



Microplastics contamination of sea surface water in Banda Aceh City and Aceh Besar District, Aceh Province, Indonesia

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ABSTRACT

Plastic debris is one of the serious problems in urban cities, including Banda Aceh city and Aceh Besar district, Indonesia. This waste is degraded into a small particle called microplastics. This waste has the potential to pollute the waters in the coastal area. The objective of the present study was to analyse the microplastic contamination of the sea surface waters of Banda Aceh City and Aceh Besar District. Sea surface water was sampled from three locations, namely Gampong Jawa (Station 1), Alue Naga (Station 2), and Krueng Raya (Station 3) during January to March 2024. The results showed that there were four forms of microplastics found in the sea surface water sample, namely fragments, fibers, films, and pellets with nine colours, namely black, brown, blue, clear, red, yellow, green, pink, and purple. The fragments and black are the dominant form and colour of microplastic in the sea surface water of Banda Aceh city. The highest number of microplastic particles was found in Alue Naga waters (21.04 particles/L) and the least in Gampong Jawa waters (16.6 particles/L). Therefore, it is concluded that the surface of the seawater studied in this study has been contaminated with microplastics.

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Introduction

Marine debris has the potential to pollute the marine environment. Several studies showed that most of the marine debris is plastic waste (Dewi *et al.*, 2015; Jambeck *et al.*, 2015; Purba *et al.*, 2019). Plastic waste can cause problems in aquatic environments because it takes a long time to degrade (Kapo *et al.*, 2020). Microplastics that have been in the water for a long time can potentially absorb dangerous pollutants such as pesticides and heavy metals (Li *et al.*, 2018), and when swollen by fish or other aquatic biota, it causes digestive problems, nutritional disorders, and even death of these biota (Galloway *et al.*, 2017), further affecting the health of humans who consume the contaminated fish, such as intestinal inflammation, endocrine disorders, oxidative stress, and long-term health problems (Smith *et al.*, 2018; Sofiana *et al.*, 2024; Akbar *et al.*, 2023).

Banda Aceh City and Aceh Besar District are areas that have coastal areas. These areas are experiencing rapid population growth, thereby

increasing activities in coastal areas that have the potential to produce plastic waste. This waste can cause a decrease in or even eliminate biodiversity in coastal ecosystems (Azharil and Paskah, 2023). Plastic waste will degrade into smaller particles called microplastics. This particle has a small diameter of less than 5 mm (Chen, 2020). Microplastics originate from fishing activities such as fishing nets and ropes, tourism activities, and domestic waste. Microplastics have floating characteristics, but some of them were sinking and swallowed by wildlife such as turtles and sea seabirds (Lusher *et al.*, 2013). Microplastics on land drifted to the waters by rain and winds (Dewi *et al.*, 2015). Microplastics have a greater potential threat to aquatic biota because they resemble marine biota food, and in the digestive tract, these materials release hazardous pollutants such as polybrominated diphenyl ethers and other addictive substances (Thakur and Kandasubramanian, 2019).

Research on microplastics in water has become a topic of current interest. Hosseini *et al.* (2020)

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reported approximately 362 microplastic particles/L in sea surface water in Chabahar Bay, Iran. Nainggolan *et al.* (2022) reported 500 particles of microplastic per ml of sea water in Karangjahe, Rembang, West Java. In the North Coast of Aceh, microplastics were also found about 202 particles/L on average (Abda, 2023). Ahmed *et al.* (2021) stated that there were 14,554 microplastic particles/L along the coast of Pakistan in the Northern Arabian Sea. Hermawan *et al.* (2023) reported 11.29 particles/L of microplastics in the coastal waters of Palu Bay, Central Sulawesi, Indonesia (Hermawan *et al.*, 2023). Study on the microplastics contamination in fish and sediment in Banda Aceh City and Aceh Besar Districts have been reported by Faradilla *et al.* (2024), Siregar *et al.* (2025a), Siregar *et al.* (2025b), and Maulana *et al.* (2023). According to these studies, some fish species and sediment in these areas have been contaminated by microplastics. However, there was no study on the microplastic contamination in the sea surface water of Banda Aceh city and Aceh Besar district, Aceh province, Indonesia. Therefore, the objective of the present study was to analyse the microplastic contamination in the sea surface water of Banda Aceh city and Aceh Besar district.

