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Spatial Distribution of Beach Macro-Litter in Ternate Island, North Maluku – Indonesia

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ABSTRACT

Beach litter in Small Island should become a special attention issue in Indonesia. This study was carried out to provide a comprehensive dataset including calculating the quantity of beach macro-litter, determine types and concentration of debris present by materials categories, and examine the actual coast cleanliness using Clean Coast Index (CCI). Total of six beaches along the South and North of Ternate Island were considered in September 2018 and March 2019. All surveys performed based on the guideline NOAA Marine Debris Program. All areas in sampling sites cover used transect 100 m × 10 m as a sampling unit with two replication transects at every location. All samples are categorized into seven groups, including polymers/plastics, rubber, cloths/fabric, paper/cardboard, processed wood, metals, and glass. Overall, there are 3332 items of beach macro-litter found in all surveyed beaches. Polymers/plastics (2040 items, 61.2%) became the highest number of items, followed by glass (403 items, 12.1%), and metals (296 items, 8.9%). During the survey, the highest number of beach litter was found on St.1 (1128 items) while the lowest discovered – on St.3 (324 items). The abundance (items/m^2) found on all beaches range from 0.04 items/m^2 to 0.23 items/m^2. Meanwhile, CCI on all beaches could be categorized from very clean to clean category.

***Keywords*:** beach macro-litter, Ternate Island, clean coast index, North Maluku

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1. INTRODUCTION

Marine debris, including beach litter, had become an attention by scientists due to its persistence in the environment. It is becoming a global issue after giving the impact on marine organisms, ecological processes, marine economic, and human health [1-5]. As recently, scientific research investigations showed that marine debris or beach litter mainly are related to anthropogenic and coming from land sources around 80% [6-7]. Therefore, they can find near anthropogenic waste inputs in the densely populated cities, or even in remote areas [8].

Indonesia, as an archipelago country, faces beach litter issues due to the increase of waste and its mismanagement. The prediction by the World Bank that Indonesia had been producing the waste of 85.000 tons/day in 2018 and it will increase till 150.000 tons/day in 2025. On another side, mismanagement of plastic waste in Indonesia led this country to stay in second place in the top 20 states ranked by mass of mismanaged plastic wastes [9]. The other factors that contribute to this issue are a large population and urban settlement density in an Indonesian coastal area and the geographic location between two big oceans. Data on BPS Statistic Indonesia shows that population numbers in Indonesia in 2017 reached 216 million and more than 65% living in coastal areas.

Geographically, ocean circulation among the Indian and the Pacific oceans has reported to be influencing the distribution of marine debris in Indonesia waters [10].

Marine debris has been a challenge for Indonesia to overcome. However, scarce scientific research about this aspect in Indonesia leads to a lack of data and information. Based on the literature tracking from google scholar, research gate, and Scopus, the research related to marine debris distribution in Indonesia, were published by Purba *et al*., in Savu sea East Nusa Tenggara [11]; Manulang in Ambon Bay [12]; Syakti *et al*., in Cilacap, Central Java [13]; Hastuti *et al*., in Pantai Indah Kapuk, Jakarta [14]; Husrin *et al*., in West Coast Bali [15]. Therefore, the research related to marine debris in Indonesia must be done continuously.

In this study, our focal point is beach macro-litter in a coastal area on Ternate Island, North Maluku Province, Indonesia. Beach surveys are essential for measuring how much marine debris there is in coastal and marine systems and is also used to measure concentrations of trash at a shoreline site over time. Although this study is a baseline study to understand the accumulation of beach macro-litter in Small Island, it provides information on spatial and temporal distribution at study locations. The objectives of the present study were to provide a comprehensive dataset including: 1) to calculate the quantity of beach macro-litter, 2) to determine the types and concentration of debris present by material category, and 3) to examine the actual coast cleanliness using the Clean Coast Index [16]. Marine debris study in this particular area will be indispensable as a pilot study to provide baseline data and to establish the new policy in overcoming this issue in the future.

