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Analisis sampah laut berdasarkan jenis dan kepadatan di Pantai Wisata Lhok Bubon, Kabupaten Aceh Barat
[Study on the type and density of marine debris at Lhok Bubon Beach, West Aceh]

Samsul Bahri[1*](iD), Hayatun Nufus[1](iD), Heriansyah[2](iD), Faliqul Isbah[2](iD)

[1] *Department of Marine Science, Faculty of Fisheries and Marine Sciences, Teuku Umar University, West Aceh, Aceh – Indonesia*
[2] *Department of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Teuku Umar University, West Aceh, Aceh – Indonesia*

ABSTRACT | Marine debris poses a serious threat to both marine ecosystems and human health. With its extensive coastline and numerous islands, Indonesia is especially vulnerable to pollution from marine waste. The waters of Aceh, including Lhok Bubon tourist beach, are becoming increasingly polluted by plastic debris due to local coastal activities and poor waste management practices. This study classifies marine debris and analyzes its composition at Kuala Bubon tourist beach in Samatiga District, West Aceh Regency. Data collection took place in July 2023 at two Stations: one close to traders and crowds, and another in a more remote area. At Station I, hard plastic waste dominated, comprising 30,73% of total waste, while at Station II, it accounted for 53,32%. The density of marine debris was 77,45 items/m² at Station I and 110,65 items/m² at Station II. Waste weight density was 2207,5 grams/m² and 2137,5 grams/m², respectively. Hard and soft plastics were the most common waste types. Hard plastic made up 56,55% of total waste at Station I, whereas soft plastic reached 89,52% at Station II. The study reveals a high concentration of plastic waste, particularly in less-maintained areas, emphasizing the need for better waste management practice.

Key words | Aceh Barat, Kuala Bubon, microplastics, marine pollution, plastic waste

ABSTRAK | Sampah laut berdampak negatif terhadap ekosistem laut dan kesehatan manusia. Indonesia memiliki garis pantai dan pulau yang luas berisiko tinggi terhadap pencemaran sampah laut. Perairan pantai wisata Lhok Bubon berpotensi tercemar oleh limbah plastik yang berasal dari aktivitas pesisir lokal dan pembuangan sampah yang tidak terkelola dengan baik. Penelitian ini bertujuan untuk mengklasifikasikan jenis sampah laut serta menganalisis komposisinya di Pantai Wisata Kuala Bubon, Kecamatan Samatiga, Kabupaten Aceh Barat. Pengumpulan data dilakukan pada Juli 2023 di dua lokasi berbeda: stasiun I berdekatan dengan pedagang dan keramaian, sementara stasiun II berada lebih jauh. Pada stasiun I, jenis sampah yang dominan adalah plastik keras, yang mencakup 30.73% dari total sampah, sedangkan di stasiun II, plastik keras mencapai 53.32%. Kepadatan sampah laut di stasiun I sebesar 77.45 item/m² dan di stasiun II sebesar 110.65 item/m². Kepadatan berat sampah di stasiun I adalah 2207.5 gram/m² dan di stasiun II sebesar 2137.5 gram/m². Plastik keras dan plastik lunak merupakan jenis sampah yang paling banyak ditemukan. Plastik keras menyumbang 56.55% dari total sampah di stasiun I, sedangkan plastik lunak mencapai 89.52% di stasiun II. Studi ini menyoroti tingginya keberadaan sampah plastik, terutama di area yang kurang terawat, sehingga menekankan perlunya pengelolaan sampah yang lebih baik.

Kata kunci | Aceh Barat, Kuala Bubon, mikroplastik, pencemaran laut, sampah plastik

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***Corresponding author** Samsul Bahri, Department of Marine Science, Faculty of Fisheries and Marine Sciences, Teuku Umar University, West Aceh, Aceh – Indonesia. **Alamat Email:** samsulbahri@utu.ac.id

