International Journal of Engineering & Technology
ISSN: 3083-9114

Analysis of the concentration microplastics on waste generation in the beach: A case study Banda Aceh City, Indonesia

Muhammad Zaki[1]*, Adisalamun[1], Saisa[2]

[1]Department of Chemical Engineering, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[2]Department of Chemical Engineering, Universitas Serambi Mekkah, Banda Aceh 23245, Indonesia

Corresponding author: m.zaki@usk.ac.id

Abstract
The area of the aquatic ecosystem has been affected by the waste from the disposal of human products and the transportation of ocean currents and winds. The waste collection system used in this study uses the transect method. The analysis results show that garbage on Alue Naga and Ulee Lheue beaches is 7,328.6 grams (macro) and for (meco) 518.9 grams. The highest density of Meco waste was found at Ulee Lheue Beach at 0.32 items/m compared to 0.04 items/m^2. The highest total density of macro waste was found at Ulee Lheue Beach at 2.04 items/m^2. Compared to 0.28 items/m^2.

Article Info
Received: 13 November 2024
Revised: 15 December 2024
Accepted: 5 January 2025
Available online: 10 January 2025

Keywords
Coastal Management
Microplastics
Waste Generation
Concentration
Marine Plastic

1. Introduction
The city of Banda Aceh is the westernmost region of Sumatra Island, which has an area of 61.36 km compared to 0.28 items/m^2 with a beach length of ± 17 km and a population of 259,913 people. Banda Aceh City is located at an altitude of -0.45 m to +1.00 m above sea level with an average altitude of 0.80 m (asl). The land surface slope ranges from 2-8%, so it is hazardous for debris collection. Debris found on the beach today has become a problem, especially sea and coastal water pollution.

Marine debris or marine debris is in the form of solids that cannot be found naturally. Marine debris is a human product found in waters and coastal areas. This will result in a direct threat to the productivity and existence of the territorial waters. Marine debris is a nonbiodegradable solid material produced by industry and disposed of freely without management (Unep 2009). Marine debris found on the beach is carried by the wind and currents from one place to another. The marine debris is classified as micro, macro, and micro, with a size of about >5 to 1 meter (Beeharry et al. 2017; Djaguna et al. 2019; Bączkowska et al. 2021). The presence of garbage in the sea harms socio-economic and decreases the value of recreation and the potential of the tourism industry (Arefian et al. 2020; Mghili et al. 2020, 2022; Bouzekry et al. 2022; Sari et al. 2022). Several kinds of waste are transported by currents and winds in waters and beaches.

Plastic bags, straps, plastic bottles, and other waste are typical in waters and beaches. (Manickavasagam et al. 2020; Poluszyńska et al. 2021; Yaghmour et al. 2021, 2022). A recent investigation of the presence of MP, SW, and plastic containers (PC) waste has been carried out on Mexico's "Holbox" island (Cruz-Salas et al. 2022). The average MP and SW concentration levels found were 49.37 ± 45.55 MP/m. Of the types of waste found, 72, as many as 28 were sourced from other sources, and the rest were produced in the research area. An evaluation of microplastic (MP) accumulation in the surface sediment of the beach at Marina and Pattinapakkam beaches has also been carried out (Holc et al. 2021; Seyfi et al. 2021; Venkatramanan et al. 2022). The analysis of MP accumulation was carried out using the FTIR, AFM, and SEM methods. Sample collection points were taken from 40 stations sourced from various MP polymers. The mean MP particles found ranged between 459 (60.8%) and 297 (39.2%). A recent evaluation of plastic and microplastic waste from four different seashores in the municipality of Niteroi has also been carried out (da Silva et al. 2022). The ATR-FTIR technique characterised by polymer was applied in their research to know the degree of soiling of the beach. The waste analysis of the Microplastic Pollution Index (MPPI) and Microplastic Impact Coefficient (CMPI) on 23 Caribbean coasts of central Colombia was also recently evaluated (Rangel-Buitrago et al. 2021; Rusin et al. 2021; Steinhoff-Wrześniewska et al. 2022). Microplastics are being assessed and investigated globally in various regions, islands, and countries. This is done as waste from human products increases and is disposed of freely without proper management.

The province of Aceh, especially the city of Banda Aceh, is an area that many foreign tourists visit nationally and internationally. Tourist attractions that foreign tourists often visit are Ulee Lheue Beach and Alue Naga. The number of visitors at these tourist sites has led to increased waste, which is different from current and wind transportation. This paper was specifically carried out to investigate the presence and types of garbage found on the beaches of Ulee Lheue and Alue Naga. The presence of waste was analysed using the transect method with a size of 5 m x 5 m. To detect the type and form of waste using ATR-FTIR spectroscopy so that the length and wavelength can be obtained.

