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Riverine Plastic Monitoring during the Rainy Season in the Citarum Estuary of Muara Gembong

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Abstract. The restoration effort to clean up the river, known as “Citarum Harum” requires monitoring to estimate both the composition and the volumes of plastic pollution. The objective of the monitoring is to obtain a scientific baseline of marine plastics from Citarum River as a function of other influencing aspects. A static net trawl (60 m x 10 m, mesh size 2.5 cm, and about 1 meter submerged) was installed under the New Muara Gembong Bridge for eight consecutive days in March and April 2021 or during the rainy season. The trapped debris was collected manually into boxes using two boats and simple tools. After the drying, weighting, classification processes and by excluding natural organics (leaves/branches), plastics contributed as the most dominant for both abundance (83%) and weight (31%) followed by textiles, hazardous materials, construction materials and rubbers. The hydrological conditions as well as the tides were also observed to be one of dominant parameters. The quantification of macro-plastic litter transport from River Citarum into the Java Sea is also an aim for the ASEANO project (ASEAN – Norway cooperation project on local capacity building for reducing plastic pollution in the ASEAN region).

1. Introduction

Monitoring methodology of riverine debris has been implemented in many ways around the globe using different approaches such as nets, floating plastic boxes and modified nets and floaters [1][2]. In Jakarta, the use of fish nets and floating HDPE boxes (static trawls) have been implemented to sample debris from the canals and rivers to estimate the amount and the composition of plastics [3][4]. Some advantages and disadvantages of the methodology have been identified such as its simplicity, relatively low-cost, only certain types of trapped debris, sampling time limitation and other site-specific challenges. So far, for the case of Indonesia, the monitoring efforts of riverine plastics are very limited [5]. Big cities and key places like Jakarta and Bali are those with several implemented approaches for the investigation of riverine plastic emissions [6][7]. However, as one of major rivers in Java, there were very few information on the monitoring of plastic emissions from the Citarum River [7]. The geometry of the river (wide, strong current, influenced by the tides, and function as a waterway) poses a challenging task for the monitoring of plastic emissions. Therefore, the current study put an extra effort into finding the most practical methodology to sample macro debris in the estuary area of Citarum River (figure 1a). The findings from the current study are very strategic as baseline information to support the “Citarum Harum” program in restoring the river by 2025. In this paper, we discuss the first two months of the sampling campaigns in the Citarum estuary of Muara Gembong or during the rainy season (March and April 2021) to test the effectiveness of the monitoring methodology and to estimate riverine debris composition including the amount of plastic pollution into the ocean.

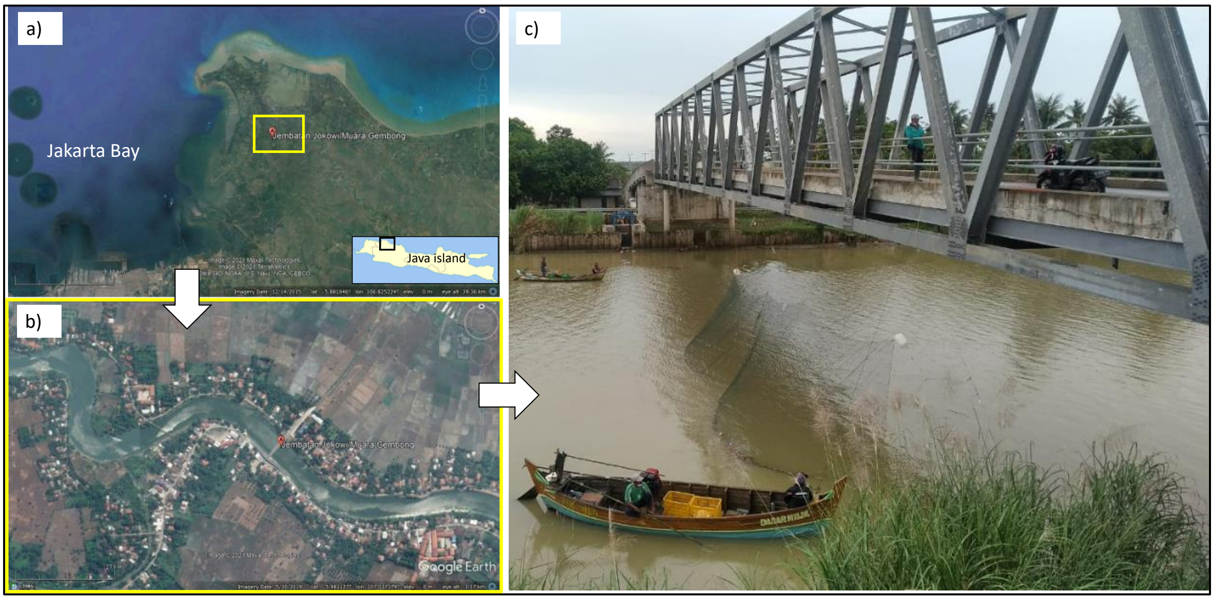

Figure 1. a) The location of Citarum estuary, at the east side of Jakarta Bay, b) District Muara Gembong where the new bridge is located, and c) The new bridge with the installed net trawl.

