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Marine Litter and Grading of the Coastal Areas of Ambon Bay, Indonesia

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ABSTRACT

The coastal is frequently impacted by marine litter that damages marine wildlife and causes economic loss to fishing and maritime industries. In this study, we described the quantity of marine litter in the inner and outer of Ambon Bay. The Sampling was carried out in September 2017. The beach litter sampling was handled by the line transect method combined with the quadrant method in 8 sites; the observation of floating litter was conducted manually with boat sampling and visual observation in a seven-line trajectory. About 2359 items of coastal litter were found in seven sites in Ambon Bay with a mean density of 18.87 items.m^{-2}. These beach litter belonging to five categories were counted (plastic, glass, metal, cloth, paper). The highest abundance of beach litter was found in the inner Ambon Bay with a mean density of 68.74 items per m^2. Plastic was the most abundant beach litter observed. Based on Clean Coast Index (CCI) evaluation, all coastal sites in Ambon Bay were identified as Very Dirty, that is most of the coastal is covered with litter. The highest floating litter was found near the market. The abundance and distribution of litter through Ambon Bay seem to be influenced by the local human population, anthropogenic activities, and seawater circulation in inner and outer Ambon Bay.

Keywords: marine debris, beach litter, plastic, Ambon Bay

ABSTRAK

Kawasan pesisir sering terdampak oleh sampah laut yang merusak satwa laut dan menyebabkan kerugian ekonomi bagi industri perikanan dan kelautan. Dalam studi ini, kami menyajikan jumlah sampah pantai di bagian dalam dan luar Teluk Ambon. Pengambilan sampel dilakukan pada bulan September 2017. Sampling sampah di pantai dilakukan dengan menggunakan transek dan kuadran; observasi sampah terapung dilakukan dengan pengamatan manual menggunakan perahu. Sebanyak 2359 puing sampah pantai telah didokumentasi di pantai Teluk Ambon dengan kepadatan rata-rata 18.87 item.m $^{-2}$. Sampah ini dikelompokkan ke lima kategori, yaitu plastik, gelas, pakaian, logam dan kertas. Kelimpahan sampah laut tertinggi di pantai terdapat di bagian dalam Teluk Ambon dengan kepadatan rata-rata 68.74 item per m^2. Dominan sampah yang ditemukan adalah sampah plastik. Berdasarkan penilaian *Clean Coast Index* didapatkan bahwa semua stasiun di Teluk Ambon dinilai Sangat Kotor, dimana hampir semua permukaan pantai ditutupi oleh sampah. Sampah mengapung ditemukan tertinggi di lokasi dekat dengar pasar. Kelimpahan dan penyebaran sampah laut di Teluk Ambon diduga dipengaruhi oleh kepadatan penduduk, aktivitas manusia dan sirkulasi air laut di dalam dan luar Teluk Ambon.

Kata kunci: sampah laut, sampah pantai, plastik, Teluk Ambon

1. Introduction

Every day we produce solid wastes such as food and drink wrapping, paper, glass, metal, plastic containers, packaging, construction wastes (bricks, tiles, concrete, rebar, lumber, sheeting, etc.), clothing, and hazardous wastes (medications, batteries, paints, chemicals, etc). If these wastes are not handled appropriately (recycled or disposed of properly), these wastes will end up in the ocean become marine litter. Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches. This litter is brought indirectly to the sea from rivers, sewage, stormwater, or winds. Among

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these litter, plastics are the most common form of marine debris found in the marine environment. Waste plastic makes up 80% of all marine debris from surface waters to deep-sea sediments (Thevenon and Carroll 2015). It is estimated that every year 8 million metric tonnes of plastic end up in the ocean (Jambeck et al. 2015). The marine litters in the coastal area are harmful to marine biota. A record in 2015 stated that 66% of marine mammal species, 50% of seabird species, and 100% of sea turtle species were exposed to plastic (Kühn et al. 2015). Plastic has been found in megafauna to planktonic marine biota (Besseling et al. 2013; Cole et al. 2013; Rochman et al. 2015, Cordova et al., 2020. Md Amin et al., 2020). They can be trapped in discarded nets or other rubbish as well. However, marine litter not only affecting marine biota but also known as a significant impact on other aspects such as tourism and transportation. As an example of the impact on tourism aspect, the English municipalities have spent approximately €18 million each year to remove the marine litter, while Belgium and Netherlands spend approximately €10 million per year (Thevenon and Carroll 2015).

