Abundance and characteristics of microplastics in Lake Towuti, East Luwu, South Sulawesi

[1]Muhammad A. Yusuf, [2]Khusnul Yaqin, [3]Ega A. Wicaksono [2]Akbar Tahir

[1] Magister Program of Fisheries Science, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia; [2] Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia; [3] Department of Fisheries, Faculty of Agriculture, Universitas Gadjah Mada, Sleman, Indonesia. Corresponding author: A. Tahir, akbar_tahir@mar-sci.unhas.ac.id

Abstract. Microplastics, less than 5 mm in size, are directly harmful to both aquatic organisms and humans because of their ability to absorb various toxic substances, threatening the safety and health of humans when consuming aquatic organisms that have been contaminated. Microplastics research is commonly carried out in marine waters, but this study was carried out in a freshwater lake, Lake Towuti, East Luwu, South Sulawesi. Water samples at nine sampling stations (10 L each) were collected by applying purposive random sampling, then filtered five times using a neuston net (330 μm mesh size). The water samples were transported to the laboratory to perform advanced filtration (cellulose filter in a vacuum pump). The filtered samples were then observed to determine the color and shape of the microplastics under a stereo microscope. Results showed that the abundance of microplastics varied from 7.36 to 26.28 items L^{-1}. Microplastics were classified based on colors: blue, black, white, red, green and colorless. Blue-colored particles were the most-dominating microplastics (63–240.8 items $station^{-1}$), allegedly derived from the blue paint that dominates the color of fishing boats. There were four shapes of microplastics identified: line, fragment, film and foam. Fragments were most dominating in the waters (36.6–232 items $station^{-1}$), presumably due to the unstable hydrodynamics of the lake waters.
Key Words: coloring paint, hydrodynamic, Lake Towuti, microplastic, toxic substance.

Introduction. This era of modernization has led to the use of plastics in many human activities. Waste resulting from the use of plastic is an object of concern, especially because of environmental pollution to both terrestrial and aquatic ecosystems. Global plastic waste production was close to 13 million metric tons (MT) in 2010. This number comes from 190 countries (Jambeck et al 2015) and the waste usually enters aquatic ecosystems. Plastic waste in aquatic ecosystems has various sizes, all of which pose a threat to waters (Tahir et al 2019). Those with a size of <5 mm are classified as microplastics (Choi et al 2020; GESAMP 2019) and are derived from plastic waste undergone fragmentation or degradation into smaller pieces, resulting plastic debris (Masura et al 2015; Zhang et al 2020). The presence of microplastics is a problem for aquatic organisms that confuse them with safe prey for consumption (Masura et al 2015). Studies reveal how terrible microplastics are to health, both in aquatic animals (Wang et al 2020) and humans (Wang et al 2018). Microplastics can absorb various toxic chemicals, such as PCBs, PAHs, HCH and DDT, so that consuming aquatic animals that have been contaminated with microplastics can be fatal to humans (Wang et al 2018). Several studies have shown that microplastics pollution occurs more frequently in marine ecosystems than in freshwater ecosystems (Basseling et al 2017; Wang et al 2020). In fact, microplastics pollution in freshwater is no less important to study (Wang et al 2020). Microplastics pollution, apart from occurring in marine, estuary and river ecosystems, is also found in lakes (Yuan et al 2019; Yin et al 2019; Pleiter et al 2020; Alfonso et al 2020). Unfortunately, research on microplastics pollution in Indonesian lakes has never been carried out to our knowledge. The occurrence of microplastics pollution in lakes is based on various reasons, namely: hydrodynamics, topography, fishing activities, agricultural activities and household waste (Yuan et al 2019).

Lake Towuti, located in East Luwu, South Sulawesi province, is the second largest lake in Indonesia after Lake Toba (Wijaya et al 2009). This lake covers an area of 560 km^2 with a depth of up to 203 m and is 293 m above sea level (Haffner et al 2001). Apart from rainwater, Lake Towuti has as water supplies Lake Matano and Mahalona, and its surrounding rivers. Several potential problems of pollution, namely household waste along with increasing population, capture fisheries activities, agriculture, industrial and mining waste pose a threat to aquatic creatures in Lake Towuti (Wijaya et al 2009). These are all at the same time a threat to the community who will consume aquatic animals from the waters of Lake Towuti.

Material and Method

Water sampling. The study was conducted in Towuti Lake, Indonesia, from August to November 2020. Water samples at nine sampling stations (10 L each) were collected by applying purposive random sampling based on the potential presence of anthropogenic activities and from unpopulated locations (Figure 1).