2. Methodology

Several considerations were taken for the selection of the monitoring methodology, including the site selection, the use of monitoring gears (net, anchors, weights, ropes) and times:

- The site should be as little as possible influenced by the tides to avoid incoming debris from the sea and to make sure that the flow is from land to the sea (upstream-downstream). This is related to the objective of the research to identify only riverine debris or debris originated from land transported to the oceans.
- The gears should not disturb the transportation in the river
- The gears used for monitoring should represent as much as possible across the width of the river to make sure the amount of debris is well represented
- The depth of the gears also should be deep enough in order not to lose some floating debris in water columns
- The gears should be strong enough to withstand the force of current, especially during the rainy season, where the discharges are higher
- The gears should be able to catch most of the macro debris, especially plastics (mesh size)
- The times and the duration of the sampling should represent the dynamics of the seasons and the populations
- Safety first is above all

Based on the above considerations and some technical aspects, the new bridge of Muara Gembong was decided as the location for the monitoring. The location is far enough from the sea and the tidal influence is minimal. The bridge also plays an important role as the supports for the gears and other equipment for the monitoring. The following design parameters were implemented for the gears and equipment for the monitoring of riverine debris in the Citarum estuary of Muara Gembong (figure 1 and figure 2):

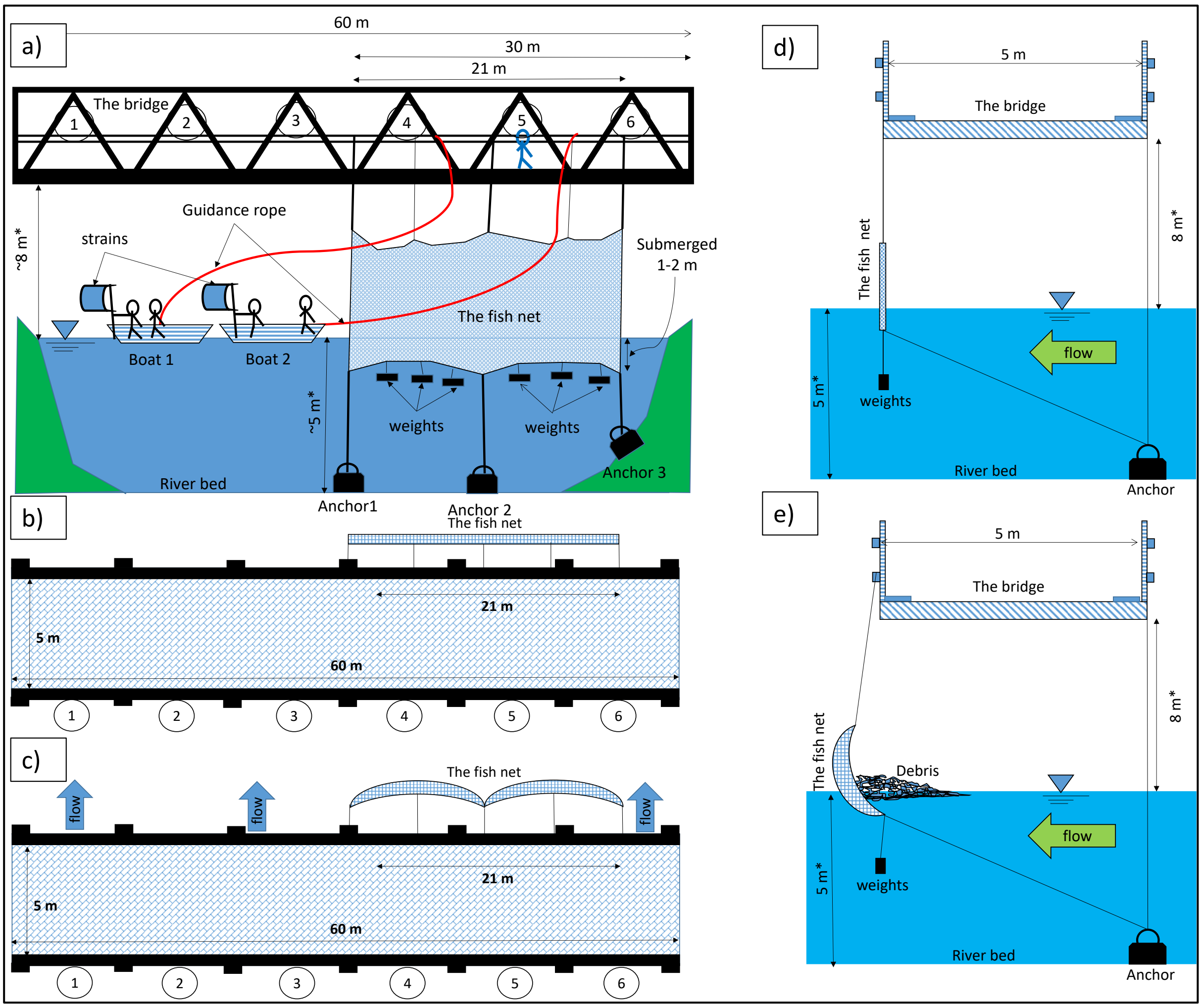

Figure 2. a) the setup of the fishnet on the bridge for trapping the debris (front view), b) the top view of the net in the bridge, c) the top view of the fishnet in the bridge when loaded by the current, c) the side view of the fishnet at the bridge, d) the side view of the fishnet when loaded by the current and debris

Figure 3. a) the trapping of the debris, b) the manual collection process, c) The collected samples in boxes, d) the sorting process of the samples, e) weighing process of the sorted samples.

- The fishnet was used to trap the macro debris with mesh size 2.5 cm, the length is 21 m and the width is 5 m. The bridge's height from the water surface is about 7 m (depending on the discharge). The net should be submerged up to 2 meters,
- The bridge was divided into six segments. The fishnet is located at segment 4, 5 and 6 with stronger ropes at each end, and in the middle for the anchors to ensure the nets are deep enough into the water columns,
- At the bottom parts of the nets, the weights were hanged to make sure the overall stability,
- The fishnet was tied by ropes into the lower structures of the bridge. There were three anchors to strengthen the stability of the nets and to reduce loads into the bridge,
