Floating macro marine debris trends in the Banda Aceh estuary environment

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Abstract. Banda Aceh is a city at the western tip of Indonesia and is one of the provinces that has a coastal area that can contribute plastic waste to the sea. The source of plastic waste comes from land and human activities which are then carried through river mouths to end up in the sea. The purpose of this study was to determine the characteristics of marine debris at the mouth of the Krueng Aceh River. Data collection is determined based on the time of the tide. The research was carried out using a boat mounted with a marine debris trap. The results showed that plastic waste dominated the mouth of the river by 90 percent, both during high and low tide conditions. There is a difference in the amount of waste that accumulates at high and low tide in the Krueng Aceh estuary.

1. Introduction

A study conducted in 2015 stated that in 2010 there were 2.6 billion tons of waste generated by 192 countries and it is estimated that this will increase by about 26% by 2025 [1]. Plastic waste accounts for about 270 tons of the total measured amount of waste. Furthermore, 99.5 million tons of plastic waste are generated from coastal areas, of which 4.8 to 12.7 tons enter the waters and pollute the sea. Based on this research, Indonesia is the world’s second largest producer of marine plastic waste, representing 10.1% of total plastic waste worldwide. The amount of plastic, especially bottles that continue to accumulate, will not only harm marine ecosystems but also have the potential to affect and damage the coastal environment [2]. Plastic waste can degrade ecosystems and is harmful to marine biota because plastic waste contains non-plastic substances known as addictive. Plastic waste pollution in coastal areas also disrupts tourism and recreational activities, the availability of clean, fresh water resources, and potentially reduce the catches of fishermen.

Several studies of marine debris in coastal and estuary areas have been carried out in several parts of Indonesia such as in Ambon and Seribu Islands [3, 4], Bajo harbor [5], particle tracking studies in southern Indonesia [6], marine debris in mangroves [7], as well as research on the impact of marine debris on coral reefs [8]. The total population of Indonesia living in coastal areas is 187.2 million compared to 187.5 million in India. However, Indonesia ranks second based on the amount of plastic waste that pollutes the sea at 0.48-1.29 million tons per year, while India ranks 12th with the amount of plastic waste 0.09-0.24 million tons per year [1]. This data confirms that the waste management system in Indonesia is still poor.
Attention needs to be paid to the river estuary area which plays a role in connecting the river and the sea. Waste originating from land can enter the sea through the estuary and pollute the sea. The presence of garbage that enters the sea and other pollutants can be harmful to the marine ecosystem if it exceeds the health threshold of the Law of the Minister of the Environment No. 51 of 2004 [11]. Several studies that have been conducted in several locations such as in Jakarta [12], Palembang [13], South China [14], Mediterranean [15], Brazil [16], and Kutai Kartanegara [17] show that marine debris found in river mouths still dominated by plastic waste. On the other hand, one area that has the potential as a source of marine debris in Banda Aceh is the Krueng Aceh River. This study focused on determining the composition and distribution of marine debris at the mouth of the Krueng Aceh River, Banda Aceh City. The results of this study may be used and taken into consideration by Aceh government, community, and fishermen to keep rivers, estuaries, and marine waters healthy.

2. Methods

2.1. Location and Time

Located in the city of Banda Aceh, Krueng Aceh is the largest river in the city. Banda Aceh itself is the capital city of Aceh Province, located on the western tip of Sumatra Island. The Krueng Aceh estuary area is dense with community activities, such as fishing boats mooring activities, trading, and fish markets. Marine debris collection has been carried out at the Krueng Aceh river estuary (Figure 1), to obtain data on marine debris entering and leaving the estuary.

![Figure 1. Map of the research area in the Banda Aceh estuary.](image)

Data collection was carried out for 2 (two) tidal periods and garbage collection was carried out using marine debris traps mounted on the front and side of the boat. The collection of marine debris in the Krueng Aceh estuary was carried out in two periods of field data collection, on March 2 - 4, 2019 for the first period, and April 29 to May 2, 2019, for collection in the second period. During the data collection process, the boat moves horizontally at the mouth of the river 4 (four) times back and forth. Data collection was carried out during high and low tide conditions. The discussion and data processing are carried out concerning the water level conditions which are in the high tide phase or the phase leading to low tide. Based on a modification from NOAA [18], this study limited data collection on wood organic waste (>2.5 cm); and inorganic waste which is divided into 7 categories, namely plastic, metal, glass, rubber, processed-wood, clothing, and ceramics.