Materials and Methods

Time and location

This study was conducted from January to March 2024 at the Chemistry and Biotechnology Laboratory of the Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh City. Sea surface water sampling was carried out in 3 locations: Gampong Jawa (Station 1), Alue Naga (Station 2), and Krueng Raya (Station 3), as shown in Figure 1.

Microplastic sampling

Water samples were taken at high tide conditions at a depth of 50–100 cm using a 25-litre plastic bucket. A total of 100 litres of sea surface water were taken, then filtered using a plankton net No. 25, and the water sample was put into the 20-ml sample bottles. Subsequently, the samples were kept in an icebox containing ice cubes (4 °C) and transported to the Marine Chemistry and Biotechnology Laboratory, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh City, for further analysis.

Sample preparation and microplastics analysis

A total of 20 ml of water sample was mixed with H₂O₂ (60 ml) and NaCl (60 ml), and the sample was stirred homogenously and kept for 24 hours. After 24 hours, the water samples were filtered using Whatmann filter paper (Sartorius Cellulose Nitrate Membrane 0.45 m), then the filter paper was rinsed with distilled water and dried using a furnace at 60 °C

for 48 hours (Nuelle *et al.*, 2014). After drying, the microplastic on the filter paper was observed using a stereo microscope (Primo Star Zeiss) with 400x and 100x magnification. The form, color, a and size of microplastics were analysed based on Basri (2021), and Widianarko and Hantoro (2018). While the abundance of microplastics was calculated as follows:

$$N = n_i \times (1/V_d) \times (V_t/V_s)$$

Where, N = number of microplastics (particles/L), N_i = total number of microplastics (particles), V_t = filtered water volume (ml), and V_s = observed water volume (ml), V_d = volume air yang disaring (L)

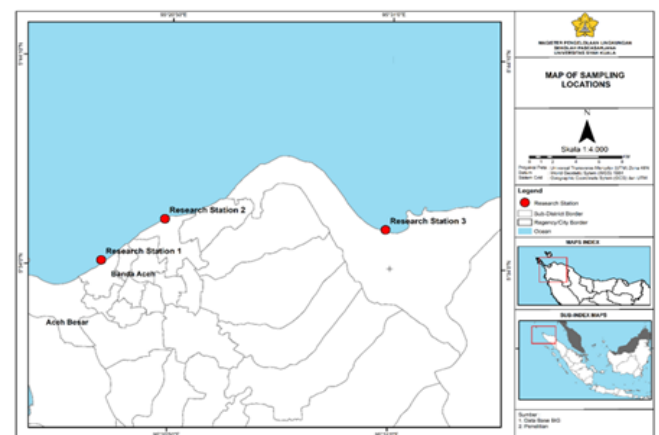


Figure 1. Map of Banda Aceh City and parts of Aceh Besar District. Red circles are water sampling locations

Data analysis

Data were presented in tables and figures, then analyzed descriptively by comparing the findings with the previous reports and other related references.

Results

There were four forms of microplastics at all locations, namely, fiber, fragments, films, and pellets (Table 1 and Figure 2), where fragments and film were the dominant forms of microplastics at all sampling locations. Based on sampling location, the highest abundance of microplastics was found in Alue Naga waters (21.04 particles/L) and the least in Gampong Jawa waters (16.6 particles/L). In January, the highest abundance of microplastics was found at station 3 (Krueng Raya) and the lowest at station 2 (Alue Naga). In February, the highest abundance of microplastics was recorded at station 2 (Alue Naga) and the lowest at station 1 (Gampong Jawa), while in March, the highest abundance was found at station 2 (Alue Naga) and the lowest at station 3 (Krueng Raya) (Figure 3). Overall, higher abundances of microplastics were recorded during the month of March.

