

# Distribution of macro plastic debris in Muaragembong coastal bay during the east moonson and the east to west monsoon transition in 2020

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**Abstract.** Marine debris pollution can threaten the sustainability of natural resources in coastal regions ecosystem. Marine debris is worldwide issue now and Indonesia considered as a second biggest polluter of plastic to the world ocean. Massive efforts have been applied to tackle marine debris, both by the central government and provincial level, to manage these problems and minimize the impact on the coastal ecosystem. Various types of marine debris threaten the mangrove and seagrass ecosystem by covering its roots and leaves, slowing down its growth rate, and even killing them. The aim of this research is to identify the composition of marine debris in estuary waters and mangrove ecosystem. The research activity was conducted in Muaragembong, Bekasi Regency, which is considered part of Jakarta Bay as the source of the marine debris site. The result showed that the marine debris composition during the east monsoon (July) was dominated by plastic with 71%, while during the transition east-to-west monsoon (November) ranged from 59% and equally distributed surrounding estuary waters and mangrove ecosystem. Fifteen types of macro plastic were found in waters in July, larger than those found in November (13 types). The predominant type of macro plastic is Styrofoam, followed by crackle plastic, sachets, and straws, most of which are single-use plastics that are transported to the estuary and then trapped in the mangrove ecosystem.

## 1 Introduction

The problem of waste in Indonesia has becomes a critical attention for the government and the society. As the increase of population growth, there will also affect the amount of waste produced. Indonesia, as the second-placed in the most produced waste countries in the world, has a target to reduce it as much as 70% in 2025. Currently, the achievement of waste reduction is around 20%. Some research reveal that the problems faced in waste management are the lack of land to dump the waste, lack of managing system of the landfill, minimum presence of organic waste composting process, and a low number of legal justification [1].

The type of waste separated into organic and solid waste. Organic waste include food leftovers, leaves and other organic. The inorganic waste consist of plastic, rubber, glass, metal, cloth, and dangerous substances of the material [2]. The source of the waste is predicted to come from river flow, carried by wind, and current, or it can be direct dumping to the river. Current condition can be affected by bathymetry, tide and also monsoon [3]. The lack of waste management impact to amount of piling waste which spread from the terrestrial environment, river, coastal and open sea

[4]. The waste which in the sea water and coastal ecosystems is called marine debris.

According to [5,6], plastic material wastes is a major source of pollution in the range of 60-80% and will end up in sea and coastal waters [7]. Most of plastic wastes comes from land activities, then it reaches the sea with amount of 12,7 tons. The rate as predicted will increase as much as 50-250 tons in 2025 [8]. Plastic wastes which in waters and coastal ecosystem is categorized based on its size that is macro plastic >25mm, mesoplastic 5-25mm and microplastic <5mm [9,10,11,12,13].

Based on [14,15,12,16], the type of waste which got trapped dominantly and most found in rivers, sea and coastal ecosystem is macro plastic compare to the other kinds of waste. It happens because plastic has an undestroyable character and is hard to degrade naturally and needs several hundred years to degraded [17,18,19].

On the environment, macro plastic trapped and deposited in sediments will incidentally eaten by sea animals and also cover the root system of mangrove and seagrass [19,20]. Those conditions can cause ecological instability, decrease the water quality and coastal ecosystem. The accumulation of macro plastic in waters and sediment can affect the health of people who lived in the nearby

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environment and all people who consumed fish, shell or crustacea in that ecosystem.

Various area in Indonesia, especially in big cities has experience environmental decrease and damage, one of them is Muaragembong, Bekasi Regency. Muaragembong is located in the eastern part of the coastal area in Jakarta Bay which has some river flows; one of them is Citarum River with a wide of 6,614 km<sup>2</sup>. The antropogenic activities come from the settlements and ponds area around the river that have potential to increase pollutant, especially macro plastic into the sea [21].

Mangrove ecosystem which has quite good condition in Muaragembong are located in Pantai Bahagia and Pantai Sederhana Villages. Mangroves in both locations are grow well after rehabilitation program and the Government of Bekasi Regency and society used those areas as marine tourism villages [22].

Currently, Indonesia still have limited data and research activities on macro plastic issue. Therefore, this research was aimed to give information on macro plastic distribution in the water based on its size as well as abundance during different seasons (i.e. east and east to west transition monsoons season). Hopefully this research can also support the management of marine debris in Indonesia and support the government goals on reducing 70% of marine debris in 2025 as stated in National Action Plan on Presidential Decree No. 83/ 2018.

### **1.1 Problems of macro plastic in river-sea water**

One of the problems that happen in rivers, seas and coastal areas is environmental pollution in form of piles of waste. Those wastes come mostly from land and partly from fisherman activities that enter the waters along with the rivers flow and tidal cycles. In general waste in the water can poison main producer (phytoplankton) and decrease marine productivity. Moreover, waste can also threat life sustainability of coastal ecosystem such as mangroves, seagrasses and corals.