2. Methodology

Determination of the location used for transects is adjusted to field conditions so that the samples collected can produce actual data. The transect area for the data collection on the coast is 100 meters parallel to the shoreline and 20 meters from the part of the beach directly adjacent to vegetation. The sampling used a 5 m x 5 m mapped sub transect. The distribution of transects for sampling is divided into five parts, each transect of 20 meters. The samples collected were taken at two different coastal locations, as shown in **Fig. 1**. The sampling locations carried out in this study in more detail are shown in the maps **Fig. 2** and **Fig. 3**. The division of each subtransect is divided into three parts to make it easier to determine the sample. The first sub-transect is located near the shoreline, the second is between the first and third transects, and the third is directly behind the beach, bordering the vegetation. The transect area for sampling mapped between each sub is within a 25-meter strip, as shown in **Fig. 4**.

(a) Alue Naga Beach (b) Ulee Lheue Beach

Fig. 1. Sampling Location

Fig. 2. Map of location transects sampling.

Microplastics with types of fibre, fragments, films, and Styrofoam were identified using 4 a microscope. Identification is seen based on the same shape, length, and thickness. At the same time, the fragments are unequal in size and cannot be crushed with a pencil. Meanwhile, film waste is in thin sheets from food packaging and plastic bags. Microplastic Styrofoam has small pieces and is soft. All samples collected were then analysed using ATR-FTIR to obtain a graph with a specific wavelength. FTIR spectra of common polymers such as polyethene and polypropylene were compared with known spectra and confirmed using SIME (Systematic Identification of Microplastics in the Environment) (Bailey et al. 2021). The study calculated the weight and type of waste using equations (1) and (2).

Sebagai langkah akhir, hasil visualisasi dan analisis dari VOSviewer diinterpretasikan untuk memahami struktur jaringan pengetahuan di bidang energi terbarukan. Dengan demikian, penelitian ini memberikan gambaran menyeluruh tentang tren riset, pengembangan teknologi, dan kolaborasi penelitian di sektor energi terbarukan, serta menjadi landasan bagi pengambil keputusan dalam memprioritaskan area riset strategis dan mempercepat inovasi teknologi.

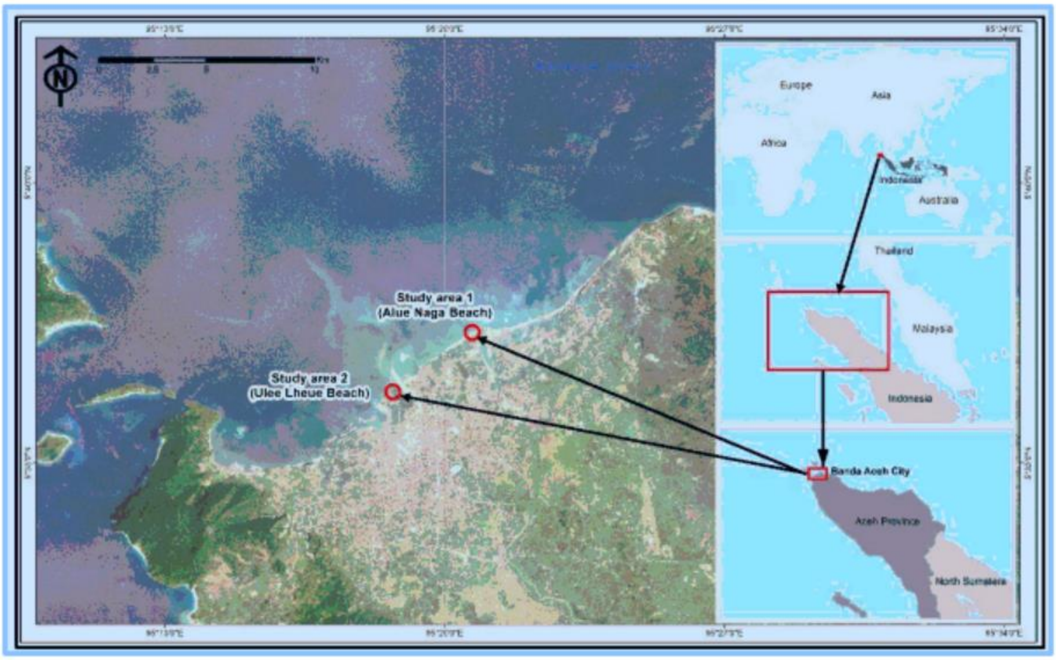
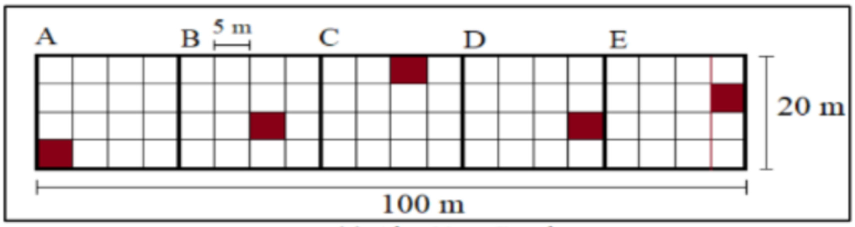
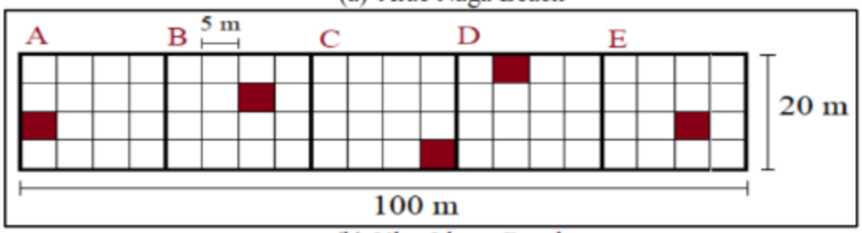