Table 1. Microplastic abundance by form in sea surface water during January-March 2024 from three locations in Banda Aceh city and Aceh Besar district

Location	Filtered Water (L)	Water Sample Observed (ml)	Types of Microplastics				Total	Particle/L
			Fiber	Fragment	Film	Pellet		
Gampong Jawa	25	20	38	286	83	8	415	16.60
Alue Naga	25	20	66	356	77	27	26	21.04
Krueng Raya	25	20	68	292	78	21	459	18.36
Total	-	-	172	934	238	56	1,400	56.00
Average	-	-	57.33	311.33	79.33	18.66	466.66	18.66

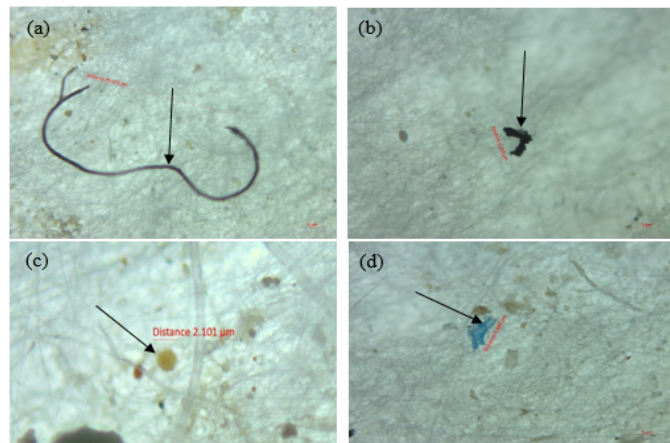


Figure 2. Types of microplastics found in surface water (a) Fiber, (b) Fragment, (c) Pellet, (d) Film

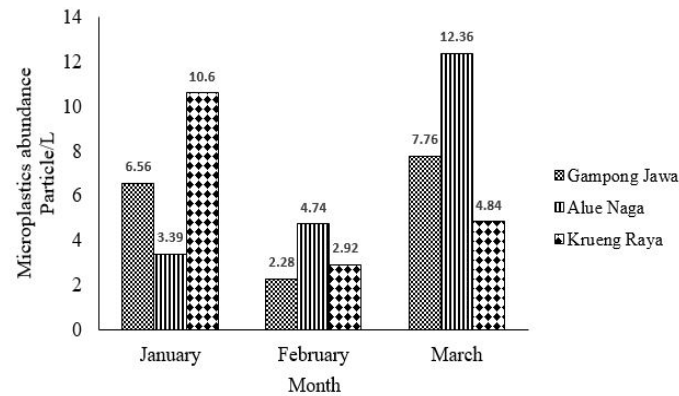


Figure 3. Microplastics abundance based on sampling locations and times from January to March 2024.

The results showed that nine colours of microplastics were found in the water samples of Banda Aceh and Aceh Besar district coastal waters, namely: black, brown, clear, red, blue, yellow, green, purple, and pink. Black was the predominant colour, while green was the least one (Table 2), where the black colour is mostly found at station 2, namely in Alue Naga (Figure 4).

Table 2. Microplastic abundance by color in January-March 2024 water and at three different locations around Banda Aceh and Aceh Besar district

Location	Color of Microplastics									Total	Particle/L
	Black	Brown	Transparent	Red	Blue	Yellow	Green	Purple	Pink		
Gampong Jawa	246	75	28	8	32	21	1	1	2	415	3.55
Alue Naga	316	98	13	14	38	38	7	1	1	526	4.51
Krueng Raya	261	107	30	12	33	14	1	1	0	459	2.80
Total	823	280	71	34	103	73	9	3	3	1,400	10.86
Average	274.33	93.33	23.66	11.33	34.33	24.33	3	1	1	466.66	3.62

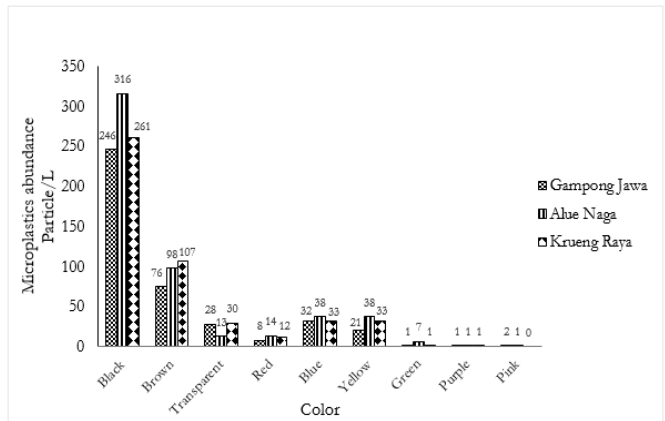


Figure 4. Color abundance of microplastics found in surface water based its color

Discussion

The findings showed that sea surface water in the three research locations has been polluted with microplastics. There were four forms of microplastics found in the sea surface water of Banda Aceh and Aceh Besar Districts, namely fragments, fibres, films, and pellets, where fragments were predominant. Fragment was also predominant in the waters of Kendari Bay, Southeast Sulawesi Province (Walyanse et al., 2021). Min et al. (2023) reported that fragments are the most common form of microplastic found in Southwestern Korean sea waters; fragments are also dominant in Palu, Central Sulawesi, Indonesia (Hermawan et al., 2023).

