

Benthic Marine Litter Accumulation at Selection Beaches in Ternate Island, Indonesia

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Abstract: The report of marine litter pollution first published in the scientific journal of the early 1970s; therefore, more than 40 years later, the scientist continues to understand the distribution of litter existing in the marine environment. The present study was carried out in Ternate Island, North Maluku Province (eastern Indonesia) which the aims are to determine litter composition, abundance, weight, and density on the seafloor and to predict the sources of seafloor litter distribution in the study areas. A conventional underwater visual survey with scuba/snorkeling. The depth of the sampling area varied between 3 and 6 m according to the slope of the island. During the survey, total of 1171 items were collected from all study sites and a total of 20.47 Kg of weight. The mass of overall debris concentration range from 0.089 items/m² to 1.04 items/m². The number percentage of plastic, metal, fibers/textiles, glass, and rubbers in total were 77%, 12%, 7%, 2%, and 2%, respectively. Plastic debris was the most dominant material category by means of number and weight.

Keywords : Marine litter; North Maluku; Plastics debris; Ternate island;

1. Introduction

Ocean pollution by anthropogenic litter has been identified as one of the main environmental problems at almost all of the countries in the world [1]. This litter could be present as marine litter on the surface, beaches, and seafloor [2]. Every year, millions of tons of debris are discharged into the ocean with potentially harmful to the ocean environment, the release of toxic compounds [3], the fatality of many marine species [4], and the changing of benthic communities' structure [5]. Moreover, marine litter has an important impact on marine economic and human health [6][7][8]. Unfortunately, The recently study notes that as the largest contributor to marine waste in the world after China, Indonesia produces 187.2 million tons per year and it will increase in 2025 if not handled seriously and all caused by anthropogenic activities [9].

Ternate city, as a part of North Maluku Province - Indonesia, is one of the small islands in this region. Basically, Ternate is a beautiful island which has many coasts as a tourist destination. Recently, Ternate was faced with solid waste management as a huge issue. Despite, the government of Ternate City has the regulation related to solid waste management but the waste production still increase gradually every year. In 2011, the production of waste reach 173.543 m³ per year and it is growth 6% in 2015 at 203.950 m³ per year. Regrettably, only 65% of waste could be managed in landfill and 35% throw into environment including rivers and coastal area [10].

Under these situations, it is essential for the conservation of marine environments and fisheries to evaluate and study the distribution of marine litter around the world including in Indonesia. On the other side, lack of data and information about marine debris and its impact on Ternate Island makes this

issue is still difficult to handle by Ternate's government. Therefore, the research about marine debris must be done continuously and becomes important topics not only today but also in the future. This study aims to determine the type and concentrations of benthic marine debris in selected beaches at Ternate Island. This research is expected to enrich information as basic data to solve this problem. The study objectives involve (1) determining litter composition, abundance, weight, and density on the seabed of three selected beach in Ternate Island; (2) Predicting the benthic marine litter origin in the surveyed area.

2. Materials and Methods

2.1 Study Areas

Geographically, Ternate is a small island that has covered of 5709 km². It consists of 7 islands and 77 villages where most of the villages located close to the coastal area including the city of Ternate. Moreover, from the demographic aspect, In 2016 the population number in Ternate City reaches 218.028 people with growth percentage was 2.36% and population density was 1.345 per km. Due to It is surrounded by ocean, consequently, the tropical climate in Ternate that strongly influenced by sea climate can be found in Ternate along the year. There are two seasons recorded in Ternate, rainy season from December to June and dry season July through to November. The topography of Ternate most dominated by highland with the volcano in the middle of the island. Meanwhile, the topographic in coastal areas has the slope of more than 10 m.

Three beaches were selected to investigate the benthic marine litter in this research (Figure 1). Those beaches have specific characteristics that represent three different areas. Site 1, Jikomalamo beach is the tourist destination area where is located in the North part of Ternate Island. This site is an unpopulated area and dominated by tourist activity such as swimming, snorkeling, and diving. Next, site 2 is Gambesi beach where is located in South Ternate Island. It is a semi-urban area in which the population number less than 1000 people. While St 3 is Falajawa beach. This beach is located in the Centre of Ternate City where it is an urban area. Moreover, this site is close to the economic center, government office, city garden, and main port. This beach is one of the activities centers of Ternate's people.

