Macroplastic distribution, abundance, and composition which flows to Cimandiri estuary, West Java

Taryono\textsuperscript{1}, E O L Pe\textsuperscript{2}, Y Wardiatno\textsuperscript{1,3,4} and A Mashar\textsuperscript{1}

\textsuperscript{1}Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Bogor 16680, ID
\textsuperscript{2}Graduate School of Aquatic Resources Management, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Bogor 16680, ID
\textsuperscript{3}Center of Environmental Research (PPLH-IPB), IPB University, Bogor 16680, ID
\textsuperscript{4}Center for Coastal and Marine Resources Studies (PKSPL-IPB), IPB University, Bogor 16680, ID

*Corresponding author: tkodiran@yahoo.com

Abstract. Mapping of macro-plastic distribution in the water bodies is important due to the potential of its chemical particle decomposition. Macro-plastic abundance is constituted by population activities which are not accompanied by adequate waste management systems. This study aims to assess the distribution, abundance, and composition of macro-plastic in the water stream of the Cimandiri River from the upper stream to the estuary area. This research was conducted from August to December 2018 using the garbage trap method, with monthly sampling. The results show that the average abundance of macro-plastic is $3.62 \times 10^{-4}$ items/m$^3$/second with the highest number is in Parung Kuda Station, and the average density is $3.17 \times 10^{-3}$ kg/m$^3$/second with the highest number is in the coastal area of Palabuhanratu Station. The research shows that plastic packaging is the most portion (42%) of all types of macro-plastic collected which is constructed of low-density polyethylene polymer.

1. Introduction

It is important to conduct a study of macroplastic contamination in the river because of deterioration of its chemical characteristics which significantly increases water pollution. Currently, the problem of plastic waste has become a national concern where the results of research from Jambeck et al. [1] show that in 2010 Indonesia became the largest contributor to plastic waste in the oceans after China, with an estimated 0.48-1.29 million metric tons/year. The abundance of plastic waste in river ecosystems is one of the complex problems that will be related to the input of waste in coastal areas [3, 4]. The source of plastic waste according to Hermawan et al. [4] and Teuten et al. [5] comes from several anthropogenic activities, namely settlements, tourist places, offices, highways, industrial, agricultural/plantation, mining as well as farm and fisheries. Plastic waste that accumulates in aquatic ecosystems can reduce physically habitat quality, transport chemical pollutants, threaten the life of aquatic biota and disrupt human health [6-8].

The role of the river in the urban context becomes very important, especially in the effort to maintain sustainable water resources since the river will not be separated from various problems, one
of which is the natural decline of resources due to waste pollution [9]. Rivers also play a role as a medium for distributing plastic waste to coastal areas and oceans [10-12]. Further explained in the study Hendrickson [13], that 95% of plastic waste disposed into the environment will enter the sea through the river flow. According to Mani et al. [14] and Shim and Thompson [15], the main factors of plastic waste distribution in aquatic ecosystems are influenced by water hydrodynamics, anthropogenic factors, meteorological factors, and geographical conditions. Garbage transportation with a certain distance in coastal areas is influenced by high flow rates and strong water currents [16, 17].

The Cimandiri watershed as one of the watersheds that drain into the bay of Pelabuhanratu has the potential to be contaminated with the macro and microplastic waste. The characteristics of the dynamic estuary region and the high population activity in the upstream part of the Cimandiri watershed are thought to be the source of plastic waste that flows towards Palabuhanratu bay [18, 19]. According to Supendi et al. [20], the Sukabumi Regency belongs to the cluster I area which has 1.75 litter of waste/person/day with a population density of 4,882 people/km². Up to the moment, still many people who throw garbages into the water river without any concern about its impact on the river water pollution and environmental-based diseases in the Cimandiri watershed [21]. The negative impact on the environmental health of the Cimandiri watershed will be greater if there is no effort to stop this throwing garbage manner. Therefore this study is expected to provide information regarding the distribution, abundance, and composition of plastic waste in the Cimandiri watershed to serve as a basis for determining plastic waste management strategies in the Cimandiri watershed.

2. Material and methods

2.1. Description of the study site

This research was conducted in August 2018 until December 2018. Sampling was taken five times with 30 days intervals each. The sampling sites consisted of seven stations spread across seven sub-districts, namely Parung Kuda District, Cikidang District, Cikembar District, Warung Kiara District, Jampang Tengah District, Lembursitu District and Palabuhanratu District (Figure 1).