2.2. Water Level

Mean sea level (MSL) obtained using the Admiralty Method, which is 11.10 m. The highest average value of the high water level at full tide (HHWL) is 11.70 m, while the measured value for The lowest
average low water level at the time of neap tide (LLWL) is 10.48 m. According to [19], the tidal harmonic constant provides information on the average value of the water level at high and low tide conditions. The following figure represents the tidal motion obtained at the Krueng Aceh location (Figure 2).

![Figure 2. Water elevation from March to June 2019.](image)

3. Results and Discussion

3.1. Existing conditions

Visually, the condition of the Krueng Aceh River shows a river area that has a fairly low environmental hygiene condition when compared to other rivers in Banda Aceh City. Human activities along the riverbanks to the estuary are considered relatively high where this could have an adverse effect on the health of the river as it flows into the sea. Field observations showed a large amount of waste floating along the river, a lot of waste piled up along the riverbanks, the fuel from ships that pollutes the environment, and the turbidity of river water. Around the river border to the sea estuary, there are many locations for the accumulation of community waste which makes it potentially thrown into the river and pollutes the sea. The level of awareness of fishermen about keeping the sea clean is also inadequate. Fishermen who go to sea around the waters of Banda Aceh are still frequently seen throwing food scraps and plastic waste into the sea, some even throwing away used fishing gear such as nylon fishing line in the sea. The number of ships that have not been functioning for a long time around the mouth of the river has made ships more damaged and has the potential to generate new waste that can damage the habitat of marine biota and human ecosystems. Furthermore, the Banda Aceh landfill site in the Gampong Jawa area is located very close to the beach so that it can contaminate the coastal zone with physical and liquid waste.

3.2. Debris collection

The data collection process follows the water level elevation chart and is carried out in low and high conditions. Figure 3 shows data on the amounts of marine debris that varies at several times of field data collection, which is divided into two periods. In the first period, data were collected at the phase towards high tide 6 (six) times and phase towards low tide 7 (seven) times. For the second period, data were collected at the phase toward high tide 7 (six) times, and toward low tide 7 (seven) times.

During the first period of data collection, a group of marine debris that was classified as wood was found, where this group of wood waste was not found in the second period. Wood waste is generally small with a length of less than 1 meter and it can be seen that the waste is generally clustered on the surface of the water (figure 4). When collecting wood waste, sometimes other types of waste are also obtained so that they become a large group of marine debris of various types. Wood waste can also be seen in the marine waters near the estuary at low tide. Plastic objects appear to dominate the number of marine debris particles in the estuary area (Figure 5). The most common types of plastic waste are food
wrappers or other packaging wrappers. In addition, it is also seen that quite a lot of glasses or saucers were found during the data collection process.

Figure 3. The number of marine debris items at high and low tides: (a) during the first period of data collection; (b) during the second period of data collection.

Figure 4. Marine debris on the surface of the Banda Aceh estuary.

Since the type of wood waste was not found in the second period of data collection, plastic objects dominate the number of marine debris particles in the estuary (Figure 6). The most common types of plastic waste are food wrappers or other packaging wrappers. In addition, it is also seen that quite a lot of glasses or cups were found.
During the first period, the highest amount of marine debris occurred on March 3, 2019, at 09.50 at the phase towards high tide. The least amounts of marine debris was found on March 3, 2019, at 03.15 at the phase towards low tide. An almost similar occurrence was also seen in the second period, where the most marine debris was found on April 30, 2019, at 10:10 which is the phase towards high tide. The least amount of marine debris occurred on May 1, 2019, at 04.00 and 16.32 at low tide. In general, it can be said that the amount of marine debris found is higher at high tide than at low tide. Based on hydrographic conditions, at high tide, the gradient formed between the water surface of the river and the sea will tend to be gentler, so that this high tide makes more water masses held in the area. Even further,
the durability and accumulation of waste that occurs in estuaries will tend to be greater at full tide [20]. In the phase leading to low tide, the waste that had accumulated in the estuary was then carried to the sea, which is thought to cause the value of the collected waste to be less than the phase towards high tide.