In daily life, plastic has a important role. Each activities used plastic as a main or a part of material. According to [23], the rate of world plastic production is always increasing every year to reach 350 million tons in 2017 and it will keep increasing up to 100 times in 2025. The problem that arise when plastic has done in use is its become a waste.

The plastic characteristic is difficult to decompose so it will experience size degradation, and will be accumulated on the sediment or water column. The type of plastic that is very popular in

use are *Polypropylene* (PP), *Polyethylene High Density* (HDPE) dan *Polyvinylchloride* (PVC). In food industries, types of PP, LDPE, and LLDPE are mainly used as food packages [23].

Indonesia has produced waste and sewage as much as 0,52 kg and 11% macro plastic per person per a day in 2010 and also found as much as 83% of waste that was not treated properly [8]. In 2013, the plastic consumption level in Indonesia reached 1.9 million tons per year with a production average of 1.65 million tons per year (Ministry of Industry and Trade, 2013). The produced plastic waste significantly reaches 0.48-1.29 metric tons per year from 187.2 million of society's life in the coastal area of Indonesia. All of the newly produced plastic is estimated around 10% of it will be thrown through the rivers and ended in the seas. This condition showed that there are still around 165 thousand tons of plastic per year that will end in the Indonesian seas [24,2]. Macro plastic which floating on the river or sea can be eaten by the animals in it. It is estimated that there are 292 reports of ingestion and entangled water creature by macro plastic [25].

## **2 Method**

Description of the study site, this research was conducted in Muaragembong, Bekasi Regency on July 2020 (east monsoon) and November 2020 (east to west transition monsoon). The study sites are surrounding rivers and coastal water of Pantai Bahagia and Pantai Sederhana Villages. The sampling sites for each location consist of five and six stations as shown in Figure 1.

The research method was carried out by purposive sampling, which is expected to represent the condition of marine debris in the estuary. Sampling of floating marine debris in the water column was done with net mesh size >2.5cm with interval systematically 10 m for each station [9,26].

Marine debris was separated into macro and meso visually. For macro plastic samples, it is certain that they come from plastic, not organic materials that resemble. The method used for marine debris sampling surrounding estuary waters was adopted from NOAA Position for each sampling area was marked with GPS. The tools used in this study were digital scales, camera, GPS, loop, roll meter, trash bags, drain, trowel, waste sieves (0.5 cm and 2.5 cm) and stationery. The samples were collected in a trash bag and taken to the basecamp and laboratory for further analysis. Wastes taken from the field are cleaned using waste sieves and then dried (under the sun), classified by



**Figure 1.** Sampling location in Muaragembong

types (plastic, metal, wood, etc) and weighed using digital scales. All waste was counted to obtain the abundance or density of macro plastics in the area.

The calculation for total type and weight of macro plastic and waste follows the equation from [9,15]:

The composition of waste was calculated as a percentage, namely the weight of macro plastic  $x$  per total macro plastic waste in the survey:

$$\text{Percentage } x (\%) = \frac{x}{\sum_{i=1}^n x} \cdot 100\% \quad (1)$$

Macro plastic abundance was calculated from the weight of macro plastic per type per m<sup>2</sup> (gram/m<sup>2</sup>).

$$K = \frac{\text{type}}{\text{area}} \quad (2)$$

### 3 Result and discussion

Muaragembong is a location for “trash shipments” from the surrounding area, either through the river flow of Cikarang-Bekasi-Laut, the pathway of Citarum River flow and also the islands located or nearby Jakarta Bay [27,28]. The results of the research that have been carried out stated that oceanographic conditions affect the movement of waste in Jakarta Bay. The waste that enters the Muaragembong waters comes from the northern part (Karawang) and also the southern part (Jakarta) [29].

Generally, people on the coastal area of Muaragembong are aware of the impact of waste, such as waste can damage the ship propellers and also reduced income due to the lack of tourist visits in Mangroves forest. The community around Muaragembong identified various sources of waste, such as waste on the riverbanks and is waste that is directly produced by local residents. Meanwhile, the waste in the mangrove ecosystem comes from the river stream [28]. Flood disasters that come several times a year also the cause of increasing macro plastics in mangrove ecosystem as well as pond areas.

