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Microplastic Accumulation in Coral Reef Ecosystems at Peukan Bada District, Aceh Besar

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ABSTRACT

Microplastics are plastic fragments measuring < 5 mm, microplastics that enter the water can damage the growth of coral reefs. The aim of this research is to obtain accurate data on the distribution of microplastics, as an initial step in conservation and mitigation of the impact of plastic waste pollution in the Ujong Pancu area. Sediment samples were taken using coring method. Microplastic identification was carried out at the Marine Chemistry Laboratory, Faculty of Maritime Affairs and Fisheries, Syiah Kuala University using a binocular microscope with zig-zag pattern identification. The results of this study are that there are three types of microplastic found in Ujong Pancu waters, namely fiber, film, and fragment types. The average abundance of microplastics in Ujong Pancu Waters ranges from 32–68 particles/kg. The highest average abundance of microplastics is in the northwestern part of Pulau Tuan and the lowest is in Lhok Mata Ie Beach. The highest type of microplastic found was film and the lowest type of microplastic found was fiber. The condition of coral reefs in Ujong Pancu waters is in the moderate category. The relationship between microplastic abundance and the percentage of live coral cover and environmental parameters was 85.01%.

Keywords: abundance, sediment, coral reef, mikroplastic.

INTRODUCTION

Ujong Pancu is located at Peukan Bada District, Aceh Besar, which has a diversity of coral species dominated by the genus *Acropora*, *Pocillopora* and *Porites* (Rudi, 2013). This area has been a hub for various fishing activities, with 129 species of reef fish primarily from the Pomacanthidae (Fazillah *et al*., 2020), The utilization of these resources by residents has not only met daily needs, but also transformed into a tourist attraction. This area is polluted by plastic waste, which potentially caused by tourists within and outside the region, and local fishing. Indonesia, a major contributor to marine debris, annually generates 0.48 to 1.29 million metric tons of plastic waste (World Bank Group, 2018). This pose a severe threat to the sustainability of the coral reef ecosystem.

Plastic waste can accumulate in the aquatic ecosystem and can be fragmented into microplastics with sizes, less than 5 mm, in various forms (Ibrahim *et al*., 2017). Microplastics can adhere to coral polyps and cause tissue death (necrosis) and bleaching (Reichert *et al*., 2018). Several studies in Indonesia have identified 13.98 microplastic particles per kilogram of sediment samples on coral reefs (Cordova *et al*., 2019), emphasizing the detrimental impact of microplastics in coral reef ecosystems health (Reichert *et al*., 2018; Cordova *et al*., 2019).

Microplastics are stored in the digestive system of corals for approximately 24 hours which can affect energy, pollutant toxicity, and trophic transfer (Allen *et al*., 2017). Despite the known the impact, the lack of information on microplastics abundance in Ujong Pancu has impeded proactive measures against this environmental threat. Thus this research is needed to obtain accurate data on the distribution of microplastics, serving as the initial step in conservation and mitigation of the impact of plastic waste pollution in the Ujong Pancu area.

MATERIALS AND METHODS

Study site

This research was conducted from May to June 2023 in Ujong Pancu Waters, Peukan Bada District, Aceh Besar (Figure 1). The 3 stations were determined as 1) southern Tuan Island, 2) northwestern Tuan Island and 3) Lhok Mata Ie Beach. The sediment samples were collected and transferred to the Marine Chemistry Laboratory, Faculty of Marine Affairs and Fisheries, Syiah Kuala University for microplastic identification. In addition, we surveyed coral reef status for all study sites, including water quality as supportive data.

Microplastic sampling and identification

The sediment was collected on coral reef substrates using a core sampler (10 cm diameter and 5 cm length of paralon pipe at a depth of 0–5 cm) for 5 replicates. Sampling was done every 20 m along the transect (100 m). Samples were labeled and kept in plastic bag for laboratory work. Sediment samples were dried in an oven at 70 °C for 24 hours to remove the water content in the sediment, and samples were then dried again at room temperature for 48 hours. The dried sediments were sieved using different mesh sizes as 2 mm, 1 mm, 0.5 mm, 0.125 mm, 0.063 mm, and 0.038 mm. Sediment samples retained on each sieve was weighed and calculated the percentage as follows:

$$Weight\ percent = \frac{Fraction\ weight\ (grams)}{Total\ sample\ weight}\ 100\% \quad (1)$$

The sediment type was determined following Folk's triangle, and each type was sieved again using a sieve with a diameter of 20 cm

