastic from land-based source can enter the ocean through estuarine waters. Makassar City with a population around 1.7 million people, provides possible sources of microplastic pollution in Makassar Strait through the flow of surrounding rivers, Tallo and Jeneberang in particular. Neuston net method was used to collect 18 surface-water samples from Makassar Estuaries for microplastic analysis. Fish gastrointestinal tracts were collected from 76 pelagic fish in study sites for microplastic analysis, using KOH digestive method. Surface-water samples from both Jeneberang and Tallo river estuaries positively contained microplastic (MPs) particles with abundance of 1.84±0.17 and 1.78±0.25 MPs m^{-3} respectively. There is no difference between microplastic abundance on both estuaries using t-test statistic, but microplastic from both estuaries, in general, has different characteristics in shape and color. The higher abundance of microplastic in riverine part on both estuaries indicated that microplastic originated from land sources. Pelagic fish from both estuaries were also contained an average of 0.91 to 3.5 MPs $individual^{-1}$ with more than 50% of contamination level on most species. This result shows that estuary water in Makassar City have been contaminated by microplastic particles and have accumulated to pelagic fish as consumption fish, posing a threat to food safety and human health.
Key Words: plastic, ingestion, water, fish, abundance, river.

Introduction. Plastic pollution globally has been reported to occur in various ecosystems such as in terrestrial, freshwater and marine environments (Cole et al 2011; Dris et al 2015). In the global scale, it is estimated that 4.8 to 12.7 metric tons of plastic waste leaked into the ocean from 192 coastal countries (Jambeck et al 2015). Plastic debris that enters the aquatic environment can contain a wide range of sizes (GESAMP 2019). Microplastics (from here on will be referred to as MPs) is a type of plastic debris with size of <5 mm (Cole et al 2011; Moore 2008). Microplastic can be derived from the fragmentation of larger plastic debris (Corcoran et al 2009; Song et al 2017) or comes from the use of personal care products/cosmetics (Boucher & Friot 2017). When larger plastic debris is easier to understand, this micro-sized plastic is still not fully understood.

Microplastic that leaked into the environment can have a different fate. Microplastic from the terrestrial location can be carried through the water flow and run-off mechanism to enter the river (Dris et al 2015). Some types of MPs that have a low density polymer (i.e., polyethylene and polypropylene) mostly will float in the surface water (Andrady 2011) and then flow into the ocean environment through the estuarine (Boucher & Friot 2017; Dris et al 2015; Lebreton et al 2017). Microplastic particles already reported exist in estuarine water globally. Estuarine water from South California, USA are known to have MPs particles up to 30 particles L^{-1} (Gray et al 2018), while estuarine water from South-east Coast Australia tends to contaminated by MPs up to 1,000 MPs m^{-3} (Hitchcock & Mitrovic 2019). The existence of MPs particles in the estuarine environment depends on the anthropogenic pressure around the estuary (Hitchcock & Mitrovic 2019). Based on the model calculation, the release of primary MPs

from the land to the ocean is at least 0.8 metric tons year^{-1} on a global scale (Boucher & Friot 2017).

The occurrence of MPs particles on surface-water will have a negative impact on the ecosystem. Microplastic can adsorb toxic compounds in the water like PCB, DDT and PAH (Wang et al 2018). In addition, MPs itself already contains dangerous compounds that can have a detrimental effect on aquatic organisms (Rochman 2015). Microplastic with a small size can resemble natural food of fish, so the fish mistook for MPs as one of its natural prey (Cole et al 2011; Dris et al 2015). The occurrence of MPs ingestion by estuarine fish has been reported. 14 species of estuarine fish in Amazone Estuary, Brazil, known to ingest pellet form of MPs (Pegado et al 2018). Another study in the northeast coast of Brazil shows that 24 species of estuarine fish tend to ingest MPs 1.06±0.30 MPs individual^{-1} on average (Vendel et al 2017). Meanwhile, a study conducted in China shows that coastal and freshwater fish from Yangtze estuary are known to uptake MPs 1.1–7.2 MPs individual^{-1} (Jabeen et al 2017). The existence of MPs in fish, especially consumption fish, will enable the transfer of toxic substances present in these MPs to be able to move and threaten the sustainability of food safety and human health (Gabriel et al 2018; Santillo et al 2017).