#### 3.1 Amount of macro debris

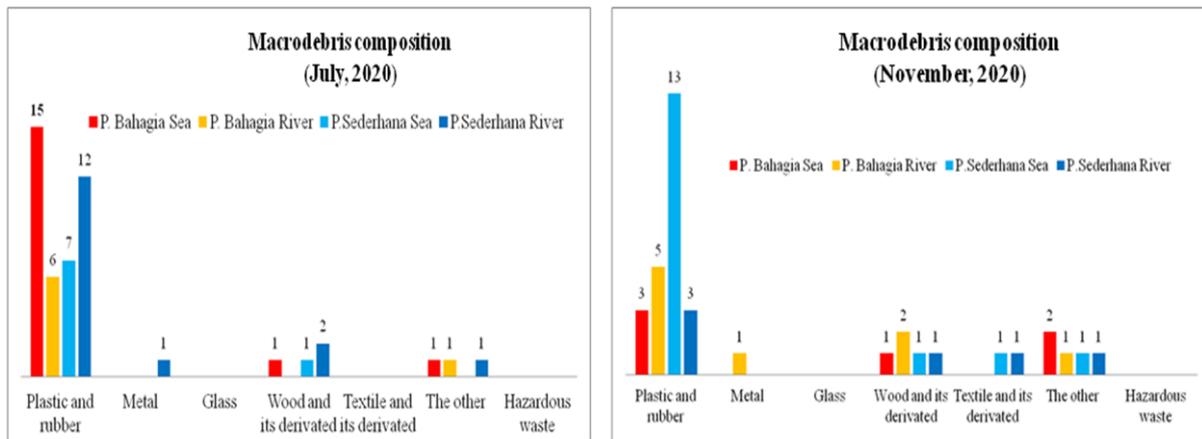
In July 2020, which is the east monsoon, the condition of sea water, estuary, and river looked pretty clean. Four types of marine debris found in the coastal and river areas of Pantai Bahagia and Pantai Sederhana Villages are plastic and rubber, metal, wood and its derivatives, and others. Based on its size, the dominant type of marine debris is macro plastic, which is around 71%.

The highest amount of macro plastic was found in the sea waters of Pantai Bahagia Village and river waters of Pantai Sederhana Village. There are more macro plastics floating in sea waters than in rivers [30].

The observation in November 2020 can be classified as an east-to-west monsoon transition. It can be seen that the water condition in river, estuary and the sea are more turbid and the amount of macro plastic floating on the surface water is also higher. Unfortunately, due to unfavorable weather conditions, the number of samples collected was very limited.

There were 5 types of marine debris found in November 2020, namely plastic and rubber, metal, wood and its derivatives, textiles and their

derivatives and others. Based on observations at two locations similar to observations in July 2020, both in river and at sea, the percentage of macro plastic is 59%. Macro plastic which is mostly found in the sea water of Pantai Sederhana Village is from the category of plastic and rubber and consists of 13 variations. Meanwhile in the river area of Pantai Bahagia Village, 5 variations of macro plastic were found with category plastic and rubber (Figure 2).



**Figure 2.** The amount of macro debris in Muaragembong in July [30] and November 2020

### 3.2 Composition macro plastic in Pantai Bahagia Village

In July 2020 15 types of macro plastic with percentage of 79% was found in Pantai Bahagia Village estuary-sea waters with the total weight of 0.365 gram/m<sup>2</sup>. Around 36% of these macro plastics are styrofoam with a weight of 0.011 gram/m<sup>2</sup> (or 16% of total weight per m<sup>2</sup>). Meanwhile, the heaviest macro plastic is pieces of shoes and sandals, which is 28% or 0.021 gram/m<sup>2</sup> where the amount is 3% (Figure 3a).

The amount of macro plastic in the river water of Pantai Bahagia Village in July was consisted of 6 types with the total weight of 0.028 gram/m<sup>2</sup>. Thick plastic and sachets have a large quantity range, about 36% with a weight of 0.002 gram/m<sup>2</sup>, and are seen floating in the water column. The heaviest macro plastic found in the river of Pantai Bahagia Village are of the type of plastic rope such as rapia, fishing net, fishing line and rope with a weight percentage of 20% or 0.007 gram/m<sup>2</sup> as shown in Figure 3a.