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INTRODUCTION

Marine garbage refers to solid objects found in the marine environment originating from human activity, either intentionally or unintentionally This waste may sink to the ocean floor, float on the surface, or become stranded along the shoreline. Its presence poses serious threats to both marine ecosystems and human health. According to Djaguna *et al.* (2019) marine garbage is defined as hard-to-decompose solid debris material. Marine debris is all kinds of solid material derived from residues of human activity, such as plastic, rubber, metal, glass, and so on, that is thrown into the surrounding environment (Amri *et al*., 2023). Plastic waste is a major components of marine garbage in Indonesia. The potential for marine garbage in Indonesia is very high because the country has a long coastline and many islands. Non-degradable plastic waste can contaminate water and jeopardize environmental sustainability. Addressing this issue has become a significant challenge for both the Indonesian government and society. Greater efforts are needed to prevent, reduce, and manage marine garbage. Data from The Ministry of Environment and Forestry (2017) shows that wood (35,06%) and plastic (24,96%) dominates the meso-sized marine garbage (0,5–2,5 cm), while plastic (31,44%) and wood (29,75%) are the main components macro-size marine garbage (>2,5 cm). Survey results 2017 further estimate the total volume of marine waste to be between 1.1 and 1.2 million tons, accounting for approximately 40% of all waste (Ningsih *et al*., 2020).

Plastic garbage, which continues to grow every day, dominates the waters of Aceh today. Various sources of plastic waste, Various sources, including local coastal activities, industrial waste, and irresponsible disposal by surrounding communities, contribute to this pollution. These plastics, not only create visual pollution along the coast, but also have a deeper impact on marine ecosystems and human life. Research conducted at Kuala Batu Beach, Kayu Island Village, and Southwest Aceh district found 232 items of marine garbage collected over 1,200 square meters, resulting in a density of approximately 0.193 items per square meter. The largest amount of plastic garbage is 79%. Recreational activities and beaches on the mainland were identified as the primary contributors of marine waste at Kuala Batu Beach (Rahmayanti *et al*., 2020).

A study conducted by the Environmental Health Risk Assessment (EHRA) in 2012 revelaed that approximately 78,1% of the population of West Aceh district lacks access to garbage transportation services. This situation reflects the ineffective implementation of the waste management system in the area (Yulianita *et al*., 2021). Marine debris negatively impacts marine ecosystems by polluting waters, disrupting marine life, and threatening environmental sustainability. Based on the initial hypothesis, the waste found along the coast of West Aceh generally originates from local tourism activities. Most of the waste consists of secondary waste, including packaging waste and discarded used items. Some of the waste also comes from other regions, carried by waves and tidal currents, into marine ecosystems such as coral reefs, seagrass beds, and mangroves.

The tourist beaches are valuable asset that offers natural beauty, attract visitors, and support local livelihoods. Unfortunately, the waste problem often taints these coastal area, disrupting the tourist experience and threatening both the local environment and economy sustainability. The litter on the tourist shores can come from a variety of sources, including irresponsible tourists, shipping activities, and landfills. The garbage includes plastic, food packaging, bottles, and other organic waste.

Lhok Bubon Beach, a tourist area with limited waste management, suffers from a lack of adequate disposal facilities and waste collection systems. It has led to the accumulation of trash, especially from tourism activities. As a result, trash often ends up in the ocean, affecting marine ecosystems such as coral reefs, seagrass beds, and mangroves. When plastic waste finds its way into the ocean, it can poison marine creatures, either through ingestion or entanglement. In addition, the organic garbage that degenerates on the beach can cause water and air pollution, as well as attract pests and diseases (Kooi *et al*., 2017). The identification of marine garbage by type and mass on the tourist beach in Lhok Bubon, West Aceh district, is crucial for preliminary research. This study aims to classify the types of marine debris and analyze the composition and percentage of waste mass found in this prominent tourist destination.