2. MATERIALS AND METHODS

2. 1. Study Area

Geographically, Ternate Island is located between 0º25’41.82” – 1º21’21.78” North Latitude and between 126º7’32.14” – 127º26’23.12” East Longitude. The wide of the city reach approximately 162.03 km^2. Based on climatology information, Ternate Island has a tropical climate that is strongly influenced by the sea climate and has two seasons, which are often interspersed with two transition periods each year. The dry season occurs between April to September and the rainy season from October to March. During 2017, the average annual temperature was 27 °C, and the warm air temperature reached 31 °C in Ternate City, whereas the coldest month occurs in June and September, with an air temperature of 24 °C. Wind direction is dominated from the southwest throughout the year, especially from September to December.

Concerning geo-morphology orientations, the slope in the Ternate coastal area is less than 10 degrees and the depth of water is between 0.5 to 3 meters. Here, from the oceanographic aspect, the tidal regime is semi-diurnal with a tidal amplitude ranging from approximately 0.8 m to 1.2 m during exceptional tides and flowing currents are affected by the tidal waves and winds.

This study was carried out at six beaches. All selected beaches for the study represent a comprehensive geographical coverage on Ternate Island. Three beaches located in the Northern part and other beaches located in the southern part (**Fig. 1**). All locations shared the common characteristics of being sandy beaches, near villages or urban area and some of them are tourist destination sites (**Table 1**).

Figure 1. Study Area

Table 1. Sampling Locations and its Chrachters

Locations	Y	X	Remarks
Kalumata (St.1)	0°45’33,92”	127°21’50,67”	Urban Area
Tobololo (St.2)	0°51’15,27”	127°21’09,05”	Village/Tourist destination
Sulamadaha (St.3)	0°51’45,16”	127°20’10,89”	Village/Tourist destination
Takome (St.4)	0°50’31,49”	127°18’19,87”	Village
Rua (St.5)	0°46’37,10”	127°18’04,81”	Village
Kastela (St.6)	0°45’39,17”	127°18’36,68”	Village/Tourist destination

2. 2. Data Collection

The survey had been conducted during two different seasons in September 2018 (the last month of the dry season) as the first survey, and March 2019 (the last month of the rainy season) as the second survey. All studies were performed based on the guideline NOAA Marine Debris Program [17]. To cover all areas in the sampling sites, transects 100 m × 10 m were used as a sampling unit and separated at least by a 5-meter stretch. Every unit sampling starts from the water’s edge to the back of the beach.

The width of transects on each beach is 3000 m^2, respectively. GPS was used to mark out the exact each location.

During the survey, ten volunteers carried out the sample collection, and it was conducted throughout low tidal phases. The abundance of beach macro-debris larger than 2.5 cm (macro-litter) in the longest dimension of each type of debris was collected. However, smaller meso-litter particles (0.5 - 2.5 cm), e.g., cigarette butts, were partly included, as well. In each transect, after the litters were sorted according to the types, the contents were placed in separate bin bags. Next, all debris gathered was brought back to the laboratory and rinsed with pipe water in a large bucket to clean off dirt and sand that might cause inaccuracy during the weighing process.

The debris was air-dried in the laboratory before being weighed separately and identified. All sampls were categorized into seven groups (polymers/plastics, rubber, cloths/fabric, paper/cardboard, processed wood, metals, and glass) based on categorization provided by IPA-Adriatic [18].

2. 3. Data Analysis

Additionally, to quantified beach litter abundance, the density (D) of items was calculated as the number of items m^2 (D = N/A), where N = total number of items per transect, and A = area (length of transect [m] × 10 [m]) [17, 19]. Here, the calculation of the Clean Coast Index (CCI) that classifies beaches according to the amount of litter on the beaches is presented by the following equation:

$$\text{CCI} = \frac{\text{Total Litter in the sampling unit}}{\text{The total area of the sampling unit}}\ x\ K$$

where for statistical analysis, coefficient K = 20 was involved in the equation. Final CCI numbers are as follows: 0-2: very clean (no litter is seen); 2-5: clean (no litter is seen over a large area); 5-10: moderate (a few pieces of litter can be detected) 10-20: dirty (a lot of debris on the shore) 20 or more: extremely dirty (most of the beach is covered with debris) [16, 20].

