Microplastic distribution and abundance in Cimandiri Watershed flowing to Palabuhanratu Bay, Sukabumi, West Java, Indonesia

[1]Elias O. Lodo Pe, [2]Ali Mashar, [2]Taryono, [2,3,4]Yusli Wardiatno

[1] Master Program in Aquatic Resources Management, Graduate School of IPB University Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia; [2] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia; [3] Environmental Research Center, IPB University, Jl. Raya Dramaga, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia; [4] Center for Coastal and Marine Resources Studies, IPB University, Jl. Pajajaran, Kampus IPB Baranangsiang, Bogor 16143, West Java, Indonesia. Corresponding author: Y. Wardiatno, yusli@apps.ipb.ac.id

Abstract. Microplastic, in the aquatic system, is becoming a critical issue all over the world. Studies on microplastic distribution in waters are essential due to the threat potential for both aquatic organisms and human health. The abundance of microplastic is highly related to the increase in human activities along with inadequate waste management systems. This study aims to assess both the distribution and abundance of microplastics in the water stream of Cimandiri Watershed, ending in the estuary areas. It was conducted from August to December 2018. The water samples were collected from seven sampling sites along the Cimandiri Watershed (water bodies) and analyzed using a monocular microscope in the laboratory. Microplastic particles that were found were counted and classified according to type, color, and size. The results revealed that the average abundance of microplastics was 685-7444 particles m^{-3}, and Palabuhanratu Station had the highest abundance with an average abundance of 1489 particles m^{-3}. The microplastics were in the form of film (44%), fragment (33%), fiber (19%), and pellet (4%). Microplastic colors were dominated by white and transparent (28%), followed by red (16%), blue (13%), yellow (6%), black (6%), and green (3%). The microplastics with the highest percentages, based on size, were films 1001-2000 µm (857 particles), fiber 1001-2000 µm (457 particles), fragment 101-200 µm (1184 particles), and pellets 20-40 µm (431 particles).
Key Words: abundance, Cimandiri Watershed, estuary, microplastic.

Introduction. The increasing use of plastics in human life in recent years has led to increased disposal of plastic waste in both terrestrial and aquatic ecosystems (Plastics Europe 2017; Kim et al 2017). The abundance of plastic in the river ecosystems is a complex problem related to the input of garbage in coastal areas (Hastuti et al 2014; Lee et al 2015; Stolte et al 2015; Zhang 2017). Plastic waste accumulating in the aquatic ecosystems can reduce the physical quality of the habitat, transport chemical pollutants, threaten the life of aquatic biota, and interfere with human health (Possatto et al 2011; Klein et al 2015; Auta et al 2017; Horton et al 2018).

Microorganisms can biologically degrade plastic waste, oxidated internally by exposure to ultraviolet radiation, or mechanically degraded to microscopic size, also called microplastic (Cole et al 2011; Yonkos et al 2014; Lassen et al 2015; Hendrickson 2017). The chemical characteristics of plastic can significantly increase water pollution due to its decaying process (Tsang et al 2017; Chatterjee & Sharma 2019).

Research carried out over the last few years revealed that microplastic has become widespread in almost all aquatic habitats. Its abundance in Jakarta Bay, according to Manalu's research (2017), ranges from 2881 to 7473 particles m^{-3}, while the average abundance of sediments ranges from 18.405 to 38.790 particles kg^{-1} sediment (Manalu et al 2017). Cordova & Wahyudi (2016) reported that microplastics had spread in Indian Ocean sediments at depths of 500 to 2000 meters. Apart from waters and sediments, microplastics have also been reported to have spread into the digestive system of marine organisms (Lavers et al 2014; Setälä et al 2014; Tanaka & Takada 2016; Digka et al 2018; Garnier et al 2019). The results of research by Hastuti et al (2019) demonstrated that nine commercial fish species at Pantai Indah Kapuk (PIK), Jakarta, were exposed to microplastics with an average abundance of 12.21±9.76 particles/individual.

The Cimandiri Watershed is a watershed that flows into Palabuhanratu bay, potentially becoming a microplastic channel from the upper land. The characteristics of dynamic estuarine areas and high population activity in the upper reaches of the Cimandiri Watershed are supposed to be a source of microplastics flowing into Palabuhanratu Bay (Prasetyo et al 2016). At this time the information related to microplastic pollution in the river flow is still limited, therefore it is expected that the results of this study can be used in the management of river ecosystems in Indonesia, especially in the area of West Java Province.

Material and Method

Description of the study sites. This research was conducted from August to December 2018. Sampling was carried out five times with an interval of 30 days. The sampling locations consisted of seven stations spread across seven sub-districts, namely Parung Kuda Station, Cikidang Station, Cikembar Station, Warung Kiara Station, Jampang Tengah Station, Lembursitu Station, and Palabuhanratu Station (Figure 1).