Ambon Island is one of the most populated small islands with a population density is over 647 people km^{2-1} (BPS, 2020). This island has two-bay, Ambon Bay (a semi-closed bay) and Baguala Bay (an opened bay). Ambon Bay is divided into two parts: Inner Ambon Bay and Outer Ambon Bay which is separated by a narrow sill between Poka and Baguala (Figure 1). Most of the population is living in the coastal areas especially in Ambon Bay. Many physical infrastructures such as traditional market, harbor, public transport stations, and terminals are taking place in the Ambon Bay coastal areas. These anthropogenic activities trigger marine litter in coastal areas. Other than that, as a small island, Ambon Island also facing the more complicated problems due to the waste management. The lack of appropriate solid waste management in small cities like Ambon could be led the plastic pollution in this area even

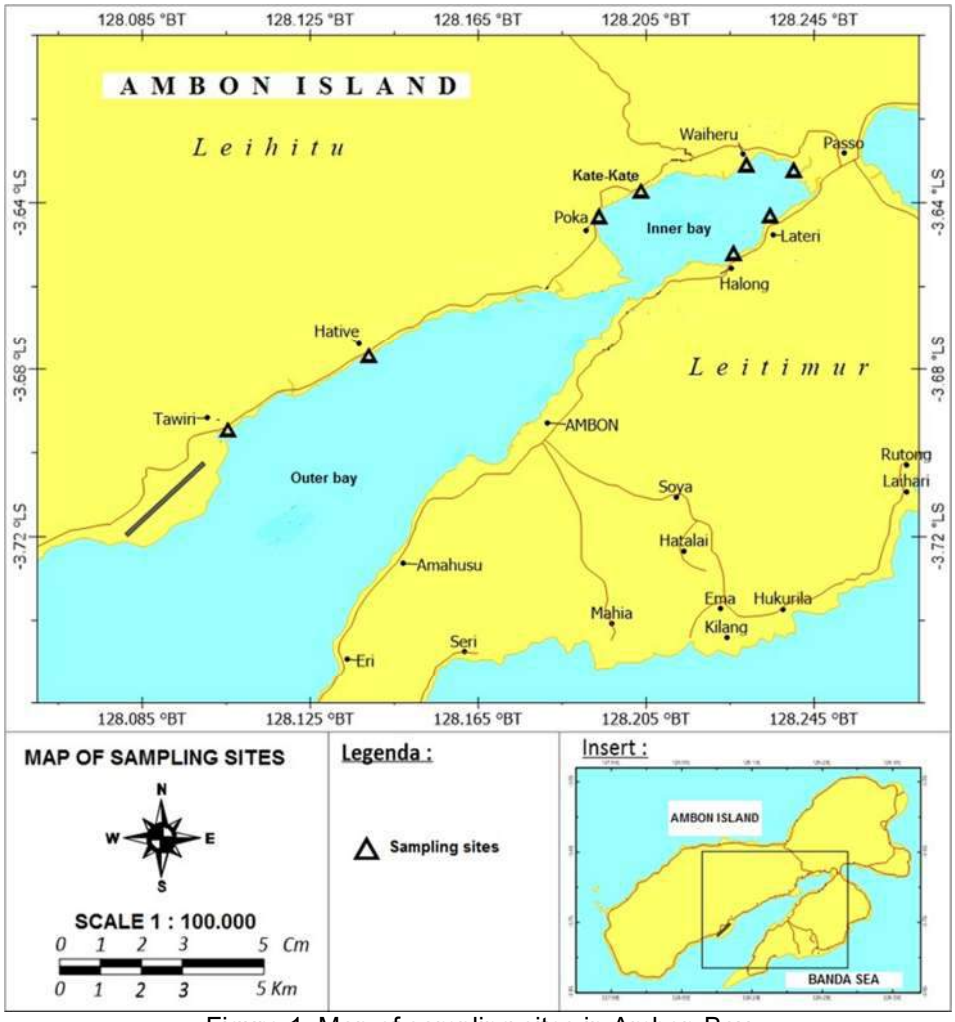

Figure 1. Map of sampling sites in Ambon Bay

worse. In 2017, it is estimated that 4.8 million tonnes of plastic waste in Indonesia have been mismanaged, about 9% of them (650,000 tonnes) are calculated entered the water bodies such as river, lake, and ocean. Surprisingly, it was approximated that mostly the mismanaged plastic waste is leaking from rural areas or small-medium cities (NPAP, 2017).

