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Distribution and types of microplastics on the coast of Aipiri and Andai Beaches, Manokwari District, Indonesia

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Abstract. *Embulaba O, Kolibongso D, Tapilatu RF, Saleh F, Bawole R. 2022. Distribution and types of microplastics on the coast of Aipiri and Andai Beaches, Manokwari District, Indonesia. Indo Pac J Ocean Life 6: 10-16.* Plastic waste enters the marine environment in various sizes, from micrometers to millimeters. The composition and occurrence of microplastics were investigated on the Manokwari coast (Manokwari District, Indonesia) from two different beaches in terms of intensity of exploitation and exposure to various activities such as urbanization, ports, tourism, and morphological characteristics of the coast. The average abundance of microplastics was between 0.001 to 0.041 items/gram of dry sediment. Fragments and fibers are the two types of microplastics found to dominate. On the other hand, there was no substantial difference in the abundance of microplastics found on unexposed beaches with other beaches. Our results show that coastal morphology with gentle slopes with high tide limits tends to have a 'better' potential for accumulating microplastics on the beach. However, the accumulation of microplastic types is also primarily determined by the characteristics possessed by microplastics. Therefore, it causes spatial and temporal variability in the composition of microplastics found on the coast.

Keywords: Abundance, beach, Manokwari, microplastic

INTRODUCTION

The territory of Indonesia, which is two-thirds of its part in the form of the sea, has abundant natural resources, both living and non-biological. In addition, the relief of Indonesia, which is very rich in islands, makes Indonesia have a long coastline exceeding 99,000 km. Unfortunately, in some places, both the sea and the coast, the conditions are abysmal due to pollution from land. The impact of this contamination occurs globally and locally caused by humans. Pollution contamination occurs both in the form of liquid and solid wastes. Examples of solid waste are plastic, metal, paper, glass, and paper waste (Abu-Hilal and Al-Najjar 2004; Leite et al. 2014) which pollute beaches, shallow waters, and the high seas, with an estimated 7,000 to 35,000 tonnes (Cózar et al. 2014) in the form of macro and microplastic scraps (Cole et al. 2011; Lima et al. 2014).

Indonesia is the second-largest country globally, estimated to contribute to the amount of waste that enters the sea (Jambeck et al. 2015). The composition of the macro marine waste (> 2.5 cm) in 18 districts/cities in Indonesia is dominated by plastic waste at 31.44%, while others are in the form of wood, glass and ceramics, rubber, cloth, plastic foam, metal, paper and cardboard, and other materials (KLHK 2017). Meanwhile, the composition of meso marine waste (0.5-2.5 cm) is dominated by wood at 35.06%, and other waste in the form of plastic, glass and ceramics, metal, plastic foam, cloth, rubber, paper and cardstock, and other materials.

The potential effects of marine chemical waste tend to increase as the size of plastic particles (microplastics) decreases. In contrast, the physical effects increase as the size of macro waste increases (UNEP 2011). In addition, macrowaste has a material impact, such as covering the sediment surface and preventing the growth of mangrove seeds (Smith 2012). The threat of waste in the marine environment is crucial because it has the risk of impacting humans (Halden 2010; Cole et al. 2011; Farrell and Nelson 2013; Tapilatu and Kolibongso 2021) due to the interaction between the sea and humans (Fleming et al. 2014) as well as through transfer mechanisms from food sources such as fish, especially plankton feeders such as Manta Rays (Thovyan et al. 2020) and mollusks, where the number increased from 1985 to 1995 (Willoughby et al. 1997).

Indonesia has committed to reducing 70% of marine waste by 2025 based on Presidential Regulation No. 83 of 2018. One of the supports for this policy is determining the level of marine waste pollution, especially those deposited on the beach. However, microplastics' spatial variability, composition, and deposition in coastal sediments are still subject to tidal influence.