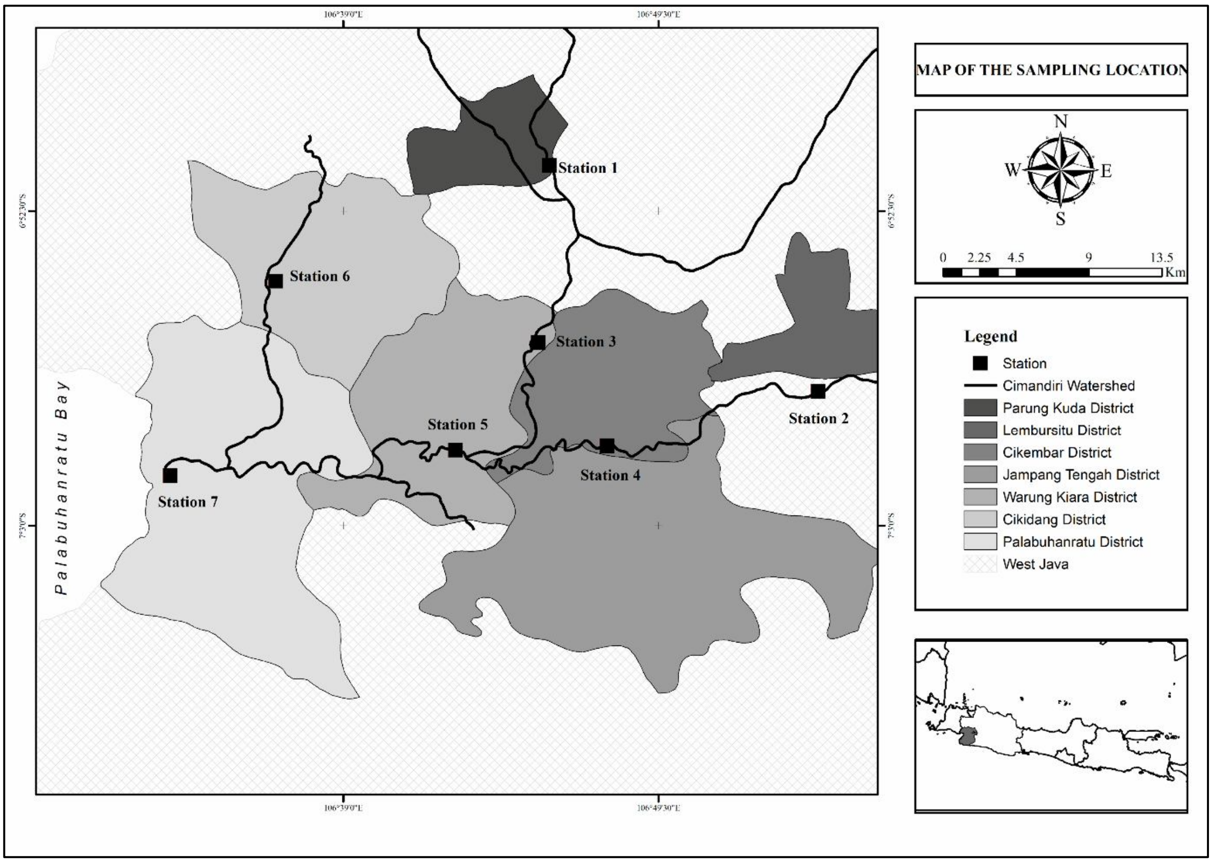

Figure 1. Map of the Cimandiri Watershed coast showing the sampling location. Small black boxes represent sampling sites.

Procedures. The sampling process in the present study was adapted to the methods by Kataoka et al (2019). The principle of salinity-based density separation separates microplastic samples in water by adding 6 grams of sodium chloride to every 20 mL of sample water (±5 mL saturated NaCl), increasing the efficiency of the microplastic identification (Masura et al 2015). This process was carried out to categorize microplastics that have fewer densities than salts such as polyethylene (PE = 0.91-0.94 ρ), polypropylene (PP = 0.83-0.85 ρ) and polystyrene (PS = 1.05 ρ) (Kataoka et al 2019). The microplastic samples in water were visually identified with the aid of a microscope (magnification of 10 × 10), micrometers, and Sedgewick-Rafter Counting Cell (SRC). Microplastic particles were calculated in terms of abundance (particles m^{-3}) and categorized by type (film, fiber, fragment, and pellet), color (transparent, white, blue, red, yellow, green, and black), and size. Size classification followed the size described by Hastuti et al (2019).

Data manipulation and analysis. The identification process was followed by a direct calculation of the number of microplastic counts to determine the alleged abundance of microplastics in each type. The formula for estimating microplastic abundance was as follows:

$$\text{Abundance (Particle m}^{-3}) = n\ \frac{1}{Vd} \times \frac{Vt}{VSRC} \times \frac{A\ SRC}{Aa}$$

where: n = the number of microplastic particles identifed;
Vd = a water filter (Liter);
Vt = volume filtered (mL);
V_{SRC} = SRC volume (mL);
A_{SRC} = SRC area (mm^2);
A_a = area observed (mm^2).

Descriptive statistical analysis was used to display the data in tables, diagrams, and graphs. Data were presented in the forms of average±standard deviation and range. All statistical analyses were performed using SPSS software. The normality test was applied by the Shapiro-Wilk test to evaluate the type of data (parametric or nonparametric) before further analysis. The nonparametric Kruskal-Wallis test was used for multiple comparisons. The non-parametric Mann-Whitney test was used for pairwise comparison for the data with significant differences under the Kruskal-Wallis test.

Results and Discussion

Microplastic abundance. Based on the results of the analysis and identification of water samples collected from seven stations, the microplastic abundance was 685-7444 particles m^{-3}. This number was smaller than those of some previous studies conducted in Jakarta Bay with 2881-7472 particles m^{-3} (Manalu 2017), Saigon-Vietnam River with 172.000-519.000 particles m^{-3} (Yan et al 2019), and the Pearl-China river with 7850-10.950 particles m^{-3} (Lahens et al 2018). However, those results were higher than that of the research conducted at the Yangtze estuary with 4137±2461.5 particles m^{-3} (Zhao et al 2014). The highest abundance was observed at Palabuhanratu Station with an abundance of 625-2222 particles m^{-3} and an average abundance of 1489 particles m^{-3}. Palabuhanratu Station is an estuary, the place of river water flowing from the Cimandiri Watershed to the Palabuhanratu Bay.

Meanwhile, the station with the lowest abundance was Cikidang Station, with an average abundance of 137 particles m^{-3}. Based on the results of this study, the high population and activity of residents in downstream had a major impact on the microplastic abundance in the estuary, coastal to ocean areas (Desforges et al 2014; Baldwin et al 2016; Hitchcock & Mitrovic 2019; Kataoka et al 2019; Yin et al 2019). Based on Kruskal-Wallis statistical tests, there was a significant difference ($p < 0.05$) in microplastic abundance among the seven sampling sites. Wastes passing through the Cimandiri Watershed consist of material from household/residential waste, agricultural waste, mining, plantations, and other materials. The major source of waste in this study was the cluster I area of Sukabumi Regency, which produces 1.75 liters/person/day on average with a population density of 4882 people km^{-2} (Adlina 2013; Prajati et al 2015). According to Kole et al (2017), vehicle wheels made from rubber are sources of microplastics in the environment. However, Siegfried et al (2017) stated that 42% of microplastics carried by the river flow to the sea originated from plastic degradation and the remnants of tires found on the highway, 29% of fiber in the form of textile products originating from laundry, 19% in the form of household dust containing plastic and 10% from beauty and body care products. In addition to population activities, natural factors such as rainfall and wind speed have played important roles in influencing the distribution and abundance patterns of microplastics in water bodies (Galgani et al 2000; Eerkes-Medrano et al 2015; Hendricson 2017). Microplastic abundance data in the Cimandiri Watershed can be seen in Figure 2.