The first paper published about marine litter from Ambon Island in 1995 has stated that Ambon coastal lines had suffered from marine litter, especially plastic debris (Evans et al., 1995). Their sampling was conducted along the coast of Ambon Island (10 sites in Ambon Bay, 6 sites on the South-east coast of Ambon Island, and 5 sites in Northeast of Ambon Island). From 21 sampling sites, they concluded that Ambon Bay had a higher litter density than other sites. The 2nd published data was established in 1997 (Uneputty and Evans 1997). They counted the amount of floating litter on the surface of Ambon Bay. They found a higher density of floating litter found near the market of Ambon and inner bay. About two decades after the first published data, the latest data from Ambon Island are focusing on marine plastic debris (Manullang, 2019; Suyadi & Manullang, 2020, Tuahatu et al., 2020; Tuhumury et al., 2021). It is reported that plastic waste on Ambon Island harms mangrove health (Suyadi and Manullang 2020). Plastic waste is found trapped in mangrove areas due to limited waste management in small islands. Tuhumury et al (2021) for the first time reported the presence of microplastic in the gut system of fish cultivated in Ambon Bay waters. This study counted and classified the marine litter in Ambon Bay after 20 years since the first reported in 1995.

2. Material and methods

2.1. Beach litter

This study was carried out in Ambon Bay, Molucca province. The methodology for marine litter in this study was established based on the first investigation about marine litter in Ambon Island (Evans et al. 1995; Uneputty and Evans 1997) with some modifications. The sampling was established at the end of the wet season during low tide on September 12th -14th, 2017. They conducted the sampling at 7 stations that represent the outer and inner bay. Two stations (Hative Besar and Tawiri) are located in the outer bay and five stations (Poka, Kate-Kate, Waiheru, Lateri, and Halong) are located in the inner bay (Figure 1). In each site, the transect was made vertically down the shore from the high tide mark to the water edge, parallel to the coastline. The distance from the high tide mark to the low water of these stations varied from 5-50 meters. Quadrants, measuring 0.5 x 0.5 m, were laid at 5 m intervals along the transect and the items of litter within these quadrants were recorded (Figure 2). The counting of marine litter in the quadrants are starting from diameter = 0.5 cm, then grouped by five litter categories, as follows:

1) Plastic & rubber (plastic bottle, food wrapping, plastic sack, plastic fragment, sandal, shoes, straw, hessian sack, string/robe, net, styrofoam, plastic rope, banner, and table covering.
2) Glass (glass and ceramic)
3) Clothing materials (cloth and diaper)
4) Metal
5) Paper (paper, cardboard).

Each type of litter was counted. The density of debris was calculated using the formula of Lippiatt et. al., 2013.

$$C_M = n/ (w * l)$$

where C_M is the density of debris (items per m^2); n is the number of debris (items); w is the width of the quadrant (0.5 m), and l is the length of the quadrant (0.5 m).

Assessment of beach condition was measured based on the Clean Coastal Index (CCI) from Alkalay et al (2007), with formula:

$$CCI = C_M * K,$$

where C_M is the density of debris (items per m^2) and K is a constant equal to 20. The beach quality was divided into 5 categories such as Very Clean (VC) with the value of CCI from 0 to 2; Clean (C) with CCI 2-5; Moderately (M) with CCI 5-10; Dirty (D) with CCI 10-20; and Very Dirty (VD) with CCI > 20.