2.2. Method

The sampling was conducted across sites (7 sampling sites) and seasons (rainy and dry season). The tools used in this study were flowmeter, nets (20 m wide), roller meters, digital scales (accuracy of 1 gram), trash bags, camera, GPS (global positioning system) and stationery. The garbage trap method was used to collect macroplastic waste in the water river. The net as a garbage trap was placed vertically across the body water for one hour. All plastic wastes that entered the trap were collected and cleaned, then put into a trash bag and taken to the laboratory for further analysis. Plastic waste taken from the field is then dried (under the sun), grouped by type and weighed using digital scales [21]. The abundance or density of macroplastic abundance/density is calculated in the unit of the volume of filtered water, which is constituted by the surface area of the garbage trap and water discharge. Water discharge is the result of multiplication between the speed of river water flow and the duration of the installation of garbage trap [22]. The statistical tests of the Kruskal Wallis test and Mann Whitney test were used to see differences in abundance and density in the seven stations and differences during the rainy and dry season.

3. Result and discussion

3.1. Macroplastics abundance and density

During the study, a total of 677 macroplastic items was collected with an average abundance of $3.57 \times 10^{-4}$ items/m$^3$ and an average density of $3.71 \times 10^{-3}$ kg/m (Table 1). The number of these macroplastics is much higher than inorganic waste collected by Walalangi [21] in Palu River (179 items weighing 3.843 gr). The highest macroplastic abundance was found at Parung Kuda Station.
with a total of 287 items with an average value of $8.83 \times 10^{-4}$ items/m$^3$, then followed by Palabuhanratu station with a total of 67 items and an average value of $6.95 \times 10^{-4}$ items/m$^3$. The lowest abundance was at Cikidang station with a total of 12 items and an average value of $2 \times 10^{-7}$ items/m$^3$ (Figure 2). The highest macroplastic density was found at Palabuhanratu station with a total weight of 684 grams and an average value of $6.54 \times 10^{-3}$ kg/m$^3$. The lowest density is at the Cikidang station with a total weight of 168 grams and an average value of $5.06 \times 10^{-4}$ kg/m$^3$ (Figure 2). According to National Oceanic and Atmospheric Administration [22], macroplastic density with an average of 0.1–1 item/m$^2$ shows that these waters have complex environmental problems and have high turbidity levels.

![MAP OF THE SAMPLING LOCATION](image)

**Figure 1.** Map of the Cimandiri watershed coast showing the sampling location. The small black box represents sampling sites.

Macroplastic abundance and density during the rainy season and dry season have significant differences, where during the rainy season abundance and density are higher than the dry season (Figure 3 and 4). According to Baldwin et al. [23] rainwater runoff is a key factor because it passes through residential and brings garbage in the environment into the river. During the rainy season, the volume of water in the Cimandiri watershed tends to increase (Table 2). The geographical and topographic conditions of the Cimandiri watershed lead to the speed of the river flow which greatly affects the macroplastic distribution process from upstream to downstream area. The monthly dynamic of the rainfall rate of Sukabumi tends to increase at the end of the year (see Table 3). The average abundance number of $3.57 \times 10^{-4}$ items/m$^3$ and an average density of $3.71 \times 10^{-3}$ kg/m$^3$, by time multiplication it can be estimated that the Cimandiri watershed potentially distributes of 11,444.41 items/m$^3$/year with a density value 99,977.45 kg/m$^3$/year of plastic waste to Palabuhanratu bay.
Table 1. Total macroplastic items and weights collected from the Cimandiri watershed body using net traps.

| No. | Station          | Item | Weight (gram) |
|-----|------------------|------|---------------|
| 1   | Parung Kuda      | 287  | 1,525         |
| 2   | Lembursitu       | 105  | 1,101         |
| 3   | Cikembar         | 29   | 841           |
| 4   | Jampang Tengah   | 44   | 380           |
| 5   | Warung Kiara     | 123  | 741           |
| 6   | Cikidang         | 12   | 168           |
| 7   | Palabuhanratu    | 67   | 684           |
|     | Total            | 667  | 5,440         |

Table 2. Physical conditions of waters at the observation station from August to December 2018: Average flow velocity (m/s), average water depth (cm), average body water width (m).

| No. | Station          | Water flow (m/s) | Depth (cm) | Cross-Cutting Body Water width (m) |
|-----|------------------|------------------|------------|-----------------------------------|
| 1   | Parung Kuda      | 0.9              | 64.5       | 13.2                              |
| 2   | Lembursitu       | 0.7              | 51.8       | 23.0                              |
| 3   | Cikembar         | 0.6              | 53.8       | 26.6                              |
| 4   | Jampang Tengah   | 0.7              | 64.6       | 35.9                              |
| 5   | Warungkiara      | 1.0              | 65.5       | 37.8                              |
| 6   | Cikidang         | 1.2              | 58.7       | 12.5                              |
| 7   | Palabuhanratu    | 0.2              | 97.6       | 124.0                             |

Table 3. Rainfall data (mm) and the nature of rain (mm) Regency and City of Sukabumi from August to December 2018.

| No. | Month      | Rainfall (mm) | The nature of rain (mm) |
|-----|------------|---------------|------------------------|
| 1   | August     | 0-20          | 51-84                  |
| 2   | September  | 51-100        | 51-84                  |
| 3   | October    | 101-150       | 51-84                  |
| 4   | November   | 151-200       | 85-115                 |
| 5   | December   | 101-400       | 85-115                 |

Source: BMKG [24].