Makassar City, the capital of South Sulawesi Province, has a population around 1.7 million people. Makassar City produces 425 tons of mismanaging garbage day^{-1} with nearly 17% of its proportion is a plastic waste (Ministry of Environmental and Forestry Indonesia 2019). The presence of mismanaging garbage can enter the environment such as rivers and canals, then flow to the estuary environment. Makassar City flanked by two large rivers, the Jeneberang and Tallo River, which both river located in the south and north part of the city respectively. The two rivers that directly feeding Makassar Strait are predicted to transport waste originating from Inland to the Makassar Strait. The fish caught from the Spermonde Archipelago, part of Makassar Strait close to the Makassar City, are already known to accumulate MPs particles (Rochman et al 2015; Tahir & Rochman 2014). However, there is a lack of information about the occurrence of MPs particles in fish captured from both estuaries.

The aims of the present study are to determine the abundance and characteristics of MPs particles present in surface-waters of the Jeneberang and Tallo estuaries. We also analyze the presence of MPs particles in the gastrointestinal tract (GIT) of pelagic fish captured from both estuaries. The results of this study will provide general information of MPs contamination in Makassar estuaries and its probability to transfer into pelagic fish from those estuaries. Further, the results of this study can dominate as one of the bases for management purpose on waste pollution in Makassar City.

Material and Method. The research was conducted in March 2019. Samples were collected from the Jeneberang and Tallo estuarine areas. The sampling was carried out at 3 stations in each estuary (Figure 1). Station points cover riverine, estuary and river-mouth sections of estuarine. The riverine section represents the upper estuarine region where the influence of freshwater is higher on this area. Estuary section represents the middle part of the estuarine area, a mixture of freshwater and seawater happens in this area. Whereas river-mouth represents the closest part of estuarine with the ocean environment.

Surface-water samples were collected 3 times from each section from both estuaries using a modified neuston net method (Syakti et al 2017). Rectangular-mouth neuston net (60 x 15 cm mouth-size, 330 μm mesh-size, and 300 mL cod-end volume) was towed across the river. Tow distance was measured using a GPS. The volume of water filtered was measured by multiplying the neuston net-mouth with the towing distance. Water that accrued in the cod-end was then transferred into polypropylene sample bottle and preserved in coolbox filled with gel ice. In the laboratory, the water samples were filtered using a vacuum pump (Rocker 410) into cellulose filter (Whatman WCN type 7141-104). Cellulose filter was then transferred into a petri dish for visual identification.