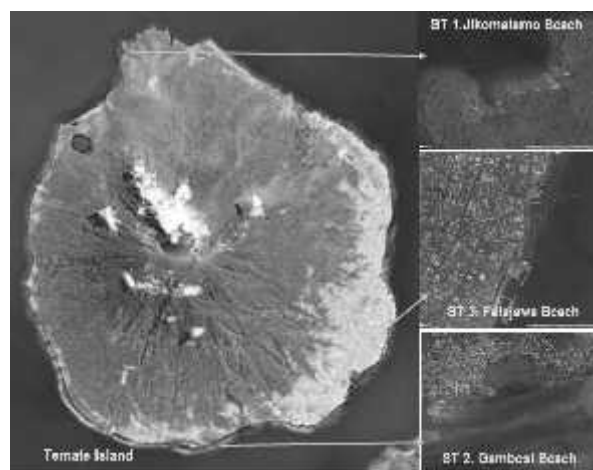


Figure 1. Study Sites in Ternate Island – North Maluku

2.2 Data Collection and Analysis

In order to understand the composition and distribution of benthic marine litter, sample was collected using underwater visual surveys with scuba/snorkeling. This method is based on line transect surveys of litter on the sea-floor, which is provided by UNEP [11]. During each dive, video recordings

were made with a forward-looking video camera. The video did not run continuously throughout all transect as most seafloor was dominated by hard substrate and benthic debris was spread. The video was turned on when objects of interest were encountered but also regularly turned off during lengthy collection efforts at stationary locations. The litter was recorded on 3-meter and 6-meter depth along the length of 100-meter transect. Transects were exploratory and quite consistently followed a linear course up the island slope. The total surveyed area in each site was approximately 800 m².

During the study, five volunteers were involved in the survey where divers move parallel to line transect. Next, all debris gathered was placed in a garbage bag and brought back to the laboratory. In the laboratory, the flowing water in a large bucket will use to clean off dirt and sand from all samples that may cause inaccuracy during the weighing and measuring process. The collected items were sorted, measured, and weighted according to the type of material such as plastics, metals, glass, rubber, and fiber/textile. Furthermore, all data collected will use to estimate the density (number of items per area, n/m²) and weight (weight per area, gr/m²).

3. Result and Discussion

3.1 Composition and Abundance of Benthic Marine Litter

The results of our surveys show that benthic marine litter on Ternate Island is composed of various types of materials (Figure 2). Total 1171 items were collected from all study sites where the composition of benthic litter dominated by plastic (77%), metals (12%), fibers/textiles (7%), and glass and rubbers, 2% respectively (Figure 3a). Plastic debris has become the high number in many beach debris and many researchers pointed out that plastics have come into public view with greater intensity over the last decade [12]. It can found in almost all research on sandy beaches [13][14] and remote islands [15][16][17]. While, based on the depth, plastic is also dominated and has been found as much as 689 items in 3-meter depth and 206 items in 6-meter depth (Figure 3b). Followed by metals (102 items in 3-meter and 43 items in 6-meter) and fibers (72 items in 3-meter and 11 items in 6-meter).



Figure 2. Some examples of marine litter collected. (a) fibers/textile; (b) glass bottle; (c) plastic food-wrap; (d) metal can; (e) rubber; (f) plastic bottle trapped in sediment

The highest number of plastic debris was collected around the study area. This may reflect the habit of people who did activities around the coastal area to throw their garbage to the ocean. Furthermore, Plastic has become the most present type of litter noted around the world [18][19][20], is capable to spread over long spatial and temporal range, especially when it consists mostly of small-sized objects

[6][21][22][23]. In fact in this study, plastic bags, food wrappers, glasses, and bottles, are confirmed to be the most common kind of plastic litter as was observed in other beaches [24][25]. Moreover, in the present work, metal litter corresponds mainly to aluminum beverage cans and glass litter to syrup bottles and jars found in 3-meter depth. According to Koutsodendris *et al* [26], that aluminum cans and glass bottle usually do not travel long distances and were probably rejected by a user close to the beach area.

The percentage of plastic debris in this research was highest compared to previous research in several seas (Table 1). It may indicate that plastic is widely used in daily activities and mismanagement of solid waste in Ternate city influent in this matter. Based on Jambeck *et al* [9], Indonesia stays in second place among 20 countries on plastic waste input from land to the ocean due to mismanagement of solid waste.

