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Abundance of Microplastic in Sediment Around The West Coast of Situbondo, East Java

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ABSTRACT

Microplastic pollution has become a serious issue worldwide. Once it enters the environment, microplastics could accumulate in the water column and sediment. This study aimed to analyze the occurrence of microplastics in the beach sediments along the western coast of Situbondo, East Java. Sediment samples were collected in the strandline areas from seven different beaches that received the high impact of human activities. In the laboratory, sediment samples were oven-dried and weighed, density separation was performed using NaCl solution, degradation of organic matter was conducted using H_2O_2 30% and microplastic particles were identified using a microscope. In total, 1041 microplastic particles were retrieved from 21 sediment samples consisting of fiber (50 %), fragment (37 %), microbeads (11 %), and film (2 %). Microplastics found in this study consists of blue color (49 %), red (26 %), white (11 %), brown (7 %), and other colors such as yellow, black, green, and transparent with a percentage between 1−3 %. Microplastics with a size of < 300 μm dominate the result of this study. Microplastic abundances were found in the range of 204.52−492.50 particles/kg sediment sample. In each sampling location, the types of microplastic were found in a different pattern. Fiber and fragments were found in all sampling sites, while film and microbeads were found only in specific sites. This study showed that several factors, such as plastic sources and hydro-oceanography parameters, influenced the occurrence of microplastics in the sampling sites. In order to address microplastic pollution in the marine environment, plastic waste management strategies are required.

Keywords: Fishing port, Mangrove, Marine Pollution, Plastics, Tourism.

ABSTRAK

Pencemaran mikroplastik telah menjadi permasalahan yang serius di seluruh lingkungan perairan di seluruh dunia. Selanjutnya mikroplastik masuk ke lingkungan perairan dan juga mengendap di sedimen. Penelitian ini bertujuan untuk menganalisis kelimpahan mikroplastik pada sedimen di sepanjang pantai barat Situbondo, Jawa Timur. Sampel sedimen diambil pada area yang terkena pengaruh pasang surut pada tujuh lokasi yang mendapat pengaruh aktivitas manusia seperti pemukiman, pelabuhan, mangrove dan juga pantai wisata. Analisis jenis mikroplastik pada sampel sedimen dilakukan di laboratorium dengan tahapan menimbang berat kering sampel, pemisahan densitas menggunakan larutan NaCl, penghancuran bahan organik menggunakan larutan H_2O_2 30% dan identifikasi jenis menggunakan mikroskop. Sebanyak 1041 partikel mikroplastik ditemukan pada 21 sampel sedimen yang terdiri dari empat jenis mikroplastik yaitu: fiber (50 %), fragmen (37 %), *microbeads* (11 %), dan film (2 %). Mikroplastik yang ditemukan didominasi oleh warna biru (49%), merah (26%), putih (11%), coklat (7%), dan warna lainnya seperti kuning, hitam, hijau, transparan dengan persentase berkisar 1−3%. Mikroplastik dengan ukuruan < 300 μm mendominasi hasil penelitian. Di setiap lokasi penelitian, mikroplastik ditemukan dengan kisaran 204,52−492,50 partikel/kg. Komposisi jenis mikroplastik bervariasi di setiap lokasi penelitian, fiber dan fragmen dominan diseluruh titik sampling, sedangkan film dan microbeads hanya ditemukan pada lokasi-lokasi tertentu. Hasil penelitian ini menunjukkan keberadaan mikroplastik pada sedimen pantai dipengaruhi oleh berbagai faktor seperti sumber masuknya plastik dan juga karakteristik fisika kimia lokasi penelitian. Pengelolaan sampah plastik yang baik sangat dibutuhkan untuk mengatasi pencemaran mikroplastik di lingkungan laut.

Kata kunci: Pelabuhan, Mangrove, Pencemaran, Plastik, Wisata

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1. Introduction

Microplastics are plastic particles that are less than 5 mm in size and consist of two types: primary and secondary microplastics (GESAMP, 2015; 2016). Primary microplastics are a type of microplastic made with micro-sized particles as the essential ingredients for forming plastic products. Secondary microplastics come from the fragmentation of plastic products due to physical and chemical processes in the environment (Andrady, 2011; Hidalgo-Ruz et al., 2012; GESAMP, 2015). The high use of plastic products in various human activities can potentially increase microplastic pollution in the environment.