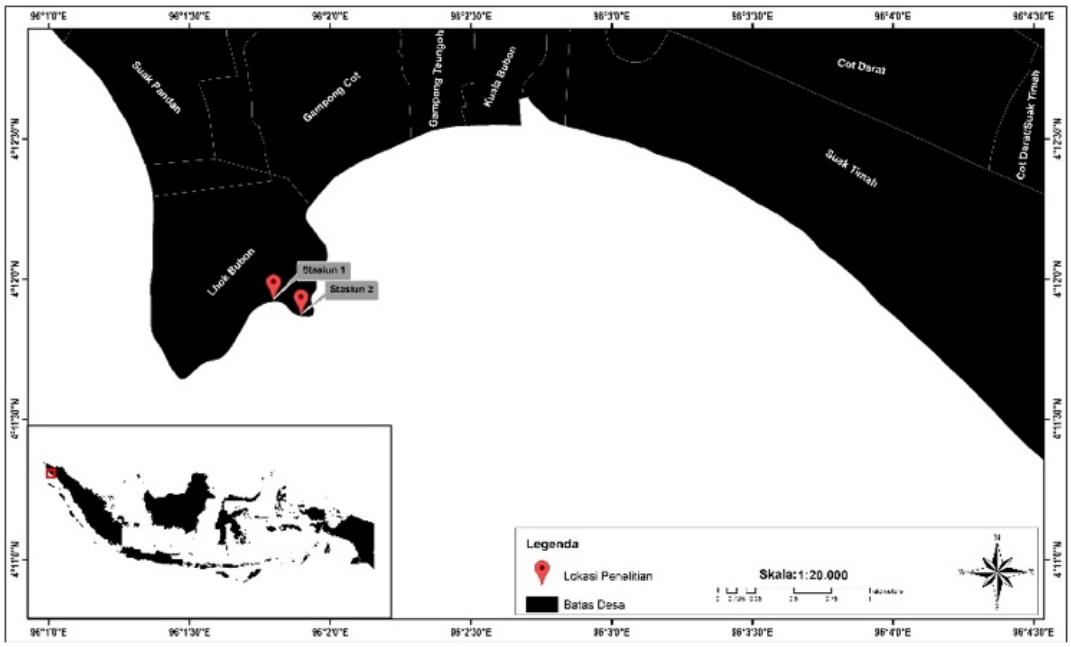

Figure 1. Map of waste data collection Stations

MATERIAL AND METHODS

Time and Station

The research was conducted on the tourist coast line of Kuala Bubon, located in Samatiga district, and West Aceh district (Figure 1). Primary data collection was completed in July 2023. Lhok Bubon is part of the marine ecosystem areas managed collaboratively by the local government and the community of the West Aceh. The beach offers shady sea views and has a coral reef ecosystem. The observation Station is 18 kilometers from the center of Meulaboh, the capital of the West Aceh district.

Data Collection

Data collection was conducted at two distinct Stations: Station I, situated near merchants and crowds, and Station II, positioned farther away from these human activities. Observations were carried out during the daytime on weekends, when ecological activity in the area tends to be at its peak. The process began with the preparation of the tools and materials. Data collection took place within a designated observation area measuring 40 m^2. Following the collection of waste samples, the materials were sorted to identify the types of waste, count the number of items per type, and measure their respective weights. All recorded data were entered into a logbook to facilitate further analysis (Ningsih *et al*., 2020).

Data Analysis

Garbage data is collected based on the characteristics of thewaste, following observation procedures include measuring the weight and counting the number of trash items. This helps determine the waste density on the tourist coast of Lhok Bubon. The analyses includes the

number density, weight density, and the relative density value, referring to research conducted by Ningsih et al., (2020).

RESULTS

Types and Proportions of Coastal Waste

At Station Station I, the largest proportion of waste was hard plastic, accounting for 30.73% of the total. This category includes items such as food containers, drink bottles, and other durable plastic product. Soft plastics followed at 25.82%, commonly made up of shopping bags, food wrappers, and flexible packaging. Wood waste contributes with 25,37%, originating from construction waste, furniture, or packaging materials. Paper and cardboard accounted for 8,13% of total garbage, including used paper, cardboard boxes, and paper packaging. Other types of garbage, like glass, rubber, foam, metal, and fabric, were found in smaller quantities (Figure 2).

Meanwhile, at Station 2 hard plastic was also the most dominant type of waste, comprising 53.32% of the total. It is followed by soft plastics, which account for 36,20%, including more flexible and shaped plastic. paper and cardboard contributed 4.97%. Wood waste accounted for 2.35%, followed by foam at 1.45% and fabric at 0.50%. Other waste categories included plastic straps (0.32%), glass (0.36%), metal (0.41%), and rubber (0.14%) (Figure 2).