MATERIALS AND METHODS

Research sites

Manokwari District is the capital city of West Papua Province and is located in the north of Bird's Head section of the island of Papua, Indonesia. This research was carried out in two locations: Andai and Aipiri Beach (Figure 1) in March 2020, with data collection carried out in two (2) different observation periods. Data collection for period I was carried out on 7-8 March 2020, and period II was carried out on 22-23 March 2020. These two beaches differ in the intensity of exploitation and exposure to various anthropogenic activities, such as proximity to city centers, ports, fishing ports, and tourist areas selected for this research.

Data collection

Microplastic survey method

At the beach, the determination of transects, which could reach 100 m, was done purposively by considering the length of the beach. The making of the transect line was based on the Coastal Waste Monitoring Guidelines (KLHK 2019), which divided the transect line into five sections (quadrants A, B, C, D, E) with a length of 20 meters each. In each quadrant, a 5 x 5 m sub quadrant was placed. In each sub quadrant, 25 plots with a size of 1x1 m were placed (Figure 2).

Marine waste samples taken in this study were in the form of microplastic-sized waste (in the substrate). Prior to sampling, a number was drawn for the boxes to be collected. From 25 numbers, five numbers were selected. The box was in the 5 x 5 meter quadrant. In each of five previously selected boxes, a 1 x 1 meter quadrant was placed, then a 1 kg substrate sample was taken at 3-5 cm depth, then the substrate was put into the sample container and coded. The separation of microplastic particles (0.045-5mm) was separated from the substrate in several stages: drying, volume reduction, density separation, filtering, and visual sorting.

Drying was carried out in an oven at 105ºC for 72 hours. First, reducing the volume of dry sediment was done by filtration (size 5 mm) (Hidalgo-Ruz et al. 2012). Next, the density separation step was carried out by mixing dry sediment samples (500 grams) with saturated NaCl solution (3L), then the mixture was stirred for 2 minutes (Claessens et al. 2011). The plastics that float are polystyrene, polyethylene, and polypropylene. Finally, the filtering step was carried out by filtering the supernatant (45 µm size). Microplastic particles were visually sorted using a monocular microscope and grouped into four types, namely film, fiber, fragment, and foam (Hidalgo-Ruz et al. 2012).

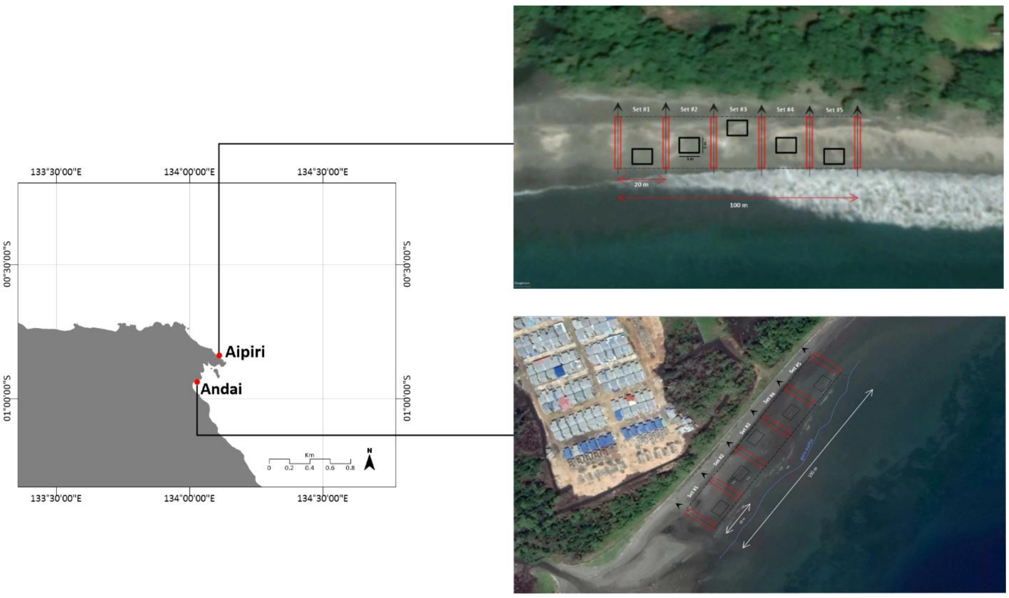


Figure 1. Research location map in Andai and Aipiri of Manokwari District, West Papua Province, Indonesia