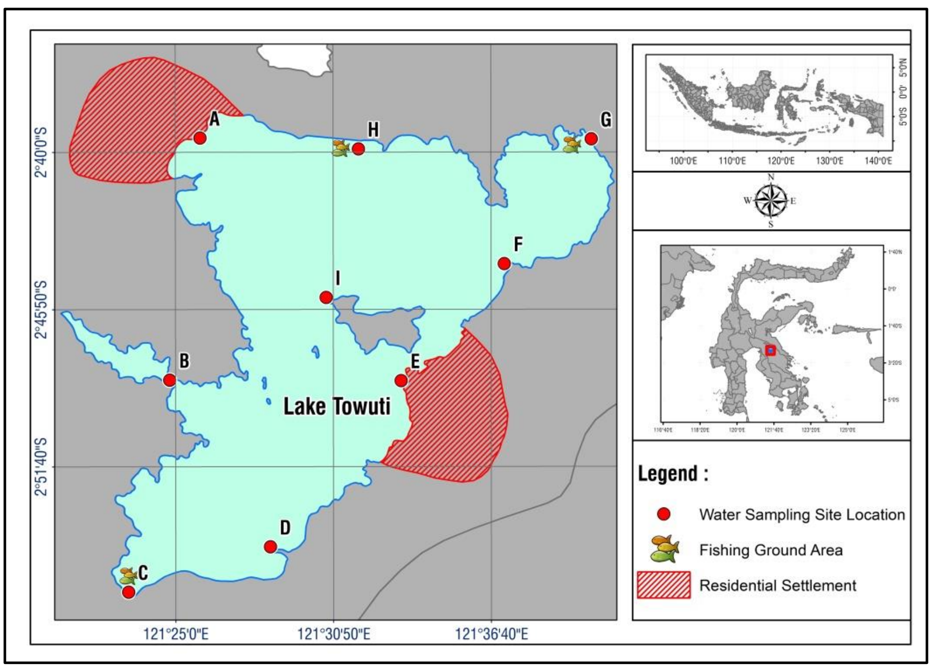

Figure 1. Sampling stations in Lake Towuti, East Luwu, South Sulawesi.

Stations A, Timampu, and E, Tokolimbo, are populated sampling locations, while the unpopulated locations are H, inlet, G, Lengkona, F, Tomeraka, I, center, D, Lengkobale, C, Lengke, and B, outlet. Water was sampled using a 10 L container at each station, with 5 replications. The water was then poured and filtered using a neuston net (mesh size 330 μm) (Covernton et al 2019; Tahir et al 2019). The filter results collected in cod-end nets with a capacity of 300 mL were taken and put into sample containers for laboratory analysis. The water samples were transported to the Marine Ecotoxicology Laboratory, Hasanuddin University, for the further processing. The collected water was then filtered using a cellulose filter (Whatman, pore size 0.45 μm) in a vacuum pump (Rocker 410). The filter results were observed under a stereo microscope (Euromax Stereoblue) to determine the color and shape of the microplastics particles. The size of all microplastics particles (<5 mm) was measured using the ImageJ software. Microplastic abundance, color, and shape difference between sampling stations were then calculated using parametric ANOVA followed by Tukey post-hoc. If the data were not homogenous or normally distributed, the analysis was conducted using the non-parametric Kruskal-Wallis test, followed by Dunn's multiple comparison test.

Results and Discussion

Microplastics abundance. The results show that all samples were contaminated by microplastic. The results of the analysis of variance showed that the abundances of microplastics in the water samples at stations H, C, and A were significantly lower than in stations I and E ($p<0.05$) (Figure 2). All sampling stations, however, apart from being categorized as populated and unpopulated, were also categorized by region. In this case, Lake Towuti was categorized based on the Southeast region (F, G, E, I, D, C) and northwest region (B, A, H) (Figure 1).

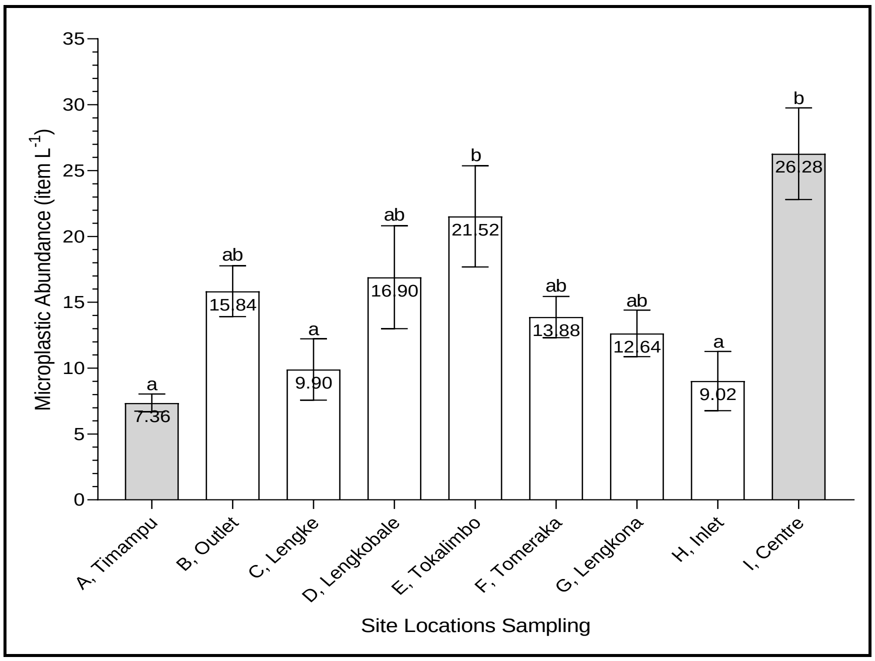

Figure 2. Microplastics abundance in Lake Towuti (items L^{-1}). Different letters show statistically significant differences ($p<0.05$).