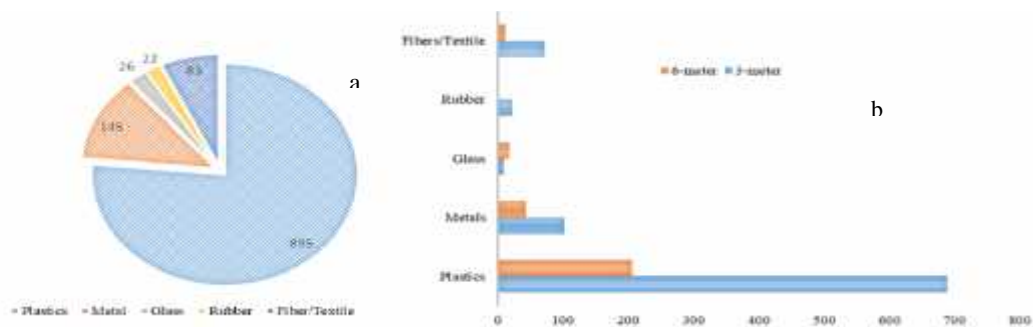


Figure 3. a) Number of Benthic Marine Litter on Study Sites. b) Composition of Benthic marine Litter on 3 meter and 6 meter Depth

Table 1. Comparative of Benthic Litter Abundance and Plastic Percentage collected from Previous Study

Location	Mean Abundance (n/100m ²)	Plastics (%)	Source
North and Central Adriatic sea	0.11	80	[27]
Straits of Sicily, Italy	0.0051	55	[28]
Black sea	0.9234	68	[29]
Adriatic Sea, Montenegro	4.61	36	[30]
Eastern Mediterranean Sea, Greece	1.5	55	[31]
Sub-east Adriatic Sea	0.25	54	[32]
Ternate Island	0.49	77	This Study

This study highlights that the abundance of benthic marine litter was correlated to human population of study sites. The lowest abundance of benthic marine debris, recorded in Jikomalamo (0.089 items/m²) is likely related to uninhabited in this region, representing a minor potential source of litter in comparison to more populated regions, such as Falajawa (1.04 items/m²). This fact supports the hypothesis that the distribution of high abundance of marine debris, particularly in coastal urban areas, is strongly correlated to the size of the surrounding human population [18][33][34].

Actually, it is possible to investigate the positive correlation between debris abundance with human population density in study areas. Therefore, we predict that the sources of marine litter recorded in this research are mostly mainland-based activities but it is also a possible origin from maritime activities. Land-based debris sources include items that were entering the marine environment through rivers, drainage systems, runoff, and sewage inputs, as well as items discarded by beachgoers

[18][31][35]. Moreover, the result shows that the density of benthic litter in shallow water (3-meter) has more abundant than deep seafloor (6-meter). It was predicted that the distribution of benthic litter also influenced by hydrodynamic circulation [18][33]. In the present study, the currents in all surveyed areas are weak and dominated by longshore-current that flows parallel to the coastline. Hence, the litter was found close to its point of dumping and sometimes it accumulates on the seafloor. Therefore, benthic marine litter dispersion on the seabed may be influenced by its original source rather than by its movement in the ocean [26]. On the other side, the tendency of benthic marine litter to trapped in shallow water areas due to low circulation and high sediment concentration [36].

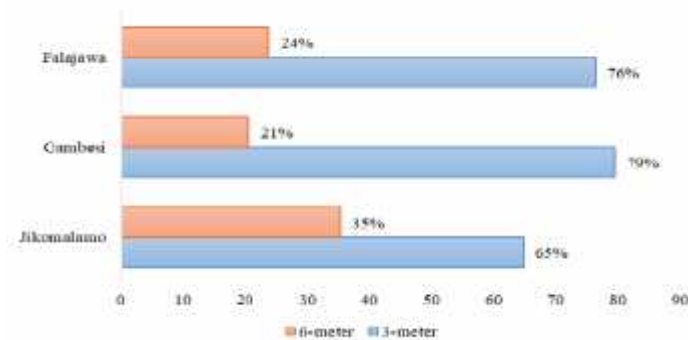


Figure 4. Total Percentage of Benthic Marine Litter Composition on Selected Beaches in Study Area (3-meter and 6-meter)

3.2 Weight and Size of Benthic Marine Litter

Overall, the weight measurement result showed in figure 5 indicates that we found 20.47 Kg of benthic marine litter from all surveyed beaches. Plastics become the heaviest benthic litter in 3-meter depth. While the glass was the heaviest items in 6-meter depth. Based on study sites, the heaviest of seafloor marine litter recorded in Falajawa due to all marine litter accumulated on this beach. While the lightest debris found in Jikomalamo sites. Both plastic bottles and glass bottles are the materials that contribute to heaviest of benthic marine litter in this research due to they are easy to sink and trapped on the seabed.