Fig. 3. Map of area study



(a) Alue Naga Beach



(b) Ulee Lheue Beach

Fig. 4. Position of Sub Transect Sampling Site

Meanwhile, the percentage of waste composition, such as type and weight, is calculated by equation (3). The level of density or concentration of each item/m2 of each transect was calculated using equation (4) to analyse the abundance of microplastics using equation (5). Jn Total = Jn Transect 1 + Jn Transect 2 + Jn Transect n.

$$\text{Jn x} = \frac{Jn\ Total}{x} \tag{1}$$

Bn Total = Bn Transect 1 + Bn Transect 2 + Bn Transect n

$$\text{Bn x} = \frac{Bn\ Total}{x} \tag{2}$$

Information:
Jn = Total of trash
X = Total of variable
Bn = Garbage Weight

$$\text{Percentage } (\%) = \frac{x}{\sum_{i=1}^{n} x_i} \quad (3)$$

$$K = \frac{n}{w \ x \ 1} \quad (4)$$

Information:
K= waste concentration/density (item/m^2)
n= number of junk items
w= transect length (m)
l = transect width (m)

$$K = \frac{m}{v} \quad (5)$$

Information:
K= microplastic concentration (gram/ ml)
m = microplastic weight (gram)
v = Sample volume (ml)

3. Result & Discussion

The sampling system of this research was mapped into three parts: macro, micro, and micro waste. The process for obtaining macro waste through a sieve with a hole size of 2.5 cm. All waste that passes through the sifting is used as meco waste. Meanwhile, macro waste is obtained through sand extraction at a predetermined point. Furthermore, the sand is sieved with a hole of 0.5 mm, and all the sand that escapes from the sieve is a waste. The waste collection and processing procedures evaluated in this work are presented in full in **Fig. 5**.