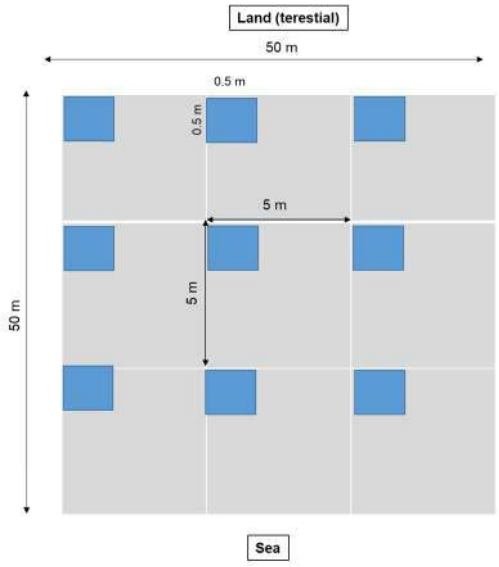

Figure 2. Sampling design of marine litter in Ambon Bay

2.2. Floating beach litter

Seven horizontal transects were conducted across Ambon Bay from the north shore to the south shore. The sampling was done during high tide on September 13th -14th, 2017. The trajectory consists of Gudang Arang – Hative Besar, Mardika-Wayame, Kapaha-Wailela, Galala-RumahTiga, Feri Harbour-Poka, Halong-Waiheru, and Lateri–Passo (Figure 8). The observation of floating waste was conducted manually with boat sampling and visual observation with 1-1.5 knots. The counting of floating litter was counted at two meters on the left side and two meters on the right side of the boat.

3. Results and Discussion

3.1. Abundance and composition of beach litter

A total of 500 quadrants have been conducted in Ambon Bay. The mean litter density in all sites can be seen in Figure 3. The total marine litter recorded in Ambon Bay was 2359 items, with an average mean litter density of 18.87 items.m^{-2}. Based on our visual identification, the litter items found in Ambon Bay were mostly generated by land-based activities. These litters were carried by winds, storms, and rivers as a result of poor waste management. This suggestion was Indicated by items that are often found on all sites as domestic waste such as food packaging, shopping bags, drink bottles, food containers, straws, and stirrers.

Poka sites in the inner bay were quantified to be the most polluted area mean density of 68.74 items.m^{-2}. Compared to the previous study in Ambon Bay, there is a significant increase in the quantification in Ambon Bay. Uneputty and Evans (1997) reported that the mean density in Poka at strandline area was 8.6 ± 1 items.m^{-2}. The least polluted site recorded in the outer bay, the Tawiri site with a mean density of 6.88 items.m^{-2}. About 79% of total marine litter in Ambon Bay was stranded in layers 0 m and 5 m (Figure 4). The debris relatively enters this area during the high tide and stays there for a long period. For that reason, these areas are often used as a focus area in coastal survey and beach clean-up activities (e.g. Lee et al., 2017). The lowest litter was sampled in the water edge areas.

The average mean litter density in inner Ambon Bay was 25.77 items.m^{-2}. This value almost three times higher than in the outer bay (8.52 items.m^{-2}). The highest density in the inner bay may not only influenced by human population and human activity in the adjacent area but also influenced by current circulation in Ambon Bay. Ambon Bay is divided by a small narrow between the inner bay and outer bay (Figure 1). The outer bay is deeper than the inner bay and opens to the Banda Sea. In contrast, inner Ambon Bay is a semi-closed water body that has limited circulation. It is stated that the inner Ambon Bay has a longer flushing time which causes the water mass and other parts that entered from the outer bay will stay longer in the inner bay (Anderson and Sapulete, 1981). During the high tide, the current will push the mass of water and marine debris from the outer bay to enter the inner bay. The maximum velocity happened in Martafons (near Poka sites), weakened in Kate-Kate, and reach out the minimum velocity in Passo-Lateri (Hamzah and Weno, 1987). It is considered that debris from the outer bay cannot pass the threshold to the outer bay and will accumulate in the inner bay. The latest study reported the higher concentration of microplastic in the inner bay compare to outer bay of Ambon (Manullang,2019).