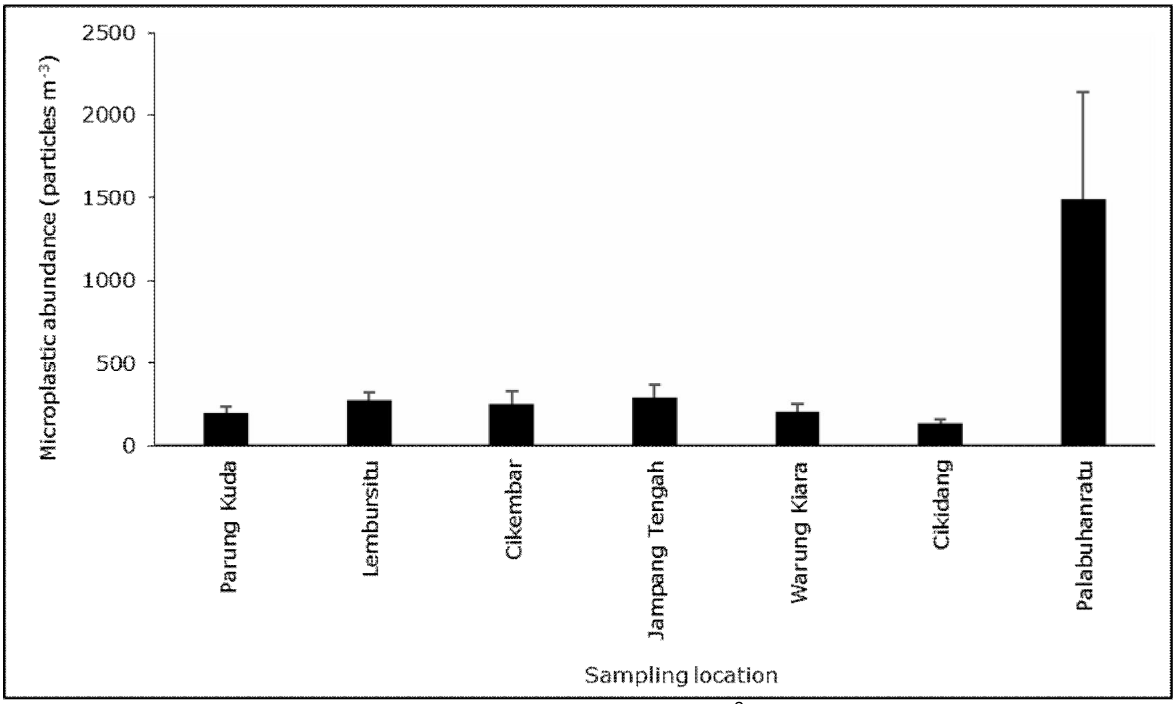

Figure 2. Microplastic abundance (particles m^{-3}) in the sampling sites.

In the water, microplastics float following the density of the polymer (Wright et al 2013). The floating ability of microplastics will determine the position in the water column and its polymer interaction with biota. For example, PVC will settle, while low-density polymer such as PE and PP will float. In this study, the density factor was assumed not to affect the abundance of microplastics at certain depths because the river flowed in the upper stream reaches of the Cimandiri Watershed. The average depth was below one meter, and the continuous water flow caused the microplastics to be carried by currents and accumulate at the mouth of the Cimandiri Watershed. Water quality data for the Cimandiri Watershed is presented in Table 1.

Table 1

Physical conditions of waters at the observation station from August to December: average flow velocity (m s^{-1}), average water depth (cm), average body water width (m)

Station	*Water current (m s^{-1})*	*Depth (cm)*	*Cross cutting water body width (m)*
Parung Kuda	0.9	64.5	13.2
Lembursitu	0.7	51.8	23
Cikembar	0.6	53.8	26.6
Jampang Tengah	0.7	64.6	35.9
Warungkiara	1.0	65.5	37.8
Cikidang	1.2	58.7	12.5
Palabuhanratu	0.2	97.6	124

Microplastic types. Four types of microplastics were found in this study, namely film, fragment, fiber, and pellet (Figure 3). The water flow carried those microplastics from upstream to downstream of the river. They were possibly consumed by organisms such as fish. Based on the results of the statistical tests, there was a significant difference among aggregated abundance at all sites by type (Kruskal-Wallis: $p < 0.05$). The highest type of microplastic found in this study was film, followed by fragment with the second-highest percentage, then fiber/line (ranked third) and pellet. Film and fragment were the types of microplastics that were formed from secondary sources often associated with areas with high population density (Lee et al 2015; Auta et al 2017; Hermawan et al 2017). Films and fragments consist of polypropylene (PP), polyethylene (PE), and polystyrene (PS) (Lippiatt et al 2013). Those components are commonly the results of the degradation of plastic material used in products (i.e., plastic bags, food and non-food packaging, plastic bottles, and plastic containers) through the physical or chemical processes, or heat and light (Cole et al 2011). Based on the macroplastic observations in the field around the sampling site, packaging bags, plastic bags, plastic bottles, and cups were the dominant wastes. Thus, it makes sense that film and fragments were dominant compared to other types of components.

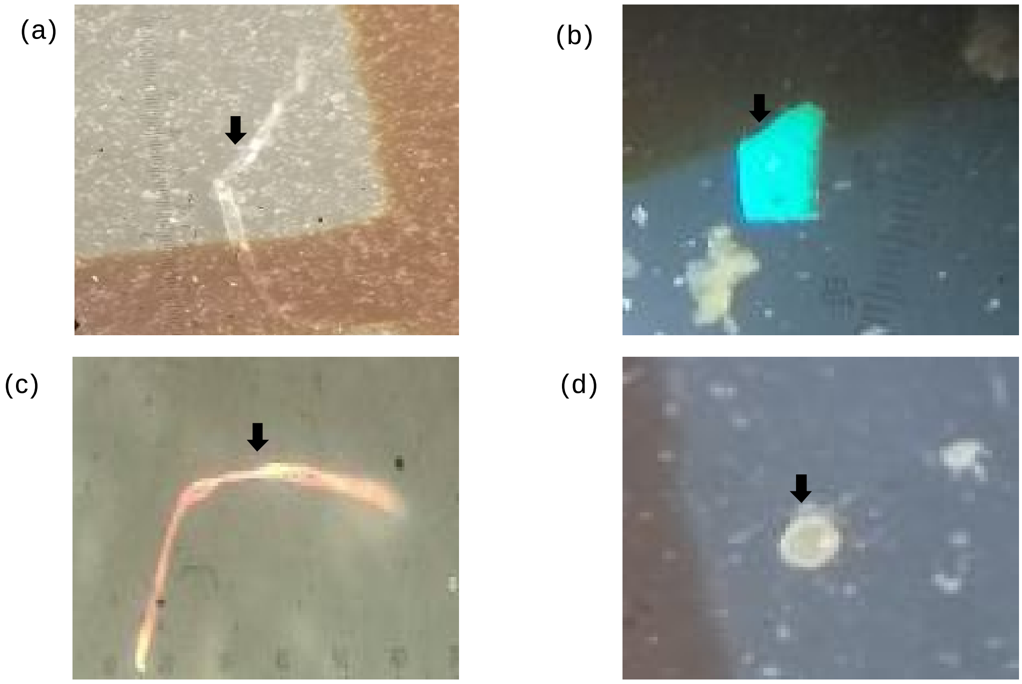

Figure 3. Microplastic type in the water stream of the Cimandiri Watershed: (a) film, (b) fragment, (c) fiber, (d) pellet.