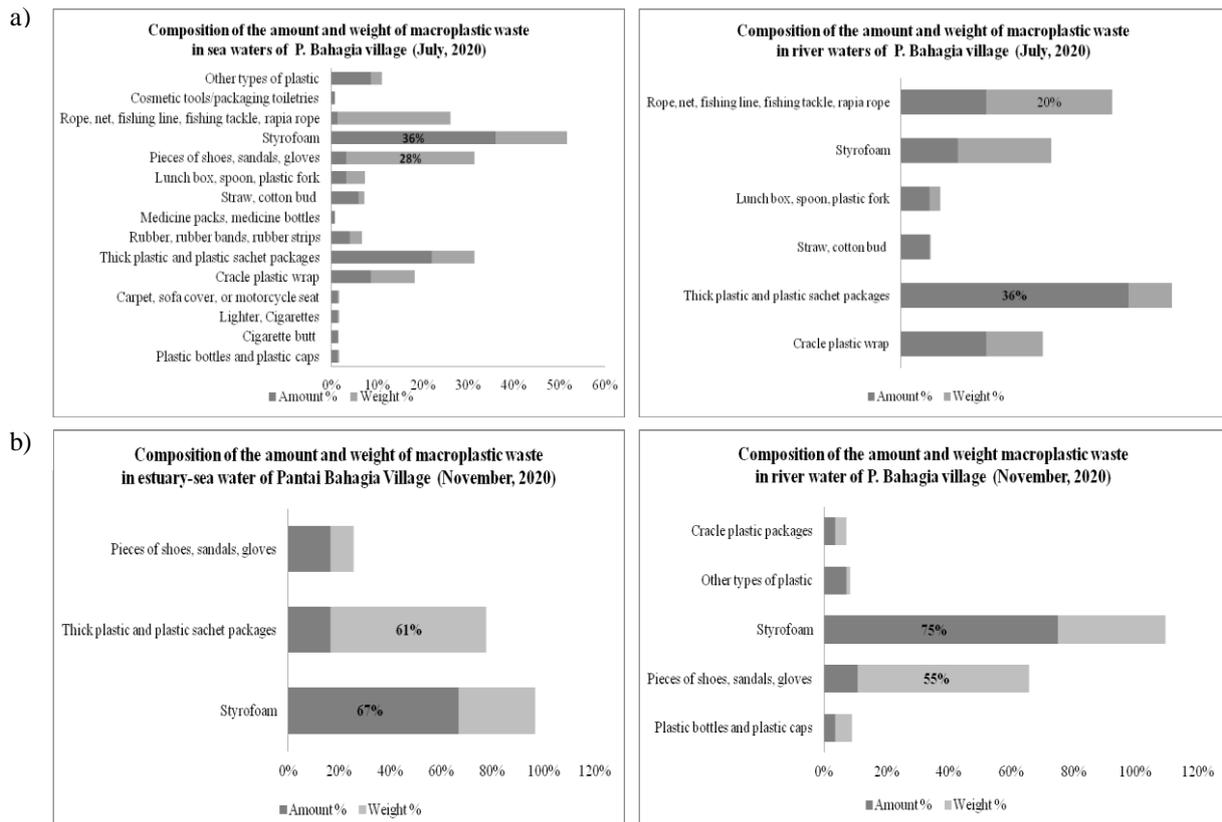
Meanwhile, in November 2020 3 types of macro plastics such as piece of shoes, sandals, gloves and their pieces, thick plastic and sachet, and styrofoam were found in the estuary and sea waters of Pantai Bahagia Village, with total weight of 0.074 gram/m<sup>2</sup>. The heaviest macro plastic was

thick plastic and sachets as much as 61% with a weight of 0.044 gram/m<sup>2</sup>. Styrofoam was mostly found floating in the estuary and sea waters with the amount of 30% and weight of 67% or 0.022 gram/m<sup>2</sup>.

The macro plastics found in Pantai Bahagia Village consisted of 5 types, namely craked plastic packaging, other types of plastic, styrofoam, piece of shoes and sandals, and bottle and bottle caps. In the river of Pantai Bahagia Village macro plastics with a weight of 0.146 gram/m<sup>2</sup> were found in November 2020. This number is greater than in sea waters. Styrofoam is still the highest, around 75% with a weight of 0.050 gram/m<sup>2</sup>. Meanwhile, pieces of sandals or shoes are the heaviest, about 55% with a weight of 0.080 gram/m<sup>2</sup> (Figure 3b).

Observation results showed that the macro plastic type of styrofoam and thick plastic or plastic sachet packaging were larger in number and weight. This indicates that those types of materials are widely used by the community. The existence of macro plastics with important economic value such as bottles and bottle caps is rarely found. Most likely this type of waste has been collected by waste pickers [27].

According to [31], the most common types of plastic waste found are PP and HDPE such as plastic bags, sachets, plastic bottles, buckets and detergent.