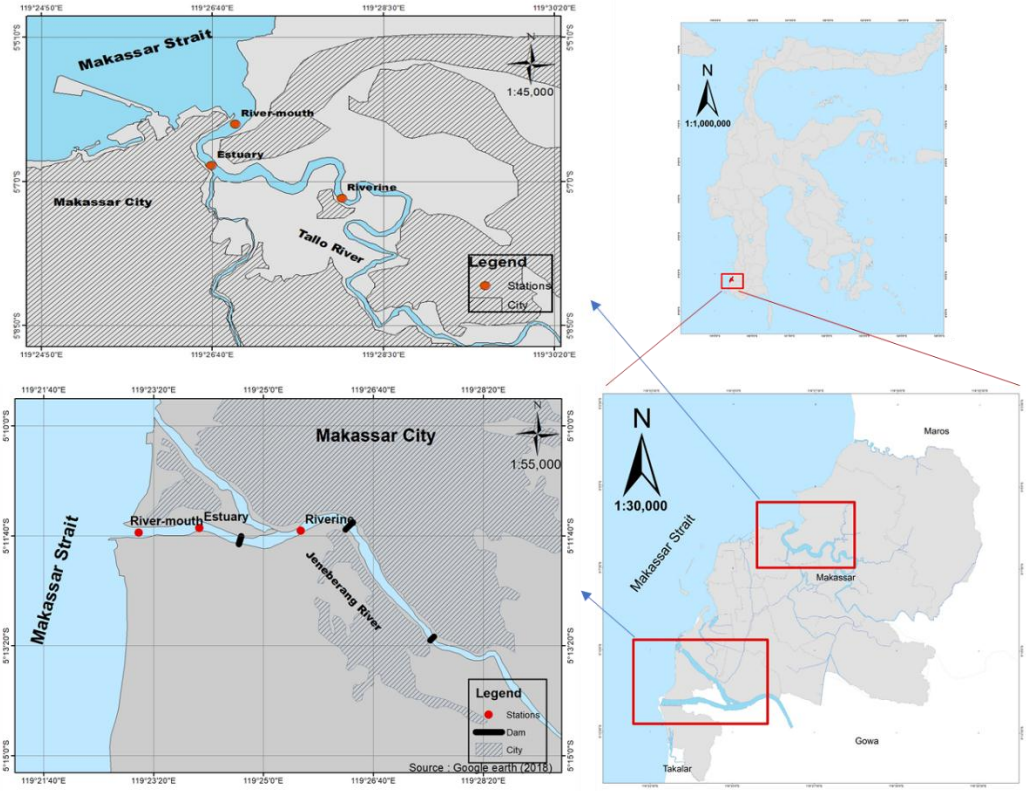

Figure 1. Study site, Tallo (top) and Jeneberang (bottom) Estuary on Makassar City.

Pelagic fish samples were collected randomly from each estuarine using gill-net. Captured fish were then placed into a ziplock plastic and introducedt into a coolbox filled with gel ice. Fish were pictured, measured for weight and length then identified up to species level, and dissected. Fish gastrointestinal tract (GIT) were taken and placed into polypropylene bottle. Samples added with 3 times samples volume of 10% KOH solution (100 g KOH crystal + 1 L double distilled water) and heated for 12 h (Rochman et al 2015). Fish samples were further observed visually using a stereomicroscope.

All samples were identified visually using stereomicroscope (Euromex SB1902) with 45x magnification. Samples were observed in a closed glass petri dish to avoid contamination. Petri dish cover was only opened when MPs were present in the samples which were taken for preservation purpose. For negative control, sample blanks were created and observed in every 5 samples. Microplastic characteristic (shape and color) identification referred to GESAMP (2019). Microplastic abundance on surface water samples was expressed in MPs m^{-3} while MPs abundance on pelagic fish samples was expressed in the unit of MPs $individual^{-1}$.

Results and Discussion. All surface-water samples (n=18) were taken from both estuaries were positively contained MPs particles with no suspected MPs particles in all sample blanks. The average abundance of MPs observed from Jeneberang and Tallo estuary were 1.83±0.17 and 1.78±0.25 MPs m^{-3}, respectively. Based on statistical analysis using unpaired T-test, there was no difference in MPs abundance between the two estuaries (P=0.82). Microplastic abundance on both estuaries shows a similar trend (Figure 2). In both estuaries, riverine section consistently shows higher MPs abundance compared by other two estuarine sections. The riverine section is the closest section to the populated area in Makassar City. The existence of settlement location may produce higher MPs particles from anthropogenic activities to the surrounding waters. Mani et al (2015) stated that the river part which is located in the high inhabited area would have higher MPs particles in surface-water, and mostly the increasing of MPs abundance in water is similar to the increasing of another anthropogenic-based pollutant (Kataoka et al 2019).