The fiber was another microplatic found in this study. It was a result of several material degradations such as fishing gear, clothes, and other textiles. The Cimandiri river is a favorite fishing ground for high economic value commodities such as eel (Affandi 2005; Hakim 2015). Thus, fishing gears are one of the possible sources of microplastic fiber. The smallest type of microplastic found in this study was pellet/granule. Pellets are primary microplastics that are directly produced by factories as raw materials for making plastics. However, the abundance of the pellet was the lowest compared to others. Microplastic abundance by type in the Cimandiri Watershed is presented in Figure 4.

Based on sampling sites, the film microplastics abundance, ranked from the highest to the lowest, is as follows: Palabuhanratu Station as the highest (3166 particles m^{-3}), followed by Lembursitu Station (646 particles m^{-3}), Jampang Tengah Station (633 particles m^{-3}), Cikembar Station (535 particles m^{-3}) Warung Kiara Station (449 particles m^{-3}), Parung Kuda Station (433 particles m^{-3}), and Cikidang Station (241 particles m^{-3}). There were at least two reasons to explain the dominance of that type of microplastic film. The type of film has a low density, making it easier to distribute in the water. The high use of plastic bags is a significant source of the film type as the community uses plastic bags found along the river stream. The second dominant component is the fragment type. Based on the results, Palabuhanratu Station had the highest particle level (2063 particles m^{-3}), followed by the Cikembar sampling site. The fiber was the third dominant component among the types of microplastics. The highest level of fiber was observed at the Palabuhanratu site and the lowest at Cikembar. The least abundant component was pellet that was rarely found on every site. Microplastic abundance by type at the study sites is presented in Figure 5.

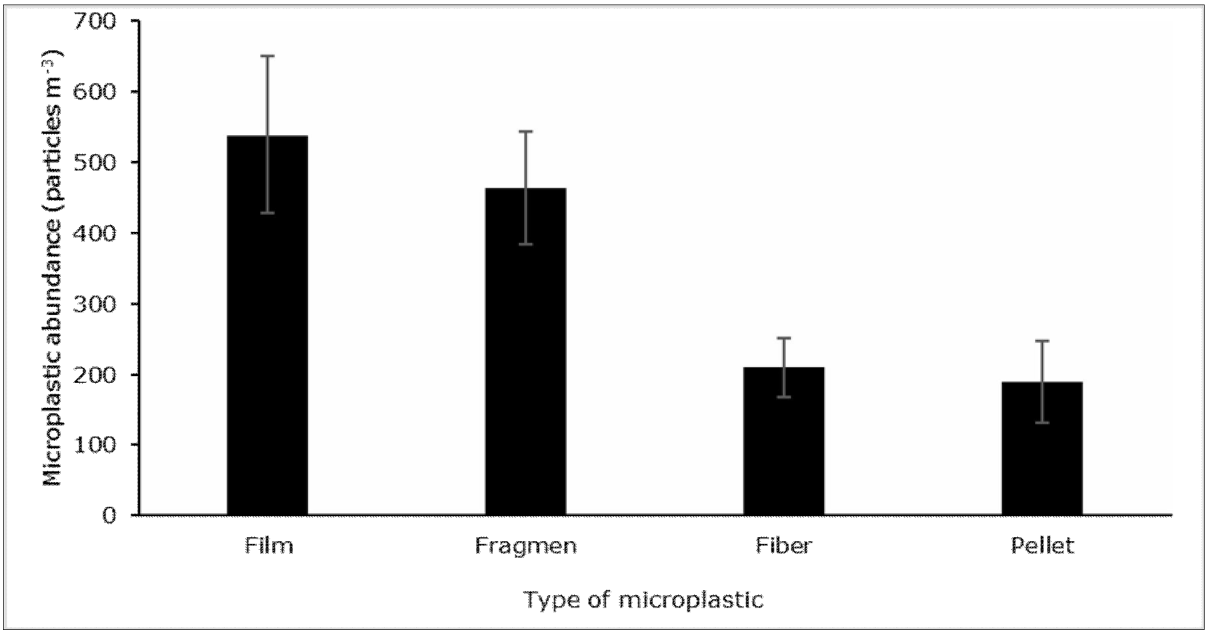

Figure 4. Microplastic abundance (particles m^{-3}) based on types in Cimandiri Watershed.