**Figure 3.** The composition of amount and weight of macro plastic in estuary-sea waters and river waters of Pantai Bahagia Village, a). in July 2020 [27] and b). in November 2020

### 3.3 Composition of macro plastic in Pantai Sederhana Village

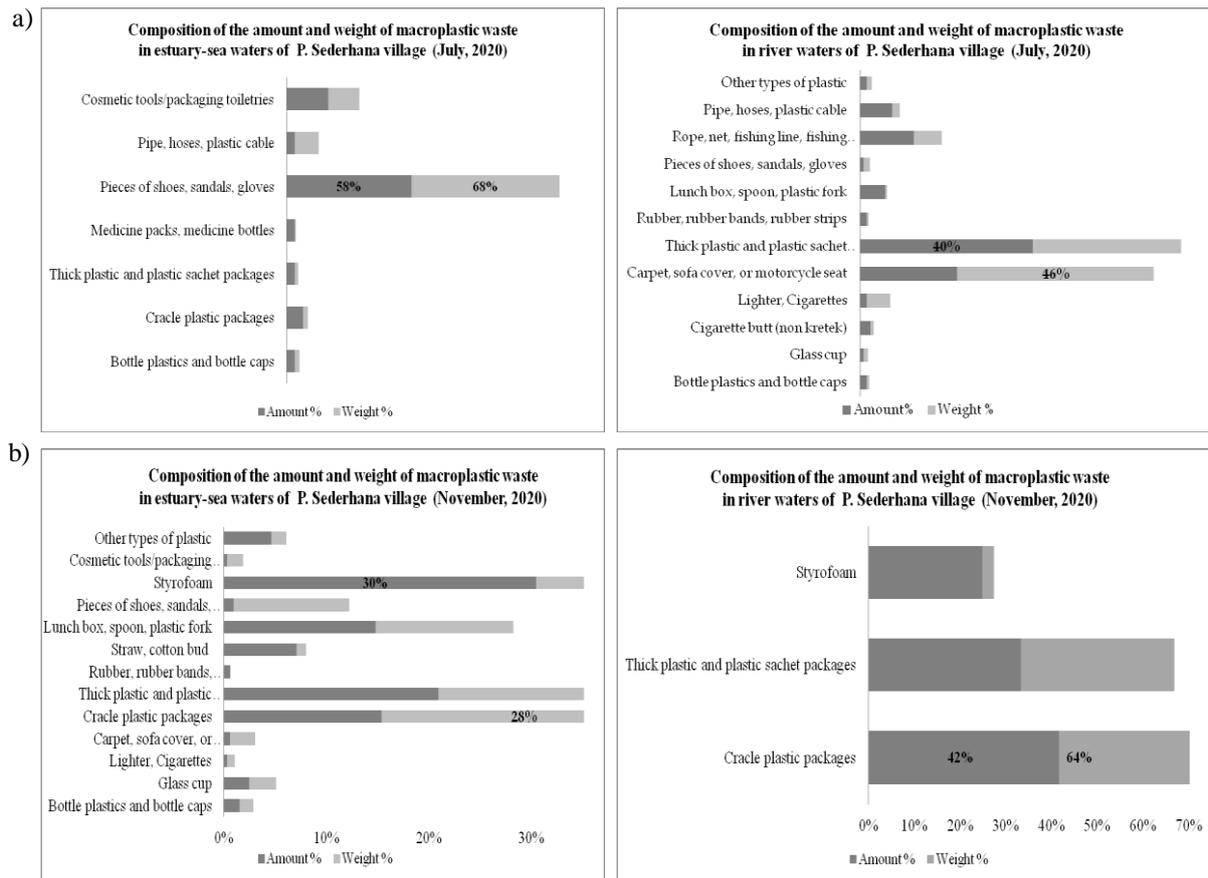
The macro plastics floating in the estuary and sea waters of Pantai Sederhana Village during July 2020 consisted of 7 types with a total weight of 0.022 gram/m<sup>2</sup>. Pieces of sandals or shoes has the largest amount and weight, around 58% and 68% or 0.014 gram/m<sup>2</sup>. Only small amount of plastic bottles were found, about 2% or 0.0004 gram/m<sup>2</sup>. It seems that this type of is collected by waste pickers. Interestingly, from the macro plastic composition, there are about 2% of drug packaging waste .

In contrast to estuary-sea waters, the number of macro plastics identified in river of Pantai Sederhana Village was more diverse, found around 12 types with a total weight of 0.076 gram/m<sup>2</sup>. Thick plastic and sachet packaging have a percentage of 40% with a weight of 0.040 gram/m<sup>2</sup>, whereas carpet and sofa covers are the heaviest, around 46% or 0.053 gram/m<sup>2</sup>. Other types of macro plastics were also found, such as plastic cable (8%), ropes and fishing nets (13%), lighters (2%), cigarette butts (3%), plastic spoons (6%), and plastic cups (1%) (Figure 4a).

Based on observations, there are daily fishing activities in Pantai Sederhana Village. It seems that

fishermen often smoke while working and bring food for their lunch that are wrapped in plastic packaging. Possibly, after eating their lunch or smoking, they throw plastic waste and cigarette butts straight into the waters. Meanwhile, the finding of carpets or sofa covers in river indicates low level of public awareness or waste management.

