Marine debris: Sources, characteristics, and environmental impact on Baturusa River, Bangka Belitung

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Abstract. Seas are highly susceptible to pollution from marine debris. Baturusa River at the Bangka Belitung Islands province may be a major source of marine debris. Anthropogenic activities such as urban settlements, ports, and coastal tourism contribute to marine debris which threatens the environment. This study located at Koala and Pasir Padi Beach and the mangrove ecosystems surrounding the Baturusa estuary. The sampling and analyzing methods were based on NOAA and MoEF guidelines which categorize debris into macro-sized and meso-sized. In terms of weight, plastic dominated the macro and meso marine debris samples from Pasir Padi Beach with 60% and 100% respectively, and from Koala Beach with 30% and 56% respectively. The density of the debris samples mostly came from plastic with 3.4 pcs/m² for macro, and cork with 0.76 pcs/m² for meso. The source of the marine debris is assumed to be households and tourism, where waste is deposited in the river and is carried to the estuary where it threatens the mangrove ecosystems. The Mangrove Health Index of the Baturusa estuary is moderate, with 41.44% and 39.42% respectively. This study will be a fundamental data for formulating the most suitable regulation of waste management in Bangka Belitung.

1. Introduction

The sea is one of 17 topics covered in the 2015–2030 Global’s Sustainable Development Goals (SDGs) which aim to balance three dimensions of sustainable development, namely environmental, social, and economic [1]. Those seas are highly susceptible to pollution due to large quantities of marine debris that end up there, such as from agricultural material, household waste, naval waste, and oil spills. Two-thirds of Indonesian territory comprises seas and marine debris is, therefore, particularly in coastal areas, a major problem [2]. The Bangka Belitung Islands province, as an archipelagic region, can become a major contributor to marine debris and negatively impact the local environment and ecosystems.

Bangka Belitung Islands is a rapidly developing province with a growing industry and economy. Correspondingly, waste production often in the form of plastics increases, and most of it ends up in the sea, becoming marine debris. Three major negative effects marine debris has, are the reduction of the appeal of beaches [3], water quality decrease [4] and the threat to estuary ecosystems such as mangroves [5]. The estuary of Baturusa River could become a supplier of marine debris in the seas of Bangka
Belitung. It covers the downstream part of the Baturusa River on Bangka Island and separates Pangkalpinang City and the Bangka Regency. Currently, many human activities take place around the Baturusa watershed, such as urban expansion, factory activities, ports, and beach tourism. All can produce marine debris and threaten mangrove ecosystems such as at Koala Beach and Pasir Padi Beach.

2. Methods
This study was located on the Baturusa River estuary area in Bangka Island in April 2021. This study location was selected based on the prevalence and proximity of human activities from community settlements, the Pangkal Balam port, and beach tourism. They have the potential to produce substantial marine debris and impact the tourist sites of Koala and Pasir Padi beaches and the mangrove in the Baturusa River estuary (Figure 1).

![Figure 1. The research location in Baturusa estuary](image)

The marine debris sampling method was based on NOAA [6] and emphasized macro (diameter from 2.5 cm to 1 m) and meso (diameter from 5 mm to 2.5 cm) sized debris. The tools used in this research are a macro and micro-sized sieve, digital weight scale and the guideline document for marine debris. The collected marine debris samples were sorted based on weight and type: plastic, cloth, cork, glass, metal, rubber, or wood. For each category, the contribution percentage (based on weight) were obtained using the following equation:

\[
\text{Percentage} \, (\%) = \frac{x}{\sum_{i=1}^{n} x_i} \times 100, \quad (1)
\]

where \( x \) is the weight each type of marine debris. Furthermore, the marine debris density at the sampling area was important to calculate because it can be extrapolated to a larger area. It was obtained by dividing the quantity of debris by the sampling area sizes [7], which were 5 \( \times \) 5 m and 1 \( \times \) 1 m for macro and meso-sized debris respectively using the following equations:

\[
\text{Debris Density} \, \left( \frac{\text{pcs}}{\text{m}^2} \right) = \frac{\text{sum each debris type (pcs)}}{\text{sampling area (m}^2\text{)}}. \quad (2)
\]

