Study on Indonesian plastic marine debris based on river survey

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Abstract. In response to Jambeck’s claim on Indonesian plastic marine debris, some academicians, scientists, as well as associations such as The Indonesian Olefin and Plastic Industry Association (INAPLAS), Indonesian Plastic Recycle Association (ADUPI), and Indonesian Plastic Recycle Industry Association (APDUPI) conducted a deeper plastic balance examination to clarify and enlight the Indonesian plastic marine debris amount. This study continued the previous work, which employed the river survey method to conduct a more accurate calculation in the actual condition. From the river survey results, Indonesian plastic marine debris amount is about 0.038 MT/y and it will reduce to 0.004 MT/y if the trash trap is strictly-applied. This result is not much different compare to the seashore approach but again also clarifies that Indonesia is not the second-largest contributor country for plastic marine debris. Moreover, aside from conserving the marine and river environments, installing a trash trap on the river could increase local people’s income at once.

1. Introduction
Based on the research conducted by Jambeck et al. (2015), Indonesia is the second-largest country for plastic marine debris after China with the amount of 0.48-1.29 MT/y and this happened due to Jambeck’s misleading assumptions such as Indonesian coastal population within 50 km from the ocean, 0.52 kg/person/day of waste generation rate, 11% of total waste is categorized as plastic waste, and 83% of total plastic waste is mismanaged [1]. This article raises some issues and speculations that plastic has become an enemy of human life. The results of Jambeck’s calculation have forced our government to implement plastic packaging tax according to Circular Letter of the Ministry of Environment and Forestry No. S.1230/PSLB3-PS /2016 about mechanism and price of paid plastic bags [2]. To follow up this matter, some academicians, scientists, as well as associations such as The Indonesian Olefin and Plastic Industry Association (INAPLAS), Indonesian Plastic Recycle Association (ADUPI), and Indonesian Plastic Recycle Industry Association (APDUPI) conducted a deeper Indonesian plastic balance examination [3,4].

The previous study on Indonesian plastic marine debris using national balance (0.17 MT/y) and seashore approach (0.004 MT/y) have different results with Jambeck’s due to the improved justifications in terms of coastal population definition which is 10 km from the ocean, 0.19 kg/person/day of waste generation rate, 9% of waste is categorized as plastic waste, and 10% of plastic waste is mismanaged [5]. To assign a more accurate Indonesian plastic marine debris amount, a direct river survey was conducted on several rivers in Java Island which lead into the ocean. It was realized that Java Island contained 6% of the Indonesian Area and contributed to 56.3% of the total population [5–8]. As
consequence, a river survey in Java Island could be applied to represent the Indonesian river [9]. The purpose of this study is to determine the actual Indonesian plastic marine debris through river survey and compared the results with Jambeck’s. A trash trap was installed in every surveyed river and the amount of plastic waste trapped was calculated annually. The plastic flow diagram from river survey was also generated.

2. Methods

The method in this study encompassed direct river survey, trash trap installation, trapped plastic waste calculation, as well as local people interview to justify the riverbank width. The interview was held for 200 respondents. This study only focused on the plastic waste that flows in the river, because has a high potential to entering the ocean. As aforementioned, river survey was conducted in Java Island’s rivers because it could represent the Indonesian river.

Eleven dominant rivers in Java Island were surveyed, namely Ciliwung-Cisadane, Citarum, Cidanau-Ciujung-Cidurian, Cisadea-Cibareno, Cisulak-Cilaki Jratun-Seluna, Wiso-Gelis, Pemali-Comal, Serayu, Bengawan Solo, and Brantas. These rivers were chosen because of their length and wide anatomy, which were distributed in five major provinces in Java: Banten, DKI Jakarta, West Java, Central Java, and East Java which directly connect to the ocean. The map of each river is shown in Figure 1.