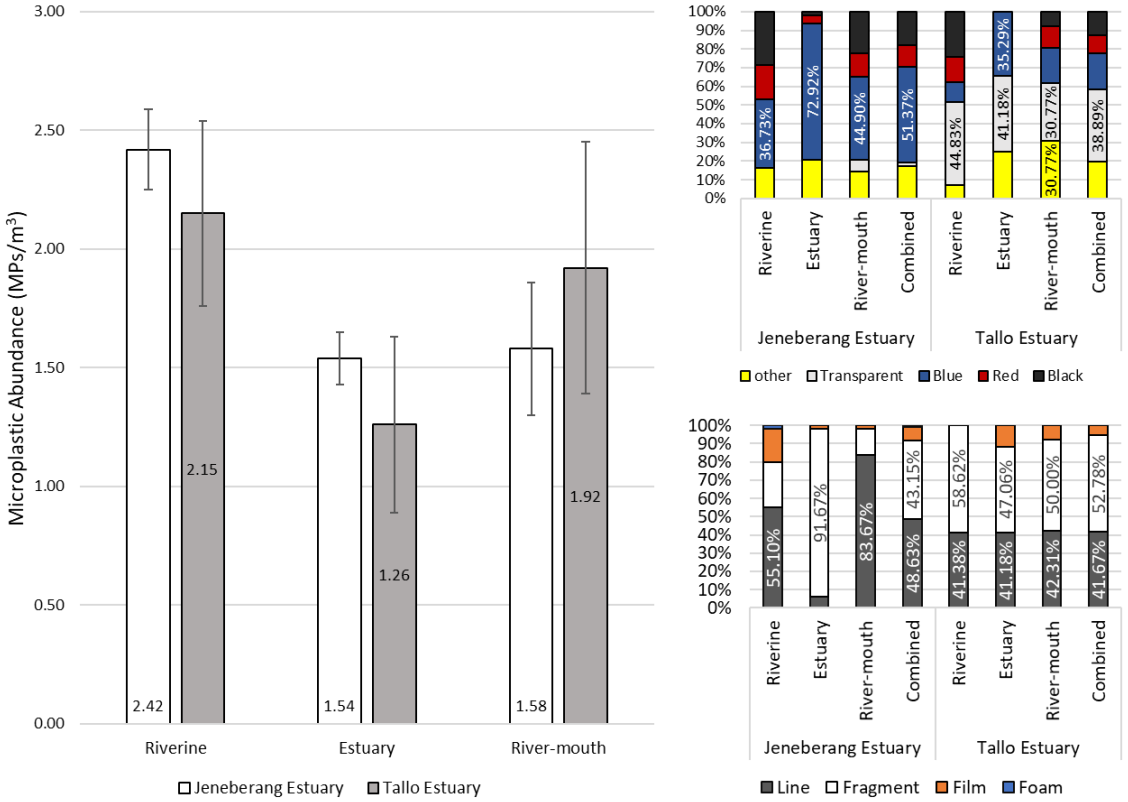

Figure 2. Microplastic abundance (left), Shape (Bottom right) and color (Top right) on surface-water of Jeneberang and Tallo Estuary.

In terms of MPs shape, the presence of MPs in Jeneberang Estuary was dominated by line (48.63%) while Tallo Estuary tends to be dominated by fragment (52.78%). In contrast, the estuary section of Jeneberang was dominated by fragment particles (91.67%). The existence of fragment generally comes from larger plastic fragmentation (Corcoran et al 2009). The higher abundance of fragment particles in Jeneberang estuary section could be the result of its position that is located near the open dumping landfill at its riverbank. The particles from the dumpsite could be exposed by the UV-B and higher temperature leads to fragmentation into the smaller plastic pieces (Corcoran et al 2009). Film and foam shape of MPs are less common compared by fragment and line in both estuaries. Even so, because there is no polymer identification, estimated of the plastic source cannot be determined accurately.

The dominant MPs colors found in both estuaries are also different. Jeneberang Estuary tended to be dominated by blue color (51.37%) while MPs from Tallo Estuary dominated by transparent colors (38.89%). Color of MPs could be useful information to determine the source of MPs particles (GESAMP 2019). A study conducted in Yangtze Estuary, China, found that the color of MPs was also dominated by colored and transparent MPs particles. The existence of transparent and colored particles of MPs mostly comes from the fragmentation of clear plastic packaging, clothing and fishing line (Cole et al 2014). Although the MPs abundance between two estuaries is not significantly different, MPs characteristics (shape and color) indicate that MPs in both estuaries originates from different sources.