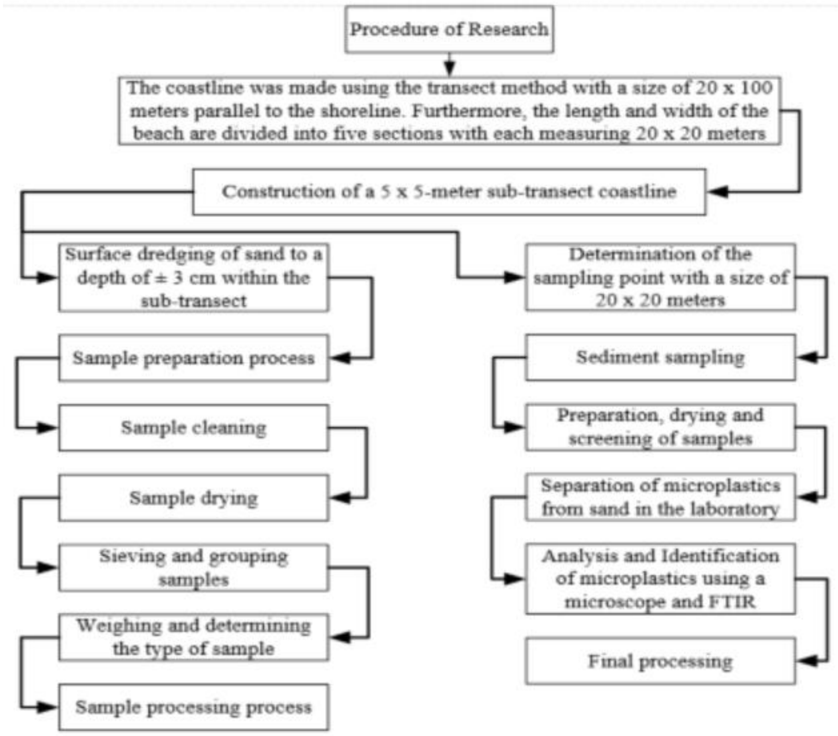
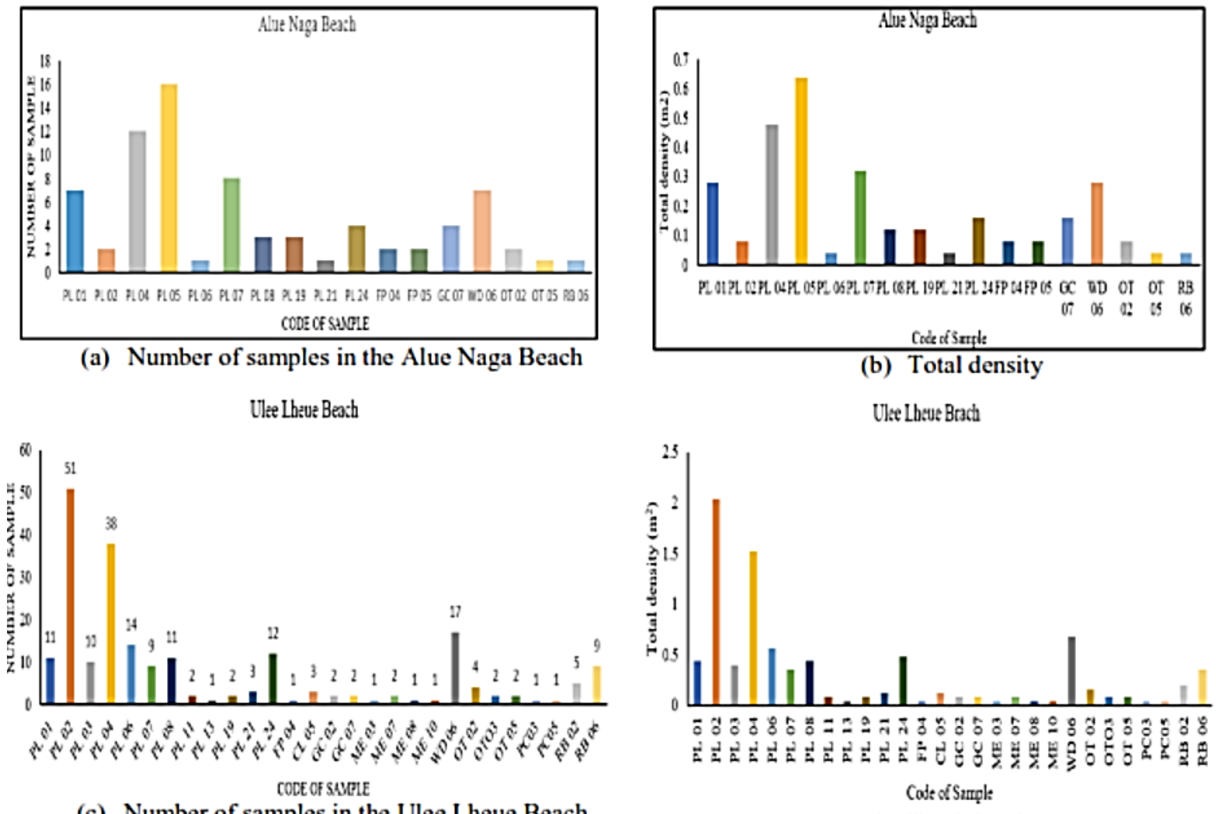


Fig. 5. Process and Procedure Sampling Data

Based on the evaluation results conducted at Alue Naga Beach, 17 types of samples were found to be divided into six categories. Microplastic waste is the most common type of waste among other types of waste. Meanwhile, the types of waste found on Ulee Lheue Beach were 28 types of nine categories. The category of microplastic waste found at Ulee Lheue Beach is also the largest compared to other waste categories. The type and amount of each waste found from the two beaches where the samples were collected in this study are shown in **Table 1** and **Fig. 6**.

Table 1. These types of garbage are found in Alue Naga and Ulee Lheue Beach.