In addition to fragments, film-formed microplastics are the second shape commonly found in water samples and are evenly distributed in all research locations. According to Kosore et al. (2022), this microplastic was also dominant in the waters of the Kenya Coast, East Africa, with an average of 589.2 particles/L, which is much higher than in this study. Film-microplastics were also dominated in the waters of Dumai City, Riau Province, and Temajo Mempawah Island, West Kalimantan, Indonesia, with an average abundance of 2.7–8.7 particles/L and 1602.98–4539.41 particles/L, respectively (Yoswaty et al., 2021; Fadhillah et al., 2023).

Fragments and films have a lower density so that they float easily on the surface of the waters (Febriani et al., 2020). This condition causes this microplastic to be easily carried by currents from the coast to the open sea, is often eaten by fish accidentally, and accumulates in the digestive tract. This characteristic also causes fragments and films to be filtered out during the sampling process. Purba et al. (2019) stated that the weight of microplastics determines the trajectory of their distribution; lighter microplastics will be carried away by currents and tides, while heavier ones will sink to the bottom of the waters. Fragments and films are mostly made from plastic bags, jar packaging, bottles, and pieces of paralon pipes (Dewi et al., 2015; Claessens et al., 2011). Based on direct observation, there was a lot of plastic waste, such as plastic bags, plastic packaging, and mineral water bottles, at the sampling sites. This debris is the source of microplastics in these waters.

Among the three locations, Alue Naga Waters has a higher abundance of microplastics than two other locations. This is probably due to the presence of residential areas, busy fishing activities such as traditional jetties and temporary fishermen settlements, and tourism sites, so the plastic waste in these locations mostly comes from these activities. This plastic waste piles up on the banks of rivers, carried by the wind or currents at high tide into the waters. According to Sianturi et al. (2021), currents influence the amount of microplastics in the waters, where the amount of microplastics increases at high tide. Therefore, currents affect microplastic abundance. Microplastic particles will experience displacement in strong current flows (Kilponen, 2016). According to Setiawan et al. (2019), fast-flowing waters have a sediment composition that tends to be dominated by gravel, while slow-flowing waters are dominated by fine sand and mud. The sediment composition in the three research locations is dominated by medium sand and fine sand, so it is thought to have a slow current speed so that microplastic particles are not easily carried by the current and are found in this study. The slow current speed causes microplastics scattered in the ocean to be slow and experience accumulation.

The size of the microplastics found is the smallest group of microplastics; this may be due to the fact that the materials have been immersed and degraded for a long time in the waters. Black is the dominant colour of microplastic in all research locations. The colour difference of microplastics is caused by the degradation process (Khuyen et al., 2021).

Microplastics in water experience physical degradation from exposure to sunlight, waves, and

currents (Andrady, 2011). Additionally, they undergo chemical degradation through oxidation and hydrolysis processes (Gewert et al., 2015). Biological degradation also occurs due to the activity of microorganisms present in the water (Urbanek et al., 2018). In general, black microplastics contain many contaminants and other organic particles because microplastics have a high ability to absorb pollutants (Hiwari et al., 2019).

Based on direct observation at the sampling location, there were no trash bins available. This facility is important to reduce the amount of plastic waste intentionally thrown away in the environment, and there is a need for the construction of plastic waste recycling facilities. Therefore, it was crucial to plan the community awareness strategy by developing regulations and enforcing strong and consistent law enforcement.

Conclusions

The waters of the three locations around Banda Aceh City and Aceh Besar District have been polluted with microplastics. There are four forms of microplastics, namely fragments, films, fibers, and pellets, with nine colour types: black, brown, clear, blue, red, yellow, green, purple, and pink. Fragments and black were the dominant forms and colours in all locations. The highest abundance of microplastics was found in Alue Naga waters (21.04 particles/L) and the lowest in Gampong Jawa (16.6 particles/L).

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