- Two boats were employed with two men in each boat. One person was in charge of observing from the bridge to make sure the safety of the transportation and to warn of large debris that may danger to the nets and the boats. Both boats and the men are responsible for setting up the nets, trapping debris and collecting the debris samples,
- The time for the collection of samples was towards the low tide. At this time, the current of the river was at the highest. During this period of time, towards low tide is between 08:00 – 11:00 AM,
- The collection process is limited by the volume and by time. The maximum sample collected from the river are four boxes. The box has a dimension 47.5 cm x 34 cm x 22 cm. Sampling time is one hour. If, in less than one hour, four boxes are full, the collection can be stopped. If not, the sampling may continue until at least one hour,
- The sampling is designed to cover wet and dry seasons as well as the transitions. The total sampling period is six months consist of two months for wet seasons, two months for dry season and two months for the transition. For each month, eight consecutive days of sampling are conducted. In the current study, the sampling was during the wet season or during March and April 2021,
- The reference for the tide is the tide station in the Jakarta Bay (Tanjung Priok port of Jakarta) belongs to BIG (the Indonesian Geospatial Information Agency)
- The hydrology characteristics such as precipitation in Muara Gembong was based on qualitative observation at the site (Muara Gembong) and BMKG (The Agency for Meteorology, Climatology and Geophysics) data in Bandung,
- The collected samples were then dried up under the sun for at least 8 hours (the next day).
- The dried samples were sorted based on the classification in www.marinedebris.id, weighted and documented,
- The flow velocity was estimated by measuring the travel time of a floating object over the distance,
- The elevation was measured at the dedicated benchmark near the bridge.

3. Results
The collection of the samples took place on March 5th-12th, 2021 (8 days) and continued on April 3rd-10th, 2021 (8 days). March and April 2021 can be considered as still within the rainy season because of high precipitation in Muara Gembong and the surrounding area (river catchment area). The data from BMKG showed that precipitation in Indonesia was 93% as normal and above normal where the Eastern part of West Java Province experienced more than 300 mm/day (above normal) of precipitation [8][9]. During the collection of samples, high discharges due to flood in the downstream were observed several times. Consequently, more large debris were also observed, causing safety issues to the sampling processes. In general, the sampling processes were running smoothly except for the first days of March 2021 due to some technical issues in preparation and for finding the ideal spots for the monitoring. The ideal spot for the monitoring of the debris samples was finally decided under the new bridge of Muara Gembong or locally known as *Jembatan Jokowi*, after the President of Indonesia who inaugurated the construction of the bridge. Fig 3 and Fig 4 show the collection results of the debris arranged based on