The trash trap installation was performed in every surveyed location and the trapped plastic waste was then weighted every day. Subsequently, Indonesian plastic marine debris calculation according to river survey was first derived from the monthly trapped plastic waste ($RPW_m$) in every river. The annual trapped plastic waste in every river ($RPW_A$) was calculated based on equation 1. To provide a plastic flow diagram, the riverbank area ($RBA$), the riverbank population density ($RPD$), and specific plastic waste generation ($SPWG$) should be determined. The riverbank area ($RBA$) calculation was presumed as a rectangle with the length ($RBL$) which was measured using google map tracing distance and the width ($RBW$) which was obtained from the interview. The riverbank population ($RP$) was determined through equation 2. The calculation for plastic waste generation ($PWG$) in every river was served in equation 3. Finally, the Indonesian plastic marine debris was determined as seen in equation 4 if no trash trap was installed and follows equation 5 if there is trash trap was installed.

\[
RPW_A = 12 \times RPW_m \tag{1}
\]

\[
RP = RPD \times RBA = RPD \times RBL \times RBW \tag{2}
\]
\[ \text{PWG} = RP \times SPWG \quad (3) \]

Indonesian Plastic Marine Debris = \[ \sum_{i=1}^{n} \frac{SF \times PWG}{J} , n = \text{total river} \quad (4) \]

Indonesian Plastic Marine Debris = \[ \sum_{i=1}^{n} \frac{SF \times (PWG - RPW_A)}{J} , n = \text{total river} \quad (5) \]

where \( SF \) is season factor (the escalation of river waste amount due to 6 months rainy season and 6 months dry season in Indonesia) and \( J \) is Java population proportion.

3. Results and discussion

3.1. Riverbank length and width

The interview is intended to determine the riverbank width and to convince the plastic marine debris contributor. According to 200 respondents, interestingly, 85.6% of them (172 respondents) were not throwing garbage into the river. Some of them fear heavy flooding due to the water drainage plugged; some of them said that it is a bad habit; some of them argued that the river and marine ecosystem and esthetical value will be damaged. Nearly 61% of respondents who ever throw garbage into the river (18 respondents, 9% of all respondents), stayed near the riverbank with a distance of less than 1 km. The people who have a house more than 1 km from the river do not throw garbage into the river due to the long-distance, so they like to be buried, burned, or disposed of the waste in the landfill.

The interview also convinced the argument that plastic marine debris is not generated by people who throw waste on the ocean because it will be dragged back to the beach due to the ocean waves. This condition is supported in Cianjur Coast survey that the twig and tree waste were dominantly found along the coastal line and not found in the ocean. Furthermore, there is a low amount of plastic waste found on Cianjur Coast. The supporting picture is served in Figure 2.

![Figure 2](image)

**Figure 2.** Domination of wood and twig trash in Ciwulan River downstream: Surveyed on November 22nd, 2017 (a,b) and November 24th, 2017 (c,d).

The plastic waste generation in the river is then strongly coming from the riverbank population who throw waste into the river, with 1 km distance from the river. The riverbank width should be multiplied by 2 due to river’s left side and right side. Meanwhile, the riverbank length measurement procedure using google map tracing distance is illustrated in Figure 3.
Figure 3. River length measurement procedure: Serayu River in Karanggayam sub-district, Central Java (a); Cidanau-Ciujung-Cidurian River in Serang sub-district, Banten (b).

3.2. Plastic waste generation from riverbank population
The river waste generation inevitably depends on the riverbank population density and riverbank area. The longer river length and denser riverbank population increase river waste generation, indeed. It is also observed that every Indonesian people throw waste theoretically at about 0.75 kg/day (Table 1), although it is lower than Malaysia and Singapore which are 1.5 kg/day [10].

| No. | Amount   | Unit       | References |
|-----|----------|------------|------------|
| 1.  | 0.70-0.80| kg/person/day | [11,12] |
| 2.  | 0.70-0.85| kg/person/day | [13,14] |
| 3.  | 0.75     | kg/person/day | [10] |
| 4.  | 0.70     | kg/person/day | [15] |
| Average | 0.75 | kg/person/day | 0.27 tonnes/person/y |

According to Tempo, 9% of total waste is categorized as plastic waste [15] and the updated one is 4.65% taken from INAPLAS, Unilever, and Bali province data. INAPLAS also complements that 17.4% of total plastic waste is recycled and 40.2% of the plastic waste after-recycled is thrown into the landfill [3,4,7]. The rest is entering the river. Therefore, the plastic waste generation per person entering the river (SPWG) is 0.0062 tonnes/person/y.

