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The abundance of Plastic Marine Debris on Beaches in Ambon Bay

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Abstract. Marine plastic pollution is one of the most serious problems in the marine environment. In this study we determined the abundance of plastic marine debris (large microplastic [1-5 mm] mesoplastic [5-25 mm] and macroplastic [>25 mm]) on 2 beaches in Ambon Bay. The sampling was conducted during March 2018 using quadrats of 2 sizes. Macroplastics were sampled using large quadrats measuring 5 x 5m. Small quadrats measuring 0.5 x 0.5 m were used to collect large microplastics and mesoplastics. The respective abundances of large micro- (1-5 mm), meso- (5-25 mm) and macroplastic (>25 mm) were 68.8, 5, and 0.722 items.m⁻². The highest abundance of marine plastic debris was found in the inner Ambon Bay. The results indicated a strong contribution of water mass circulation within Ambon Bay to the distribution of plastic debris abundance throughout the Bay.

1. Introduction

The development of synthetic polymers in the middle of the 20th century has driven a significant rise in the global average production and consumption of plastic. From around 1.5 million tonnes in 1950, by 2015 the total global production of plastics had grown to 322 million tonnes [1, 2]. Plastics that are light weight, inexpensive, strong, able to be printed into many forms and often transparent are very suitable for a variety of products used in our daily lives [3]. However, the high production and consumption of plastics has led to an accumulation of plastic debris in the environment around the world [4]. Recent studies have estimated that 8 million metric tonnes of plastic waste per year have entered the ocean from land-based sources[5]. Moreover, Indonesia is claimed to be the world's second-largest contributor to plastic marine pollution.

Plastic debris is one of the most challenging problems for marine environment because one of its features is that it can be degraded into smaller particles (less than 1 to 5 mm), referred to as microplastics, that even small organisms can ingest [3]. This type of plastic waste has become one of the global marine debris issues because the pervasive presence of these particles in the marine environment, not only locally close to the coastal areas where they degraded, but also in the open ocean. Their small size means that microplastics are often confused with food and ingested by marine fishes, which can lead to irritation or obstruction of the digestive system. Many studies have proved that plastics have entered the bodies of a wide range of organisms through ingestion, including zooplankton [6], tuna [7], whales [8], corals [9] and crabs [10]. The presence of plastic waste in marine fishes found in eastern Indonesian waters has been reported; for example, a study found that at least 28% of fish sampled from a Makassar market were contaminated with plastics [11].



The seas around Maluku are known to have high potential in terms of fisheries resources. Data released by the General Directorate of Fisheries, Indonesian Ministry of Marine Affairs and Fisheries, estimated that the potential annual catch is around 538 kilotons/year [12]. However, as in many other parts of the world, the Maluku seas are highly affected by anthropogenic activities that can lead to serious issues at sea. Marine plastic pollution is one the most serious problems faced by Ambon Island today. A report published in 1995 indicated a growing volume of plastic debris in Ambon Island [13]. Their findings were later confirmed by an Indonesian Institute of Sciences (LIPI) study in 2017 which reported the exponential growth of marine plastic waste in Ambon Bay during the last twenty years (*personal communication*). However, the body of data available regarding plastic marine debris, especially data on meso and microplastics that can easily be ingested by marine biota around Ambon Island, is surprisingly limited. To our knowledge there is only one publication, a newspaper article that estimated the volume of microplastics in the Maluku area of the Banda sea at 5000 to 6000 per km² [14]

In order to provide information regarding plastic waste contamination around Ambon Island, here we report findings from the first study on the distribution of macro-, meso- and large microplastic debris on two beaches in Ambon Bay.

2. Sampling Methods

This study was conducted in Ambon Bay, located in Ambon Island (Moluccas). Ambon Bay comprises an inner and outer area, connected by a narrow and shallow bar with an average depth of about 12 m (Fig. 1). The inner bay has an average depth of 30 m with an area of about 6 km². The outer bay opens into Banda Sea, and has an area of about 100 km² with an average depth over than 100 m. Two beaches (Poka and Wayame) were selected as sampling sites in Ambon Bay through purposive sampling, to represent the outer and inner bay. The Poka site is located in the inner bay, as illustrated in Fig. 1., while the Wayame site is located in outer bay. Compared to the outer bay which opens into the Banda Sea, water mass circulation in inner bay is relatively low, because of the narrow and shallow bar separating the two sections of the bay. Wayame is in a more densely populated area than Poka [15].