10 debris classifications (plastics, papers, rubbers, textiles, organics, metals, glasses, ceramics, hazardous material, and others). For organics, we considered both natural categories (leaves, branches, etc) and construction materials (wood materials and alike). The number of items were counted and the weight of each classified debris were measured. The percentage of each debris classification was tabulated and analysed considering the dynamics of the population and hydrological conditions. The hydrological condition is very important and determine the amount of debris and the characteristic of the debris as observed in the field. Therefore, the weather conditions at the location of the sampling and the weather conditions upstream were also taken into consideration.

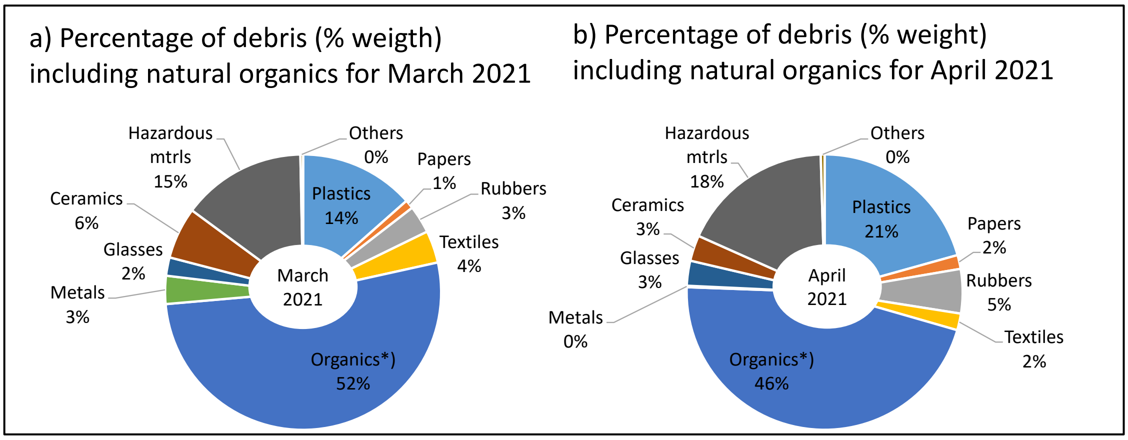

Figure 4. Percentage of the debris with natural organics included.

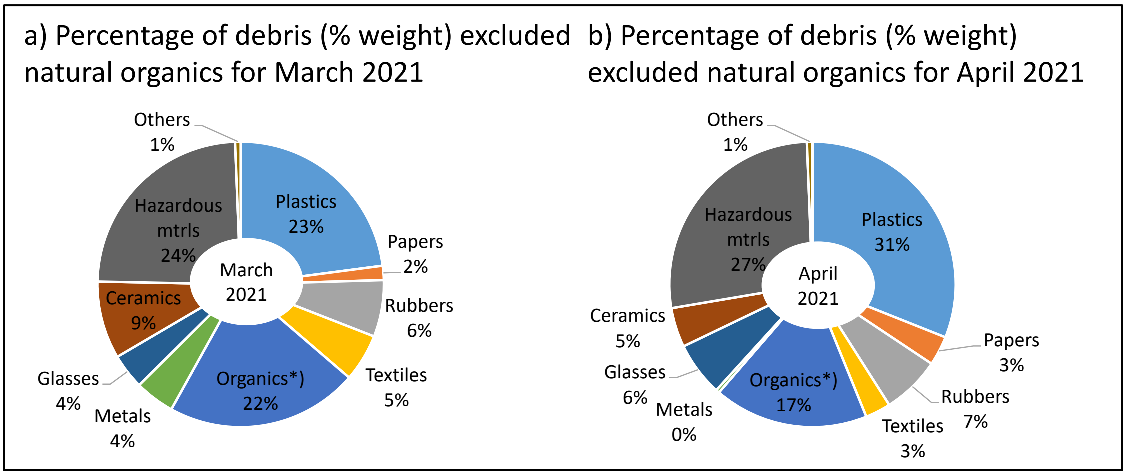

Figure 5. Percentage of the debris without natural organics.