Observations in November 2020 show that during the east-to-west transition monsoon both estuary-sea waters and river become turbid. Due to stronger river flow and ocean current, the transport of wastes from land or upstream to the sea tend to increase. This condition can be seen from the observation results. Macro plastic in estuary-sea waters were more abundant, consisting of 13 types with total weight of 0.287 gram/m<sup>2</sup>. The most dominant type of macro plastic is styrofoam, around 30% with weight of 0.049 gram/m<sup>2</sup>. Meanwhile, the heaviest macro plastic is crackle plastic packaging, around 28% with weight of 0.081 gram/m<sup>2</sup>. Other types of macro plastic found and also have a large amount and weight are thick plastic and plastic sachet packaging (21% and 0.052 gram/m<sup>2</sup>), plastic spoons (15% and 0.038 gram/m<sup>2</sup>), straws and cotton buds (7% and 0.003 gram/m<sup>2</sup>), as well as pieces of sandals or shoes (1% and 0.032 gram/m<sup>2</sup>).



**Figure 4.** The composition of amount and weight of macro plastic in estuary-sea waters and river of Pantai Sederhana Village, a). in July 2020 [27] and b). in November 2020

Meanwhile, there were only 3 types of macro plastic in the river at Pantai Sederhana Village in November, namely styrofoam, thick plastic and plastic sachet and crackle plastic packaging. The total weight macro plastic in this waters is 0.031 gram/m<sup>2</sup>. The most type of macro plastic with a percentage of 42% and heaviest with weight around 64% or 0.020 gram/m<sup>2</sup> is crackle plastic packaging.

The results above show that styrofoam is always the dominant macro plastic in both monsoons, both in estuary-sea waters and rivers. Other types of macro plastic that are also dominant in both monsoons are thick plastic packaging, plastic sachet packaging and pieces of shoes or sandals.

### 3.4 Abundance of macro plastic

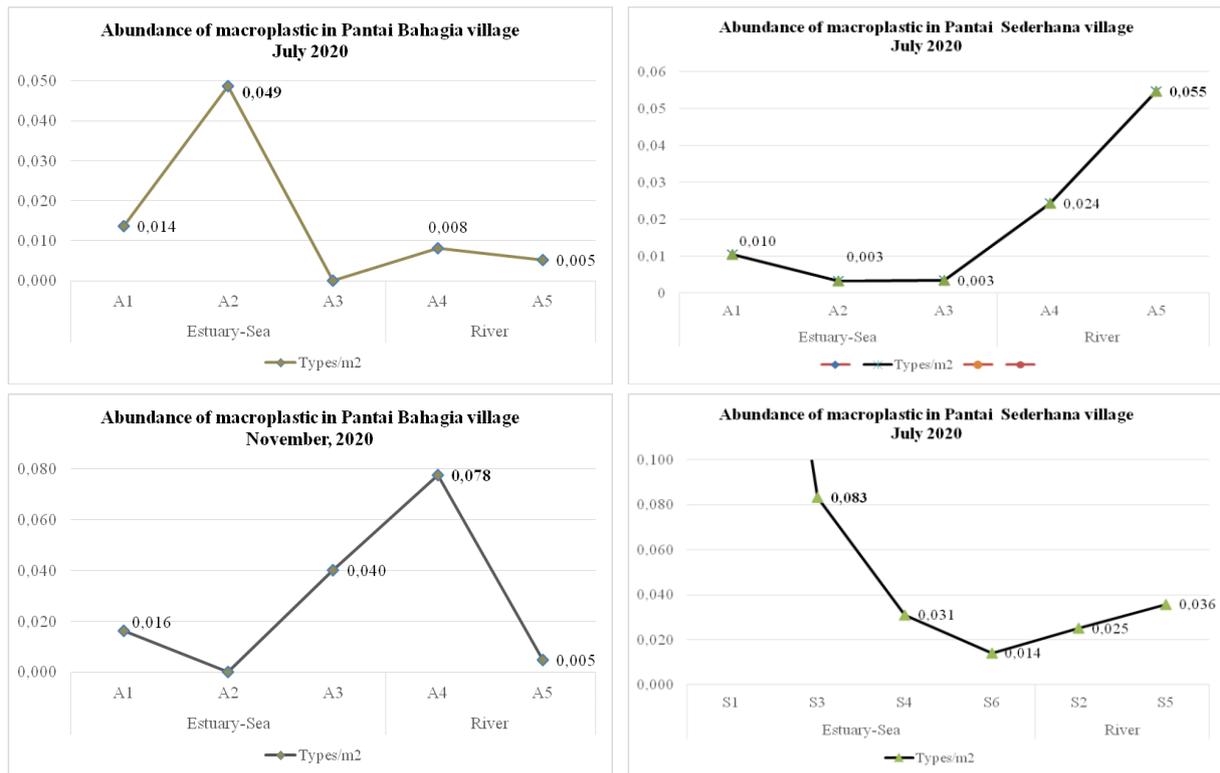
Waste worldwide is dominated by plastic waste which found on coastlines, sea surfaces and oceans, reaching up to 90% of the total waste like on the coastlines around 32-90%, sea surface amount of 86% and seabed around 47-85%. The plastic waste floating in the water column and settles on the ocean floor. The rate of increase in the amount of plastic waste in the world's ocean is around 100.000 particles per m<sup>2</sup> while in coastal

environments around 350.000 particles per km<sup>2</sup> [32].