The methodology used in this study followed methods used by NOAA [16] and a previous study on a Korean beach [17]. The plastic marine debris collected was classified into three size classes: large microplastics [1-5 mm], mesoplastics [5-25 mm] and macroplastics [>25 mm]. Particles smaller than 1 mm were not included, because they cannot be identified and counted with the naked eye.

At each site, macroplastics were collected from within 10 large (5m x 5 m transects randomly placed along the centre of the high tideline. The plastic debris collected was classified into: hard plastics, films, fibres, Styrofoam, pellets and other polymers. Then, in the centre of the large quadrats, we placed small quadrats (0.5m x 0.5 m), from which we collected sand to a depth of 2 cm and sieved the sand sequentially with a 1-mm² stainless steel sieve. The sieved materials were stored in zipper bags and brought to the laboratory. For wet sand, we used water to facilitate the sieving process (seawater that has been sieved through a 0.1 mm screen is sufficient for this purpose). In the laboratory, the sieved debris was dried at 90 °C for 24 hours. The meso- and microplastics were then identified and sorted using the naked eye.

The concentration of plastic debris items (number of debris items.m⁻²) per transect was calculated as follows:

$$C = \frac{n}{(w \times l)}$$

where:

C= concentration of plastics debris (items.m⁻²)

N= width (m) of shoreline section observed during sampling

L= length (m) of shoreline sampled

The abundance and weight of the plastic debris were expressed in items.m^{-2} and weight.m^{-2} , respectively. The marine plastic debris abundance data were presented as mean values with standard deviation (SD). The difference in plastic marine debris particle abundance between Poka and Wayame was analysed using a t-test. Spearman's rank correlation was applied to the relationship between the abundance of the large micro, meso and macroplastics size classes in Ambon Bay.