A shown in figure 3, considering natural organics, the percentage of the debris was clearly dominated by natural organics with percentage up to 52% (averaged in March 2021). In March, the five largest categories belong to organics, plastics, hazardous material, ceramics, and textile. While in April, the dominant categories are still the same, only hazardous materials were a little bit higher than plastics. If natural organics were excluded, the dominations were replaced by hazardous material in March and by plastics in April. Organics (woods materials) are still one of the most dominants debris, counted 22% in March and 17% in April. In general, the percentage of organics was reducing considerably from March to April by 6%. If natural organics were excluded, the reduction of organics was about 5 %. Meanwhile, the number of plastics increased significantly by 6%. Hazardous materials also increased about 3% while the others generally remained stable. Based on counted items (abundance), plastics are the most dominant for both March and April, followed by hazardous materials. The domination of plastics based on counted items due to large numbers of sachets and wrapping plastics. For the case of hazardous materials, diapers are the most dominant items.

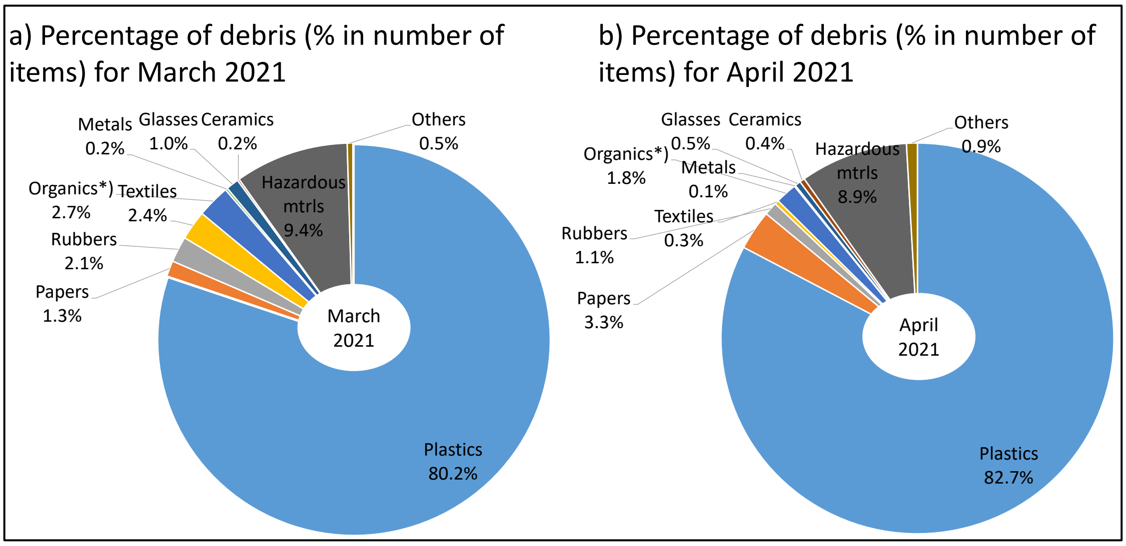

Figure 6. Percentage of the debris based on counted items.

The sampling of the debris was based on the number of collected boxes in one hour. Figure 7 shows the amount of trashes in number of boxes for one hour of sampling. The figure shows that for both March and April, one peak reaches up to 25 boxes. For both months, the pattern similarly was observed where after the peak always followed by significant drop on the following days. Gradual increases were observed in March, while almost zero debris were observed in April. These dynamics are closely related to the hydrological condition of the river as well as the weather conditions at the local scale. The characteristics of the collected debris, their amount and the hydrological conditions are analysed in the discussion.

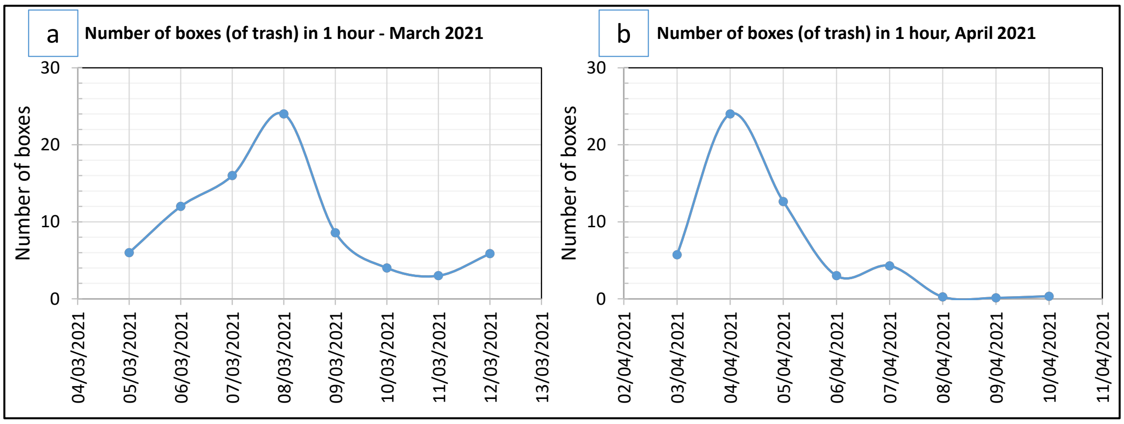

Figure 7. The amount of collected debris based number of boxes in an hour, a) for March 2021, and b) for April 2021.