Macro plastic accumulation in waters is strongly influenced by human activities (land-based and sea-based). Meanwhile, environmental factors play an important role in their abundance and distribution when compare to anthropogenic factors [33,34]. The abundance of macro plastic waste will be high if environmental factors are intense [35,36,37]. Figure 5 shows the estimation of macro plastic abundance both in Pantai Bahagia and Pantai Sederhana Villages in July and November 2020.

In July 2020, the abundance of macro plastic in estuary-sea waters of Pantai Bahagia Village was high at station A2, about 0.049 types/m<sup>2</sup>, whereas in November 2020, the abundance was greater, occuring in river with a value of 0.078 types/m<sup>2</sup>.

The abundance of macro plastic in July and November 2020 indicates that Pantai Sederhana Village has the highest value in the river (station S5). Macro plastic abundance in November was 0.036 types/m<sup>2</sup>, higher than in July, 0.024 types/m<sup>2</sup>.



**Figure 5.** The abundance of macro plastic in Muaragembong in July 2020 [30] and November 2020

### 3.5 Distribution of macro plastic

The non-degradable macro plastic waste dominates in two research locations, such as plastic, styrofoam, sandals or rubber. This condition can cause tidal currents to be disturbed due to piles or garbage which can have an impact on reducing the balance of nutrients carried by currents or coastal ecosystems such as mangrove.

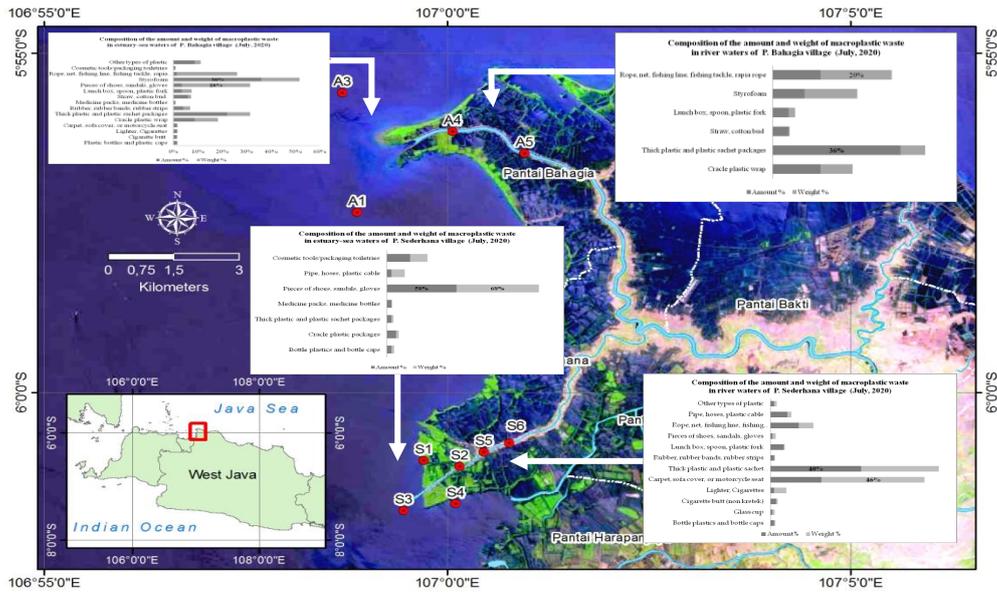
The distribution of macro plastics depends on environmental factors such as ocean currents and waves and surface winds [38]. Besides that conditions, the distribution of macro debris in sea water also influenced by human activities [19]. Other studies indicated that main total marine debris in Jakarta Bay is macro plastic around 77,7% followed by styrofoam (18,1%) [14]. According to [39], Muaragembong waters are influenced by the oceanographic conditions of Jakarta Bay which are driven by monsoon, i.e. the west monsoon in December to February and the east monsoon in June to August. Jakarta Bay water consisted of shallow water ranging from 5 to 32 meters [40]

In general, macro plastics in river of Pantai Sederhana Village in November 2020 are heavier than in July 2020. This condition is clearly influenced by meteorological and oceanographic conditions in the Java Sea. The distribution of macro plastic at two different monsoon at both locations can be seen in Figures 6 and 7.