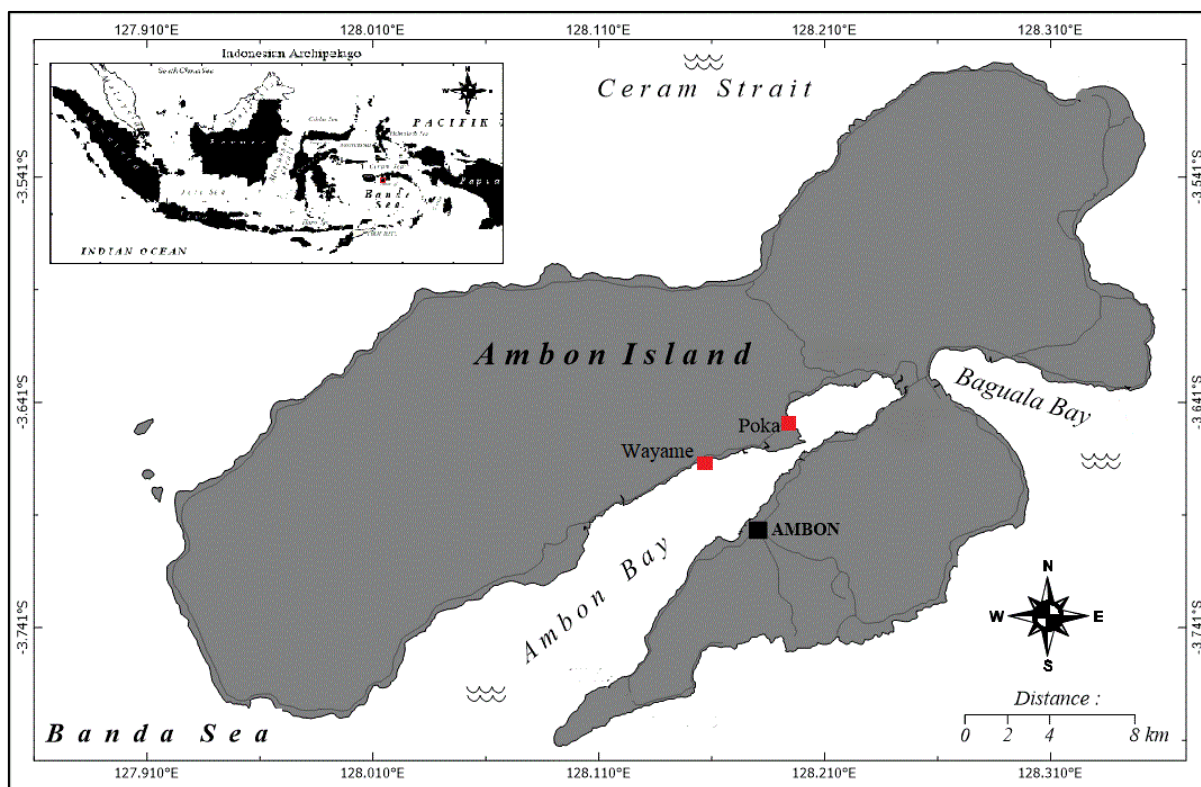


Figure 1. Map of Ambon Island showing the sampling sites

3. Results and discussion

3.1 Abundance of plastic Marine Debris

The mean abundances of large micro- (1-5 mm), meso- (5-25 mm) and macroplastic (>25 mm) along the strandlines of 2 beaches in Ambon Bay were 68.8, 5, and 0.722 items.m^{-2} , respectively (Fig. 2). The t-test with $\alpha=0.05$ showed a statistically significant difference in marine plastic debris particle abundance between Poka and Wayame ($P<0.05$). The number of macroplastic particles was higher at the Wayame site. In contrast, the abundance of meso and large microplastic was found to be higher at the Poka site. Based on figures for the human population of Ambon in 2015, Poka is less densely populated than Wayame. These contrasting results indicate that the abundance of plastic marine debris in Poka and Wayame is not only influenced by the human population and human activity in the two adjacent areas, but also influenced by current circulation patterns in Ambon Bay. The inner Ambon Bay has a longer flushing time which causes the water mass and other items that enter from the outer bay to stay longer in the inner bay [18].

Based on our observations, both Poka and Wayame have minimal, inadequate waste disposal infrastructure. This means that the accumulation of plastic debris in Poka and Wayame is to be expected. However, when compared to some other countries, the density of macro debris particles in Ambon Island was lower than that reported from sites in Turkey ($0.9. \text{m}^{-2}$), Brazil ($29.1.\text{m}^{-2}$) and Korea ($1.\text{m}^{-2}$) [18]. The mean abundance of macroplastic particles in Ambon Bay was also lower than that reported for Cilacap, a coastal area in western Indonesia [19]. The abundance of meso and large microplastic debris particles found in Ambon Bay is also lower than those reported for sites in Hong

Kong (mesoplastics), Brazil (mesoplastics), Hawaii (mesoplastics) and Korea (meso and large microplastics) [17]. However, this comparison has limitations due to the difference in sampling methods and the classification methods used.