The series of the statistical test involves the analysis of variance (ANOVA) used to determine significant differences in total debris between beaches at the p = 0.05 levels. Significant results were investigated further using the Tukey's Honestly Significant Difference post hoc test to identify specific differences between levels. Furthermore, Levene's test was used to test for homogeneity of variances.

3. RESULT AND DISSCUSSION

3. 1. Composition and Weight of Beach Macro-Litter

Throughout this research, beach litter items varied widely in composition. Totally, 3,332 pieces of beach macro-litter were found in all surveyed beaches, where on the first survey (September 2018) 2,288 items were found, and 1,044 particles on the second survey (March 2019). The composition of beach litter during two sampling periods shows that polymers/plastics (2,040 items, 61.2%) became the highest number of particles at all beaches. Next, glass (403 items, 12.1%) and metals (296 pieces, 8.9%) stand in the second and third positions, whereas, the least amount of macro litter is rubber (81 pieces, 2%). Furthermore, based on the surveyed beaches, the highest number of beach litter was found on St.1 (Kalumata) where it reached 1,128 ±250 items while ST.6 (Kastela) got 668 ±120 items in the second place. The lowest number of beach litter recorded on St.3 (Sulamadaha) 324 ±75 items (**Fig. 2**).

Our study found that the quantity of beach macro debris (i.e., number of items) on the six beaches of Ternate Island is dependent on the interaction of location and period of sampling. In the first sampling, no significant difference across beaches was observed. Whereas in the second sampling, the amount of debris present on one beach was significantly higher than the amount found on five other beaches. Nevertheless, based on total items collected at all sampling locations, statistical analysis shows an insignificant difference ($F = 0.759$; $p > 0.05$) between all study sites. As a result, the homogeneity of variance test indicates that all samples are homogenous. Detail view of beach macro-litter percentage on all surveyed beaches during two periods sampling has been shown in **Fig. 3**.

3. 2. Density of Beach Macro-Litter and Clean Coast Index

The density (items/m^2) of macro litter on all beaches is strongly associated with the composition and distribution of beach litter. Density found ranged from 0.07 items/m^2 to 0.23 items/m^2 in September 2018. Meanwhile, in March 2019, the abundance starts from 0.04 items/m^2 to 0.16 items/m$_2$. Clean Coast Index (CCI) is one approach to assess cleanliness levels of beaches [19]. The calculation result of CCI found that four beaches (St.1, St.4, St.5, and St.6) in the study locations on the first sampling were pointed out as clean, and two stations (St.2 and St.3) were under very clean categories. On the second sampling, all beaches were indicated as very clean, except St.1 placed in clean class (**Table 2**).