Macroplastic abundance and density significantly vary in each station, due to the different factors of each station. Residents who lived around of Parung Kuda Station chose to dump garbage directly into the river because there is no temporary waste disposal site (WDS) in the nearby, while at Lembursitu, Cikembar, Central Jampang, and Warung Kiara already had a WDS but had not been fully operated. Cikidang Station is one of seven stations that operate a temporary WDS properly, so the microplastic percentage in the waters and the surrounding environment is the smallest than others. In all of the stations, the 3R (reuse, reduce, and recycle) is not yet implemented at the household level and the public building. The recreational areas without temporary WDS or improper waste management potentially increase volume of waste discharged to water rivers, such as rafting sites at Warung Kiara Station and hot spring bathing tours at Lembursitu Station.

The Kruskal Wallis test results differences in abundance and density among the seven observation stations. According to Mann Whitney's test, there are differences in abundance between Cikidang Station and six other stations (Parung Kuda, Lembursitu, Cikembar, Central Jampang, Warung Kiara, and Palabuhanratu). Warung Kiara Station is significantly different from the two stations (Cikidang Station and Palabuhanratu Station). Central Jampang Station is significantly different from the 2
stations (Cikidang and Palabuhanratu). But, Mann Whitney's test also results that Parung Kuda Station was not significantly different from Palabuhan Ratu Stations.

**Figure 2.** Macroplastic distribution in Cimandiri watershed: (♦) the average abundance of macroplastic (item/m$^3$) and (■) the average density of macroplastic (kg/m$^3$).

**Figure 3.** Macroplastic abundance in the rainy and dry seasons: (绌) dry, (쯩) rainy season.
Figure 4. Macroplastic density in the rainy and dry season: (■) dry season, (▲) rainy season.

3.2. Macroplastic composition

Based on the types of plastic found in the field, macroplastic is divided into nine main groups, namely plastic bags, product packaging, styrofoam boxes, plastic bottles, sponges (cigarette butts, head protector foam), plastic utensils and drinks (spoons, cups, straws), baby equipment (diapers, verbs, towels), slippers and others. Based on the data collected, the product packaging (281 items) is the most dominant. This plastic packaging is applied for snacks, kitchen ingredients, shampoo, and detergent. The next rank is in order by plastic bags (166 items), styrofoam boxes (93 items), foam (64 items), plastic bottles (28 items), food utensils (18 items), baby equipment (10 items), other slippers (6 items), and other (one item). From the results of this grouping, it can be illustrated that household waste dominates the types of macroplastic that have been collected in the Cimandiri watershed (Figure 5).

The macroplastic collected then classified according to the type of polymer constituents. According to secondary data and observation at label packages signs, five types of polymers were identified, namely polyethylene terephthalate, polystyrene, high-density polyethylene, polypropylene, low-density polyethylene and other. The most commonly found polymer is low-density polyethylene (67%). Low-density polyethylene is a constituent polymer of plastic bags and packaging. Polystyrene is found at 25% which is a constituent of boxes made of styrofoam and cigarette butts. Polyethylene terephthalate is found as much as 4% that constitute of bottled mineral water. Polypropylene creates as much as 3% which is composed of plastic spoons, plastic straws, and cups (Figure 6).

4. Conclusion

Macroplastic in the Cimandiri watershed is strongly associated with an increase in population activities that are not provided by an adequate waste management system. The macroplastic in the Cimandiri watershed comes from household waste, recreation areas and several community economic support activities such as markets, stalls, and sand mining. The abundances and densities of macroplastic are significantly difference between rainy and dry seasons and vary among the sites. The Cimandiri watershed can potentially distribute 11,444.41 items/m$^3$/year of macroplastics to Palabuhanratu bay with a total density of 99,977.45 kg/m$^3$/year. Plastic packaging is the largest part (42% of all macroplastic collected) with low-density polyethylene is the polymer type that is dominant of all types of polymer present.
Figure 5. Macroplastic percentage collected from trash trap categorized into nine groups. Product package (□), plastic bag (●), styrofoam boxes (▲), sponge (■), plastic bottle (▲), plastic utensil and drink (■), baby equipment (■), slipper (■), and other (●).

Figure 6. Macroplastic percentage collected from Cimandiri watershed classified based on polymer type. Low-density polyethylene (■), polystyrene (●), polyethylene terephthalate (▲), polypropylene (▲), High-Density Polyethylene (□), and others (■).