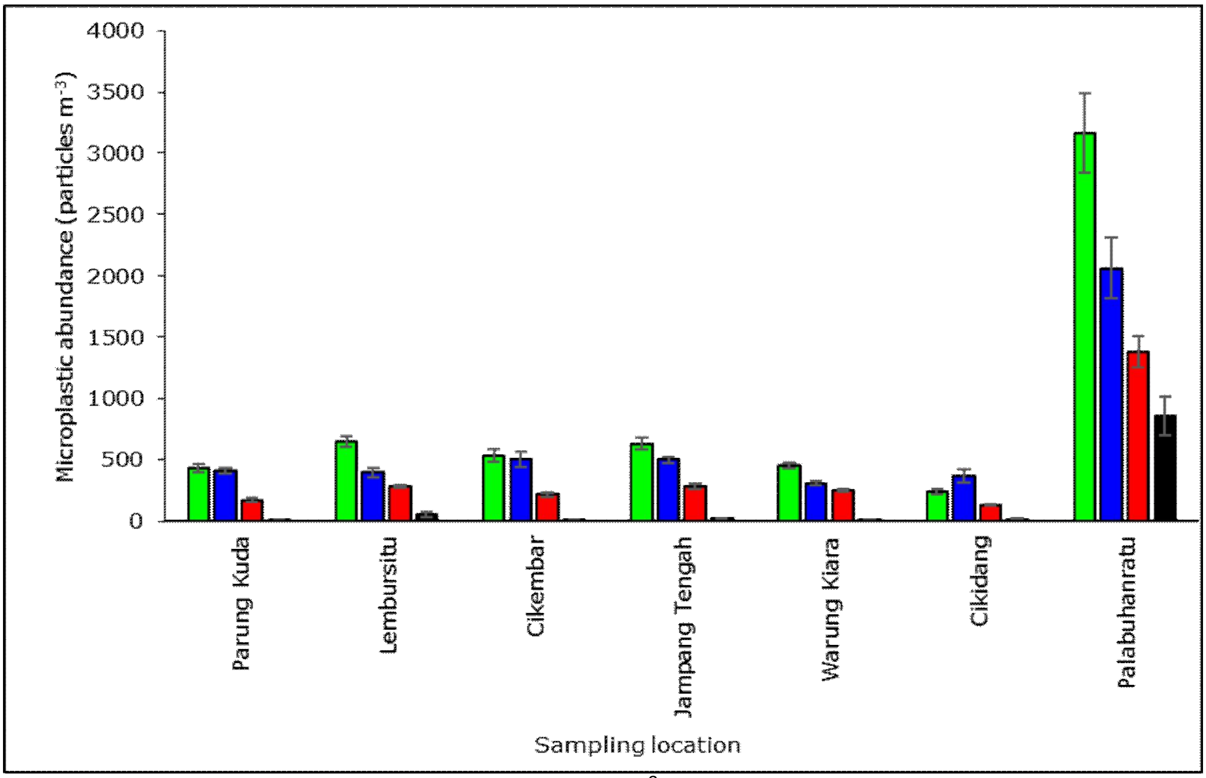

Figure 5. Microplastic abundance (particles m^{-3}) based on types in the water column at sampling sites summarized through bathymetically: films (■), fragments (■), fibers (■), and pellets (■).

Colour of the microplastics. Microplastic colors, identified from water samples, were categorized into seven main color groups: transparent, white, blue, red, yellow, green, and black. White had the highest dominance level in the present research with a percentage of 27.55% (4440 particles m^{-3}) followed by transparent (27.47%; 3948 particles m^{-3}), red (15.75%; 2265 particles m^{-3}), blue (12.68%; 1823 particles m^{-3}), black (5.69%; 818 particles m^{-3}), yellow (5.23%; 752 particles m^{-3}), and green (2.26%; 326 particles m^{-3}). White was mostly found in microplastics such as fragments and pellets, while transparent was mostly found in film and fiber. Blue, red, green, yellow were colors found in three types of microplastics, namely film, fragment, and fiber, while black was found in fragment.

Based on the statistical test results (Kruskal-Walis: $p < 0.05$), there was a significant difference among the microplastic groups by color. White was not significantly different from transparent but significantly differed from the five other color groups (blue, red, yellow, green, and black). The white color abundance was significantly different from the five other color groups (blue, red, yellow, green, and black). The blue color group was significantly different from the four other color groups (red, yellow, green, and black). The red color group was significantly different from the other three color groups (yellow, green, and black). The yellow color group significantly differed from the green group, but not significantly different from the black group. The green group was significantly different from the black group. According to Boerger et al (2010), Wright et al (2013), Ismail et al (2019), microplastics with white, blue, and clear colors resemble the color of plankton as fish potentially consume them. Transparent, blue, red, green, and black microplastics have been found in the digestive system of plankton-eating fish (Neves et al 2015; Bellas et al 2016; Bessa et al 2018). Total number of microplastic particles distinguished based on color composition is presented in Figure 6.

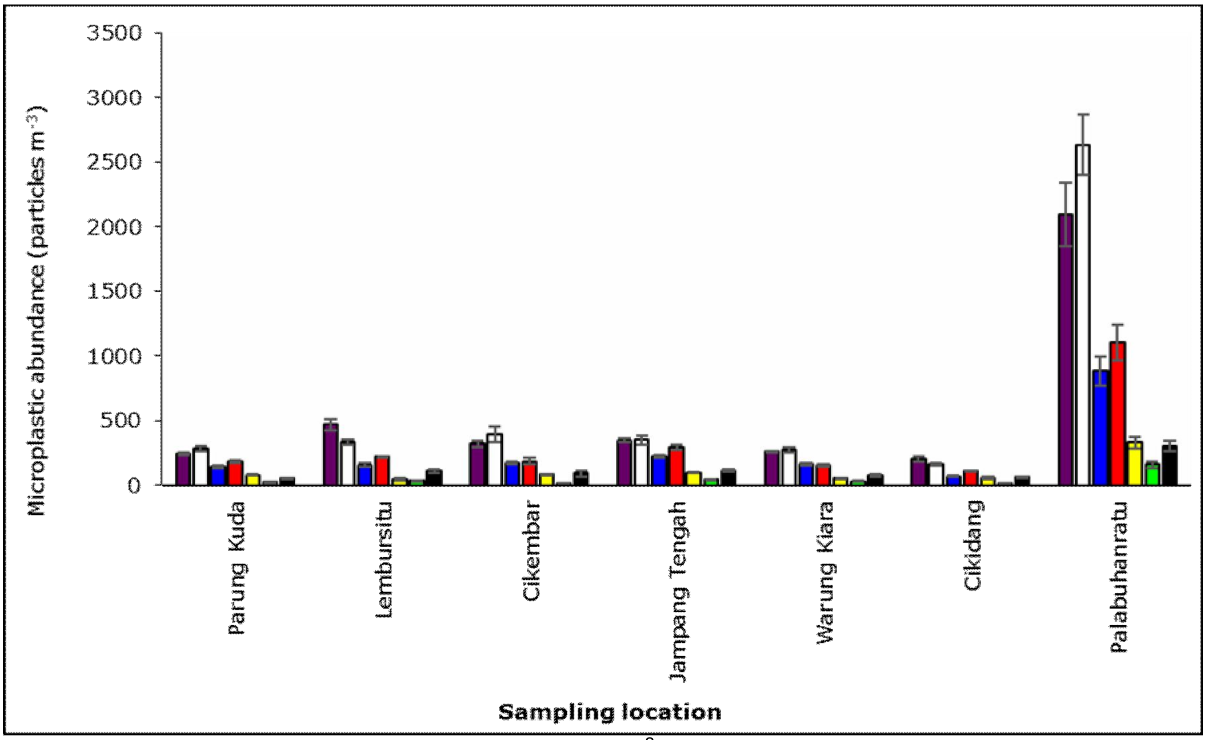

Figure 6. Microplastic abundance (particles m^{-3}) by color: transparent (■), white (□), blue (■), red (■), yellow (■), green (■), and black (■).