In general, the pattern on microplastic abundance in Towuti lake did not follow the pattern of the populated areas, but followed the pattern of lake region. The southern region of Towuti lake contains more microplastics compared to the northwest region. Station I (center) is located in unpopulated area, but had the highest abundance of microplastics among all stations (26.28±7.781 items L^{-1}). Station A is located in a populated area, but had the lowest microplastics abundance (7.36±1.513 items L^{-1}) of all stations. Stations with residents do not always have a high abundance of microplastics, while non-populated ones do not always have low microplastics abundance values. Yin et al (2019) report that urban areas do not always have a high abundance of microplastics and rural areas do not always have a low abundance of microplastics. Several studies report the low abundance of microplastics in urban areas due to the high public awareness to carry out environmental conservation (e.g., procurement of cleaning facilities, waste disposal, and waste processing), controlling the abundance of plastic waste in the waters (Eckert et al 2018; Yin et al 2019).

The high abundance of microplastics in rural areas may be driven by low public awareness, disposing of plastic waste directly into waters and inadequate waste treatment facilities (Wang et al 2018; Jiang et al 2019; Yin et al 2019).

Lake Towuti, unfortunately, still lacks plastic waste processing facilities and awareness of the surrounding community. A lot of plastic waste is generated from daily activities, being dumped directly into lake waters or into rivers and irrigation canals directed to the lake. The waste is then photodegraded into small plastic debris and increases the abundance of microplastics in the waters (Cole et al 2011). Capture fisheries that apply plastic-based gear, agricultural activities, and industries whose waste is directly connected to waterways to the lake also encourage an increase in the abundance of microplastics in lakes (Basseling et al 2016; Yuan et al 2019). Similar studies in populated and non-populated locations also showed the influence of domestic waste, fishery, agricultural and industrial activities on waters (Li et al 2013; Yuan et al 2019; Yin et al 2019; Ding et al 2019).

Microplastics particles in water are very sensitive to hydrodynamic forces, and quickly move across sampling stations (Chubarenko et al 2018; Yuan et al 2019; Yin et al 2019). The concept of hydrodynamics can be influenced by turbulence conditions in the region (Cahyana 2005). Lake Towuti experiences turbulence under certain conditions, which cause high waves in the waters. Strong currents and waves with irregular directions allow microplastics particles to be scattered inconsistently. The abundance of microplastics in this study can also be observed in the southeast region (sampling tations F, G, E, I, D, C) and in the northwest region (H, A, B). The southeast part of the lake has a high abundance of microplastics. It is suspected that the current activity is dominant in the southeast part of the lake. At station B, the abundance of microplastics was high, presumably because particles from all areas of the lake were carried by currents to the discharge. These particles were finally trapped due to the lake's topography, which narrows towards the outlet. Various causes allow the uneven distribution of microplastics at the sampling stations. Microplastic particles start from point E, which is populated, then lead to station I, and finally spread randomly throughout Lake Towuti

Microplastics color abundance. Observation of Lake Towuti water samples found five colors: blue, black, white, red, and green (Figure 3). Colorless microplastics also exist in every sampling point (Figure 4). In general, blue is the dominant color (63–240.8 items location^{-1}). In addition to blue, black and red are also colors of microplastics that consistently appear at all stations.

Color variations in microplastics particles were diverse. Yuan et al (2019) stated that microplastics particles should be grouped into four color categories: white, black, colored and transparent. However, this study determines the color according to the conditions at the time of observation. Blue microplastics particles dominate the variety of colors found. Another study revealed that the origin of blue microplastics can be mainly sourced from fishing gear (Wu et al 2020). The majority of the people around Lake Towuti work as fishermen. In addition, the blue microplastics particles may come from boats, which are mainly painted blue. The boats in Towuti Lake are widely used both for catching fish and transportation.