No	Alue Naga Beach		Ulee Lheue Beach	
	Code of trash	**Beach Trash**	**Code of Trash**	**Beach Trash**
1	PL 01	Bottle cap	PL 01	Bottle cap
2	PL 02	Bottle < 2 L	PL 02	Bottle < 2 L
3	PL 04	Knives, forks, spoons, straws, stirrers, and cookware	PL 04	Bucket
4	PL 05	Equipment packages Drink food containers (Fast food, cups, lunch boxes, and the like)	PL 05	Knives, forks, spoons, straws, stirrers, and cookware
5	PL 06	Fast food container	PL 06	Fast food container
6	PL 07	Plastic Bag (Opaque or Clear)	PL 07	Plastic Bag (Opaque or Clear)
7	PL 08	Toy	PL 08	Toy
8	PL 19	Mine Rope	PL 11	Cigarettes, butts & filters
9	PL 21	Plastic tape strap	PL 19	Oyster Net
10	PL 24	Other plastic materials	PL 21	Mine Rope
11	FP 04	Cork (coolant insulation and packing)	PL 21	Plastic tape strap
12	FP 05	Other Cork Material	PL 24	Other plastic materials
13	GC 07	A glass of Broken Ceramics	FP 04	Cork (coolant insulation and packing)
14	WD 06	Other wood categories	CL 05	Carpet
15	OT 02	Other Cleaning Tools	GC 02	Glass bottle
16	OT 05	Other Ingredients	GC 07	A glass of Broken Ceramics
17	RB 06	Rubber bracelet	ME 03	Aluminium Cans
18	OT 05	Other Ingredients	ME 07	Fishing Equipment
19	PC 03	Cigarette Pack	ME 08	Metal flakes
20	PC 05	Other paper categories	ME 10	Other metals
21	RB 02	Slippers	WD 06	Other wood categories
22	RB 06	Rubber bracelet	OT 02	Other Cleaning Tools



(a) Number of samples in the Alue Naga Beach

(b) Total density

(c) Number of samples in the Ulee Lheue Beach

(d) Total density

Fig. 6. Number of types and total density for sample (a. Number of samples in the Alue Naga Beach; b. Total density; c. Number of samples in the Ulee Lheue Beach; d. Total density)

The investigation results of meco waste collected from Alue Naga Beach and Ulee Lheue were five and twelve items in the five sub-transects where the samples were taken. Types of meco waste found from Alue Naga Beach included food containers, cups, food boxes, and the like, as well as wood and other materials. Meanwhile, the types of waste found at Ulee Lheue Beach were opaque and transparent plastic bags, cork, cooling and packing insulation, wood, and others. The types of waste found from the two beaches are more fully presented in Table 2. At the same time, the total amount and density of waste are shown in **Fig. 7**.

Table 2. Types of meco waste from the two beaches where samples were taken

No	Alue Naga Beach		Ulee Lheue Beach	
	Code of samplings	**Type of sampling**	**Code of samplings**	**Type of sampling**
1	PL 06	Food containers (fast food, cups, lunch boxes & the like)	PL 07	Plastic Bag (Opaque or Clear)
2	WD 06	Other wood categories	FP 04	Cork (coolant insulation and packing)
3	OT 05	Other Ingredients	WD 06	Other wood categories

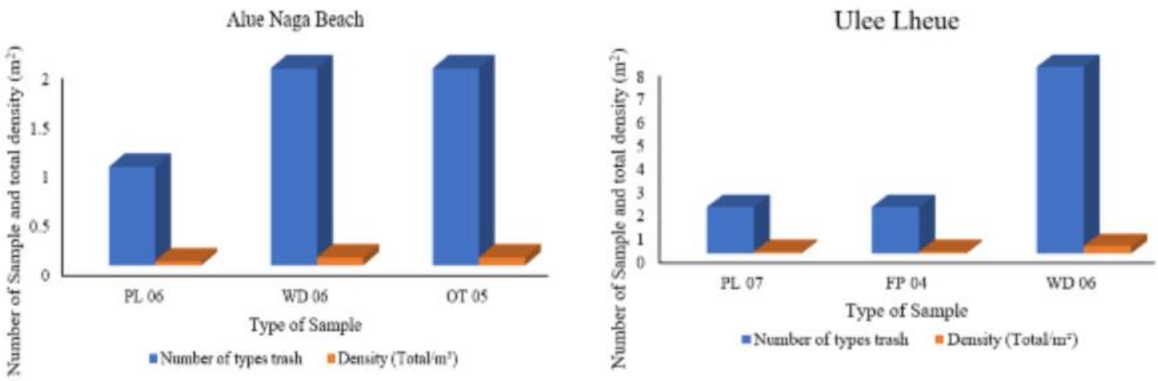


Fig. 7. Amount and density of meco waste from Alue Naga and Ulee Lheue Beach

Microplastics on the Alue Naga beach were observed using a microscope. The observations showed several types of waste, such as fibre, fragments, films, monofilament, and pellets. Meanwhile, microplastics on the Ulee Lheue beach, monitored by microscopes, were of six types. One type of microplastic was not found on the Alue Naga beach, namely, foam, as shown in Fig. 8 and 9. The percentage of waste types analysed directly on the Alue Naga and Ulee Lheue beaches using a microscope is shown in **Fig. 8**.

