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# Microplastic Abundance in Mangrove Sediments Based on Mangrove Density at Cemara Beach, Jember

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**Keywords**

*Microplastics, Mangroves, Abundance, Sediment, Cemara Beach*

**Abstract**

*Mangrove ecosystems play an essential ecological role in coastal environments by stabilizing sediments and trapping various pollutants, including microplastics. Increasing plastic waste generated by human activities has contributed to the accumulation of microplastics in coastal ecosystems, particularly within mangrove sediments. This study aimed to analyze microplastic abundance in mangrove sediments based on mangrove density in the mangrove area of Cemara Beach, Puger, Jember. Sediment sampling was carried out at four observation points representing different environmental characteristics and levels of human activity, namely tourism areas, residential areas, central mangrove zones, and areas remote from human activities. Microplastic abundance was determined by calculating the number of particles identified in each sediment sample and expressing the results as particles per gram of sediment. The findings revealed that microplastics were present at all sampling locations with a total abundance of 0.885 particles/gram. The highest abundance was recorded at the residential area (0.650 particles/gram), while the lowest abundance was found at the site far from human activities (0.019 particles/gram). Mangrove density varied among observation points and contributed to sediment retention; however, microplastic abundance was not determined solely by vegetation density. Human activities, particularly those related to settlements and tourism, appeared to play a substantial role in increasing microplastic inputs into the mangrove ecosystem. These findings highlight the ecological function of mangroves as natural traps for microplastics and emphasize the need for improved coastal waste management and mangrove conservation to reduce microplastic contamination in coastal environments.*

## INTRODUCTION

Microplastic pollution has emerged as a major environmental concern due to its persistence and widespread distribution across aquatic ecosystems (Saini et al., 2026). These particles, defined as plastic particles measuring less than 5 mm and are derived either from the fragmentation of larger plastic debris or from the direct release of primary plastic materials into the environment (Pradit et al., 2026). Because of their small size and resistance to natural degradation, microplastics can be transported through currents, waves, and tidal processes and eventually accumulate in coastal environments (Kesavan et al., 2025). The growing accumulation of plastic waste in coastal regions has intensified concern regarding microplastic contamination worldwide (Johnson et al., 2023). Indonesia, as an archipelagic country with extensive coastlines and intensive coastal activities, faces considerable challenges related to plastic leakage into marine ecosystems. Inputs of plastic debris from settlements, tourism, fisheries, and inadequate waste management are transported to coastal and estuarine environments, where they gradually fragment into microplastics (Gonçalves et al., 2025). Mangrove ecosystems are recognized as one of the coastal habitats with a high capacity to retain sediments and suspended materials (Paray et al., 2025). The complex structure of mangrove roots reduces water flow and promotes the deposition of organic matter and fine particles, including microplastics (Austria-Ortíz et al., 2026).

As a result, mangrove ecosystems often function as natural sinks, where contaminants transported from terrestrial and marine sources are trapped and accumulate within the sediments (He et al., 2025). Previous studies have reported

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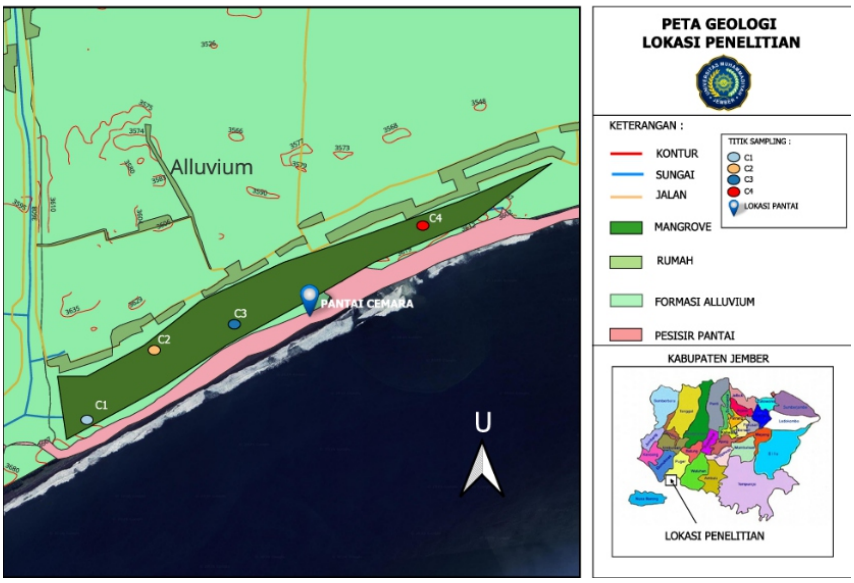
the presence of microplastics in mangrove ecosystems and emphasized the role of mangrove vegetation in sediment retention (Sabar et al., 2026). However, the influence of variation in mangrove density on microplastic abundance remains insufficiently understood, particularly in local coastal environments characterized by different levels of human activity (Valsan et al., 2024). Most existing studies focus primarily on the occurrence of microplastics or their ecological impacts, while limited attention has been given to how differences in mangrove density may influence microplastic accumulation patterns (Vidayanti & Retnaningdyah, 2024). Cemara Beach in Puger, Jember, represents a relevant location for examining this issue because the area contains mangrove stands with varying density levels and is simultaneously influenced by tourism and residential activities (Iskandar et al., 2024). These environmental and anthropogenic characteristics may affect both the input and retention of plastic particles within mangrove sediments (Alihudien et al., 2025). Therefore, understanding microplastic distribution in this ecosystem is important not only for evaluating pollution conditions but also for supporting coastal management and conservation efforts (Valsan et al., 2024).