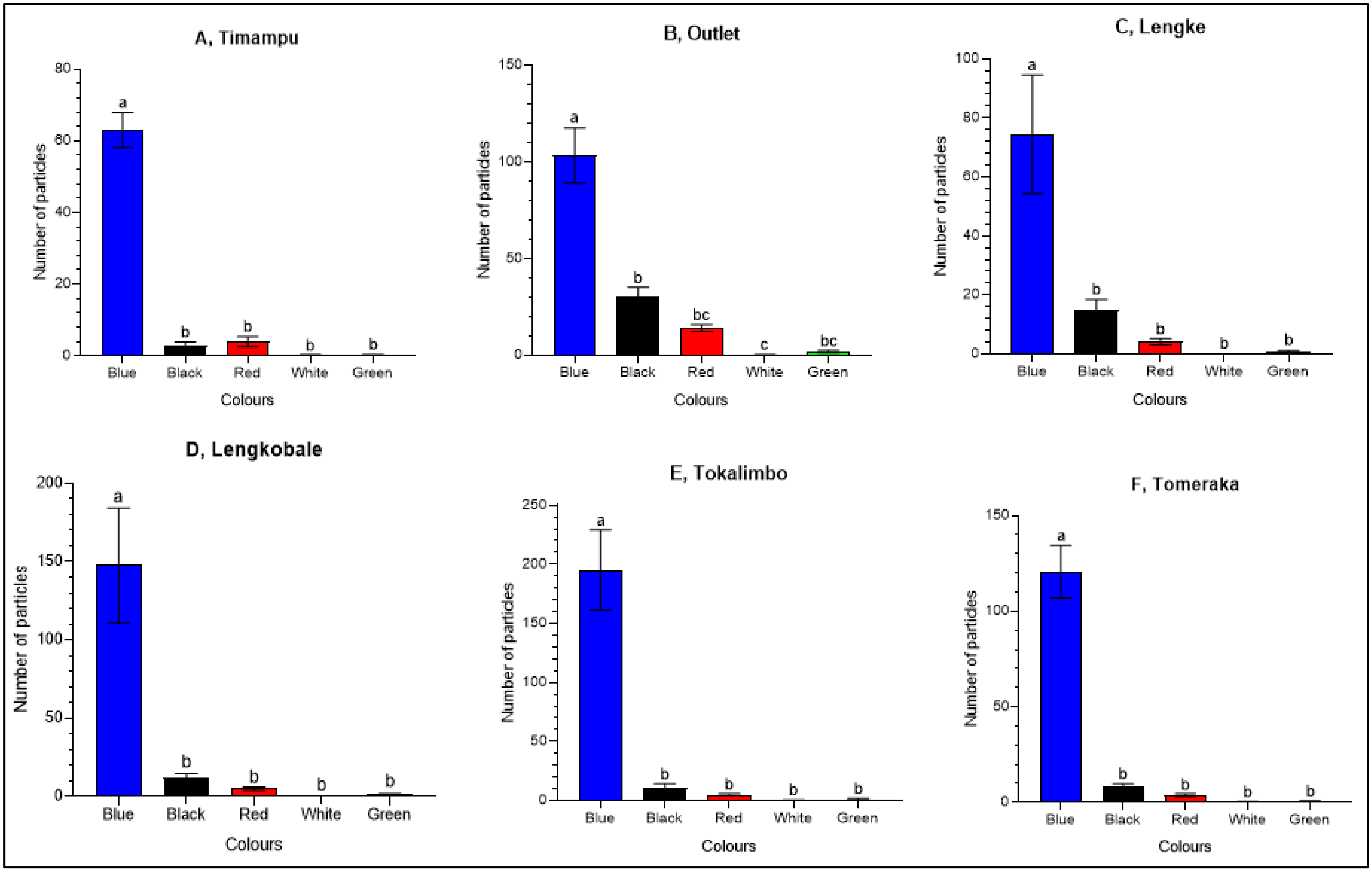

Figure 3. Microplastics color abundance in Lake Towuti (items location^{-1}). Different letters show statistically significant differences ($p<0.05$).

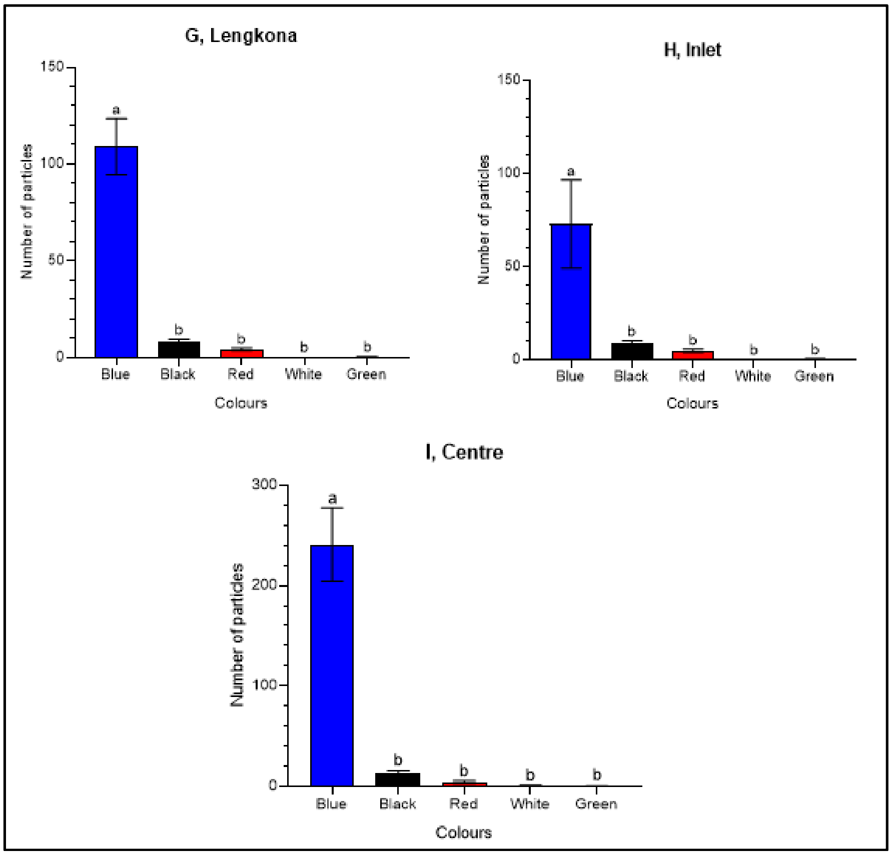

Figure 3 (continuation). Microplastics color abundance in Lake Towuti (items location[-1]). Different letters show statistically significant differences ($p<0.05$).