Size of microplastics. The data reflecting the microplastic based on the size groups were presented in Figure 7. Five size groups which having the highest number of microplastics sorted by type were 1001-2000 µm (328 particles m^{-3}), 701-800 µm (154 particles m^{-3}), 301-400 µm (152 particles m^{-3}), 601-700 µm (147 particles m^{-3}), and 401-500 µm (120 particles m^{-3}) in fiber types while the sizes of 1001-2000 µm (492 particles m^{-3}), 601-700 µm (346 particles m^{-3}), 201-300 µm (340 particles m^{-3}), 701-800 µm (325 particles m^{-3}), and 401-500 µm (303 particles m^{-3}) mostly found in film types. The size groups of 101-200 µm (582 particles m^{-3}), 41-60 µm (404 particles m^{-3}), 20-40 µm (390 particles m^{-3}), 61-80 µm (361 particles m^{-3}), and 81-100 µm (334 particles m^{-3}) dominated the fragment types while in pellet, the size group of 20-40 µm (527 particles m^{-3}) and 41-60 µm (15 particles m^{-3}) have the highest number over the study.

According to Zhao et al (2014), microplastic abundance in the water will increase along with the decrease in particle size. Besides, its size which is close to the size of plankton will facilitate the transportation process and its spread in water, allowing it to be ingested by organisms such as fish both directly and indirectly (Leite et al 2014; Di Mauro et al 2017; Canniff & Hoang 2018; Figueredo & Vianna 2018). The research results of Hastuti et al (2019) revealed that microplastics in the digestive system of commercial fish were dominated by sizes less than 20 µm in the fragment type, 100-200 µm in the fiber type, and 1000-2000 µm in the film type. According to Hakim et al (2015) and Triyanto et al (2019), the Cimandiri Watershed is a living habitat for three eel species. Thus, it has the potential to increase people's income. As a consequence, the microplastic size found in this study had a great chance to be swallowed by eel or other fish species living in the Cimandiri Watershed or the area of the gulf of Palabuhanratu.

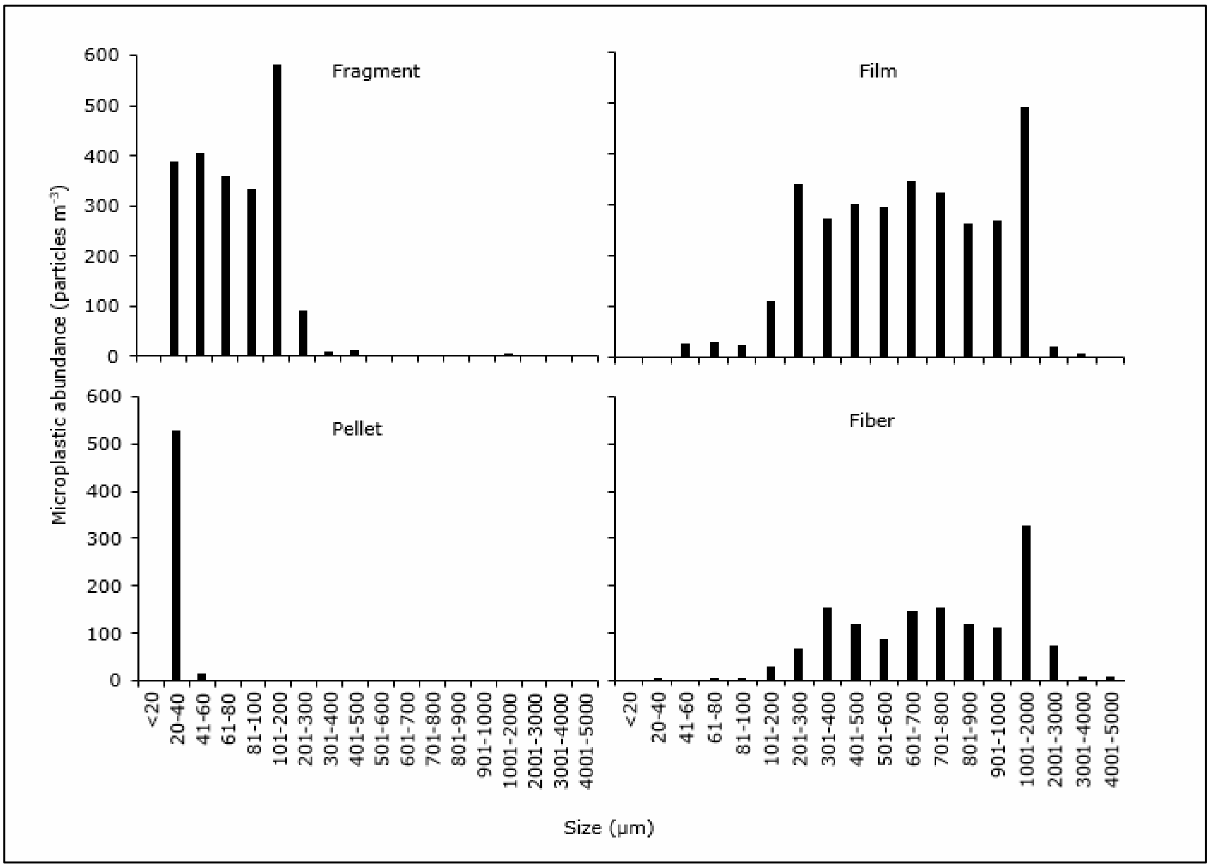

Figure 7. Microplastic abundance by particle size group collected from the water column of Cimandiri Watershed, West Java, Indonesia.

Conclusions. The Cimandiri Watershed was contaminated with microplastics with an average abundance of 685-7444 particles m^{-3}. The highest abundance was at Palabuhanratu Station, which is the estuary area of the Cimandiri River basin. The most commonly found type of microplastic was a film as a result of the degradation of plastic bags and product packages. The microplastic colors most commonly found were white and transparent. Microplastic sizes found in this study varied, namely the film with a size of 1001-2000 µm (492 particles m^{-3}), fiber with 1001-2000 µm (328 particles m^{-3}), fragment with 101-200 µm (582 particles m^{-3}), and pellet with 20-40 µm (527 particles m^{-3}).