4. Discussion

Based on the data from BMKG, March and April 2021 for West Java region were considered as rainy season characterised as normal and above normal with precipitation may reach above 50 mm/day [8][9]. The data from BMKG station in Bandung (upstream of Citarum River) showed that rainy even in March was more intense compared to April (figure 8). The sampling period in March was from 5-12 of March 2021, where daily rainy even was almost every day in Bandung with a maximum precipitation rate about 30mm/day. Meanwhile, the precipitation during the sampling in April was much lower or below 5 mm/day. But, one day before the sampling, there was a rainy even with 30 mm/day (figure 8).

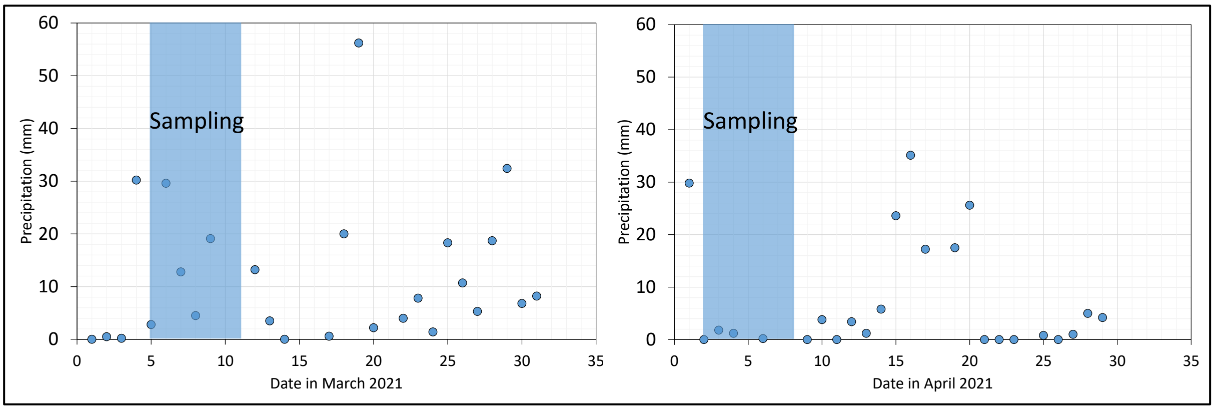

Figure 8. Precipitation in Bandung Station in March and in April 2021(https://dataonline.bmkg.go.id).

Precipitation greatly influences the characteristics of the riverine debris [5][3]. A significant amount of debris will also be observed during the first rain. This explains the logic of accumulated debris along the river banks that washed away by the first rains leaving much less debris in the following days [7]. Higher discharges will bring more debris in the river, especially organic materials while other types of debris, including plastics tend to be stable [4]. Comparing Fig 7 and Fig 8, the amount of debris seemed to correlate with the precipitation in the upstream of the river. Considering the distance between the sampling location and the rain gauge (~150 km) and the flow velocity (0.5 m/s - 1m/s), the amount of the washed debris may travel along the river from the gauge station to the sampling location for about 42 – 83 hours or in two or three days. These explained why in March there was a peak at the fourth day of the sampling and then the amount of debris reduced significantly. The rising amount of debris up to the fourth day could be due to the rain started a day earlier followed by days after. However, as rains continued up to the 5th day, the amount of debris reduced gradually. A stronger correlation between the rain (discharges) and the amount of debris was more visible in April, where the significant rain after days of dry conditions were observed before the sampling. Large amount of debris were observed on the second day of the sampling or the 3rd day after the rain even. After that, there were no rains and the debris was drastically reduced.

Another factor that may also affect the amount and characteristics of the transported debris is the tide [6][2]. The tide in the river mouth or the flood plain is very dominant in controlling the hydrological characteristics of the river. During the sampling period, the tidal data from BIG (Tanjung Priok Port) in March was blank for few days but the tidal data in April was complete (figure 9). The tides during the sampling showed that the tides were at high position at the beginning and then got lower at the end of the sampling days. In other words, these may also weaken the discharge of the river due to smaller gradient water levels at the estuary. This situation was observed during the sampling, especially in the afternoon where the flow seemed completely to stop for few hours. During this time, the other force that controlling the flow was the wind. When strong winds were present and the river's flow was very weak (e.g. during no rain and low tide even), the river flow direction followed the direction of the blowing winds (sometimes in the upstream direction).