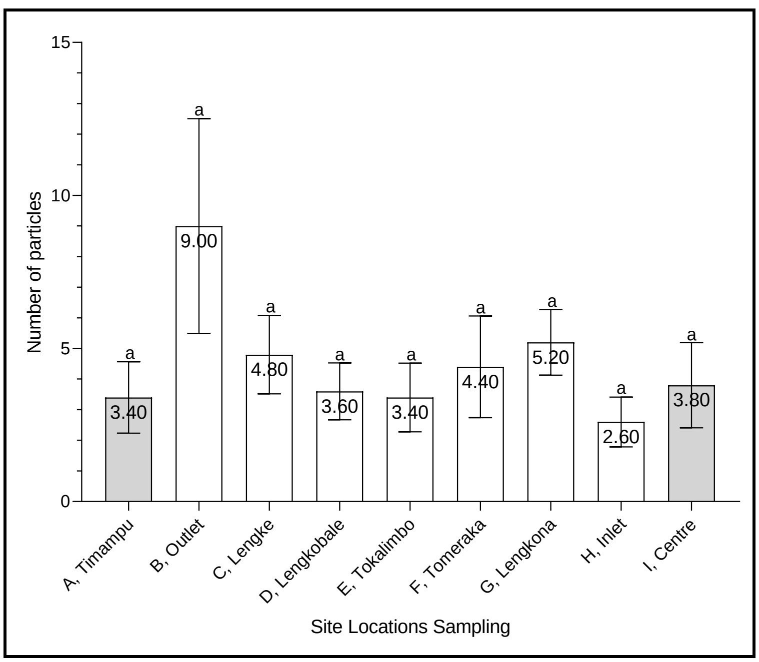

Figure 4. Microplastics colorless abundance in Lake Towuti (items location[-1]). Different letters show statistically significant differences ($p<0.05$).

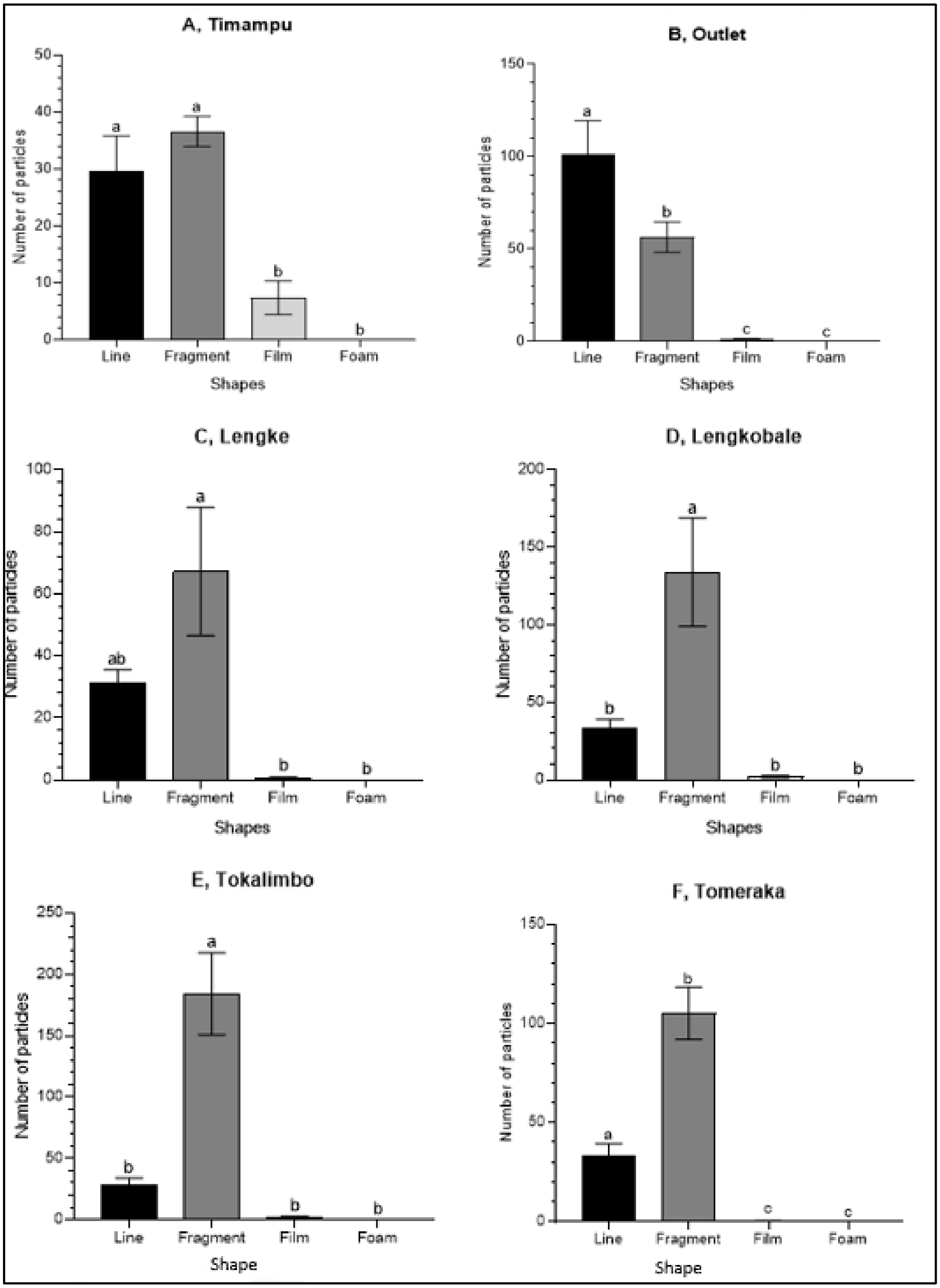

Figure 5. Microplastics shape abundance in Lake Towuti (items location^{-1}). Different letters show statistically significant differences ($p<0.05$).