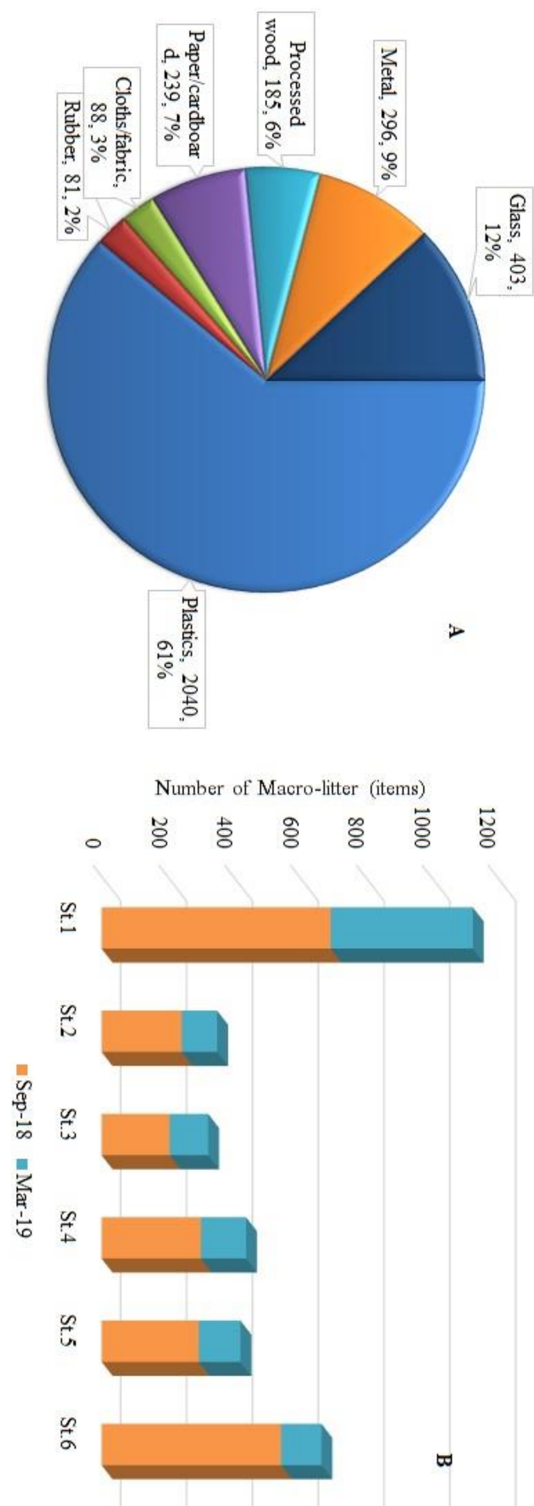

Figure 2. Total Amount and percentage of beach macro-litter based on the type during two sampling periods **(A)**. The distribution of beach macro-litter on six beaches in Ternate Island in September 2018 and in March 2019 **(B)**

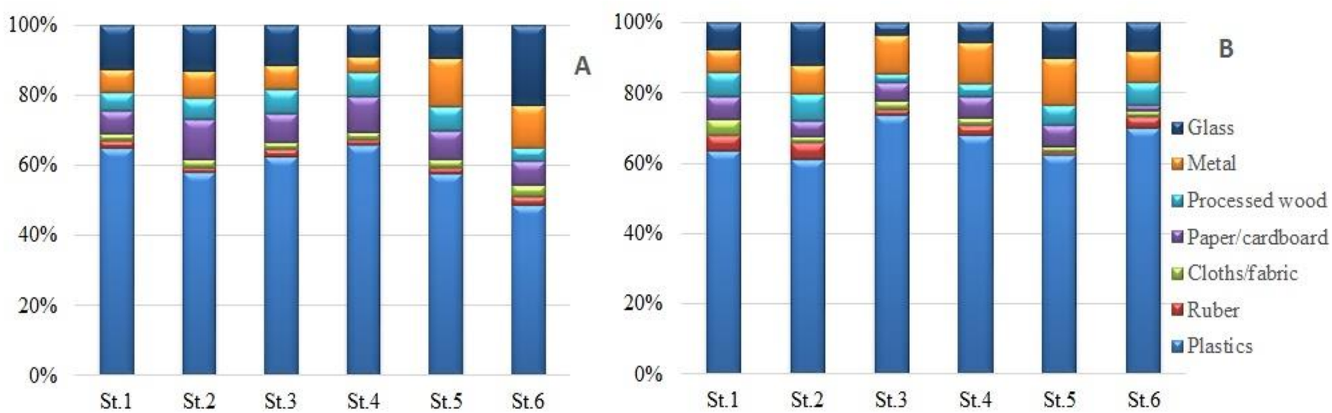

Figure 3. Graphic with the type and percentage of seven macro-litter categories on six beaches in Ternate Island in September 2018 **(A)**; in March 2019 **(B)**.

Table 2. Density of Beach Macro-litter and Coast Clean Index on Six Beaches in Ternate Island.