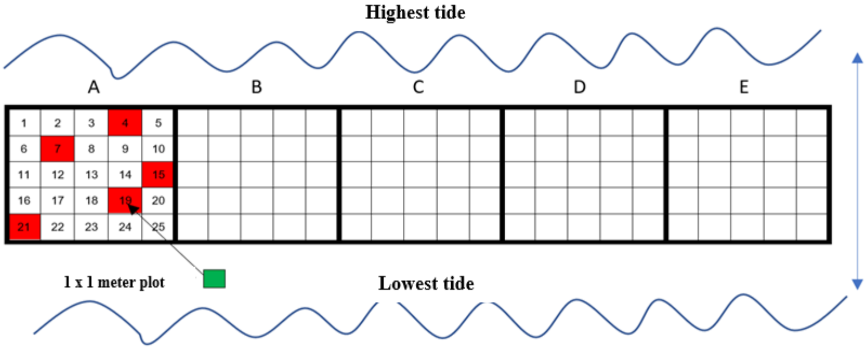


Figure 2. Schematic of transect and sub transect sampling

Oceanographic parameters

Water current data were taken in situ and from the Copernicus Marine Environment Monitoring Service (CMEMS) (http://resources.marine.copernicus.eu) with a resolution of 1/12º or 0.083x0.083 km. The database in the physics analysis model in CMEMS used NEMO Model version 3.1. The measurement of the slope of the coastal slope was carried out using a waterpass hose and a scaling pole (Kalay et al. 2018). The measure was started from the shoreline (highest tide area) to the lowest tide area at 10 m from the observation point (r-axis).

Data analysis

Data on the abundance of microplastics were analyzed statistically. The Kruskal-Wallis test was used to examine non-parametric significant differences, including the quantity and composition of microplastics between the two locations and observation points. If the test results were significantly different, it was continued with the Mann-Whitney Test to identify significant differences between the two groups (Claessens et al. 2011).

RESULTS AND DISCUSSION

Types and abundance of microplastics

There were four types of microplastics on the Manokwari beach: fragments, foam, fiber, and film (Tables 1 and 2). Microplastic fragments, fibers, foams, and films were all found on the Andai coast. Meanwhile, the types of fragments, fiber, and foam were found only on the coast of Aipiri. The abundance of fragment types was the most dominant microplastic found compared to other types, with a range of 0.004-0.052 items/gram of dry sediment (Table 1). The lowest abundance was found for foam with 0.002-0.006 items/gram of dry sediment. The fragments were abundant on the Andai coast, with an average abundance of 0.041 items/gram of dry sediment. Meanwhile, fiber was found with the highest abundance on the Aipiri coast, with an average of 0.008 items/gram of dry sediment (Table 2). The differences in the types of microplastics found were caused by several factors, such as the type of substrate and water conditions.