Microplastics have been discovered in various aquatic environments, including those near human activity, such as rivers and lakes (Eriksen et al., 2013; McCormick et al., 2016; Alam et al., 2019; Dusaucy et al., 2021) to areas of the high seas that are not affected by human activity (Cincinelli et al., 2017; Imhof et al., 2017; Isobe et al., 2017; Yona et al., 2020b). Microplastic particles that have entered the environment have the potential to continue to float and move due to water movement (Eriksen et al., 2014; Iwasaki et al., 2017), settling in sediments (Woodall et al., 2014; Kammann et al., 2018), or ingested by aquatic biota (Yona et al., 2020b, 2021; Maghsodian et al., 2021).

Coastal sediments are one of the potential areas for microplastic accumulation. This is because coastal sediments can accumulate microplastics due to human activities on land (Auta et al., 2017; Jeyasanta et al., 2020) as well as microplastics in seawater due to tidal influences (Zobkov and Esiukova, 2017; Lo et al., 2018). Research on the accumulation of microplastics in coastal sediments has been carried out in various regions, both in Indonesia (Mauludy et al., 2019; Azizah et al., 2020; Ridlo et al., 2020; Yona et al., 2020a) and abroad (Doyen et al., 2019; Bridson et al., 2020; De-la-Torre et al., 2020; Schröder et al., 2021). Schröder et al. (2021) found that the accumulation of microplastics in coastal sediments is affected by wind and waves. Coastal areas with calm winds and waves tend to trap more microplastic particles. Harris (2020), in his review of microplastic in sediment environment, stated that the oceanographic parameters highly influence the physical transport and dispersal of microplastics in the coastal environment. The types of microplastic found in beach sediments vary, but fiber is the most common (Mauludy et al., 2019; Bridson et al., 2020). The dominance of this type of microplastic is influenced by waste input sources from the surrounding environment and human activities that impact it.

Situbondo is one of the areas in East Java Province with a long coastline. The beaches in Situbondo are a source of various human activities, such as settlements, ports, and tourism, and are also close to mangrove ecosystems. These different types of human activities can potentially contribute plastic waste to the environment, which in turn can increase the amount of microplastics in sediments. Therefore, this study was conducted to analyze the abundance of microplastics in sediments along the west coast of Situbondo, East Java.

2. Material and methods

2.1. Study Area

This study was conducted at seven locations along the west coast of Situbondo, East Java: Banyuglugur I (1), Banyuglugur II (2), Besuki Port (3), Dubibir I Beach (4), Dubibir II Beach (5), Mlandingan/ Tambak (6), and Pasir Putih Beach (7) (Figure 1). All of the sampling location are close to anthropogenic activity sources, such as Banyuglugur I, which is close to human settlement; tourism activities in Dubibir Beach and Pasir Putih Beach; near mangrove area such as in Banyuglugur II and Dubibir Beach II, and ports. Sediment samples were collected in October 2020 using the purposive sampling method, assuming that the sampling point represents the overall condition of the study area (Satriadi, 2012), and allows the collection of various types of microplastics.

2.2. Sample Collection

A 1 x 1 m^2 transect quadrate was used to collect sediment samples. In each beach, sediment collections were repeated three times in a distance approximately 20 m each. Sediment samples were collected along the transect with a shovel and filtered through a 5 mm sieve. The shovel and sieve are made of metal to avoid plastic contamination (Mauludy et al., 2019). The sediment was sampled at a depth of 5 cm because it is assumed that microplastic samples carried by tidal waves settle at a maximum depth of 5 cm (Joesidawati, 2018). The sediment is then collected and placed in a glass jar, tightly sealed and placed in a cool box containing dry ice for further laboratory analysis. The samples were identified and analyzed at the Fisheries and Marine Resources Exploration Laboratory (ESPK), Faculty of Fisheries and Marine Sciences, Brawijaya University.

Figure 1. Research site map along the west coast of Situbondo consisting of seven coastal sediment sampling locations: Banyuglugur I (1), Banyuglugur II (2), Besuki Port (3), Dubibir Beach 1 (4), Dubibir Beach 2 (5), Mlandingan (6), and Pasir Putih Beach (7).

2.3. Laboratory Analysis

The procedure for analyzing the microplastic content of sediments in the laboratory refers to the method developed by Masura and Foster (2015) and Mauludy et al. (2019) with slight modifications. This laboratory analysis underwent several stages: sample preparation, separation/floatation based on specific gravity, destruction of organic matter, filtering and identification of microplastics.