3.3. Indonesian plastic marine debris from river survey
Every year, Indonesia has 6 months of rainy season and 6 months of dry season. During rainy season with a high wind occurs, the river flow rate becomes much higher, the waste amount in the river is 10 times higher, and waste transportation has more frequently occurred, reaching 10-30 times daily. The season factor is 1 when dry season and is 10 when heavy rain and windy. Thus, the annual marine plastic waste is generated from cumulative trapped plastic waste in the river multiplied by 5 as an average season factor. It is found that there is a huge of wood and trunks (Figure 4a) and also 15 tonnes of trunk (Figure 4b) were dragged by the river stream during rainy season and this could increase the probability
of trash trap breakage. Frequent maintenance of the trash trap is imperative to hinder plastic waste enter the ocean.

![Image](a)  ![Image](b)

**Figure 4.** Wood and trunks waste in the Manggarai River during rainy season (a); 15 tonnes of trunk found in Manggarai river (red area).

Plastic marine debris calculated in every province is outlined in Table 2. From the survey, Indonesian plastic marine debris result is about 0.038 MT/y and if the trash trap is strictly-applied, the value is reduced to 0.004 MT/y. The comparison between several methods on Indonesian plastic marine debris amount is served briefly in Table 3. The number of plastic marine debris counted from the river survey lower than the IPNB, yet almost the same with the seashore approach and the three are still lower than Jambeck’s calculation. The activity of daily river waste trapping is depicted in Figure 5.

| Table 2. Indonesian plastic marine debris result based on river survey. |
| --- | --- | --- |
| **Province** | **No Trash Trap (MT/y)** | **With Trash Trap (MT/y)** |
| Banten | 0.00264 | 0.0017 |
| DKI Jakarta | 0.00922 | 0.00111 |
| West Java | 0.00337 | 0.00040 |
| Central Java | 0.00329 | 0.00045 |
| East Java | 0.00297 | 0.00039 |
| Total | 0.02149 | 0.00253 |
| **Indonesian Plastic Marine Debris** | **0.038** | **0.004** |

| Table 3. Comparison of several methods on Indonesian plastic marine debris amount. |
| --- | --- | --- |
| **Calculation Methods** | **Indonesian Plastic Marine Debris** | **Reference** |
| Jambeck | 0.48 – 1.29 MT/y | [1] |
| IPNB | 0.17 MT/y | |
| Seashore Approach | 0.004 MT/y | [5] |
| River Survey + Trash Trap | 0.004 MT/y | This study |
Indonesian population is about 268 million people [6] and coastal population is 44.75 million people. From the river survey, every person generates 0.27 tonnes/person/y of waste and the percentage of plastic waste is 4.65%. The plastic waste generates in the coastal area, hence, is 0.57 MT/y while in the non-coastal area is 2.84 MT/y. The plastic waste is mostly recycled, thrown into the landfill, burned, buried, and the rest is thrown into the river. About 0.034 MT/y of river plastic waste was picked up and together with recycled plastic waste from non-coastal area to form 1.655 MT/y of annual recycled plastic [3,4,7]. After picking up, 0.004 MT/y of plastic enters the ocean as marine debris. The Indonesian plastic material balance from river survey is described in Figure 6. The plastic marine debris amount from river survey is not far different from IPNB and seashore approach [5] as shown in Figures 7 and 8. Again, the river survey calculation does not support Jambeck’s claim. The difference is might caused by misleading assumptions and inaccurate methods of Jambeck’s calculation.

**Figure 5.** Daily river waste trapping by riverbank community (a); River waste trapped (b).

**Figure 6.** Indonesian plastic flow diagram based on river survey.
Figure 7. Indonesian plastic balance based on IPNB [5].

Figure 8. Indonesian plastic flow diagram based on seashore approach [5].

4. Conclusions and closing remarks

From this study, it is agreed that Indonesia has a problem with plastic marine debris although the number is much lower than Jambeck’s calculation. The river survey with the season factor correction gives a more accurate plastic marine debris amount with similar results to the previous study, 0.004 MT/y. However, it could increase to 0.038 MT/y if no trash trap is installed on the river. The river survey study also confirmed that Indonesia is not the second-largest contributor country for plastic marine debris.
Installing a trash trap on the river protects the river waste flow to the ocean, it also facilitates local people to clean the river as well as increasing their income from recycled plastic waste selling activity. From the river survey activities, many local people show their big thanks and hoped that this could be a long-term program. The government should show the synergy and would be more appreciated if each village and district are equipped with trash trap, plastic shredder machine, incinerator, and further plastic pyrolysis unit, as an implementation part of integrated waste management.

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