Based on the debris sample composition, for both March and April showed that organics were the dominant items, followed by plastics, hazardous material, ceramics, rubbers and textiles. These compositions are at least in agreement with the report from the World Bank [7] for the sampling in the North of Jakarta where organics, plastics, hazardous materials, rubbers and textile are among the most dominant items. Even if the natural organics are excluded, the most dominant items remained similar and only percentages of each items changed, except for textiles in April which was replaced by glass materials. Domination of plastics, rubbers, textiles and hazardous materials for the area of Tanggerang, Jakarta and Bekasi (Jakarta bay area) was also observed as reported by [4]. Aside from plastics, diapers were the most prominent item for the hazardous material category. This findings in line with the data from the World Bank, where diapers contributed up to 21% for marine litters [6]. For the case of rubbers, items such as sandals and shoes (foot wares) are the most dominant for both abundance and weight.

Ceramics or construction materials in the form of light weight concrete bricks (hebel blocks) were quite significant not because of the abundance but due to their weights.

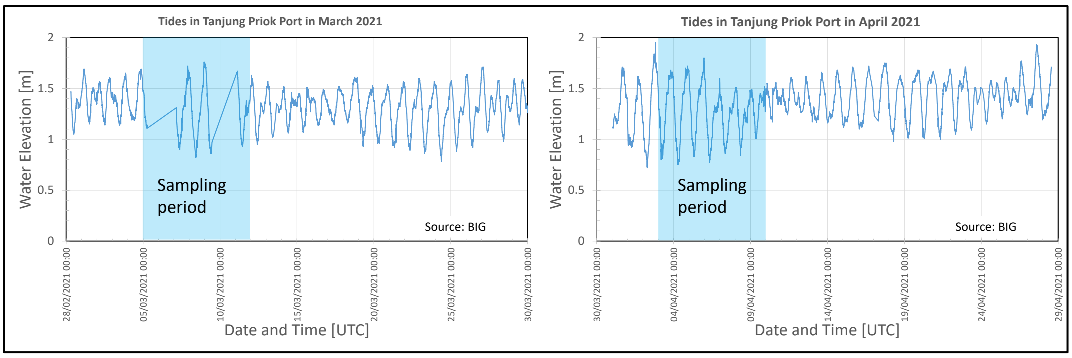

Figure 9. Tides of Jakarta Bay in March and April 2021 near the sampling location (http://tides.big.go.id/)

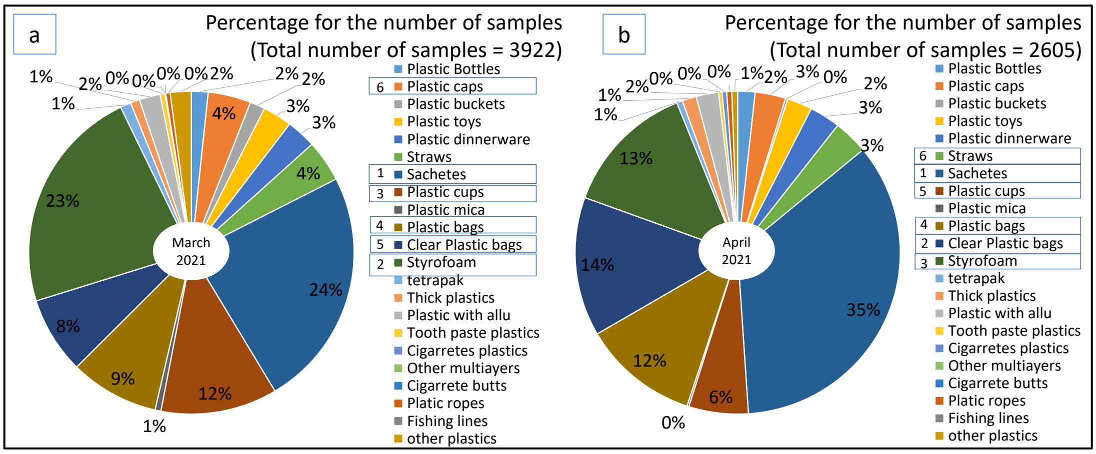

Figure 10. The abundance of plastics (%) for March and April 2021. The six squared boxes on the legend (the right side of the pie chart with numbers) represent the six most dominant plastic items.