Locations	Sep-18			Mar-19		
	Total Items	Density (items/m^2)	CCI Index	Total Items	Density (items/m^2)	CCI Index
Kalumata (St.1)	696	0.23	4.6	493	0.16	3.3
Tobololo (St.2)	243	0.08	1.6	136	0.05	0.9
Sulamadaha (St.3)	207	0.07	1.4	121	0.04	0.8
Takome (St.4)	302	0.10	2.0	163	0.05	1.1
Rua (St.5)	295	0.10	2.0	190	0.06	1.3
Kastela (St.6)	545	0.18	3.6	161	0.05	1.1

The highest number of beach macro-litter in this study was predicted concerning the population growth, community behavior, and mismanagement of solid waste conducted by the Ternate city government. Increasing population numbers in Ternate Island is one of the main issues related to the waste production. In 2011, the population in Ternate City was 190.184 people, and in 2015 it increased to 223.507. Here, the population density reaches 1.797 people/km^2 and Ternate residents experienced growth approximately 2.33 per cent annually. Consequently, in 2011, the production of waste reached 173.543 m^3 per year and it means growth of 6% in 2015, at 203.950 m^3 per year [21].

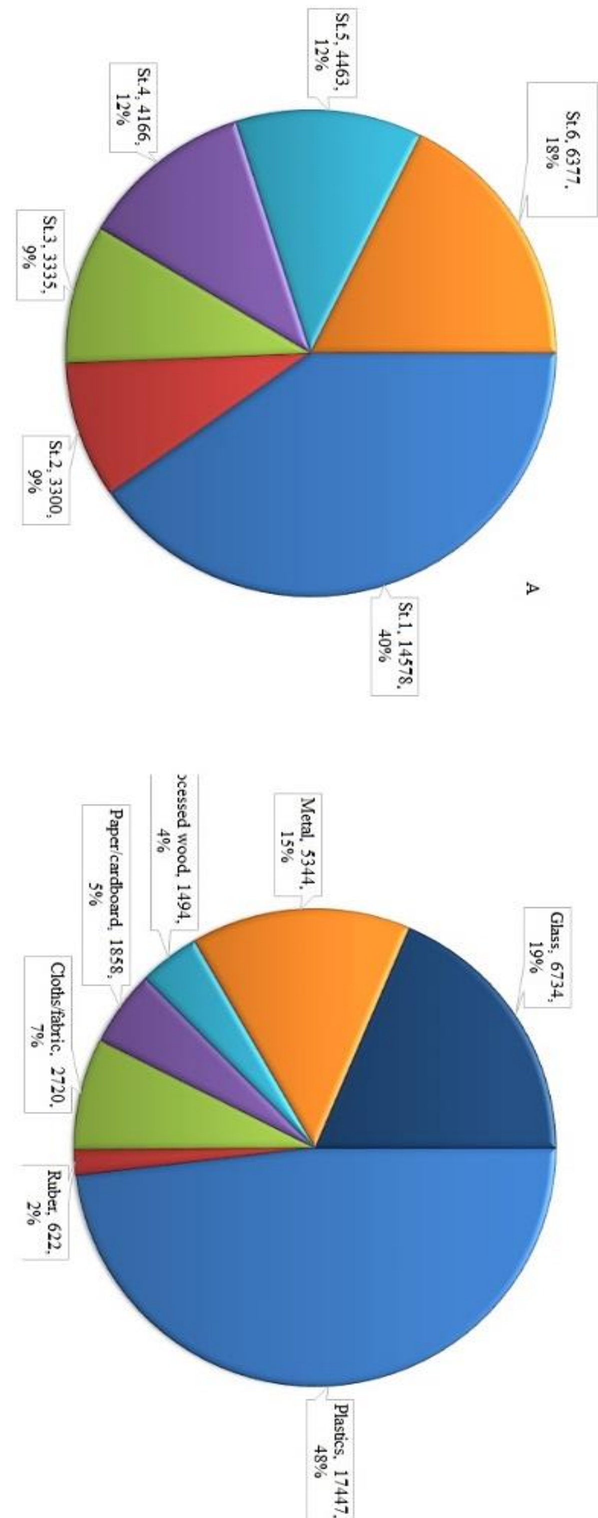

Figure 4. Weight (gr) Percentage of beach litter based on study locations **(A)** and categories of litter **(B)**