2.4. Sample Preparation

The sediment samples were dried by placing it on a stainless pan and manually homogenized using a metal spatula. The sample was then dried in an oven at 90°C overnight, and the dry sample was weighed up to 150 g. This drying process reduces the amount of water in the sediment samples (Peng et al., 2017).

2.5. Separation or flotation based on density

All In a beaker glass containing dry sediment samples, 300 ml of saturated NaCl solution (450 g of NaCl per 1 liter of distilled water, density of 1.2 g/cm3) was added to the sediment samples. The mixture was then homogenized for a few minutes with a magnetic stirrer before being covered with aluminum foil. To obtain a clear and perfect supernatant, the samples were left for 24 hours. After that, the supernatant were transferred carefully to the beaker glass, where the organic matter destruction stage was carried out.

2.6. Destruction of Organic Matter

With a volume of 20 ml of each solution, the sample was added to a 30% H_2O_2 solution, which destroys organic substances that may be present in the sediment samples, and a 0.05 M Fe II solution, which acts as a catalyst solution. The sample was then heated and homogenized for 30 minutes on a hotplate stirrer at 75 °C. If the organic matter isn't destroyed, the process was repeated with the adding of 20 mL of a 30% H_2O_2 solution. If the organic matter has disintegrated, the beaker glass is wrapped in aluminum foil and placed in the refrigerator overnight to form a clear precipitate.

2.7. Filtering

Filtering was conducted using Whatman filter paper No. 41 with a diameter of 90 mm and was aided by a vacuum pump to speed up the filtering process. This filtering is done on the water's top layer, containing microplastics. On the other hand, the visible microplastics are separated first with tweezers on different filter papers. The part that settles on the beaker glass must not be filtered out during this stage of the filtering process. After filtering the sample, the results on the filter paper are transferred to a petri dish and allowed to dry for further identification of microplastics.

2.8. Microplastic Identification

The dried filter paper was then examined for microplastics with an Olympus Biological CX33 microscope equipped with 4X and 10X lens magnification and linked to the Optical Viewer 3.0 software, which allows for easier image capture. This microscope aims to identify the type, color, and size of microplastics. Microplastics were differentiate into fiber (a thread-like particles), fragment (has an irregular shape with sharp and broken edge), microbead (round type of plastic pellets), and film (a very thin particle of plastic) (Sartain et al., 2018; Yona et al., 2023). The size of microplastic was determined using Optilab Viewer Lab 3 and Image Raster 3.0 software. The number of microplastic particles obtained per kilogram of dry sediment was used to calculate microplastic abundance (kg).

3. Results

3.1. Microplastic abundance composition

This study analyzed 21 beach sediment samples and 1041 microplastic particles were found in all samples. There were four shapes of microplastic found: fiber, fragment, film, and microbeads (Figure 2). Fiber was the most common type of microplastic found (50%), followed by fragments (37%), microbeads (11%), and films (2%) (Figure 3). Fibers and fragments were the dominating types of microplastic in many researches in aquatic environments (Dai et al., 2018, Lo et al., 2018, Zhao et al., 2018, Mauludy et al., 2019, Jeyasanta et al., 2020). Several studies have discovered the dominance of fragment (Alomar et al., 2016; Li et al., 2018; Yona et al., 2019), while film and fiber dominance was found in Pasuruan Regency coastal sediments (Yona et al., 2020a).

The variation in the dominance of microplastic types is primarily determined by the source of entry of microplastic as an environmental pollutant and natural processes that affect the fragmentation of large plastic waste (Li et al., 2018). Similar to other studies that found fiber as the dominant type, the high percentage of fiber found along the west coast of Situbondo can be caused by anthropogenic activities, such as