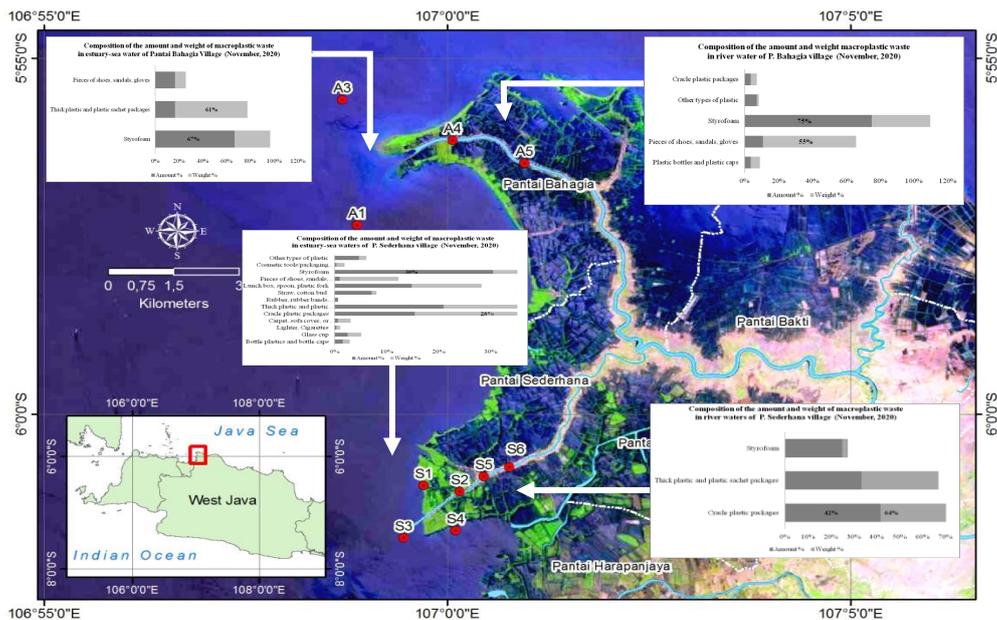
This observation is reinforced by the statement from [41], that the distribution of debris was influenced by the water hydrodynamics. One of the west monsoon characteristics is rainfall and strong wind while the east monsoon is small and dry wind [42], the wind and current condition in Jakarta Bay is strongly influenced by the monsoons [29].

According to [39], In general at Muaragembong waters that the movement of current influenced by tides, moves to northeast and southeast following topographical pattern. The velocity of current to the southeast is low tide. This condition is assumed can transport marine debris along the coast of Muaragembong. Java Sea current also affect the distribution of waste in Muaragembong [39], because its assumed that Java Sea current enters the Muaragembong waters with a speed of 0.1 m/dt at high tide to low tide in April-October. The high tide current speed is greater than low tide [39].

The simulation of microplastic waste transportation by [29] shows that macro plastic waste transported from rivers which leads to Jakarta Bay will be trapped on the north coast of Jakarta. The distribution of macro plastic in other major rivers in Indonesia, such as Musi River, South Sumatra, shows an abundance of macro plastic originating come from upstream as much as 5-32 types/m<sup>2</sup> with an average of 27.82-126.89 gr/m<sup>2</sup> [43].



**Figure 6.** Distribution of macro plastic waste in the sea and river of Pantai Sederhana and Pantai Bahagia Village in July 2020 [30]



**Figure 7.** Distribution of macro plastic waste in the sea and river of Pantai Sederhana and Pantai Bahagia Villages in November 2020

## 4 Conclusion

This study has succeeded in identifying the type, composition, as well as distribution of macro plastics in Muaragembong during the east monsoon and the east-to-west monsoon transition. From this study, it can be identified several important factors that influence the characteristics of macro plastics that contaminate Muaragembong, such as

community activities and habits, poor waste management on land, and characteristics of the waters.

The distribution of macro plastic in the estuaries-sea waters and rivers of Pantai Bahagia and Pantai Sederhana Villages based on observations can come from upstream, floods, river stream and their interaction with Jakarta Bay. In July 2020, 15 types of macro plastics were found,

while in November 2020, 13 types were found. The dominant macro plastic types were Styrofoam, thick plastic packaging, plastic sachets, and plastic bags. These three types of plastic are materials that are widely used to package food.

To complete the data in the west monsoon and west-to-east monsoon transition, this research needs to be continued. Thus, the results can be comprehensively used in formulating recommendations related to reducing plastic waste in the rivers and oceans and supporting sustainable development goals (SDGs). Further studies on the effect of macro plastic waste on the growth of organisms such as mangroves in the area will also be the next challenge that must be carried out.

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