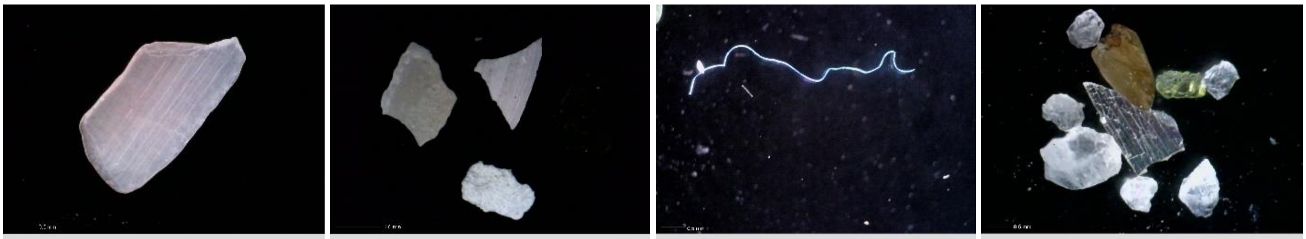
The highest abundance was found for microplastic fragments with a percentage of 22.2% to 83.9%. Meanwhile, the lowest percentage was found for foam types, from 4.8 to 33.3%. The highest mean abundance for fragments (77.7%) was on the Andai coast. Meanwhile, on the coast of Aipiri, it is fiber (44.4%) (Table 2). The fragments had a morphology similar to pieces of plastic products with white, red, and clear colors (Figure 3). Fragments were known to come from the result of cutting plastic products and the breakdown of rigid plastics with solid synthetic polymers. Sources of fragments found in sediments could come from plastic waste generated by local human activities (Sutton et al. 2016) such as in Andai and Aipiri (Siburian et al. 2022). The fiber was morphologically similar to fibers or fishing nets with dark blue, light blue, and red colors. The fiber was widely used in clothing, boats, fishing nets, and household appliances, so microplastic fiber types are easier to find and widely distributed in sediments and waters. Browne (2015) stated that microplastic fibers found in marine habitats could come from domestic waste. Marine activities such as fishing were a source of fiber because most fishing nets are made of fiber (Browne 2015; Alomar et al. 2016; Sutton et al. 2016; Lots et al. 2017; Piñon-Colin et al. 2018; Zhao et al. 2018). The dominant type of microplastic found in this study was the same as several studies on the coast of Indonesia, including Yona et al. (2019) in sediments in East Java; Manalu et al. (2017) in Jakarta.

Table 1. Microplastic percentage and abundance at Andai and Aipiri Beaches, Manokwari, West Papua, Indonesia, in both observation periods

Microplastic Type	Andai			Aipiri		
	Abundance by weight (items/g dry sediment)	Abundance per area (items/m2)	Percentage (%)	Abundance by weight (items/g dry sediment)	Abundance per area (items/m2)	Percentage (%)
Periode I						
Fragment	0.052	1.04	83.9	0.004	0.08	22.2
Foam	-	-	-	0.006	0.12	33.3
Fiber	0.006	0.12	9.7	0.008	0.16	44.4
Film	0.004	0.08	6.4	-	-	-
Periode II						
Fragment	0.030	0.6	71.4	0.008	0.16	44.4
Foam	0.002	0.04	4.8	0.002	0.04	11.1
Fiber	0.010	0.2	23.8	0.008	0.16	44.4
Film	-	-	-	-	-	-

Table 2. Percentage and mean abundance of microplastics on Andai and Aipiri Beaches, Manokwari, West Papua, Indonesia

Microplastic type	Andai			Aipiri		
	Abundance by weight (items/g dry sediment)	**Abundance per area (items/m2)**	**Percentage (%)**	**Abundance by weight (items/g dry sediment)**	**Abundance per area (items/m2)**	**Percentage (%)**
Fragment	0.041	0.82	77.7	0.006	0.12	33.3
Foam	0.001	0.02	2.4	0.004	0.08	22.3
Fiber	0.004	0.16	16.8	0.008	0.16	44.4
Film	0.005	0.04	3.2	-	-	-



A B C D

Figure 3. Examples of microplastics which were found on the coast of Manokwari, West Papua, Indonesia. A. Fragment; B. Foams; C. Fibers, D. Film

Spatial variability

The in situ weathering process of plastic waste is the mechanism that probably produces most of the microplastics on the beach (Andrady 2011). Plastic is the dominant type of marine waste on beaches, resulting from mechanical processes due to waves and tides and the influence of oxygen and sunlight, which affects the fragmentation of plastic into smaller pieces (Rosevelt et al. 2013; Topçu et al. 2013; Laglbauer et al. 2014; Urban-Malinga et al. 2020). The abundance of microplastics on the Manokwari coast found on the Andai coast (0.02-0.82 items/m^2) and the Aipiri coast (0.08-0.16 items/m^2) did not show a substantial difference (Table 2). Film-type microplastics were the least present, only found on the Andai coast. These microplastics were also only found in period I of observation. Microplastic films were identified as polymers of polyethylene and polypropylene, which were commonly used in plastic wraps and bags. This microplastic was easily destroyed and had a low density.