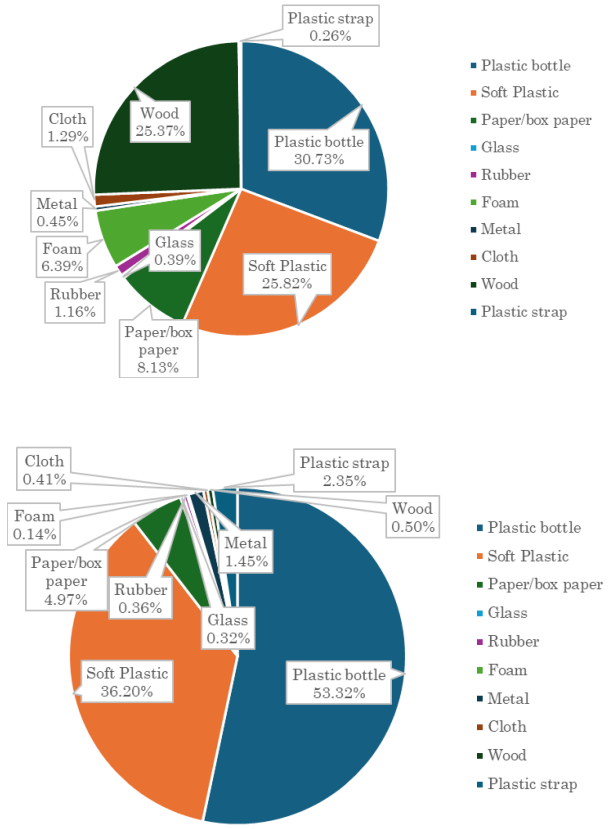

Figure 2. Composition of Marine Debris Station I and Station II

Debris Density (items per m²) A vertical bar chart (Figure 3) illustrates the results of a comparative data analysis of the garbage density per area at Station I and Station II (Figure 3). Station I has a density value of 77,45 items/m², while Station II has a density of 110,65 items/m². These two Stations show significant differences in the amount of garbage density per square meter.

A detailed examination of waste composition indicates that Station I recorded higher densities of hard plastic, soft plastic, paper, and cardboard compared to Station II. In contrast, both Stations exhibited minimal quantities of glass, rubber, foam, metal, and fabric waste. Wooden debris was not observed at Station I, while a small amount was identified at Station II. Plastic strapping was found in both Stations, with slightly greater presence at Station II (Figure 4).

The lower overall waste density observed at Station I may be attributed to its function as a tourist destination, where local vendors occasionally carry out informal cleaning around their sales areas. In contrast, Station II lacks regular maintenance efforts, contributing to a more neglected environment and increased waste accumulation.

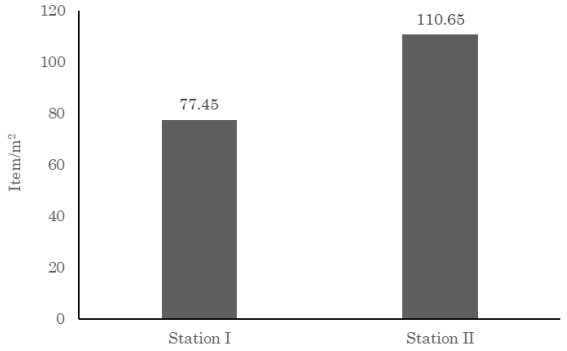

Figure 3. Comparison of the total density of debris of waste at Station I and Station II

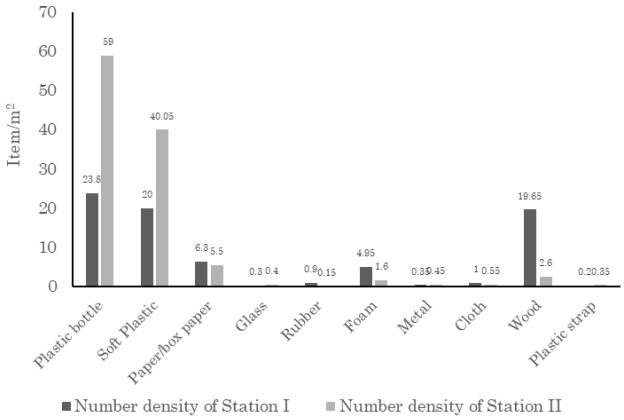

Figure 4. Comparison of the density of each type of debris at Station I and Station II

Waste mass density and relative density

The results of the total waste mass analysis at station I indicate a waste weight density of 2207,5 grams/m². This shows that the total accumulated waste weight per square meter of Station I' is higher. In comparison, the waste mass density at station II is 2137,5 /m² (Figure 5). Although it is lower than Station I, Station II also has a significant accumulation of waste. Overall, Station I had a higher waste-weight density compared to Station II.