The Mangrove Health Index (MHI) was consulted to establish the conditions of the mangrove surrounding the mouth of the Baturusa River. According to [8] the MHI provides a value or parameter that represents the overall quality of a mangrove ecosystem. The mangrove was measured using
purposive sampling and per the Ministry of the Environment Decree No. 201 of 2004, and with the MHI formula:

\[
MHI (\%) = \left[ \frac{S_{c} + S_{d} + S_{Nsp}}{3} \right] \times 10,
\]

where \(S_{c}\) represents the canopy coverage (%), \(S_{d}\) represents the mangrove diameter at breast height (if \(D<0\) then \(SD=0\); if \(D>10\) then \(SD=10\); else 0.45 Canopy coverage + 1.42), and \(S_{Nsp}\) represents the mangrove shoots per area (if \(N<0\) then \(SNsp=0\); if \(N>10\) then \(SNsp=10\); else \(SNsp=0.13Nsp+4\)).

3. Results and Discussions

3.1. Marine Debris Characteristics

Various types of marine debris were found at Koala Beach of both macro and meso in size. Based on weight, macro marine debris was dominated by plastic (30%), followed by rubber (29%) and glass/ceramic (27%) (Figure 2a). Meso marine debris was dominated by plastic and cork-type waste for 56% and 43% respectively (Figure 2b).

![Figure 2](image.png)

**Figure 2.** The weight composition of macro (a) and meso (b) marine debris from Koala Beach.

![Figure 3](image.png)

**Figure 3.** The weight composition of macro (a) and meso (b) marine debris from Pasir Padi Beach.

Figure 3 presents the composition of macro and meso waste obtained from the Pasir Padi Beach sampling location based on weight. Macro marine debris was dominated by plastic (60%) followed by glass/ceramics (30%) (Figure 3a). Only one type of marine debris of meso-size was found, namely plastic (Figure 3b). Comparing the composition of marine debris from the two beaches, both were dominated by plastic and glass/ceramic. If we compared with the research of makro-size marine debris in Pasir Padi Beach in 2019 [3], there is an increase of glass/ceramic type from 3% to 30% but the plastic...
is still dominant by 70%. The plastic-type of marine debris is dominant can be caused by its low-density, compared to metal, glass and the other so it is easier to be transported [9]. This indicated the plastic waste needs to be handled seriously, especially by reducing its use and managing the waste.

At both sampling locations, plastic was the dominant type both in weight and density. The density of macro-sized marine debris from Koala Beach and Pasir Padi Beach is presented in Figure 4. The figure shows that the density of macro-sized marine debris at Pasir Padi Beach and Koala Beach was dominated by plastic with 1.88 pcs/m² and 3.04 pcs/m² respectively. Plastic marine debris stood out far above other types such as cork and rubber. Differently with makro-sized marine debris, the highest density on meso-sized on Koala Beach is cork at 0.76 pcs/m², followed by plastic types at 0.36 pcs/m² and 0.32 pcs/m² at Pasir Padi Beach. The density of marine debris on both area still lower than at Tanjung Bunga Beach (around 5 kilometers from Pasir Padi Beach) which can reach 6.6 pcs/m² on 2018 [2]. It is apparent that plastic is one of the most polluting materials found in these coastal and marine areas and requires additional attention, especially managing the plastic waste to avoid the accumulating in the sea.

### 3.2. Debris Sources

The mouth of the Baturusa River is contains Koala Beach and Pasir Padi Beach and a mangrove ecosystem. The similarity of the marine debris characteristic of the two beaches is strongly suspected to have come from the Baturusa River itself. The marine debris mainly comes from four sources, fisherman, beach tourism, industry and the mainland (human activities) [6]. There are many anthropogenic activities that were located in Baturusa river, from urban settlements, port activities, and
coastal tourism (Figure 1). Most waste originates from human activities, enters the river, empties into the sea [3].