According to Kingfisher (2011), the film is a secondary plastic polymer derived from plastic bags or plastic packaging fragmentation and has a low density. A possible explanation for the emergence of microplastic films is that currents transported them in period I, which moved from the south along the coast and were then deposited on the Andai coast. It is reinforced by the not-so-strong average current velocity (0.2 m/s), making it easy to deposit. Next, no microplastic film was found in the second period of observation due to the direction of the average current, which tends to move away from the coast towards the open sea (out of the Manokwari coast) with a reasonably strong speed, which is twice the speed in the previous period (0.4 m/s). Surprisingly, the type of microplastic foam appeared at both observation sites. In fact, Aipiri Beach which has lower exposure to anthropogenic activities has four times the abundance of Andai Beach. This condition indicated that the higher number of microplastic particles found in the sediment could not be a measure or an indicator of a higher level of contamination for microplastic studies on the coast. Microplastics were easily transported as suspended particles by currents, waves, tides, and erosion processes on the coast from one place to another. Thus, there was a quantity of microplastic present in the sediment according to where it was deposited in a short time on the beach. According to Stolte et al. (2015), microplastics were distributed more evenly by natural forces than macroplastics which usually accumulated near urban areas and recreational areas. Added by Reisser et al. (2015), the amount and distribution of plastic were influenced by the depth and vertical mixing, where the amount of plastic was more abundant on the surface. In addition, distance to land (Uneputty and Evans 1997), season, wind, ecosystem location, and ecosystem use affected the amount and distribution of microplastics (Abu-Hilal and Al-Najjar 2004). The characteristics of microplastics determine their distribution and impact on the environment. For example, plastic particles with a heavy density will be easier to contact with sediment grains than microplastics with a lighter density. This difference is important because it can affect the degree of degradation, surface characteristics, and shape of the microplastic particles. The specific density of plastic particles varies greatly depending on the polymer and the manufacturing process (Lie et al. 2018). After the mixing process, large-sized sediments will be quickly deposited while small-sized particles will remain in a state of suspension or float and can be transported by physical water factors (Hidalgo-Ruz et al. 2012).