Acknowledgments
The author 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
[1] Jambeck J R, Geyer R, Wilcox C, Siegler T R, Perryman M, Andrady A, and Law K L 2015
Plastic waste inputs from land into the ocean *Science* **347**(6223) 768-771

[2] [Kemenperin] Ministry of Industry and Trade 2018 Prospective downstream plastics and rubber industries in Indonesia [Internet]. [downloaded 2018 September 29]. [in Bahasa] Retrieved from http://www.kemenperin.go.id/artikel/16079/Industri-Plastik-dan-Karet-Hilir-Prospektif-di-Indonesia

[3] Lee J, Lee S J, Jang C Y, and Hong Y S 2015 Distribution and size relationship of plastic marine debris on beaches in South Korea *Arch Environ Contam Toxicol* **69**: 288-298

[4] Hermawan R, Damar A, and 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

[5] Teuten E L, Rowland S J, Galloway TS, and Thompson R C 2007 Potential for plastics to transport hydrophobic contaminants. *Environmental Science & Technology* **41**(22) 7759-7764

[6] Auta H S, Emenike C U, and 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

[7] Tsang Y Y, Mak C W, Liebich C, Lam S W, Sze E T, and Chan K M 2017 Microplastic pollution in the marine waters and sediments of Hong Kong *Marine Pollution Bulletin* **115**(2) 20-28

[8] Possatto F E, Barletta M, Costa M F, do Sul J A I, and Dantas D V 2011 Plastic debris ingestion by marine catfish: an unexpected fisheries impact *Marine Pollution Bulletin* **62**(5) 1098-1102

[9] Chakraborti C huq M M, Ahmed S, Tabassum T, and Miah M R 2013 Analysis of the causes and impacts of water pollution of Buriganga river: a critical study *Int J Eng Res Technol* **2**(9) 245-252

[10] Suarna I W 2008 *Model of handling urban and rural waste problems. Bali environmental research center* [Thesis] (Bali: Udayana University) [in Bahasa]

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

[12] Victoria A V 2017 Microplastic contamination in freshwater *Jurnal Teknik Kimia ITB* 1-10

[13] Hendrickson E S 2017 *Microplastics in the surface water and sediments of western Lake Superior as determined via microscopy, PYR-GC/MS, and FTIR* [Thesis] (Minnesota, US: University of Minnesota)

[14] Mani T, Hauk A, Walter U, and Burkhardt- Holm P 2015 Microplastic profile along the Rhine River *Scientific Reports* **5** 17988

[15] Galgani 2000 Litter on the seafloor along European Coasts *Marine Pollution Bulletin* **40**(6) 516-27

[16] Shim J W and Thompson C R 2015 Microplastics in the Ocean *Arch Environ Contam Toxicol* **69** 265-268

[17] Prasetyo A B, Sulistiyono E, and Mayangsari W 2016 Study of development material forward from minerals Cimandiri Watershed *Proceedings National Seminar on Science and Technology (Jakarta)* p 2407 [in Bahasa]

[18] Hakim A A, Kamal M M, Butet A N, and Affandi R 2016 Water quality conditions, fishing activities, and stakeholders in eel fisheries in the Cimandiri watershed *Conferece, National Seminar For Coastal Management And River Flow (Yogyakarta)* p 497 [in Bahasa]

[19] Adlina A and Rahardyan B 2010 Identification of the influence of socioeconomic and population factors on waste generation in West Java *Teknik Lingkungan ITB* 1–11

[20] Supendi A, Nurmilla A, Nurasiah I, Ginalita E R, Tsani A, Uswatun A D, and Wulanard H 2017 Community empowerment through environmental management programs in the Citatih-Cimandiri Sukabumi River Basin. *Proc. National Seminar. PPM (Yogyakarta)* p 240 [in Bahasa]
[21] Walalangi J Y 2012 *Analysis of the composition of organic and inorganic waste and its impact on the coastal environment of Palu City, Central Sulawesi* [Thesis] (Bogor: Bogor Agricultural University) [in Bahasa]

[22] [NOAA] National Oceanic and Atmospheric Administration 2013 *Marine Debris Monitoring and Assessment. NOAA Technical Memorandum* (Silver Sping (US): National Oceanic and Atmospheric Administration)

[23] Baldwin A K, Corsi S R, and Mason S A 2016 Plastic debris in 29 great lakes tributaries: relations to watershed attributes and hydrology *Environmental Science & Technology* **50**(19) 10377-10385

[24] [BMKG] Meteorology, Climatology, and Geophysics Agency 2018 West Java Province Climate Information Bulletin [Internet]. [downloaded 2018 October 16]. [in Bahasa] Retrieved from http://dataonline.bmkg.go.id/akses_data