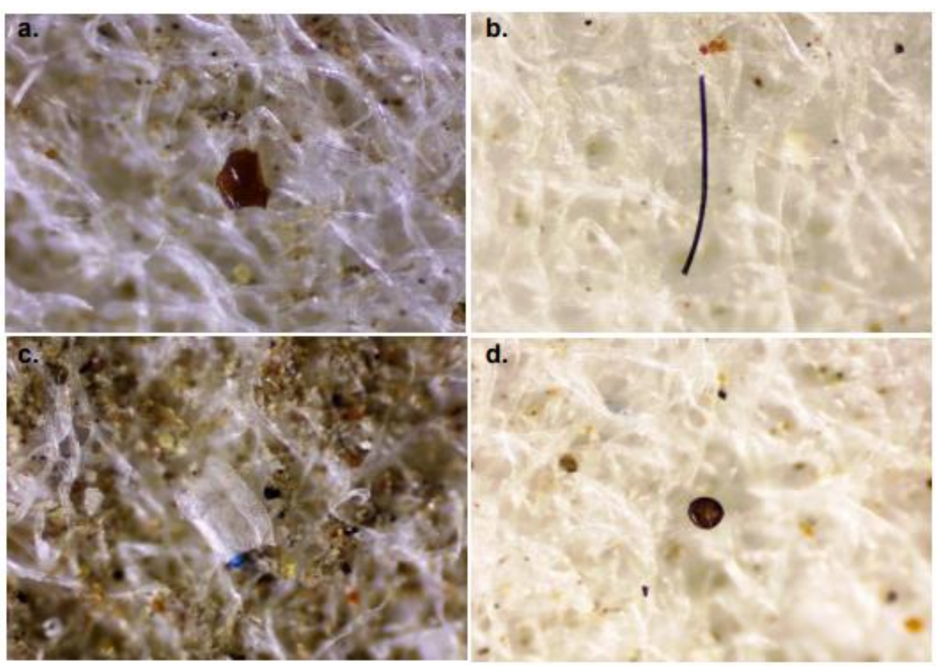

Figure 2. Microplastic shapes found in this study (a) fragment, (b) fiber, (c) film, and (d) microbeads.

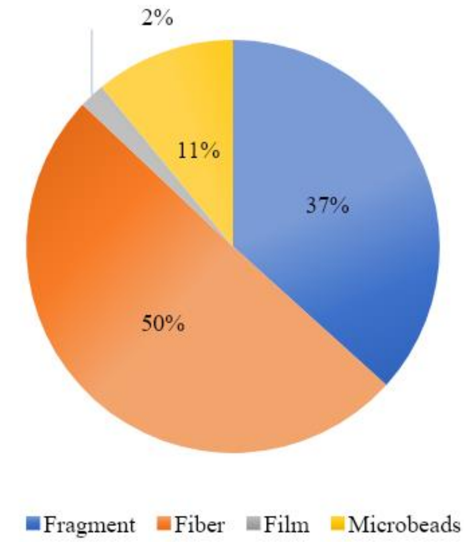

Figure 3. Percentage of microplastic types found in the sediments of the west coast of Situbondo.

from the washing clothes and the use of nets in fishing activities (Alomar et al., 2016). Furthermore, because of its small size and lightweight, fiber has the potential to travel long distances, making it a source of pollution in the environment (Jeyasanta et al., 2020).

The total abundance of microplastics was found in almost similar value among study locations along Situbondo's west coast (Figure 4). It showed that the west coast of Situbondo was contaminated with microplastic pollutants. Statistical analysis revealed no significant difference in the total abundance of microplastics between study locations ($p > 0.05$). The total abundance of microplastics were between 204.52-492.50 particles kg^{-1}. Dubibir Beach (Location 5), Banyuglugur (Location 1), and Pasir Putih Beach had the highest concentrations of microplastics (Location 7). Each location has an average abundance of 492.50±143.26 particles