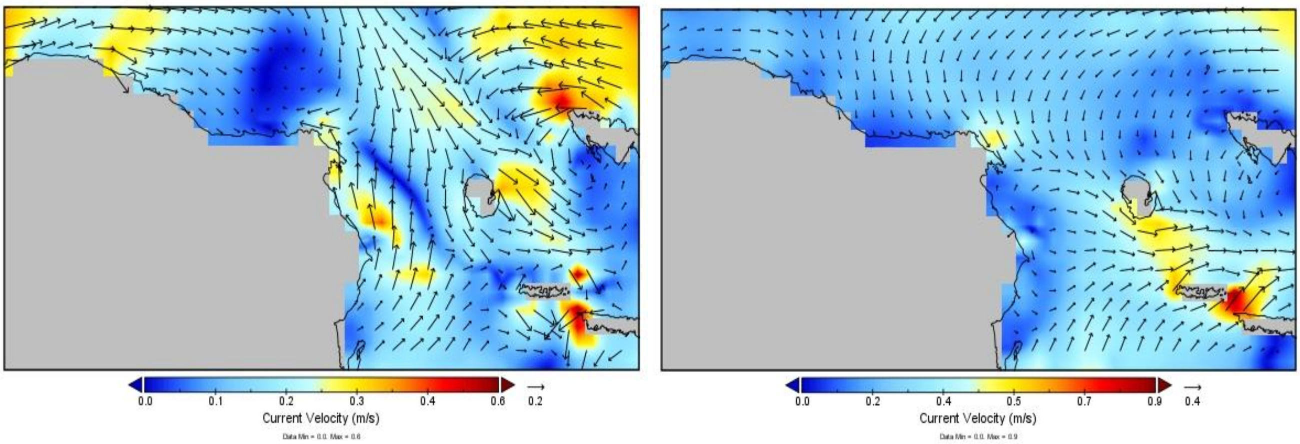


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Figure 4. The average flow pattern in March 2020 in the Manokwari Waters, West Papua, Indonesia. A. Current direction in observation period I; B. Current direction in observation period II

Microplastic distribution vs. coastal slope

The spatial variability and composition of microplastic deposited on the beach vary significantly because it follows the morphology of the beach. In this study, many microplastic types were found on Andai Beach (Figure 5), indicating that beaches with gentle slopes tended to be easier to deposit microplastics. This condition was related to the combination of interactions between tides and waves as the main factor in determining the direction and distribution of sediment on the coast. Sloping coastal slopes tend to have large high tide limits. These conditions indicated that the tidal area (coastal line) in Andai was under high pressure due to waves and tidal currents (Tapilatu et al. 2022), so the sediment in the vicinity was eroded and displaced. It was indicated by the grain size of the sediments found to be more varied, including gravel, sandy, and muddy sand. This condition caused microplastics on beaches with gentle slopes with a grain size of sandy sediments to accumulate more easily than the microplastics transported by tides and waves. According to Rey et al. (2021), the highest density of microplastics was found on coarse sandy beaches, indicating that densities were higher on beaches with high wave energy. McLachlan and Brown (2006) also found that suspended particles in water bodies and sediment surfaces were transported by waves to the sand bodies and adsorbed to the surface of the sand grain size. In addition, storms that generate tidal waves also cause coastal erosion. These remobilizing microplastics were buried back into the water column and might be suspended in the water column or transported back to shore (Vedolin et al. 2018). The highest microplastic densities were usually associated with coastlines and physical processes in the ocean (Lie et al. 2018). Diffusion of microplastics on the coast was strongly related to tides, which was caused by the accumulation of microplastics along the highest tide line, especially at high tide (Jualaong et al. 2021).