Based on this background, the present study aims to analyze microplastic abundance in mangrove sediments based on mangrove density in the mangrove area of Cemara Beach, Jember. The novelty of this study lies in examining the interaction between mangrove density variation and local anthropogenic activities in explaining microplastic accumulation within a coastal mangrove ecosystem (Cao et al., 2025).

## RESEARCH METHOD

This study was conducted in the Cemara Beach mangrove area in Jember Regency. The location was chosen because it is at risk of microplastic pollution due to human activities and the accumulation of plastic waste in the coastal area. The mangrove area covers approximately 5 hectares and stretches for about 1.32 km, making it one of the largest mangrove areas along the coast of Jember Regency.

Sampling was conducted at four observation points: C1 (tourism area), C2 (residential area), C3 (central mangrove area), and C4 (area remote from human activity). Sampling points were selected using purposive sampling, taking into account differences in environmental conditions, human activity, and mangrove vegetation characteristics at each location. The selection of these four points aimed to




Source: Processed Primary Data, (2025)

**Figure 1**
**Research Location**

represent the overall conditions of the Cemara Beach mangrove area so that the distribution and abundance of microplastics could be observed under various different environmental conditions (Dai et al., 2024). Sedimen sampling was conducted in mangrove sediments at each observation point, following the ECOTON Laboratory guidelines, which adhere to the *Guidelines for Monitoring Microplastic Waste in the Sea* issued by the Ministry of Environment and Forestry of the Republic of Indonesia. The collected samples were then sent to the ECOTON Laboratory for further analysis to determine microplastic abundance. Microplastic abundance was calculated based on the number of particles found relative to the weight of the analyzed sediment sample. The formula for microplastic abundance, as per the ECOTON Laboratory guidelines, the formula can be seen in Equation (1).

$$C = \frac{\sum n}{W} \tag{1}$$

Where C is the abundance of microplastics (particles $g^{-1}$), n is the number of microplastic particles detected, and W is the dry weight of the sediment (g). This is the formula used to measure or determine the abundance of small plastic debris (microplastics) mixed with salt. It calculates the number of microplastic particles out of the total number of particles found in the sample.

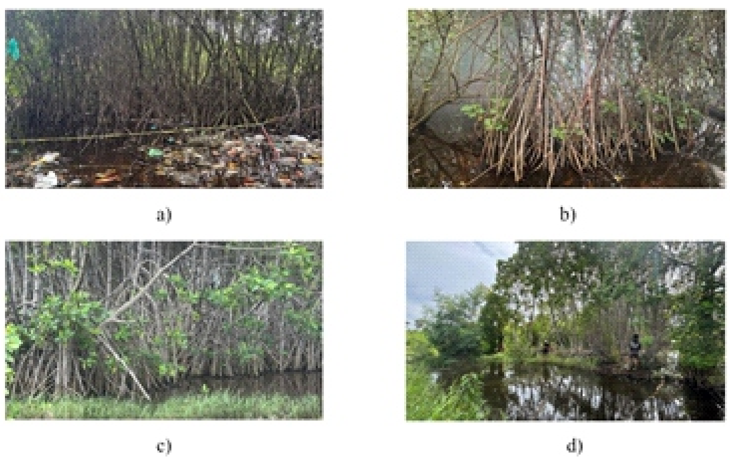
The microplastic abundance is then expressed in particles per gram, obtained by dividing the total number of microplastic particles by the weight of the sediment sample, measured in grams (Onyena et al., 2026).