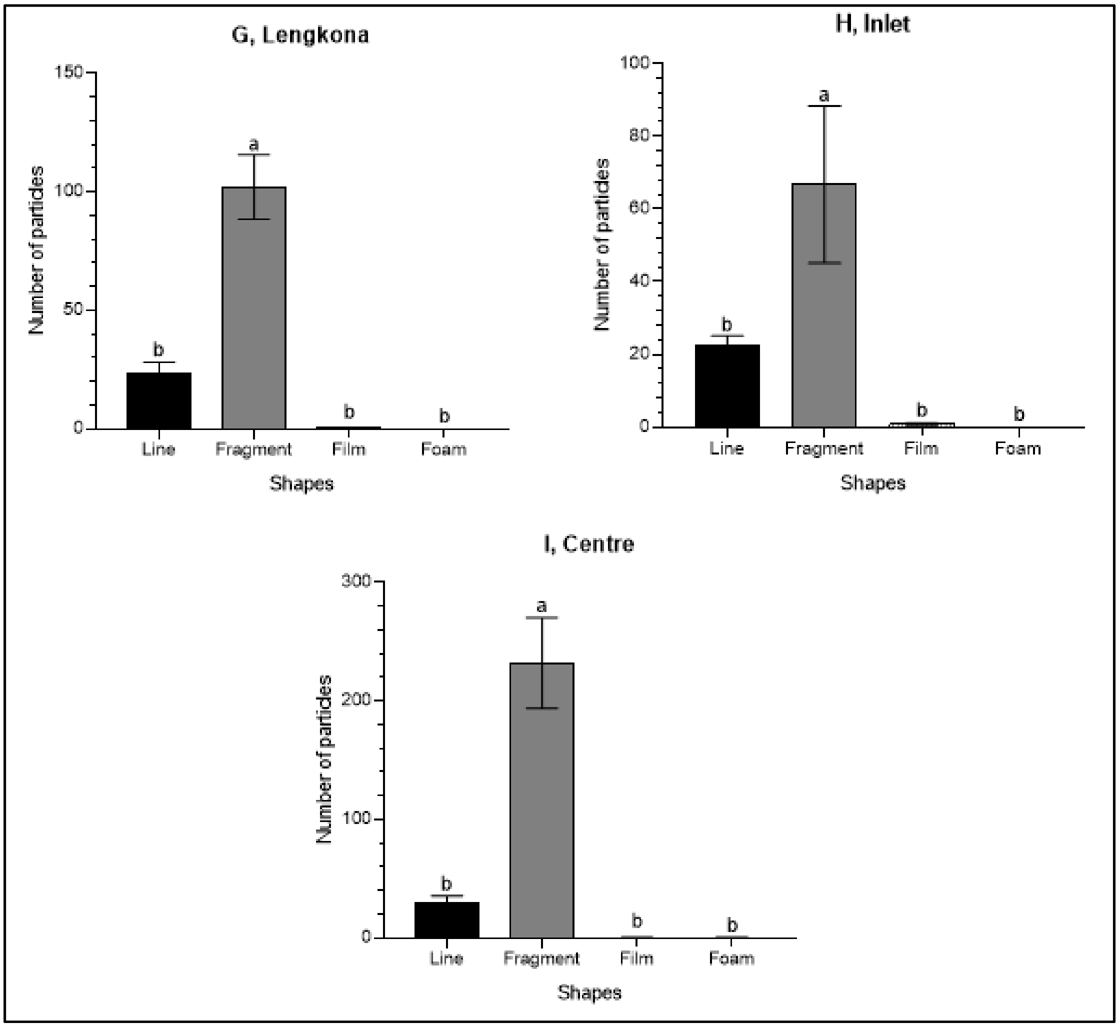

Figure 5 (continuation). Microplastics shape abundance in Lake Towuti (items location^{-1}). Different letters show statistically significant differences ($p<0.05$).

Microplastic shape abundance. Observations of the microplastics from the water samples of Lake Towuti showed that microplastics could be categorized in four shapes: line, fragment, film and foam (Figure 5). Fragment was the statistically dominant shape (36.6–232 items location^{-1}). Station B had a higher abundance of line microplastics than other stations (101 items location^{-1}). The most film microplastics were found at station A (7.4 items). Some representative shapes and colors of microplastics in water samples are presented in Figure 6.