A breakdown of waste by type reveals significant differences between the two Stations. At Station 1, the weight density of rigid plastic garbage at reached 2207,5 grams/m². Station II reported a lower density of rigid plastic waste, at 2,137.5 grams/m². Similarly, the density of soft plastic waste was higher at Station I than at Station II. This trend continues across other categories: paper/cardboard waste also had a higher weight density at Station I. Materials such as glass, rubber, foam, metal, and fabric were either absent or present in very low quantities at both stations. Interestingly, while plastic rope was scarcely found at Station I, its presence was slightly higher at Station II (Figure 6). In conclusion, Station I consistently demonstrated a higher waste weight density across most waste types compared to Station II.

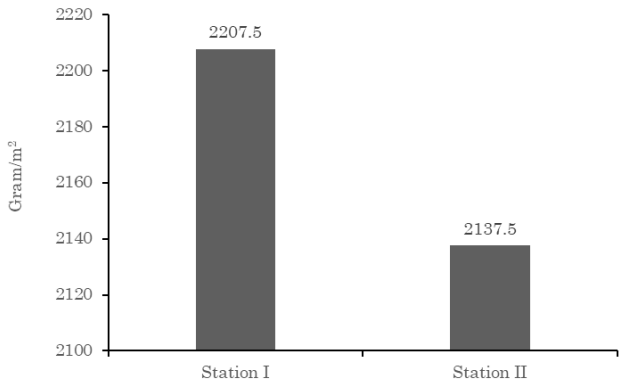

Figure 5. Total mass of waste types at both Stations

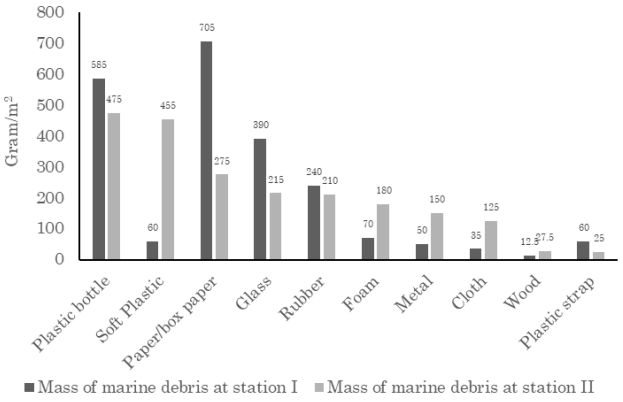

Figure 6. Comparison of the mass of each type of waste at the two Stations

Table 2. Relative density of marine debris

Waste Type	Number Density (%)		Weight Density (%)	
	Station I	Station II	Station I	Station II
Plastic bottle	30,73	53,32	26,50	22,22
Soft Plastic	25,82	36,20	17,67	10,06
Paper/box paper	8,13	4,97	3,17	8,42
Glass	0,39	0,36	2,72	21,29
Rubber	1,16	0,14	2,27	7,02
Foam	6,39	1,45	2,72	1,17
Metal	0,45	0,41	1,59	5,85
Cloth	1,29	0,50	10,87	9,82
Wood	25,37	2,35	31,94	12,87
Plastic strap	0,26	0,32	0,57	1,29

DISCUSSION

Type and Amount of Waste

Observations conducted at both stations reveal that plastic garbage, comprising both hard and soft plastic, is significantly more prevalent than other types. A similar trend is evident on the coast of the mangrove eco-ecosphere of western Oesapa, Kupang City, where the most common type of garbage found is plastic trash (accounting for 45.45%) and plastic foam at 9% (Salestin *et al*., 2021). The predominance plastic waste is because plastic is a practical commodity and is present in everyday use due to its profitable uses (Cordova, 2017). Plastics are used in almost every aspect of human activity, including household activities, industry, building materials, transportation, and a variety of other human needs that cannot be exempt from the use of plastics (Rocha-Santos & Duarte, 2015). This increase in plastic use is due to technological advances, industrial growth, and population growth. In Indonesia, plastic demand continues to rise, with an average increase of about 200 metric tons per year. In 2002, there were 1,9 million metric tons of plastic used, then in 2003 it increased to 2,1 million metric tons, and in 2004 it reached 2,3 million metric tons per year. In 2010, the plastic demand was around 2,4 million metric tons, and in 2011, it rose to 2,6 million metric tons.

The impact of the increased use of such plastics is the increasing amount of plastic waste produced (Surono, 2013). According to estimates from the Ministry of Environment, Indonesians produce an average of 0,8 kg of garbage per day per person, or a total of 189,000 metric tons per day. 15% of the total amount is plastic, which is the equivalent of approximately 28,4 thousand metric tons of plastic per day (Cordova, 2017). The significant increase in plastic pollution directly harms marine organisms by trapping them and obstructing their digestive tracts. Ocean garbage traps more than 370 identified species of marine animals, some of which even swallow it worldwide. (Galgani *et al*., 2013; Gregory, 2009).