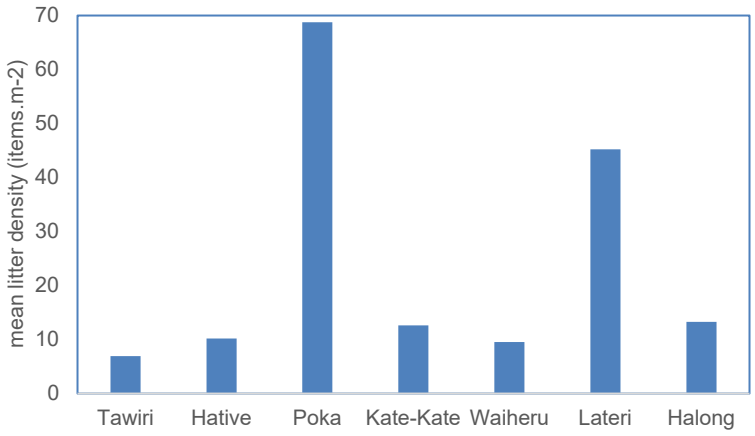

Figure 3. The mean litter density at 7 sites in Ambon Bay

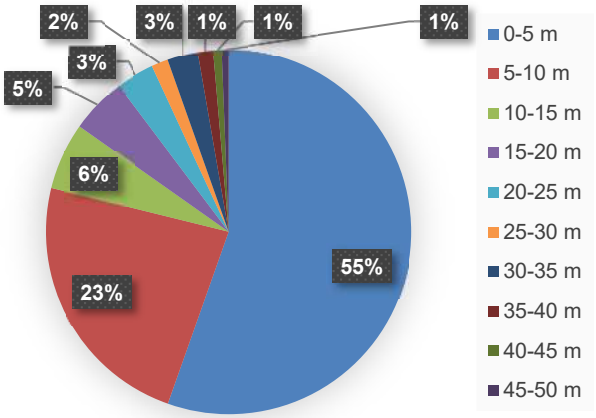

Figure 4. The percentage of marine litter abundance in each layer in Ambon Bay.

The percentage composition of marine litter from 7 sites in Ambon Bay was presented in Figure 5. Overall, the coastal sampled debris was mostly composed of plastic and rubber. 2046 out of the total marine litter in Ambon Bay (approximately 87.73%) were confirmed as plastic & rubber materials, followed by glass (7.29%), clothing materials (4.66%), metal (0.51%), and paper (0.81%). The litter contents were similar from site to site, except for site Lateri and Halong (Figure 6). Plastic marine litter was found over 70% in 5 sites (Tawiri, Hative, Poka, Kate-Kate, and Lateri). The most abundant types of plastic were plastic packaging that single-used. Litter materials made of glass (e.g bottle glass, ceramic) were found in high concentrations in site Lateri and Halong. Clothing materials (waste clothes, baby and adult diapers) were found in all sites.

Compared to other countries (developing and develop coutry), the mean density of marine litter in Ambon Bay was absolutely higher. The litter content in Ambon Bay was higher than Brazil (0.14 items.m^{-2}) (Oigman-Pszczol & Creed, 2007); Australia (0.1 items.m^{-2}) (Cunningham & Wilson, 2003); Chile (1.8 items.m^{-2}) (Bravo et al., 2009); Japan (3.4 items.m^{-2}) (Kusui & Noda, 2003); South Korea (1 items.m^{-2}) (Lee et al., 2013); Taiwan (0.15 items.m^{-2}) (Kuo & Huang, 2014) and Turkey (0.88 items.m^{-2} (Topçu et al., 2013).

3.2. Grading of the coastal

The litter grading of sample sies along the coastal areas of Ambon Bay was examined by Clean Coast Index (CCI) from Alkalay et al (2007) that already in several studies recently (e.g. Okuku et al., 2020). Table 1 presented the summary of the evaluation of each site. Based on the CCI guide and field coastal evaluation, 7 sites in Ambon Bay were graded Very Dirty, that is most of the coastal is covered with litter. The Litters covering the coastal areas in several sites in Ambon Bay were showed in Figure 7.

3.3. Floating Litter

Figure 8 presented the distribution of floating litter in Ambon Bay by boat sampling with visual observation. The most abundant types of floating litter were plastic films. These plastics type relatively corresponds to items commonly composed of Polyethylene (PE) polymers that have a lower density than seawater and are thus buoyant (Andrady, 2011). The highest

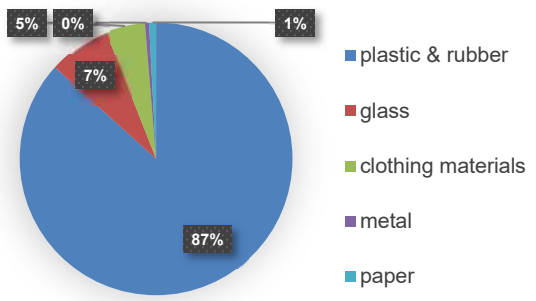

Figure 5. Percentage composition of marine debris according to the number on hard ground near 8 beaches at Ambon Bay, Indonesia

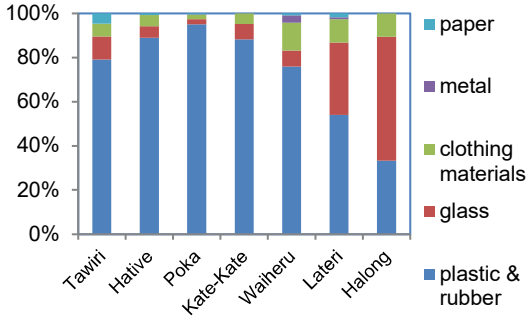

Figure 6. Comparing the percentage of marine litter composition in each of the sites sampled.