Pelagic fish caught from Jeneberang and Tallo Estuaries consisted of 76 fish, which were divided into 3 different species (Table 1). 48 fish (63.16%) were positively contained MPs on their GIT. The average abundance of MPs in pelagic fish ranged from 0.91 to 3.5 MPs individual^{-1} (Figure 3). In general, MPs abundance in fish from Jeneberang were higher (2-3.5 MPs individual^{-1}) than Tallo Estuary (0.91–1.83 MPs individual^{-1}). Based on MPs accumulation trend, Indo-Pacific tarpon (*Megalops cyprinoides*) as carnivorous fish has the highest MPs abundance (1.83-3.5 MPs individual^{-1}).

Silver barb (*Barbonymus gonionotus*) as omnivorous fish showed the lowest MPs abundance (0.91-2 MPs individual^{-1}).

Table 1

Characteristic of pelagic fish captured from Jeneberang and Tallo Estuaries

Location	*Species*	*No. of samples*	*Total length ± SE (cm)*	*Total weight ± SE (g)*	*MPs contamination (%)*
Tallo Estuary	*Oreochromis niloticus*	25	13.6±0.31	51.14±3.31	68.00
	Megalops cyprinoides	12	25.75±0.61	154.44±10.36	66.67
	Barbonymus gonionotus	23	17.45±0.37	76.15±6.45	47.83
Jeneberang Estuary	*Oreochromis niloticus*	2	23.5±6	165.05±72.05	100
	Megalops cyprinoides	2	28.8±1.8	197.1±47.8	100
	Barbonymus gonionotus	12	20.28±1.14	146.39±20.16	66.67