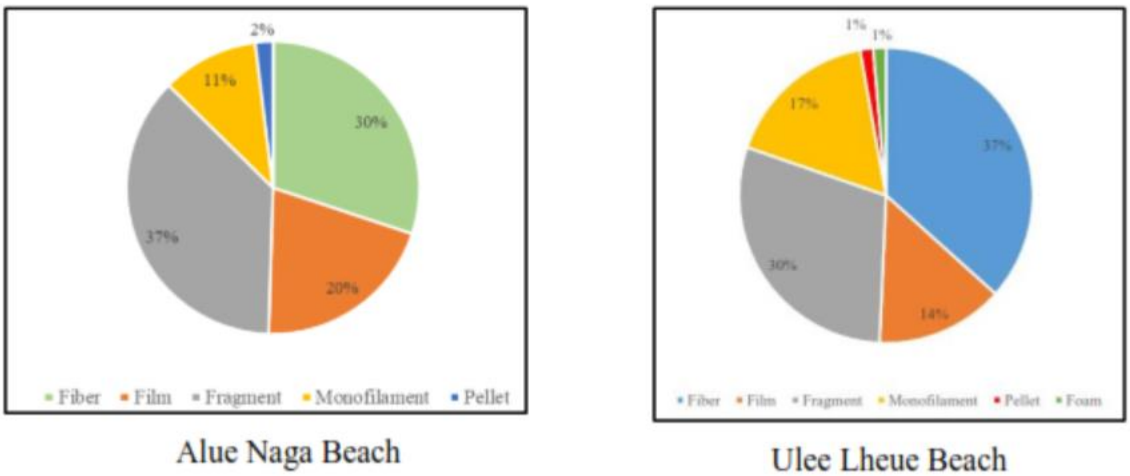


Fig. 8. Percentage of Microplastics in Alue Naga and Ulee Lheue Beaches by Shape

The main characteristics of microplastic fragments are broken pieces of plastic, unlike films in the form of sheets or fibres (Widianarko and Hantoro 2018). Meanwhile, the microplastic found on Ulee Lheue Beach increased by one type. Foam-type microplastics were not found in Pantau Alue Naga, but the other types were the same. Fragments are plastic fragments in bottles, jars, mica folders, and small pieces of parallon pipe. Plastic waste often found on beaches or at sea is generally sourced from leftover food or processed human products, as explained by (Widianarko and Hantoro 2018). In situ, waste from fishing or shipping (commercial and recreational) can increase microplastic pollution in marine ecosystems (Tamminga et al. 2018). Some forms of microplastics visually observed with a microscope at Alue Naga and Ulee Lheue beaches are presented in **Fig. 9**.