By excluding natural organics, plastics are the most dominant for both abundance and weight (figure 10 and 11). This is consistent as compared to the studies from [6][4][5][7] for the Indonesian cases. Based on the categorisation of plastics, there are six most dominant items in terms of abundance. There were more items in March (3922 items) compared to April (2605 items or -34%) due to low precipitation in April as discussed earlier. For March, the abundance of plastics were sachets, styrofoams, plastic cups, plastic bags, clear plastic bags and caps of drinking plastic bottles. Meanwhile, for April, sachets were still the most dominant ones followed but clear plastic bags, styrofoams, plastic bags, plastic cups and straws. In terms of abundance, the domination of those items was commons, as reported by [6][4][5][7]. Recalling other studies on marine debris, those plastics items (i.e. food wrappers and plastic bags categories) were also in fact, are the most commonly found items in Indonesian waters [10][11][12][13][5].

Based on weight, the total weight of collected plastics in March was 37772 gr. In April, the total weight of the sample reduced by 40% or 22312 gr (figure 11). This reduction occurred mainly due to the characteristics of the precipitation, tidal and wind characteristics at the sampling area and the catchment area of the river. There is a slight change on the most dominant plastics based on weight compared to abundance. Based on weight, the six most dominants items of plastics remain similar for both March and April. They are plastic bags, styrofoams, clear plastic bags, sachets, plastic cups and drinking plastic bottles. This confirms many previous reports that food wrappers and plastics bags are the most dominant categories for plastic wastes. Meanwhile, Plastics bottles and plastics cups were also found to be among the most dominant. This means efforts for recycling valuable plastic may still be low in this area as also reported by the World Bank though intense efforts for recycling valuable plastics were high [7]. So far, the results from the current study in terms of abundance and weight of debris (percentage) and plastics are consistent with previous studies in the nearby area [5][4]. The presented results of the current study have shown the importance of continuous monitoring in the river mouth as the main source of marine plastic emission into the Indonesian seas [3][14].

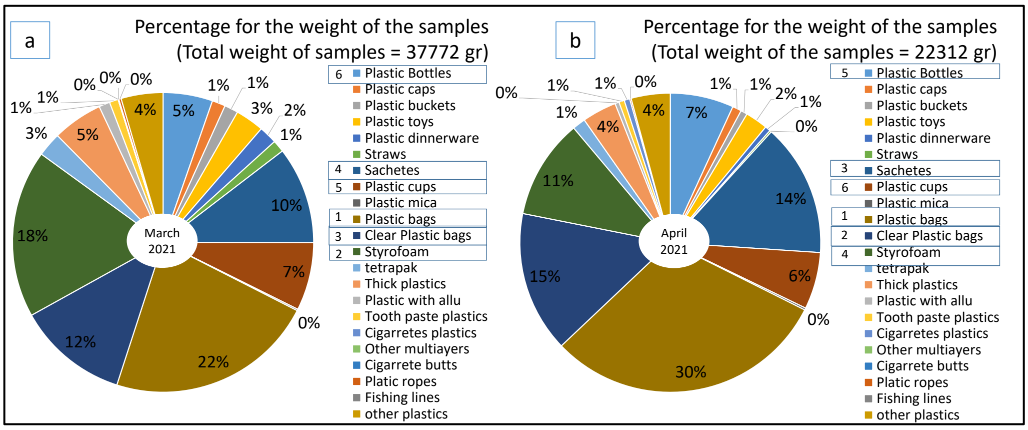

Figure 11. Weight of plastics (%) for March and April 2021. The six squared boxes on the legend (the right side of the pie chart with numbers) represent the six most dominant plastic items.

5. Conclusion and Recommendation

Based on the above discussion, a strong correlation of rain intensity (precipitation) to the amount and characteristics of debris collected from the river was confirmed. Significant amount of debris was observed after heavy rains in the area (or the river catchment area). Local rains, however, were less significant in producing river discharge as well as the debris. Another important aspect is the time of the first rain after days without rain. In this case, a single day of rain may flash out all the debris in the river / riverbanks and subsequently leaving less debris in the following days. The dynamic of the tide and strong wind also clearly influenced the dynamic of the estuary and the transported debris in the area. The current study also confirms the need for research and deeper investigation on riverine monitoring for plastic emission into the marine environment in Indonesia due to lack of field data, rare continues monitoring and the affecting factors to support the goal of 75% marine plastic reduction by 2025 (Presidential Decree No. 83/2018). The two months of monitoring have already provided insight characteristics of the transported litters and challenges in the estuary of a large river like Citarum. Thus, the monitoring should continue for other months representing different seasons (transition and dry seasons) which will be covered by the ongoing ASEANO Project (ASEAN – Norway Cooperation Project on Local Capacity Building for Reducing Plastic Pollution in the ASEAN Region) until the end of 2021.

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