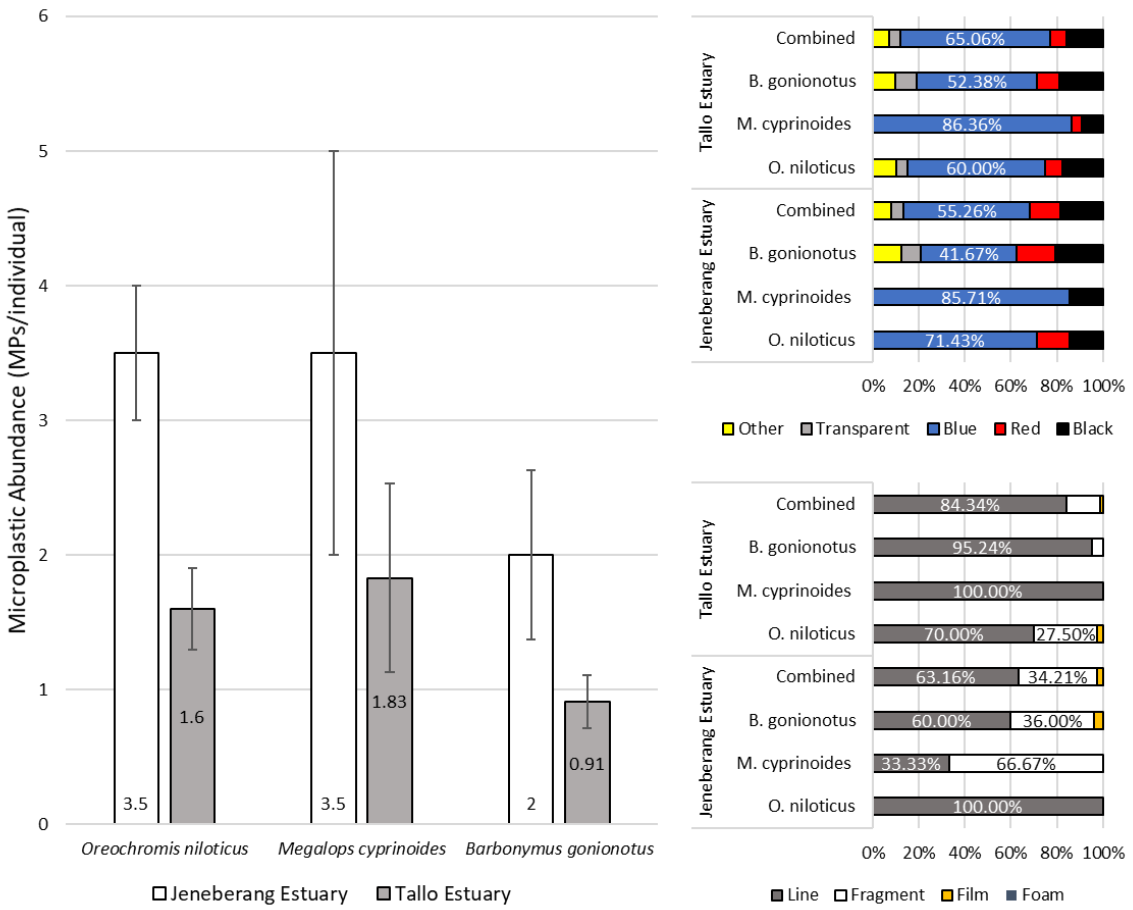

Figure 3. Microplastic abundance (left), Shape (Bottom right) and color (Top right) in Pelagic Fish captured from Jeneberang and Tallo Estuary.

It has been stated that the different trait species is known to make a difference in MPs uptake. Microplastic uptake in fish can occur through two mechanisms, directly from its habitat (i.e., from water and sediment) and indirect pathway (i.e., from trophic transfer).

A study conducted by McNeish et al (2018), showed that zoobenthic fish generally accumulate higher MPs particles compared by detrivore and omnivore fish. *M. cyprinoides* which is a carnivore fish are able to uptake MPs particles through the direct and indirect mechanisms, may lead to the higher level of MPs abundance in its GIT compared to the two other species considered.

In terms of MPs shape, MPs found in pelagic fish captured in Jeneberang and Tallo Estuaries was dominated by line-shaped (63.16% and 84.34%, respectively). Line-shaped MPs basically can mimic natural food forms in the aquatic ecosystem, for example, could resemble the shape of filamentous algae and phytoplankton (Cole et al 2011; Dris et al 2015). Phytoplankton is the preferred food of tilapia (*Oreochromis niloticus*) and *B. gonionotus*. This condition will lead to a higher abundance of line-shaped particles in the GIT of *N. niloticus* (70-100 %) and *B. gonionotus* (60-95.24%). Microplastic of blue color was the most dominant in all fish in both estuaries (55.26–65.06%), followed by red and black MPs. Fish tends to ingest more lighter color of plastic (i.e., white, blue, green and yellow) and less in red and black colors (Crawford & Quinn 2016). Lack of red wave spectrum in the blue aquatic environment will make the red particle to look like black particles (Land et al 2011) which are not preferable to fish.

The present study provides a general description of MPs contamination in the estuary environment in Makassar City. The result of this study consistently shows the presence of MPs pollutants which may originate from highly populated cities located in the upstream of estuary. The pelagic fish caught on this study area are all classified into consumption fish which are usually consumed by people around the estuary. The contamination of MPs particles into consumed fish clearly threatened food safety and human health. This research shows the need for waste management improvement in Makassar City, especially in plastic waste management.

Conclusions. Surface water on Jeneberang and Tallo Estuaries has been contaminated by MPs particles. There was no difference in MPs abundance at both estuaries, but MPs characteristics suggest that the MPs contamination came from different sources. Microplastic in surface water may have accumulated in pelagic fish which are also consumed by human, posing a threat on food security and human health. Further research on Jeneberang and Tallo rivers as a water source on both estuaries should be done for a complete picture of MPs pollution on the aquatic environment in Makassar City.

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