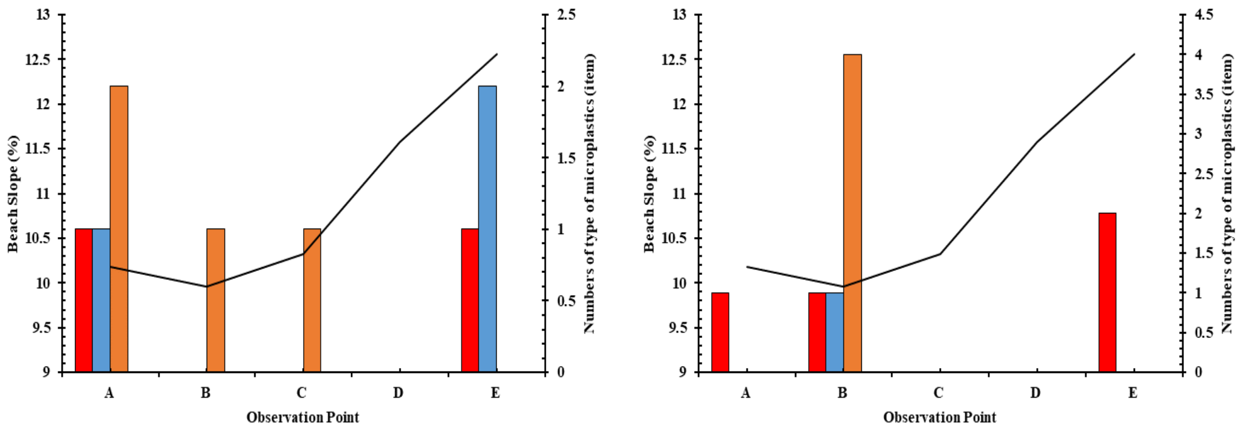

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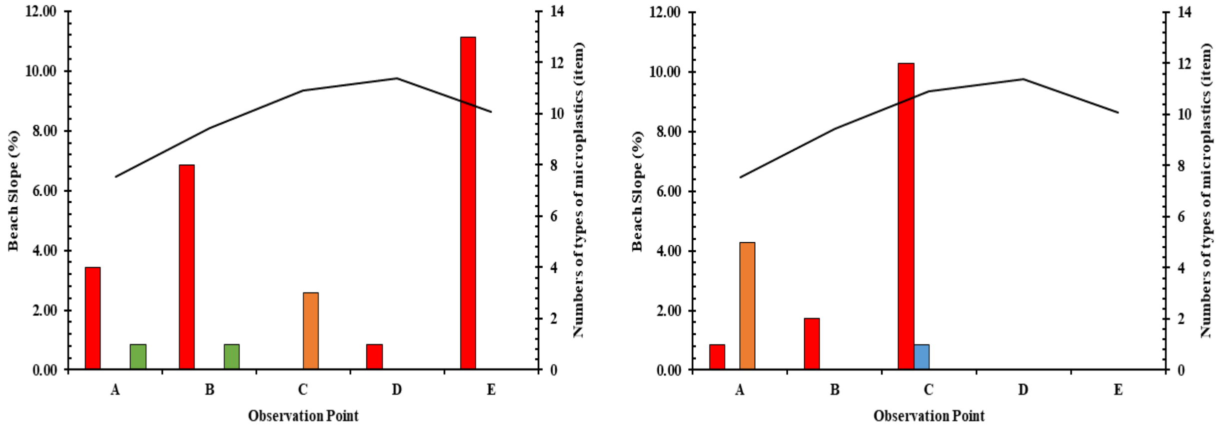
Figure 5. Distribution of microplastics vs. Coastal Slope at Aipiri Beach, Manokwari, West Papua, Indonesia. A. Observation of period I; B. Observation of period II. Note: Bar chart: type of microplastic (red: fragment, blue: foam, orange: fiber, green: film); Line chart: Coastal slope



A B

Figure 6. Distribution of microplastics vs. coastal slope at Andai Beach, Manokwari, West Papua, Indonesia. A. Observation of period I; B. Observation of period II. Note: Bar chart (red: fragment, blue: foam, orange: fiber, green: film); Line chart: Coastal slope

Most of the microplastic present in sediments was carried from other places and arrived at the depositional site by tides, waves, and currents. Therefore, the slope would be a determining factor in the accumulation process of microplastics on the beach. However, it was interesting that the accumulation of microplastic types on the beach was also strongly influenced by the characteristics of each type of microplastic itself. First, it caused spatial and temporal variability in the composition of microplastics found on the coast. Therefore, the abundance of microplastics in sediments on the coast was not directly related to activity at the location where the microplastics were deposited. Next, microplastics generally had a low density, so waves easily transported them through currents, tides, and erosion processes on the coast as suspended particles. Finally, microplastics also had a short residence time in sediments. These characteristics were hazardous because they had a high potential to pollute the water column and threaten marine organisms and ecological systems. Thus, they were difficult to clean from the fragile marine environment.

In conclusion, the microplastics found on the Andai and Aipiri coasts, Manokwari consisted of fragments, foam, fiber, and film. Fragments are the most common type of microplastic found on the coast. The average abundance of microplastics was between 0.001 and 0.041 items/gram of dry sediment. The abundance of microplastics was found on Andai Beach (0.02-0.82 item/m^2) and on Aipiri Beach (0.08-0.16 item/m^2). There was no substantial difference in the abundance of microplastics found on the unexposed beach with other beaches. However, beaches with gentle slopes tend to be easier to deposit microplastics.

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