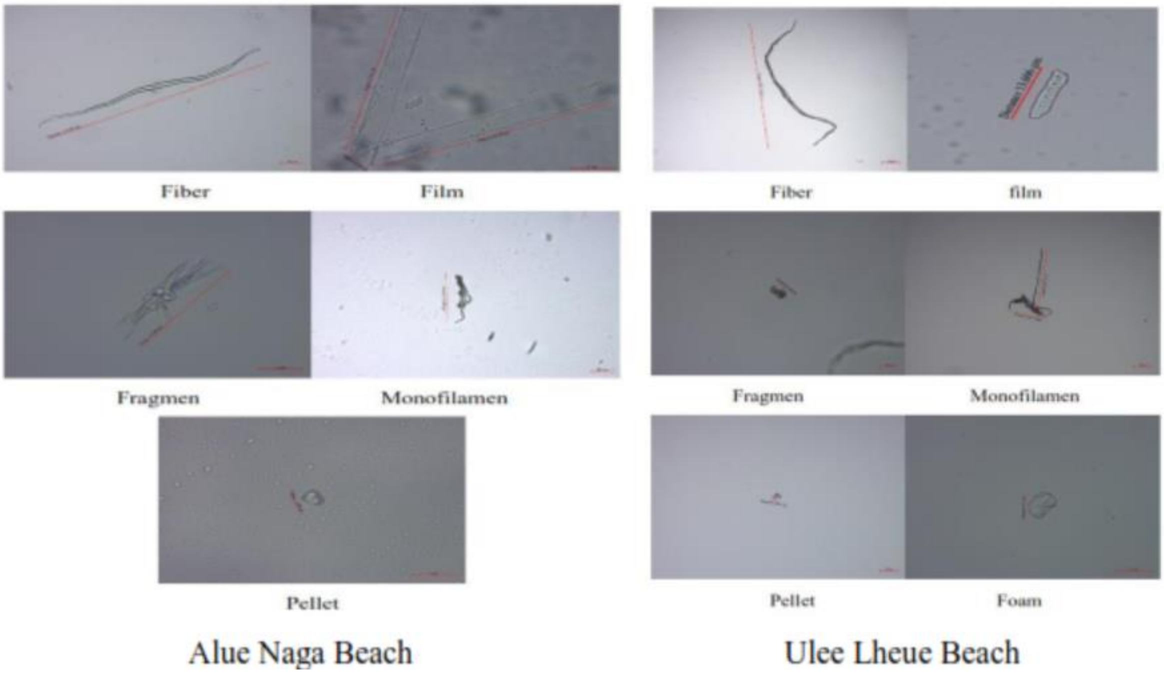


Fig. 9. Types of microplastics in Alue Naga and Ulee Lheue Beach

Microplastics found in the sea and beaches can cause pollution in aquatic ecosystems. The disposal of processed human waste and indiscriminate garbage disposal can cause the number of microplastics found on beaches today. In addition, microplastic waste is also sourced from current sources, and wind transportation is sourced from other places. Fisherman's tools that are not used and are thrown on the beach carelessly are also a source of garbage, which causes the accumulation of microplastics. This can increase the accumulation of waste in the future if it is not handled and processed correctly. The role of various parties, especially stakeholders, is expected to provide understanding to the community so that they are more sensitive to the impact of microplastics. Better management and waste disposal systems in the future are expected to reduce pollution in aquatic ecosystems. Better waste management and public awareness of the environment can reduce the accumulation of microplastic waste on beaches. Thus, aquatic biota can be saved, and human health is maintained correctly and safely.

4. Conclusion

This research proves the presence of solid waste and microplastics in the Alue Naga and Ulee Lheue Beaches. It found as many as 30 different types of garbage from the two beaches that became the research sampling sites. The results show that most waste comes from human products, such as food waste and industrially processed products. In addition, the garbage found on the beach from other places is transported by currents and winds. The presence of waste on Alue Naga and Ulee Lheue beaches can cause considerable pollution if the management is not in line with the increasing number of tourists. Microplastics are so tiny that they are difficult to remove and spread in different habitats. Thus, it can threaten the species of flora and fauna found in the area, especially in large categories. On the other hand, indiscriminate disposal of garbage on the beach on the beach, sea and water can affect marine life through entanglement, consumption, and formation of MP and its ecosystem. The evaluations carried out in this study can help determine possible sources of waste and microplastics in a particular study area and propose strategies to reduce or prevent their presence.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We want to express our sincere gratitude to all the authors for their invaluable contributions and collaboration throughout the research process. This work represents each author's collective efforts and dedication, whose expertise and insights were essential in completing this study.

References

Arefian M, Tahmourespour A, Zia M (2020) Polycarbonate biodegradation by newly isolated Bacillus strains. Arch Environ Prot 46:14–20

Bączkowska E, Kalinowska A, Ronda O, et al. (2021) Microbial and chemical quality assessment of the small rivers entering the South Baltic. Part I: Case study on the watercourses in the Baltic Sea catchment area. Arch Environ Prot 47:55–73. https://doi.org/10.24425/aep.2021.139502

Bailey K, Sipps K, Saba GK, et al. (2021) Quantification and composition of microplastics in the Raritan Hudson Estuary: comparison to pathways of entry and implications for fate. Chemosphere 272:129886

Beeharry YD, Bekaroo G, Bokhoree C, et al. (2017) Sustaining anti-littering behavior within coastal and marine environments: Through the macro-micro level lenses. Mar Pollut Bull 119:87–99. https://doi.org/https://doi.org/10.1016/j.marpolbul.2017.04.029

Bouzekry A, Mghili B, Aksissou M (2022) Addressing the challenge of marine plastic litter in the Moroccan Mediterranean: A citizen science project with schoolchildren. Mar Pollut Bull 184:114167