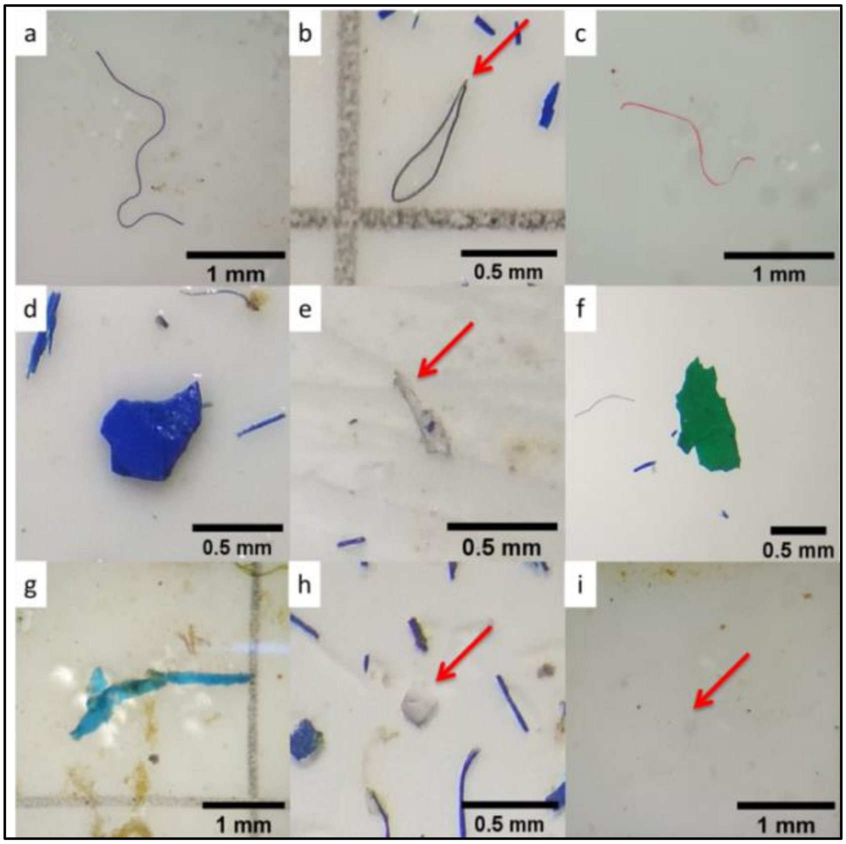

Figure 6. Microplastics shape and color in Lake Towuti; (a) blue line; (b) black line; (c) red line; (d) blue fragment; (e) white fragment; (f) green fragment; (g) blue film; (h) white foam; (i) colorless line.

The microplastics contained in the water of Lake Towuti were dominated by fragments, followed by line. Yin et al (2019) and Ding et al (2019) suggest several possible causes of the shaping of microplastics particles in fragments, one of which is the high activity of water transportation vehicles. In addition, inconsistent water hydrodynamics triggering irregular current waves, photodegradation reactions, and thermal degradation also contribute to the abundance of secondary microplastics particles sourced from larger size primary plastic debris (Cole et al 2011; Frias & Nash 2019). Most secondary microplastics that originate from fragmentation of larger microplastics will continue to exist as fragment microplastics. Several sampling stations in Lake Towuti have become the concentration points for domestic plastic waste, such as food and beverage packaging. Plastic waste that is scattered in several points is most likely influenced by the lake currents. In addition, the activity of waterborne vessels in Lake Towuti is high, so that it can explain the high abundance of fragment-shaped microplastics.

Conclusions. Lake Towuti is contaminated with microplastics with abundance values between 7.36-26.28 items L^{-1}. Blue was the most dominant microplastics color (63-240.8 items location^{-1}), while the red and black colors consistently appeared at the stations. Fragments were the most abundant shape (36.6–232 items location^{-1}). The existence of microplastics in all water samples in Lake Towuti shows the need of plastic waste management in Towuti lake.

Acknowledgements. The authors thank Saipul Saparuddin, Amriana, Anugerah Saputra, Dian Lestari, Yusdalifa Ekayanti, their parents, Mr. H. Andi Atte Herianto, Mrs. Hj. Astina Dg. Bau and Sitti ‘Aaisyah Raabiyah Al-Adawiyah Hardiyanti for all the field and laboratory support.

Conflict of Interest. The authors declare that there is no conflict of interest.

References

Alfonso M. B., Scordo F., Seitz C., Mansretta G. M. M., Ronda A. C., Arias A. H., Tomba J. P., Silva L. I., Perillo G. M. E., Piccolo M. C., 2020 First evidence of microplastics in nine lakes across Patagonia (South America). Science of the Total Environment 733:139385.

Besseling E., Quik J. T. K., Sun M., Koelmans A. A., 2017. Fate of nano- and microplastic in freshwater systems: A modeling study. Environmental Pollution 220:540-548.

Cahyana C., 2005 Marine hydrodynamic model. Buletin LIMBAH 9(2):24-32.

Choi J. S., Hong S. H., Park J., 2020 Evaluation of microplastic toxicity in accordance with different sizes and exposure times in the marine copepod *Tigriopus japonicus*. Marine Environmental Research 153:104838.

Chubarenko I. P., Esiukova E. E., Bagaev A. V., Bagaeva M. A., Grave A. N., 2018 Three-dimensional distribution of anthropogenic microparticles in the body of sandy beaches. Science of the Total Environment 628-629:1340-1351.

Cole M., Lindeque P., Halsband C., Galloway T. S., 2011 Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin 62(12):2588-2597.

Covernton G. A., Pearce C. M., Gurney-Smith H. J., Chastain S. G., Ross P. S., Dower J. F., Dudas S. E., 2019 Size and shape matter: A preliminary analysis ofmicroplastic sampling technique in seawater studies with implications for ecological risk assessment. Science of the Total Environment 667:124-132.

Ding L., Mao R. F., Guo X., Yang X., Zhang Q., Yang C., 2019 Microplastics in surface waters and sediments of the Wei River, in the northwest of China. Science of the Total Environment 667:427-434.