The existence of marine debris in the estuary is also influenced by the buoyancy of certain types of marine debris so that it becomes adrift in the estuary at high tide [21]. The most common type of marine debris found in the research in Krueng Aceh was the plastic waste, which consisted of various forms such as food wrappers or packaging wrappers; drinking bottles, and cups. Recently, plastic waste has been found as the dominant type of marine waste and has become common in various waters [22, 23, 24]. In particular, the presence and accumulation of plastic marine debris in the estuary are also influenced by some processes and interactions that occur in the estuary, such as topography, wind, waves, and density gradients [20]. Furthermore, marine plastic debris made from certain constituents such as LDPE is able to produce specific buoyancy properties, so it is often found floating and tends to be easily collected when data collection is carried out [21].

4. Conclusion
There are various types of marine debris found in the Krueng Aceh estuary, including plastic, metal, glass, rubber, processing wood, and clothes. Plastic was found to be the dominant amount with a percentage of about 90%. The condition of estuary waters that are in the high tide phase shows a higher amount of waste accumulation compared to the low tide phase.

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References
[1] Jambeck J R, Geyer R, Wilcox C, Siegel T R, Perryman M, et al., 2015 Science. 347 768-771
[2] Ondara K and Dhiauddin R 2020 J. Kelaut. Trop. p43
[3] Uneputty P and Evans S M 1997 Mar. Environ. Res. 44 233-242
[4] Uneputty P A and Evans S M 1997 Mar. Pollut. Bull. 34 652
[5] D jaguna A, Pelle W E, SchaduwJ N, Manengkey H W, Rumampuk N D and LA Ngang E 2019 7 174–182
[6] Purba N P, Faisal I, Cordova M, Abimanyu A, Afandi N, Indriawan D, et al., 2021 J. Ecol. Eng. 22 82-98
[7] Paulus C A, Soewarlan L C and Ayubi A A 2020 AACL. Bioflux. 13 2897–2909
[8] Arindra Putra M G, Zamani N P, Natih N M and Harahap S A 2021 J. Ilm. Perikan. dan Kelaut. 13 11–19
[9] Suryono D D 2019 J. Ris. Jakarta 12 17–23
[10] Kusumawati I and Nasution M A 2019 J. Ilmu. Lingkung. 1 15
[11] Mulyadi A, Siregar S H and Nurachmi I 2011 J. Ilmu. Lingkung. 5 103–113
[12] Rahmad S, Purba N, Agung M and Yuliadi L 2019 DEPIK. 8 9-17
[13] Maherlsa R 2018 Identifikasi Surface Macro Debris di Aliran dan Muara Sungai Musi Provinsi Sumatera Selatan (Thesis: Sriwijaya University)
[14] Cheung P K, Cheung L T O and Fok L Sci. Total. Environ. 562 658–665
[15] Mansuri J, Molcard A and Ourmières Y 2015 Mar. Pollut. Bull. 91 249-257
[16] Possatto F E, Barletta M, Costa M F, Ivar J A D S and Dantas D V Mar. Pollut. Bull. 62 1098–1102
[17] Dewi I S, Budiarsa A A and Ritonga I R 2015 DEPIK. 4 121-131
[18] Lippiatt S, Opfer S and Arthur C 2013 “Marine Debris Monitoring and Assessment,” NOAA Tech. Mem. NOS-OR&R-46 p 88
[19] Hicks S D 2006 Understanding tides. Silver Spring, MD: NOAA National Ocean Service
[20] Ghosh A, Suara K, McCue S W, Yu Y, Soomere T and Brown R J 2021 Sci. Total Environ. vol. 781 146808
[21] Kurniawan S B and Imron M 2019 Environ. Technol. Innov. 15 1–7
[22] Widyarsana I M W, Damanhuri E, Ulhusna N and Agustina E 2020 A Preliminary Study: Identification of Stream Waste Quantity and Composition in Bali Province, Indonesia, E3S Web Conf. 148
[23] Wicaksono E A, Werorilangi S, Galloway T S and Tahir A Toxics 9 1–13
[24] Cordova M R and Nurhati S 2019 Sci. Rep. 9 1–8