Density of the Number of Pieces of Waste

Station II has the highest waste density due to the lack of activity from traders and tourist visitors, resulting in limited exposure and poor maintenance. In contrast, since Station I is close to the activities of sellers and tourist visitors, this Station tends to be better maintained and kept clean. The aim is to create a cleaner and more comfortable environment so that tourists will be more interested in visiting the tourist Station. The plastic waste found at both Stations was generally rigid and soft plastic originating from plastic product packaging. Despite being a long-standing issue, the problem of plastic packaging waste remains unresolved, particularly in coastal areas downstream from the waste cycle (Fleming *et al*., 2014; Jambeck *et al*., 2015).

Most of the plastic waste found at both Stations was packaging waste originating from ecotourism activities at the Station itself. This reflects that although traders have begun to realize the impact of the presence of waste on their economic activities, the mitigation efforts carried out have not been optimal. Apart from tourism activities, waste at the two Stations also comes from other areas carried by the dynamic activities of water currents (Ourmieres *et al*., 2018; Seo & Park, 2020). Tides are the main factor in the distribution of waste along the coastal waters in West Aceh (Assuyuti *et al*., 2018; Rochman *et al*., 2015). Garbage carried by the current will move with the flow of the water mass and float for days, eventually undergoing changes in density that cause it to sink (Noya and Tuahatu, 2021). This condition will cause the waste to degrade into microplastic particles, which will then mix with the aquatic substrate and enter the marine biota food chain system. Consequently, microplastic content is to be found in many fish bodies, which are also consumed by humans.

Waste Weight Density and Relative Density

Station I recorded the highest total mass of of waste, while Station II fhad a higher waste density. At Station I, the most commonly found waste was plastic, consisting of hard and soft plastic; along with some wooden waste carried in by seawater. Station I has a large total mass of waste due to relatively fresh condition, which hasn't undergone any density changes. This makes the waste heavier, as it primarily consists of recently used product packaging discarded by tourists and traders. In contrast, the waste at Station II tends to be lighter and more degraded. Prolonged exposure to sunlight causes it to dry out, reducing its weight. Since Station II is not a primary ecotourism destination, routine waste collection and maintenance efforts are minimal.

Additionally, because Station II is not the primary destination for ecotourism visitors, it does not regularly clean its rubbish. There have not been many studies comparing waste density and mass. A high waste density does not necessarily indicate a high waste mass, and vice versa. This happened at the Lhok Bubon tourist beach, which had

a contradictory comparison between the density and mass of rubbish found. Domestic waste, originating from tourism activities in the region itself, dominates the high mass of waste. Domestic waste, thought to originate from household activities in areas around mangrove ecosystems and river estuaries, accounts for the large amount of plastic waste (Salestin *et al*., 2021).

In general, the percentage of waste that dominates both in terms of density and weight is the type of plastic waste consisting of rigid plastic and soft plastic. This indicates that the use of plastic packaging at the Lhok Bubon beach ecotourism Station is still very high. The findings of plastic waste at Stations I and II, with percentages of 56,55% and 89,52%. The high percentage of density and weight of waste found in the tourist area of Lhok Bubon beach is very worrying if waste management is not carried out properly. The coastal area acts as a collection point for waste from both upstream and local sources, serving as the final destination for various land materials. Improper management will lead to the degradation of plastic waste into the sea, its transformation into marine waste, and its suspension in the ocean's food chain system. Similar conditions also occur on tourist beaches in Midway Atoll, Pacific Ocean, with the largest percentage of waste being plastic waste at 91%, or a density of 4940 grams grams/m^2 (Ribic *et al*., 2012).

CONCLUSION

Plastic waste, both hard and soft, dominates marine debris at Lhok Bubon Beach, similar to other coastal areas. The rising use of plastics due to industrial growth and technological advancements contributes to increasing waste pollution. Observations reveal that Station II has the highest waste density due to the lack of maintenance, whereas Station I, closer to tourism activities, is better managed. Tidal currents transport waste, leading to microplastic contamination in marine ecosystems. The high percentage of plastic waste (56.55% at Station I and 89.52% at Station II) highlights the urgent need for improved waste management to prevent further environmental degradation.

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