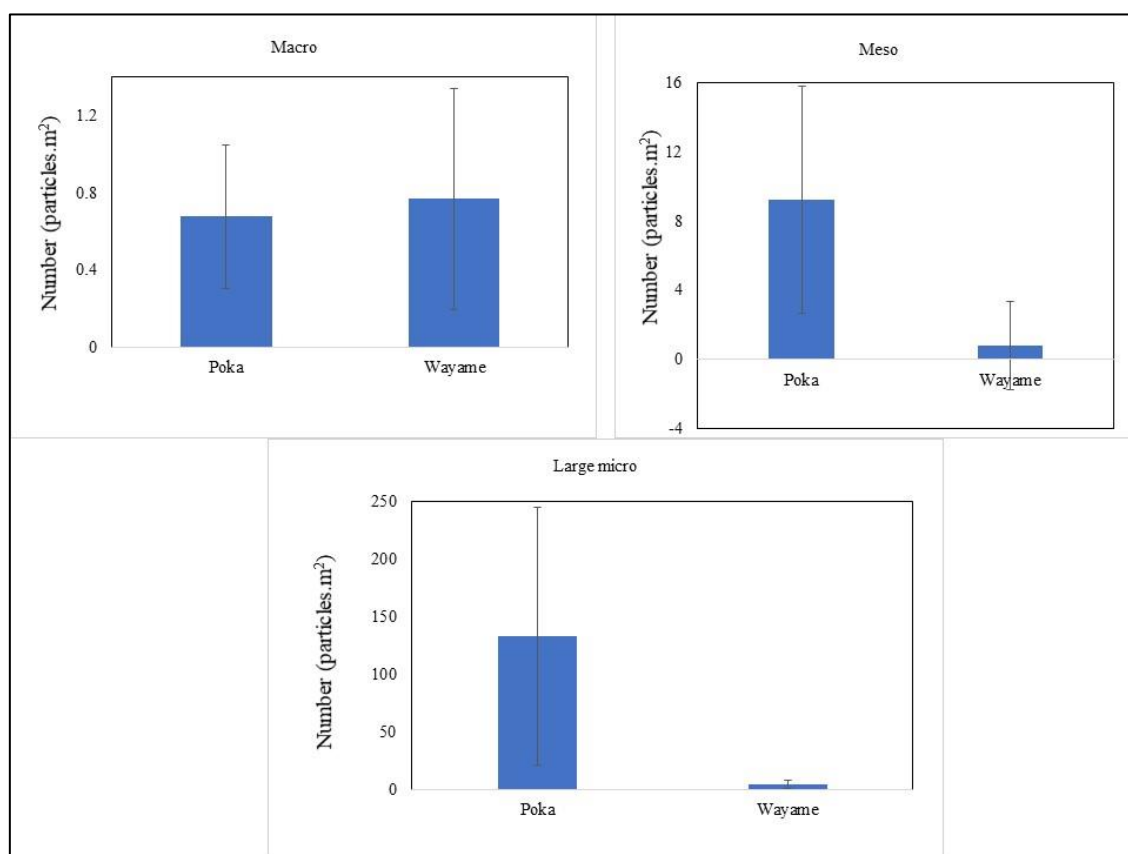


Figure 2. Abundance of plastic marine debris on 2 beaches in Ambon Island, expressed as density (items.m⁻²) and classified by size class: large micro [1-5 mm], meso [5-25 mm] and macro [>25 mm].

3.2 The relationship between abundances of macro, meso and microplastic debris in Ambon Island

The Spearman's rank correlation was applied to examine the correlation between particle abundance (density) of macro-mesoplastics, meso-large microplastics and macro-large microplastics. The mesoplastic particle abundance was strongly correlated with large microplastics ($\rho=0.776$, $P<0.01$). No correlation was observed between macro-mesoplastics and macro-large microplastics. A strong correlation was also found between meso and large microplastics on Korean beaches [18].

3.3 Composition of macroplastic debris

The composition of macroplastic debris collected from Poka and Wayame is presented in Fig. 3. At the Poka site, film debris were dominant in terms of the number of particles (91%), followed by hard plastics (8%) and other polymers (1%). In Wayame, the film debris type was also dominant, contributing approximately 63% of particles, followed by Styrofoam (20%), hard plastic (12%) and other polymers (2%).

Plastic films are used in a wide variety of applications. These include: packaging, plastic bags, labels, building construction, landscaping, electrical fabrication, photographic film, etc. In both Poka and Wayame we found that the most abundant film type debris were food packaging and plastic bags. The abundance of those plastics type in Ambon beaches can be expected given that Indonesian habits still perform poorly in terms of managing the use of plastics and plastic waste disposal.