In addition to microplastic sampling, mangrove vegetation surveys were conducted using the line transect plot method. In this study, four 10 × 10-meter survey plots were used, tailored to the sampling locations. The surveys involved counting the number of mangrove individuals, identifying mangrove species, and measuring tree diameter and height in each survey plot (Saini et al., 2026). The formula can be found in Equation (2)

$$K = \frac{\sum Ni}{A} \tag{2}$$

Where K is the mangrove density (individuals $m^{-2}$), Ni is the population size (number of individuals), and A is the plot area ($m^2$). The calculation used to determine mangrove density involves counting the number of individuals of a given mangrove species and then dividing that number by the area of the plot at the sampling point identified through observation.

The results of the field observations are presented in the form of location maps and documentation of environmental conditions at each observation point. Field conditions can be seen in Figure 2. Area C1 (tourism) exhibited an accumulation of




Source: Processed Primary Data, (2025)

**Figure 2**

**Observation points: (a). C1 Tourism Area, (b). C2 Residential Area, (c). C3 Central Mangrove Area, (d). C4 Area Remote from Human Activity,**

anthropogenic waste, particularly plastic debris, around mangrove roots, providing a potential source of microplastic accumulation. In C2 (settlement), the mangrove vegetation is dominated by Rhizophora mucronata with dense prop roots capable of trapping sediment and domestic waste from the surrounding area. Meanwhile, C3 (central area) has more natural conditions with dense mangrove vegetation and less surface waste. In C4 (far from human activity), the environmental conditions appear cleaner with calm waters and minimal plastic waste, indicating a low impact of human activity at that location.

## RESULT AND DISCUSSION

Mangrove vegetation characteristics were observed at each sampling point to determine ecosystem conditions and support the analysis of microplastic abundance in sediments. Observations included mangrove species, root type, trunk diameter, tree height, and estimated vegetation age at each location. The vegetation characteristics are presented in Table 1.

The dominant mangrove species identified at all observation points was *Rhizophora mucronata*, characterized by prop root systems. Although species composition was relatively similar across locations, differences were observed in vegetation structure and age. Sampling point C1 (tourism area) and C2 (residential area) were dominated by younger mangrove stands with estimated ages of approximately ±26 years, while C3 (central mangrove area) and C4 (area remote from human activities) contained relatively older vegetation with estimated ages of ±47 years. Mangrove density varied among observation points. Based on Table 3, the highest density was recorded at C3 (0.37 ind/m²), followed by C1 (0.35 ind/m²), C2 (0.25 ind/m²), and C4 (0.20 ind/m²). These findings indicate that mangrove vegetation in the Cemara Beach area is distributed unevenly and reflects different ecological conditions and levels of disturbance. Microplastics were detected in sediment samples collected from all observation points. The highest abundance was found at C2 (residential area) with 0.650 particles/gram, whereas the lowest abundance occurred at C4 (area remote from human activities) with 0.019 particles/gram. C1 (tourism area) showed an abundance of 0.115 particles/gram, while C3 (central mangrove area) recorded 0.099 particles/gram.

**Table 1**
**Characteristics of Mangrove Vegetation**

| No | Sample Name | Mangrove Species | Root Type | Diameter (cm) | Height (m) | Tree Age (years) |
|---|---|---|---|---|---|---|
| 1 | C1 Tourism Area | *Rhizophora mucronata* | Prop | 20 – 30 | 7 - 10 | ±26 |
| 2 | C2 Residential Area | *Rhizophora mucronata* | Prop | 15 - 35 | 8 - 10 | ±26 |
| 3 | C3 Central Mangrove Area | *Rhizophora mucronata* | Prop | 35 - 45 | 15 - 20 | ±47 |
| 4 | C4 Far From Human Activities | *Rhizophora mucronata* | Prop | 15 - 35 | 10 - 15 | ±47 |