Eckert E. M., Cesara A. D., Kettner M. T., Andres M. A., Fontaneto D., Grossart H. P., Corno G., 2018 Microplastics increase impact of treated wastewater on freshwater microbial community. Environmental Pollution 234:495-502.

Frias J. P. G. L., Nash R., 2019 Microplastics: Finding a consensus on the definition. Marine Pollution Bulletin 138:145-147.

Haffner G. D., Hehanussa P. E., Hartoto D. I., 2001 The biology and physical processes of large lakes of Indonesia. In: The great lakes of the world: Food-web health and integrity. Backhuys, Leiden, pp. 183-194.

Jambeck J. R., Geyer R., Wilcox C., Siegler T. R., Perryman M., Andrady A., Narayan R., Law K. L., 2015 Plastic waste inputs from land into the ocean. Science 347:768-771.

Jiang C., Yin L., Li Z., Wen X., Luo X., Hu S., Yang H., Long Y., Deng B., Huang L., Liu Y., 2019 Microplastic pollution in the rivers of the Tibet Plateau. Environmental Pollution 249:91-98.

Li F., Huang J., Zeng G., Yuan X., Li X., Liang J., Wang X., Tang X., Bai B., 2013 Spatial risk assessment and sources identification of heavy metals in surface sediments from the Dongting Lake, Middle China. Journal of Geochemical Exploration 132:75-83.

Masura J., Baker J., Foster G., Arthur C., Herring C., 2015 Laboratory methods for the analysis of microplastics in the marine environment: Recommendations for quantifying synthetic particles in water and sediments. NOAA Technical Memorandum NOS-OR&R-48, 39 p.

Plieiter M. G., Velazquez D., Edo C., Carretero O., Gago J., Sola A. B., Hernandez L. E., Yousef I., Quesada A., Leganes F., Rosal R., Pinas F., 2020 Fibers spreading

worldwide: Microplastics and other anthropogenic litter in an Arctic freshwater lake. Science of the Total Environment 722:137904.
Tahir A., Taba P., Samawi M. F., Werorilangi S., 2019 Microplastics in water, sediment and salts from traditional salt producing ponds. Global Journal Environmental Science Management 5(4):431-440.
Wang F., Wong C. S., Chen D., Lu X., Wang F., Zeng E. Y., 2018 Interaction of toxic chemicals with microplastics: A critical review. Water Research 139:208-219.
Wang W., Ge J., Yu X., 2020 Bioavailability and toxicity of microplastics to fish species: A review. Ecotoxicology and Environmental Safety 189:109913.
Wijaya D., Samuel, Masak P. R. P., 2009 [Study of water quality and production potential of fish resources in Lake Towuti, South Sulawesi]. Bawal 2(6):291-297. [In Indonesian].
Wu J., Lai M., Zhang Y., Li J., Zhou H., Jiang R., Zhang C., 2020 MIcroplastics in the digestive tract of commercial fish from the marine ranching in east China sea, China. Case Studies in Chemical and Environmental Engineering 2:100066.
Yin L., Wen X., Du C., Jiang J., Wu L., Zhang Y., Hu Z., Hu S., Feng Z., Zhou Z., Long Y., Gu Q., 2019 Comparison of the abundance of microplastics between rural and urban areas: A case study from East Dongting Lake. Chemosphere 244:125486.
Yuan W., Liu X., Wanga W., Di M., Wang J., 2019 Microplastic abundance, distribution and composition in water, sediments and wild fish from Poyang Lake, China. Ecotoxicology and Environmental Safety 170:180-187.
Zhang Z., Wu H., Peng G., Pei X., Li D., 2020 Coastal ocean dynamics reduce the export of microplastics to the open ocean. Science of the Total Environment 713:136634.
*** GESAMP, 2019 Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean. Kershaw P. J., Turra A., Galgani F. (eds), IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, Rep. Stud. GESAMP No. 99, 130 p.

Received: 19 July 2021. Accepted: 25 September 2021. Published online: 16 March 2022.
Authors:
Muhammad Amri Yusuf, Magister Program of Fisheries Science, Faculty of Marine Science and Fisheries, Hasanuddin University, Perintis Kemerdekaan St., KM 10 Tamalanrea, 90245 Makassar, Indonesia, e-mail: muhammad.amriyusuf@yahoo.co.id
Khusnul Yaqin, Faculty of Marine Science and Fisheries, Hasanuddin University, Perintis Kemerdekaan St., KM 10 Tamalanrea 90245, Makassar, Indonesia, e-mail: khusnul@gmail.com
Ega Adhi Wicaksono, Department of Fisheries, Faculty of Agriculture, Universitas Gadjah Mada. Jl. Flora, Bulaksumur, 55281 Sleman, Yogyakarta, Indonesia, e-mail: ega.a.w@ugm.ac.id
Akbar Tahir, Faculty of Marine Science and Fisheries, Hasanuddin University, Perintis Kemerdekaan St., KM 10 Tamalanrea, 90245 Makassar, Indonesia, e-mail: akbar_tahir@mar-sci.unhas.ac.id

How to cite this article:
Yusuf M. A., Yaqin K., Wicaksono E. A., Tahir A., 2022 Abundance and characteristics of microplastics in Lake Towuti, East Luwu, South Sulawesi. AACL Bioflux 15(2):621-631.