Acknowledgements. The authors would like to acknowledge Directorate General of Research and Development Strengthening, Ministry of Technology Research and Higher Education for research costs sourced from BOPTN (Biaya Operasional Pendidikan Tinggi Negeri) to grant this study.

References

Adlina A., 2013 [Identification of socioeconomic and population factors towards waste collection in West Java]. MSc Thesis, Bandung (ID): Institute Teknologi Bandung, 87 pp. [in Indonesian]

Affandi R., 2005 [Strategy for the utilization of eel fish resources]. Jurnal Iktiologi Indonesia 5(2):77-81. [in Indonesian]

Auta H. S., Emenike C. U., Fauziah S. H., 2017 Distribution and importance of microplastics in the marine environment: a review of the source, fate, effects, and potential solutions. Environment International 102:165-176.

Baldwin A. K., Corsi S. R., Mason S. A., 2016 Plastic debris in 29 Great Lakes tributaries: relations to watershed attributes and hydrology. Environmental Science and Technology 50(19):10377-10385.

Bellas J., Martínez-Armental J., Martínez-Cámara A., Besada V., Martínez-Gómez C., 2016 Ingestion of microplastics by demersal fish from the Spanish Atlantic and Mediterranean coast. Marine Pollution Bulletin 109(1):55-60.

Bessa F., Barria P., Neto J. M., Frias J. P. G. L., Otero V., Sobral P., Marques J. C., 2018 Occrrence of microplastics in commercial fish from a natural estuarine environment. Marine Pollution Bulletin 128:575-584.

Boerger C. M., Lattin G. L., Moore S. L., Moore C. J., 2010 Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin 60 (12):2275-2278.

Canniff M. P., Hoang C. T., 2018 Microplastic ingestion by *Daphnia magna* and its enhancement on algal growth. Science of the Total Environment 633:500-507.

Chatterjee S., Sharma S., 2019 Microplastics in our oceans and marine health. Field Actions Science Reports. The Journal of Field Actions 19:54-61.

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.

Cordova M. R., Wahyudi A., 2016 Microplastic in the deep-sea sediment of southwestern sumatran waters. Marine Research in Indonesia 41(1):27-35.

Desforges J. P., Galbraith M., Dangerfield N., Ross P. S., 2014 Widespread distribution of microplastic in subsurface seawater in the NE Pacific Ocean. Marine Pollution Bulletin 71(1):94-99.

Digka N., Tsangaris C., Torre M., Anastasopoulou A., Zeri C., 2018 Microplastics in mussels and fish from the Northern Ionian Sea. Marine Pollution Bulletin 135:30-40.

Di Mauro R., Kupchik M. J., Benfield M. C., 2017 Abundant plankton-sized microplastic particles in shelf waters of the northern Gulf of Mexico. Environmental Pollution 230:798-809.

Eerkes-Medrano D., Thompson R. C., Aldridge D. C., 2015 Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps, and prioritisation of research needs. Water Research 75:65-82.

Figueiredo G. M., Vianna T. M. P., 2018 Suspended microplastics in a highly polluted bay: abundance, size, and availability for mesozooplankton. Marine Pollution Bulletin 135:256-265.

Garnier Y., Jacob H., Guerra A. S., Bertucci F., Lecchini D., 2019 Evaluation of microplastic ingestion by tropical fish from Moorea Island, French Polynesia. Marine Pollution Bulletin 140:165-170.

Galgani F., Leaute J. P., Moguedet P., Souplet A., Verin Y., Carpentier A., Goraguer H., Latrouite D., Andral B., Cadiou Y., Mahe J. C., Poulard J. C., Nerisson P., 2000 Litter on the sea floor along European coasts. Marine Pollution Bulletin 40(6):516-527.

Hakim A. A., 2015 [Determination of refugia eels (*Anguilla* spp.) fisheries area from some rivers that flows to Palabuhanratu Bay, Sukabumi, West Java]. MSc Thesis, IPB University, Bogor, 77 pp. [in Indonesian]

Hakim A. A., Kamal M. M., Butet N. A., Affandi R., 2015 [Species composition of freshwater eels (*Anguilla* spp.) in eight rivers flowing to Palabuhanratu Bay, Sukabumi, Indonesia]. Jurnal Ilmu dan Teknologi Kelautan Tropis 7(2):573-586. [in Indonesian]

Hastuti A. R., Yulianda F., Wardiatno Y., 2014 [Spatial distribution of marine debris in mangrove ecosystem of Pantai Indah Kapuk, Jakarta]. Bonorowo Wetlands 4(2):94-107. [in Indonesian]

Hastuti A. R., Lumbanbatu D. T. F., Wardiatno Y., 2019 The presence of microplastics in the digestive tract of commercial fishes off Pantai Indah Kapuk coast, Jakarta, Indonesia. Biodiversitas 20(5):1233-1242.

Hendrickson E. S., 2017 Microplastics in the surface water and sediments of western Lake Superior as determined via microscopy, PYR-GC/MS, and FTIR. MSc Thesis, University of Minnesota, Minnesota (US), 99 pp.

Hermawan R., Damar A., Hariyadi S., 2017 Daily accumulation and impacts of marine litter on the shores of Selayar Island coast, South Sulawesi. Waste Technology 5 (1):15-20.

Hitchcock J. N., Mitrovic S. M., 2019 Microplastic pollution in estuaries across a gradient of human impact. Environmental Pollution 247:457-466.

Horton A. A., Vijver M. G., Lahive E., Spurgeon D. J., Svendsen C., Heutink R., van Bodegom P. M., Bass J., 2018 Acute toxicity of organic pesticides to *Daphnia magna* is unchanged by co-exposure to polystyrene microplastics. Ecotoxicology and Environmental Safety 166:26-34.

Ismail M. R., Lewaru M. W., Prihadi D. J., 2019 Microplastics ingestion by fish in the Pangandaran bay, Indonesia. World News of Natural Sciences 23:173-181.

Kataoka T., Nihei Y., Kudou K., Hinata H., 2019 Assessment of the sources and inflow processes of microplastics in the river environments of Japan. Environmental Pollution 244:958-965.

Kim D., Chae Y., An Y. J., 2017 Mixture toxicity of nickel and microplastics whit different functional groups on *Daphnia magna*. Environmental Science and Technology 51 (21):12852-12858.

Klein S., Worch E., Knepper T. P., 2015 Occurrence and spatial distribution of microplastics in river shore sediments of the Rhine-Main area in Germany. Environmental Science and Technology 49(10):6070-6076.