Table 1. Coast Clean Index (CCI) of 7 sites in Ambon Bay

Site	CCI Value	Quality	Definition
Tawiri	137	Very dirty	Most of the coastal areas is covered with litter
Hative	203	Very dirty	Most of the coastal areas is covered with litter
Poka	1374	Very dirty	Most of the coastal areas is covered with litter
Kate-Kate	251	Very dirty	Most of the coastal areas is covered with litter
Waiheru	189	Very dirty	Most of the coastal areas is covered with litter
Lateri	904	Very dirty	Most of the coastal areas is covered with litter
Halong	264	Very dirty	Most of the coastal areas is covered with litter

Poka site Hative Site Kate-Kate site

Figure 7. Litters covering the coastal areas in several sites in Ambon Bay

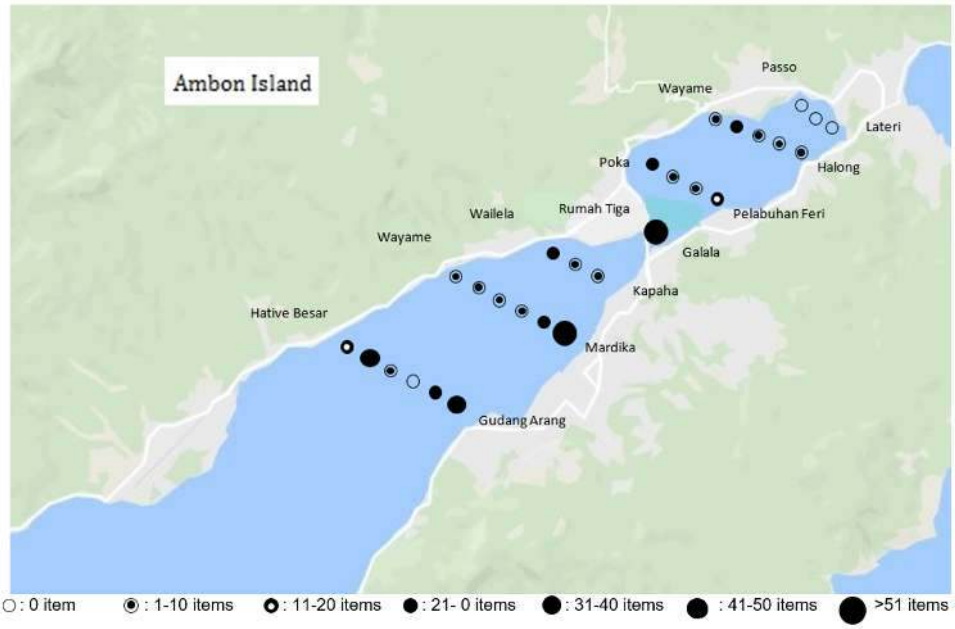

Figure 8. Floating litter in Ambon Bay

abundance is found across Mardika to Wayame and Galala to Rumah Tiga. The floating litter is zero in across Lateri to Passo. The abundance of floating litter in Ambon Bay was highest in the Rumah Tiga Market and Mardika Market areas strongly indicated that anthropogenic activity in Ambon Bay has an important role in the amount of marine litter in Ambon Bay. However, we found none of the litter in trajectory along Lateri to Passo. The floating debris entered the inner Ambon Bay during the high tide. During the sampling, the number of floating litters in Passo and Lateri decreased over the slowdown of the tide.

4. Conclusions

Ambon Bay has been suffered from marine litter especially from the plastic litter that increased rapidly in the last two decades. The abundance and distribution of litter through Ambon Bay were suspected to be influenced by the local human population, human activities, and the physical oceanography behavior of Ambon Bay. The litter items in Ambon Bay were

mostly generated by land-based activities. These litters were carried by winds, storms, and rivers as a result of poor waste management. This conclusion was Indicated by items that are often found on all sites as domestic waste such as food packaging, shopping bags, drink bottles, food containers, straws, and stirrers. There is urgently required for establishing an advanced marine litter study in Ambon Bay due to the abundance of marine litter in Ambon Bay or Ambon Island.

Acknowledgment

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