Source: Processed Primary Data, 2025

The high abundance observed at C2 suggests that residential activities contribute substantially to plastic inputs in the mangrove ecosystem. Domestic waste generation, daily community activities, and proximity to settlements may facilitate plastic accumulation and fragmentation into microplastics. Similarly, C1 showed relatively elevated abundance, which may be associated with tourism activities and waste generated by visitors around Cemara Beach. Although C3 exhibited the highest mangrove density, microplastic abundance at this point was lower than that at C2. This finding indicates that mangrove density alone does not determine microplastic accumulation. Dense mangrove root systems may enhance sediment retention and trap suspended particles; however, the amount of microplastics entering the environment is also strongly influenced by surrounding human activities. A descriptive comparison between mangrove density and microplastic abundance indicates that the relationship between these variables is not entirely linear (Austria-Ortíz et al., 2026). The findings indicate that sites with higher mangrove density do not necessarily contain higher microplastic abundance, implying that anthropogenic pressures may play a more significant role than vegetation density in determining microplastic accumulation. Therefore, the presence of microplastics at Cemara Beach is likely controlled by an interaction between ecological factors, such as mangrove root retention capacity, and external factors, particularly tourism and residential waste inputs. Overall, the findings support the role of mangrove ecosystems as natural traps for suspended particles and pollutants. Nevertheless, human activities remain an important determinant of microplastic accumulation within the mangrove environment (Pradit et al., 2026).

*Microplastic Abundance in Mangrove Sediments*

This study demonstrates the presence of microplastics in mangrove sediments at the study site. Sediment samples were collected at four sampling points representative of the study site conditions. Microplastic abundance at each sampling point was calculated based on the number of particles found in each sample. The data from the sample observations at each point are presented in Table 2 .

Based on the results in Table 2, microplastics were found in all mangrove sediment samples, with a total abundance of 0.885 particles/gram across all four points. The highest abundance was found at point C2, located near a residential area, with a value of 0.650 particles/gram, while the lowest abundance was found at point C4, located far from human activity, at 0.019 particles/gram. This difference in values indicates that human activity influences the presence of microplastics in

**Table 2**
**Microplastic Abundance Results**

| No | Sample Name | Count (particles) | Sample Weight (g) | Abundance (particles /g) |
|---|---|---|---|---|
| 1 | C1 Tourism Area | 29 | 251.97 | 0.115 |
| 2 | C2 Residential Area | 164 | 251.97 | 0.650 |
| 3 | C3 Central Mangrove Area | 25 | 251.97 | 0.099 |
| 4 | C4 Far From Human Activities | 5 | 251.97 | 0.019 |
| | **Total** | | | **0.885** |

Source: Processed Primary Data, 2025

mangrove areas. The high microplastic abundance at point C2 likely stems from domestic activities of the local community, beach access, and visitor activities in the coastal area. These conditions cause plastic waste to accumulate more easily in the mangrove area and subsequently undergo fragmentation due to exposure to sunlight and other environmental factors, transforming into microplastic particles. These results align with (Rezaei et al., 2026), who reported that mangrove areas near human activities tend to have higher microplastic concentrations than to areas with low anthropogenic pressure.

Conversely, the low abundance of at Point C4 is attributed to its relative distance from human activity centers, resulting in fewer sources of plastic pollution in that area. Nevertheless, microplastic particles were still found at that point, likely originating from transport by wind and water currents. Small microplastics, particularly those <1 mm in size, are more easily carried by the wind due to their low mass and can be transported to mangrove areas far from pollution sources. Additionally, tidal conditions and water flow in coastal areas also play a role in distributing microplastic particles into mangrove sediments. This finding is supported by the study by (Capparelli et al., 2025), which explains that microplastics in mangrove ecosystems can be dispersed through coastal water hydrodynamics and accumulate in sediments. Similar results were reported by Putri et al. (2023), who stated that small microplastic particles are more easily transported by wind and ocean currents and can therefore be found in areas with minimal anthropogenic activity.

*Mangrove Vegetation Density at Each Observation Point*

Field observations at Cemara Beach revealed that plastic debris dominated the coastal area and extended into the mangrove zone. The debris likely originated from tourism-related activities, nearby residential areas, and wind-driven transport before becoming trapped within the mangrove vegetation, where it gradually fragmented into secondary microplastics through environmental weathering. In addition to environmental factors, the presence of microplastics is also related to mangrove vegetation, which is capable of trapping plastic particles in the sediment. Therefore, an analysis of mangrove density was conducted to determine the vegetation density at each observation point. Based on these mangrove density calculations, density values were obtained for each observation point, which are presented in Table 3.