Kole P. J., Löhr A. J., Van Belleghem F. G. A. J., Ragas A. M. J., 2017 Wear and tear of tyres: a stealthy source of microplastics in the environment. International Journal of Environmental Research and Public Health 14(10):1265.

Lahens L., Strady E., Kieu-Le T. C., Dris R., Boukerma K., Rinnert E., Gasperi J., Tassin B., 2018 Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. Environmental Pollution 236:661-671.

Lassen C., Hansen S. F., Magnusson K., Hartmann N. B., Jensen P. R., Nielsen T. G., Brinch A., 2015 Microplastics: occurrence, effects and sources of releases to the environment in Denmark. Environmental Project, Danish Environmental Protection Agency, Copenhagen, Denmark, 206 pp.

Lavers J. L., Bond A. L., Hutton I., 2014 Plastic ingestion by flesh-footed shearwaters (*Puffinus carneipes*): implications for fledgling body condition and the accumulation of plastic-derived chemicals. Environmental Pollution 187:124-129.

Lee J., Lee J. S., Jang Y. C., Hong S. Y., Shim W. J., Song Y. K., Hong S. H., Jang M., Han G. M., Kang D., Hong S., 2015 Distribution and size relationship of plastic marine debris on beaches in South Korea. Archives of Environmental Contamination and Toxicology 69(3):288-298.

Leite A. S., Santos L. L., Costa Y., Hatje V., 2014 influence of proximity to an urban center in the pattern of contamination by marine debris. Marine Pollution Bulletin 81 (1):242-247.

Lippiatt S., Opfer S., Arthur C., 2013 Marine debris monitoring and assessment. NOAA Technical Memorandum NOS-OR&R-46, 82 pp.
Manalu A. A., 2017 [Microplastic abundance in Jakarta Bay]. MSc Thesis, IPB Universty, Bogor, 69 pp. [in indonesian]
Manalu A. A., Haryadi S., Wardiatno Y., 2017 Microplastics abundance in coastal sediments of Jakarta Bay, Indonesia. AACL Bioflux 10(5):1164-1173.
Masura J., Baker J., Foster G., Arthur G., 2015 Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. NOAA Technical Memorandum NOS-OR&R-48, 31 pp.
Neves D., Sobral P., Ferreira J. L., Pereira T., 2015 Ingestion of microplastics by commercial fish off the Portuguese coast. Marine Pollution Bulletin 101(1):119-126.
Possatto F. E., Barletta M., Costa M. F., do Sul J. A., Dantas D. V., 2011 Plastic debris ingestion by marine catfish: an unexpected fisheries impact. Marine Pollution Bulletin 62(5):1098-1102.
Prajati G, Padmi T., Rahardyan B., 2015 [The influence of economic and demographic factors to waste generation in capital city of Java and Sumatera]. Jurnal Teknik Lingkungan 21(1):39-47. [in Indonesian]
Prasetyo A. B., Sulistiyono E., Mayangsari W., 2016 [Study of advanced material development minerals from the Cimandiri Watershed]. Proceedings of National Seminar on Science and Technology (Jakarta), pp. 2407. [in Indonesian]
Setälä O., Fleming-Lehtinen V., Lehtiniemi M., 2014 Ingestion and transfer of microplastics in the planktonic food web. Environmental Pollution 185:77-83.
Siegfried M., Koelmans A. A., Besseling E., Kroeze C., 2017 Export of microplastics from land to sea. A modeling approach. Water Research 127:249-257.
Stolte A., Forster S., Gerdts G., Schubert H., 2015 Microplastic concentrations in beach sediments along the German Baltic coast. Marine Pollution Bulletin 99(1-2):216-229.
Tanaka K., Takada H., 2016 Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. Scientific Reports 6:34351.
Triyanto, Affandi R., Kamal M. M., Haryani G. S., 2019 [The functions of coastal swamp as a habitat for the tropical eel *Anguilla* spp. in Cimandiri River estuary, Sukabumi West Java]. Jurnal Ilmu dan Teknologi Kelautan Tropis 11(2):475-492. [in Indonesian]
Tsang Y. Y., Mak C. W., Liebich C., Lam S. W., Sze E. T., Chan K. M., 2017 Microplastic pollution in the marine waters and sediments of Hong Kong. Marine Pollution Bulletin 1151(1-2):20-28.
Wright S. L., Thompson R. C., Galloway T. S., 2013 The physical impacts of microplastics on marine organisms: a review. Environmental Pollution 178:483-492.
Yan M., Nie H., Xu K., He Y., Hu Y., Huang Y., Wang J., 2019 Microplastic abundance, distribution, and composition in the Pearl River along Guangzhou city and Pearl River estuary, China. Chemosphere 217:879-886.
Yin L., Jiang C., Wen X., Du C., Zhong W., Feng Z., Long Y., Ma Y., 2019 Microplastic pollution in surface water of urban lakes in Changsha, China. International Journal of Environmental Research and Public Health 16(9):1650.
Yonkos L. T., Friedel E. A., Perez-Reyes A. C., Ghosal S., Arthur C. D., 2014 Microplastics in four estuarine rivers in the Chesapeake Bay, USA. Environmental Science and Technology 48(24):14195-14202.
Zhang H., 2017 Transport of microplastics in coastal seas. Estuarine, Coastal and Shelf Science 199:74-76.
Zhao S., Zhu L., Wang T., Li D., 2014 Suspended microplastics in the surface water of the Yangtze Estuary system, China: first observations on occurrence, distribution. Marine Pollution Bulletin 86(1-2):562-568.
*** Plastics Europe, 2017 Plastics – the Facts 2017: an analysis of European latest plastics production, demand, and waste data. Available at: https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf. Accessed: August, 2018.

Received: 26 November 2019. Accepted: 12 January 2019. Published online: 27 March 2020.
Authors:
Elias Oktovianus Lodo Pe, Master Program in Aquatic Resources Management, Graduate school of IPB University Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia, e-mail: eliaslodope@gmail.com
Ali Mashar, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia, e-mail: ali_mashar@apps.ipb.ac.id
Taryono, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia, e-mail: tkodiran@yahoo.com
Yusli Wardiatno, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia, e-mail: yusli@apps.ac.id

How to cite this article:
Lodo Pe E. O., Mashar A., Taryono, Wardiatno Y., 2020 Microplastic distribution and abundance in Cimandiri Watershed flowing to Palabuhanratu Bay, Sukabumi, West Java, Indonesia. AACL Bioflux 13(2):657-668.