Beach macro-litter density found at six beaches in Ternate seems to be very high in a number of pieces, but lower in total weight when compared with other studies in Indonesia (**Table 3**). This Comparison should take into consideration that litter is highly variable in time and space. Differences between the sampling area and study sites employed in this and other studies make it difficult to relate the results to the factors that control the geographical and temporal distribution of the litter. The first reason for the high amounts of beach litter found in this study can be attributed to the wide-area and sampling location. Significantly, the number of debris recorded can be influenced by site selection [22].

The sampling area we chose included 18 transects and covered 18000 m^2. Therefore, the potential to find beach litter is high. Furthermore, our study locations are mostly close to the village and urban areas where sometimes the awareness of people to keep their environment is very low and very limited in waste management facilities. The highest source of the solid waste in Ternate city comes from urban settlement, and lack of temporary waste sites led the people throw their trash anywhere.

Table 3. Comparison of the Total Litter (items) and Weight (Kg) of Beach macro-litter found in the Ternate Coastal Area with those found in other coastal in Indonesia

Location	Total Litter (items)	Weight Litter (kg)	Sources
Ternate Island, North Maluku	3332	36.22	This study
Savu Sea Marine park, East Nusa Tenggara	2585	52.14	[11]
West Coast of Bali	552	6.0	[15]
Cilacap, Central Java	2313	n.a.	[13]
Takalar, South Sulawesi	3203	79.47	[23]
Pantai Indah Kapuk, Jakarta	6079	53.4	[14]

During two periods of sampling, the first sampling found more than twice of macro beach litter on both, numbers and weight compared to the second sampling. It was caused by the first survey reflecting the long-term accumulation of beach litter in a coastal area without beach cleaning. In terms of beach macro-litter composition, plastics have become both, the highest number of items and weight (2,040 items, 19.5 kg) at six beaches in this research during September 2018 and March 2019. It was followed by glass (420 pieces, 6.9 kg) and metal (343 pieces, 7.3 kg). Principally, this study result could support the statement that the problem of marine litter and plastics has increased with higher intensity over the last decade [24]. This polymer had been found in almost all research on sand beaches [25, 25] and remote islands [27-29]. Plastics also had been investigated in some of Earth's most remote areas and deep ocean environments in the Southern Ocean, Arctic Ocean, the Atlantic, Pacific, and Mediterranean Sea [30-33].

The existence and distribution of beach macro-litter surrounding research locations are closely related to the natural process and anthropogenic activities. St.1 (Kalumata) has the highest number of macro-liter components and weight due to its location near the urban settlement and the harbor, reclamation areal, and trade center. According to [34, 35], harbors can introduce significant local debris in coastal beaches. Besides, this location also has a river mouth that flows during the rainy season (October to March). This river has potentially the entrance of debris to this beach. The river gives a significantly higher number of land-based litters on the beach [36, 37].

Meanwhile, the presence of beach litter in other study sites was also influenced by tourism activities, especially at St.2 (Tobololo), St.3 (Sulamadaha), and St.6 (Kastela). Our sample shows that many types of beach litter in those locations related to tourism activities, such as cigarette butts, cans, drink bottles, food containers, cosmetics tubes, straws, crisps wrappers, etc. Lack of education and awareness among the visitors and recreational activities are one of the significant sources of debris in a tourism destination area.

4. CONCLUSIONS

Evaluations of the types of coastal litter are useful for identifying the sources and types of such material. Although marine debris found during this study may have been generated from land (urban activities, tourism) or sea-based sources, this study presents that beach litter in all study sites is related to inadequate waste disposal infrastructure and management and also a lack of public knowledge about their environmental impacts. Similar to previous studies, plastic debris in this research has also become the most abundant from all study locations. It's because the human had used plastics for a variety of utilization, such as clothing, transport, telecommunications, and packaging.

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