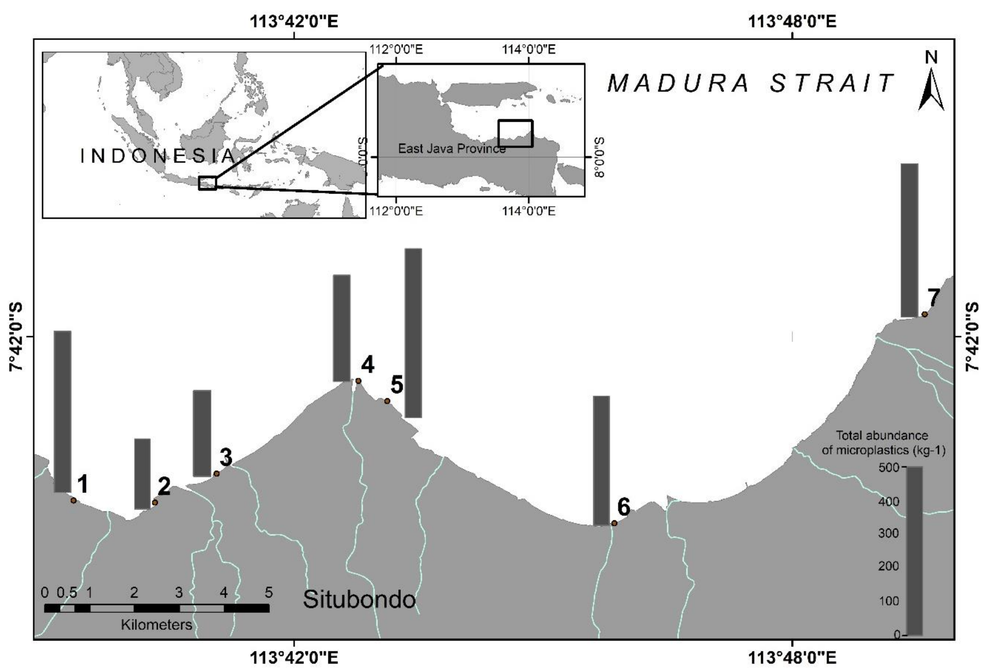

Figure 4. Spatial distribution of total microplastic abundance along the west coast of Situbondo.

Table 1. Comparison of the abundance of microplastics in coastal sediments from various studies with the same unit, namely particles kg^{-1} dry weight of sediment

Location	Total abundance (particles kg^{-1} dry weight of sediment)	Reference
Beach in Hong Kong	16.8	Lo et al. (2018)
Beach in Qinzhou Bay, China	3266.0 ± 6390.8	Li et al. (2018)
Tourism beach of Kabupaten Badung, Bali		
Doublesix Beach	71.5 ± 28.9	Mauludy et al. (2019)
Kuta Beach	148.9 ± 103.8	
Melasti Beach	67.2 ±46.1	
Mengiat Beach	95.4 ± 52.1	
Tanjung Benoa	70.5 ± 29.6	
Po River Delta Beach, Italia	2.92± 4.86 – 23.30±45.43	Piehl et al. (2019)
Hauts-de-France Beach	23.4± 18.9 – 69.3± 30.6	Doyen et al. (2019)
Niteroy, RJ, Beach, Brazil	138.41	Castro et al. (2020)
Beach in Southern Caspian Sea	196±11.58	Manbohi et al. (2021)
West Coast of Situbondo	204.52±127.73 – 492.50±143.26	This research

kg^{-1}, 476.11±86.30 particles kg^{-1}, and 445.47±86.42 particles kg^{-1}, respectively. Some of the sampling sites, such as Besuki Port and Dubibir Beach, were discovered to have large piles of plastic waste during field sampling. It results from a lack of awareness of waste management from the local people, resulting in a large amount of plastic waste being thrown into the environment and eventually degraded into microplastics. Moreover, human activities and different type of land use could also lead to the accumulation of microplastic in beach sediment (Kieu-Le et al., 2023).

When the results of this study were compared to other studies that used the same microplastic abundance units (particles kg^{-1} dry weight of sediment), the total abundance of microplastics was found to be relatively high (Table 1). In the study of Li et al. (2018) in Qinzhou, China, the amount of microplastics in coastal sediments was very high, reaching 3266±6390 particles kg^{-1}. The contribution of microplastics in that study is thought to be caused by very intensive shellfish ponds, most of which come from styrofoam waste. The abundance of microplastics along Situbondo west coast is almost identical to the abundance of microplastics on Kuta Beach, Bali. Apart from the high level of beach tourism in Kuta Beach, one of the factors suspected to cause the high number of microplastics on Kuta Beach is the phenomenon of waste being carried away during the west monsoon (Mauludy et al., 2019). The beach is heavily influenced by wind and waves, and these two factors significantly impact the process of coastal sediment accumulation (Hyndman and Hyndman, 2016). Wind and wave movements also significantly impact microplastic accumulation in coastal sediments (Strand et al., 2021). As a result, in addition to dense human activity, the high accumulation of microplastics along Situbondo west coast may be caused by hydro-oceanographic factors. More research into the effect of hydro-oceanographic factors on the spatial distribution of microplastics along Situbondo west coast is needed.

3.2. Color composition and size of microplastics

The majority of microplastics discovered were blue (49%) followed by red (26%), white (11%), and brown (7%) (Figure 5). The remainder were discovered in small number of yellow, green, black, and transparent. The colors of the microplastics that dominate several studies differ significantly, and no general pattern has been discovered. Doyen et al. (2019) found a predominance of black fiber (74-80%) in coastal sediments at Hauts-de-France. Blue predominates in coastal sediments to the south of the Caspian Sea (Manbohi et al., 2021), while black and blue were the dominant color of microplastic in Vava`u sediments of Tonga (Markic et al., 2023).