Cruz-Salas AA, Alvarez-Zeferino JC, Ojeda-Benitez S, et al. (2022) Solid waste and microplastics on the beaches of Holbox island, Mexico. Reg Stud Mar Sci 53:102423. https://doi.org/https://doi.org/10.1016/j.rsma.2022.102423

da Silva EF, do Carmo D de F, Muniz MC, et al. (2022) Evaluation of microplastic and marine debris on the beaches of Niterói Oceanic Region, Rio De Janeiro, Brazil. Mar Pollut Bull 175:113161. https://doi.org/https://doi.org/10.1016/j.marpolbul.2021.113161

Djaguna A, Pelle WE, Schaduw JNW, et al (2019) Identifikasi sampah laut di pantai tongkaina dan talawaan bajo. J Pesisir dan Laut Trop 7:174–182

Holc D, Mądrecka-Witkowska B, Komorowska-Kaufman M, et al. (2021) The application of different methods for indirect microbial development assessment in pilot scale drinking water biofilters. Arch Environ Prot 47:37–49. https://doi.org/10.24425/aep.2021.138462

Manickavasagam S, Kumar S, Kumar K, et al. (2020) Quantitative assessment of influx and efflux of marine debris in a water channel of South Juhu creek, Mumbai, India. Reg Stud Mar Sci 34:101095

Mghili B, Analla M, Aksissou M (2022) Medusae (Scyphozoa and hydrozoa) from the Moroccan Mediterranean coast: abundance and spatiotemporal dynamics and their economic impact. Aquat Ecol 56:213–226

Mghili B, Analla M, Aksissou M, Aissa C (2020) Marine debris in moroccan Mediterranean beaches: an assessment of their abundance, composition and sources. Mar Pollut Bull 160:111692

Poluszyńska J, Ciesielczuk T, Biernacki M, Paciorkowski M (2021) The effect of temperature on the biodegradation of different types of packaging materials under test conditions. Arch Environ Prot 47:74–83. https://doi.org/10.24425/aep.2021.139503

Rangel-Buitrago N, Arroyo-Olarte H, Trilleras J, et al. (2021) Microplastics pollution on Colombian Central Caribbean beaches. Mar Pollut Bull 170:112685. https://doi.org/https://doi.org/10.1016/j.marpolbul.2021.112685

Rusin M, Gospodarek J, Nadgórska-Socha A (2021) Time-delayed effect of petroleum-derived products in soil and their bioremediation on plant – herbivore interaction. Arch Environ Prot 47:71–81. https://doi.org/10.24425/aep.2021.138465

Sari MM, Inoue T, Septiariva IY, et al. (2022) Identification of Face Mask Waste Generation and

Processing in Tourist Areas with Thermo-Chemical Process. Arch Environ Prot 48:79–85. https://doi.org/10.24425/aep.2022.140768

Seyfi S, Katibeh H, Heshami M (2021) Investigation of the process of adsorption of heavy metals in coastal sands containing micro-plastics, with special attention to the effect of aging process and bacterial spread in micro-plastics. Arch Environ Prot 47:50–59. https://doi.org/10.24425/aep.2021.138463

Steinhoff-Wrześniewska A, Strzelczyk M, Helis M, et al. (2022) Identification of catchment areas with nitrogen pollution risk for lowland river water quality. Arch Environ Prot 48:53–64. https://doi.org/10.24425/aep.2022.140766

Tamminga M, Hengstmann E, Fischer EK (2018) Microplastic analysis in the South Funen Archipelago, Baltic Sea, implementing manta trawling and bulk sampling. Mar Pollut Bull 128:601–608

Unep R (2009) El Maghara scenario a search for sustainability and equity: An Egyptian case study. J Futur Stud 14:55–90

Venkatramanan S, Chung SY, Selvam S, et al. (2022) Characteristics of microplastics in the beach sediments of Marina tourist beach, Chennai, India. Mar Pollut Bull 176:113409. https://doi.org/https://doi.org/10.1016/j.marpolbul.2022.113409

Widianarko YB, Hantoro I (2018) Mikroplastik dalam Seafood dari Pantai Utara Jawa

Yaghmour F, Al Bousi M, Al Naqbi H, et al. (2021) Junk food: Interspecific and intraspecific distinctions in marine debris ingestion by marine turtles. Mar Pollut Bull 173:113009. https://doi.org/https://doi.org/10.1016/j.marpolbul.2021.113009

Yaghmour F, Samara F, Ghalayini T, et al. (2022) Junk food: Polymer composition of macroplastic marine debris ingested by green and loggerhead sea turtles from the Gulf of Oman. Sci Total Environ 828:154373. https://doi.org/https://doi.org/10.1016/j.scitotenv.2022.154373