Based on Table 3, the mangrove density values at each observation point show varying conditions. The highest density value was found at point C3 at 0.37 ind/m², while the lowest value was at point C4 at 0.20 ind/m². Meanwhile, point C1 had a density of 0.35 ind/m² and point C2 had a density of 0.25 ind/m². These differences indicate that the mangrove

**Table 3**
**Mangrove Density at Each Observation Point**

| Observation Point | Number of Trees | Plot Area ($m^2$) | Density ($idn/m^2$) |
|---|---|---|---|
| C1 | 35 | 100 | 0.35 |
| C2 | 25 | 100 | 0.25 |
| C3 | 37 | 100 | 0.37 |
| C4 | 20 | 100 | 0.2 |

Source: Processed Primary Data, 2026

vegetation at the study site exhibits non-uniform density levels. The study results also indicate that microplastic abundance is not solely determined by mangrove density. Human activities are suspected to be a more dominant factor in the presence of microplastics in the study area. This is evident at point C2, which has a relatively high microplastic abundance despite not having the highest mangrove density. This is likely because point C2 is near a residential area and facilitating the transport and accumulation of plastic waste form community and visitor activities in the mangrove area. This finding is supported by of Gonçalves et al. (2025), who found that mangrove areas near anthropogenic activities tend to have higher microplastic concentrations than areas with minimal human activity.

At point C1, microplastics presence is also likely linked to tourism activities around Cemara Beach. Plastic waste originating from visitors or river currents is trapped in the mangrove area. This finding aligns with the research by Valsan, Paul, et al. (2024), who explained that coastal tourism areas have a higher potential for microplastic accumulation due to increased human activity and plastics waste buildup. Meanwhile, point C3 has the highest mangrove density, and microplastics were still found there, although the quantity was not as high as at point C2. This indicates that dense mangrove vegetation is more effective at trapping sediment and microplastic particles in coastal areas. The dense root structure of mangroves can slow the movement of particles, making it easier for microplastics to become trapped in sediments. This finding aligns with the research by (Gonçalves et al., 2025), which states that mangrove ecosystems function as natural traps for microplastic particles due to the ability of mangrove roots to retain sediments and suspended matter.

The lowest microplastic abundance was found at point C4, which is located relatively far from the center of human activity. The low number of microplastics at this location is believed to be due to minimal input of plastic waste from domestic and tourism activities (Kesavan et al., 2025). Nevertheless, microplastic particles were still found at this observation point, likely originating from the transport of small particles by wind and water currents. Microplastics smaller than 1 mm tend to be more easily carried by the wind due to their light mass, allowing them to disperse to areas far from their pollution sources. (Deakin et al., 2025) explain that microplastics in mangrove ecosystems can be transported and distributed through coastal water hydrodynamics, so particles can still be found even when observation sites are far from human activity. Additionally, research by (Valsan et al., 2024) also notes that small microplastic particles exhibit high mobility and easily accumulate in mangrove sediments due to the influence of currents and winds in coastal areas.

## CONCLUSION

Microplastics were detected in all mangrove sediment samples collected from Cemara Beach, Puger, Jember, with a total abundance of 0.885 particles/gram. The highest abundance was recorded at C2 (residential area), while the lowest abundance occurred at C4 (area remote from human activities). These findings suggest that microplastic accumulation in mangrove sediments is influenced not only by the characteristics of mangrove vegetation but also by the intensity of surrounding anthropogenic activities. Although C3 exhibited the highest mangrove density, microplastic abundance did not consistently increase with vegetation density, suggesting that anthropogenic inputs remain a major contributing factor. Overall, mangrove ecosystems function as natural traps capable of retaining and accumulating microplastic particles within coastal sediments. Therefore, reducing microplastic contamination at Cemara Beach requires not only mangrove conservation but also improved coastal waste management practices. Strengthening community awareness programs, improving waste disposal facilities in tourism and residential areas, and conducting routine coastal clean-up activities are recommended to minimize plastic leakage into mangrove ecosystems and support the long-term coastal environmental sustainability.

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