Urban settlements will produce household waste which if not handled properly, will mostly be wasted into rivers and flows into the sea. Based on the dominant type of marine debris is plastic, it can be assumed that household waste plays a major role in contributing to the marine debris at Baturusa river estuary. Furthermore, the activities on Koala and Pasir Padi beach itself, will contribute to the marine debris in those areas because those beach are the main destination of beach tourism in Pangkalpinang. Generally, marine debris could significantly increased mainly because the improper household and the habit of people who throw waste carelessly [10]. Therefore, it needs a waste regulation to hold the amount of marine debris in the Baturusa river which could damage the estuary both in the water quality [4] and the ecosystems around it [11].

3.3. Mangrove Conditions

The mangroves at the observation site consist of 3 types, namely Rhizophora apiculata, Ceriops decandra, and Ceriops tagal. The mangrove in the Baturusa estuary with the highest Important Value Index (IVI) value is Rhizophora apiculata (300 in SPPM01 and 221.36 in SPPM02), which indicates that this species plays a leading role in compiling the ecosystem in the area. The mangrove stand-density value for trees ranged from 1,048 to 1,574 trees/ha. When compared to the results of [12] and [13] based on 2019, there has been a decline in the quality and quantity of functions and types of mangroves in the coastal area of Pangkalpinang City, particularly in the estuary of the Baturusa River.

Based on the Decree of the Ministry of the Environment No. 201 of 2004, the status of the mangrove vegetation community in Pangkalpinang was classified as good and damaged with poor and medium density, with an MHI of 39.42–41.44% (Moderate) (Table 1). This indicates that the mangroves at the mouth of the Baturusa River are threatened, presumably by ecological pressures in the surrounding area, such as from the clearing of mangrove land for docks, ponds, and other human activities. Akhriani and Gustomi (2019) stated that increasing population growth, rapid development activities, and high levels of utilization of mangrove forests encourage the destruction of mangrove forest ecosystems either directly or indirectly (e.g., through marine debris) [5].

Table 1. The conditions of the mangrove survey location in the Baturusa estuary

| No. | Item                          | Monitoring Stasions                      |
|-----|-------------------------------|-----------------------------------------|
|     |                               | SPPM01                                  | SPPM02                                  |
| 1   | IVI of mangrove type          | Rhizophora apiculata (IVI: 300)         | Ceriops tagal (IVI: 39.73)              |
| 2   | MHI                           | 41.44% (Moderate)                       | Ceriops decandra (IVI: 38.93)           |
|     | Status                        | Good, medium density (Threat: Low)      | Rhizophora apiculata (IVI: 221.36)      |
|     |                               |                                         | 39.42% (Moderate)                       |
|     |                               |                                         | Damaged, poor density (Threat: medium)  |

4. Conclusion

Plastic still dominates the marine debris found on Pasir Padi Beach and Koala Beach, located at the Baturusa estuary. Based on weight, macro and meso marine debris at Koala Beach consisted for 30% and 56% respectively of plastic. The density of the debris mostly came from plastic as well, namely 3.4 pcs/m² from Koala Beach and 1.88 pcs/m² from Pasir Padi Beach. At Pasir Padi Beach, macro and meso marine debris were dominated by plastic for 60% and 100% respectively. Notable, however, was that at Pasir Padi Beach, cork dominated meso-sized marine waste in terms of density, with 0.76 pcs/m². The dominant types of marine debris are strongly suspected to have originated from human activities in the area surrounding the Baturusa River, such as from urban settlement, ports, and beach tourism. The
marine debris will also have an indirect effect on the quality of the mangrove ecosystem in the Baturusa estuary area, which currently has a moderate MHI of 41.44% and 39.42% respectively. Marine debris and especially that in the form of plastics that dominates the Baturusa River estuary area requires immediate attention to reduce the impact on the surrounding environment, particularly the mangrove ecosystem.

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