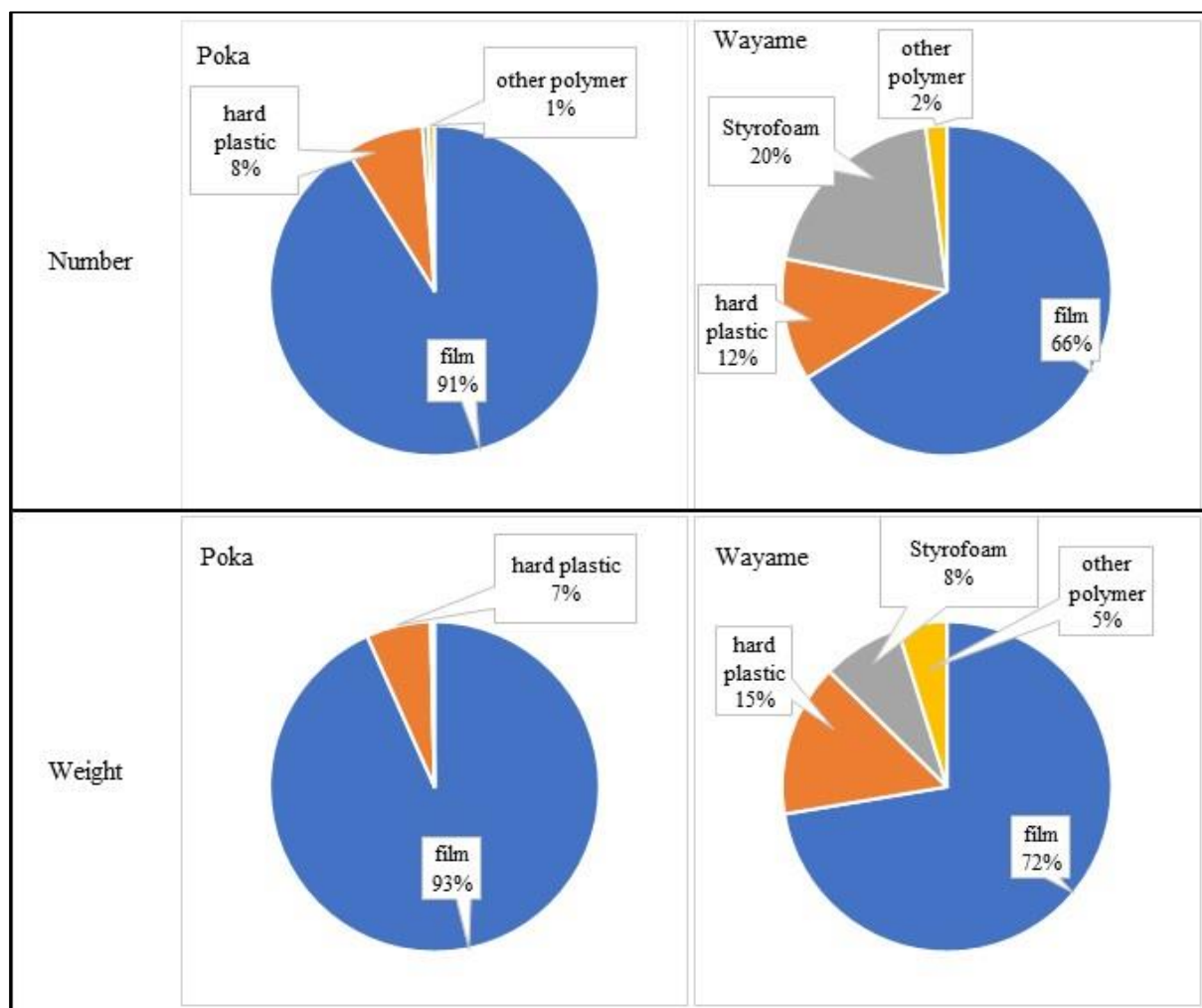


Figure 3. Composition of macroplastic debris particles sampled from two beaches in Ambon Bay by particle number (above) and weight (below)

4. Conclusion

This study found that Ambon Bay has been contaminated by plastic marine debris, especially plastic bags and food packaging. The presence of this plastic debris accumulated on the beaches may be caused by the lack of inadequate waste disposal infrastructure and management in Poka and Wayame. There is an urgent need for improving waste disposal infrastructure in coastal areas, especially in Ambon Bay, and also for citizen outreach programs to increase public awareness about plastic debris. This study has limitations in that it only provides a snapshot of marine debris particles recently deposited on the beaches. A more advanced study on marine litter in Ambon Bay is also urgently needed to explore more fully the abundance of marine plastic debris in Ambon Bay.

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