The length characteristic of benthic litter in this study present that most of the litter collected are dominated by meso-plastic and macro-plastic sized. In which, the average size of benthic litter in 3-meter depth is 27 ± 51 mm and in 6-meter depth is 24 ± 89 mm (Figure 6a). The plastic marine debris was classified into three size classes: “large micro-” (1–5 mm), “meso-” (5–25 mm), and “macro-plastics” (>25 mm) [37]. Generally, meso-plastic in this study gathered from plastic food-wrap and macro-plastic collected from bottles, fibers, fishing line, and plastic strap

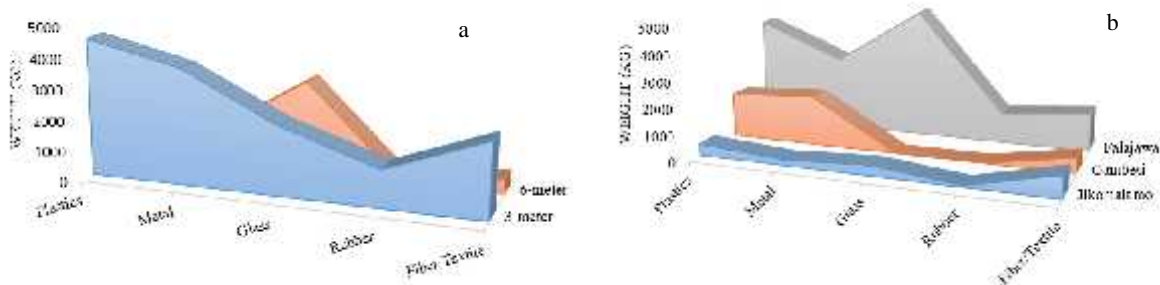


Figure 5. The Weight Percentage of Benthic Marine Litter Based in 3-meter and 6-meter (5a) and Surveyed Locations (5b)

This study also indicates that the meso-plastic sized particles, the percentage above 60%, are dominated in Falajawa and Gambesi. While the Jikomalamo site has almost the same percentages both meso- and macro-plastic (Figure. 6b).

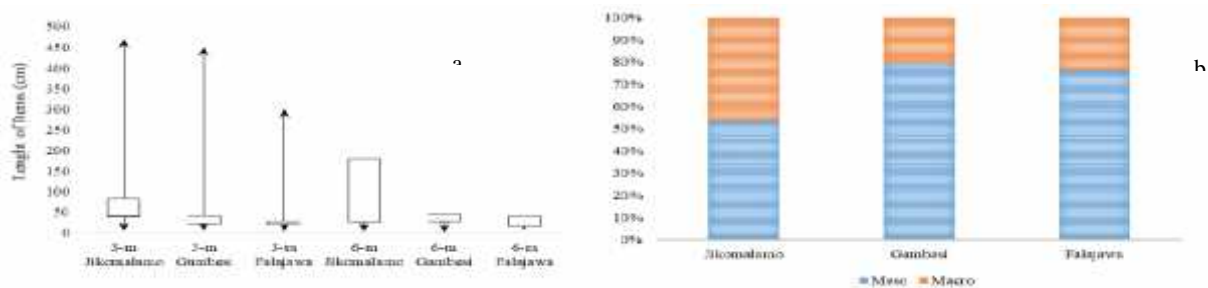


Figure 6. a) The Length of Benthic Marine Litter (Average, Minimum, Maximum, and Stdev) in 3-meter and 6-meter Depth in Study Areas. b) The Percentage of Meso- and Macro Litter in Study Areas

4. Conclusion

Overall, the present study informs that the benthic marine litter had been found in Ternate coastal areas. It is strongly influenced by human activities. There is no current local management framework in Ternate to assess, manage and monitor benthic litter items. Therefore, the continuous monitoring of benthic litter items is important in order to properly quantify these problems, find out their sources, develop appropriate measures to mitigate such pollution and assess the effectiveness of national regulations

5. References

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