Microplastic color variations found in the environment can indicate various sources of plastic waste (Akhbarizadeh et al., 2018; Manbohi et al., 2021). Furthermore, the color of microplastics can be used to identify the types of microplastic polymers, such as a transparent white color that is typically identical to

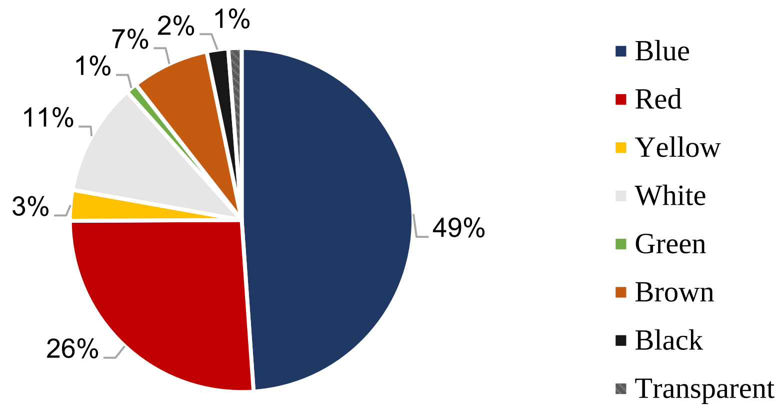

Figure 5. Composition and color proportion of microplastics found in all research samples.

polypropylene (PP) polymers (Hidalgo-Ruz et al., 2012). The weathering process caused by solar heating, on the other hand, can potentially change the colors of microplastics in the environment (Andrady, 2011; Cole et al., 2011; Hidalgo-Ruz et al., 2012).

The size composition of the microplastics found followed a similar pattern among the study sites (Figure 6). The most common microplastic particle size is 300 μm. Microplastics larger than 1000 μm in size are visible without a microscope and are most common in the Dubibir 2 Beach area. This is a mangrove ecotourism area, and the mangrove tree structure can potentially trap plastic waste (Mohamed Nor and Obbard, 2014). Allami et al., (2023) in their study found that bigger size of microplastic (1000–5000 μm) predominant in the surface sediment, while smaller size was higher in deep sediment. They concluded that the small size of microplastic might be due to the long-term presence on the beach and exposure to erosion process of environmental factors.

4. Conclusions

According to this study, the abundance of microplastics on the sediment of seven different beaches along the Situbondo west coast were found in almost similar number. The presence of microplastics was the result of human activities such as anthropogenic, tourism and fishing activities. The results of this study showed rather similar finding with the result of others studies, and it can be a warning that microplastic pollution is a serious problem.

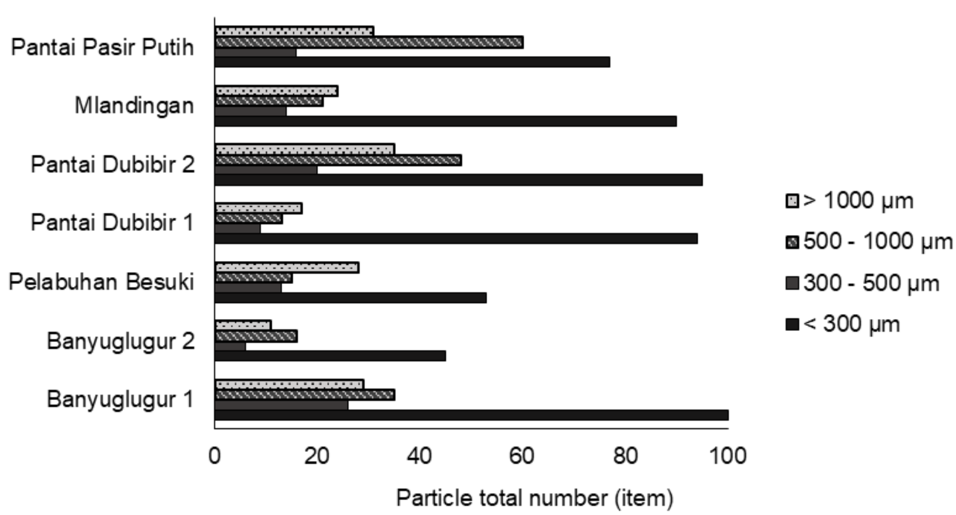

Figure 6. Variations in the size of microplastics found in each study site.

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