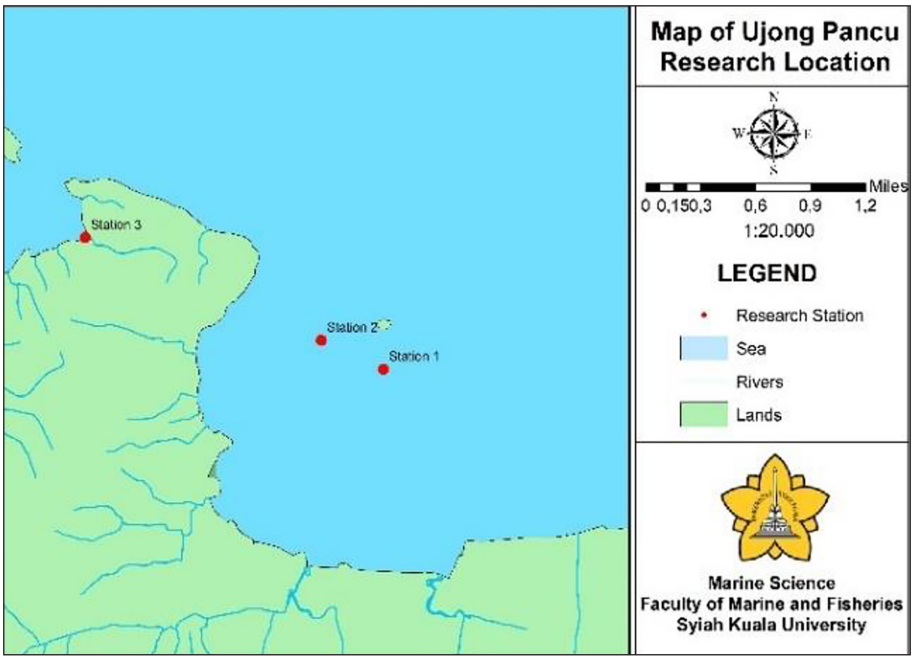

Figure 1. Location of the study sites, Ujong Pancu Waters

with a pore size of 4 mm, to reduce the volume of sediment and took micro size for 250 g. The micro-sediment was heated on a hot plate at 80–90 °C for 30 minutes with 250 ml of 30% H_2O_2, to remove organic material contained in the sediment. The micro-sediment was then suspended in saturated NaCl solution with a salt concentration of 300 gr/l water (Muljani *et al.*, 2021), and was stirred with a stir bar for 2 minutes to homogenize the solution (Peng *et al.,* 2017). After the stirring process, the samples were left for 24 hours at room temperature. The supernatant produced after 24 hours was filtered using 0.45 µm cellulose nitrate filter paper. Microplastic particles on filtrated paper were identified under a binocular microscope (lens magnification 10 x/0.25) in a zig-zag pattern (Peng *et al.*, 2017). The abundance of microplastics was calculated using the following formula Ayuningtyas (2019):

$$Microplastic\ abundance = \frac{Number\ of\ microplastic\ particles\ (particles)}{Sediment\ weight\ (kg)} \quad (2)$$

Coral reef data

The coral coverage was performed using the Underwater Photo Transect (UPT) method, and analyzed using CPCe software (Giyanto, 2013). In the field, top view photography was done using the quadrat (about 250 cm^2) every 1 meter along the 100 meter transect line. The water quality parameters in coral reef, temperature, current speed, pH and salinity were also recorded. The percentage of coral cover was processed by the CPCe application analyzing photos obtained from the field (Giyanto *et al.,* 2010; 2014). The analysis process used 30 random points from each photo quadrat, to obtain the category coverage and coral life form of each random point was identified. The formula determined category percentage has shown as follows:

$$L = \frac{\Sigma Li}{N} \cdot 100\% \quad (3)$$

where: L – percentage of category coverage (%), Li – Number of category points, N –Number of random.

Principal component analysis (PCA) was used for analysis of microplastic abundance, percentage of live coral cover, and other benthic coverage, water quality parameters.

RESULTS

Microplastics in coral reef sediment

The sediment in coral reef showed a type of gravelly sand, which averaged 77.42% of sand based on Folk's triangle (Table 1). The different amounts of microplastic were presented according to station, ranged from 32–68 particles/kg. The highest microplastic abundance was recorded at station 2 with 68 particles/kg, while the

Table 1. Types of sediment sampling from coral reef at the Ujong Pancu

Station	Station point	% Gravel	% Sand	% Sludge	Sediment type
1	St 1.1	20.03	79.97	0.00	Gravel sand
	St 1.2	19.39	80.61	0.00	Gravel sand
	St 1.3	29.08	70.92	0.00	Gravel sand
	St 1.4	30.27	69.73	0.00	Sandy gravel
	St 1.5	24.54	75.46	0.00	Gravel sand
2	St 2.1	20.79	79.21	0.00	Gravel sand
	St 2.2	16.21	83.79	0.00	Gravel sand
	St 2.3	23.35	76.65	0.00	Gravel sand
	St 2.4	12.66	87.34	0.00	Pebbled sand
	St 2.5	14.27	85,73	0.00	Pebbled sand
3	St 3.1	20.24	79.76	0.00	Pebbled sand
	St 3.2	23.60	76,40	0.00	Pebbled sand
	St 3.3	22.82	77.18	0.00	Gravel sand
	St 3.4	31.70	68.30	0.00	Sandy gravel
	St 3.5	29.70	70.30	0.00	Gravel sand
Average		22.58	77.42	0.00	Gravel sand

lowest was found at station 3 with 32 particles/kg (Figure 2a). We found three types of microplastics in sediment samples those were fiber, film, and fragments. Most of microplastic type found in coral reef at Ujong Pancu was dominated by film, with a total abundance of 57 particles/kg and the lowest was fiber with an abundance of 29 particles/kg (Figure 2b and 3). However, the high accumulation of film microplastic was investigated only in station 2 (northwestern Tuan Island), whereas other stations were dominated by other microplastic types.

Coral reef condition and environment

The total coverage of live corals was 49% (Table 3) that was in the sufficient category based on the Indonesian Institute of Sciences (LIPI) in 2018. The highest percentage of coral was recorded at station 2 (northwestern Tuan Island) by 65%. *Acropora* genus dominated in all stations of Ujong Pancu area. The water quality measured at coral reef around Ujong Pancu ranged in marine biota quality standards stipulated in Government Regulation No. 22 of 2021 (Table 5).

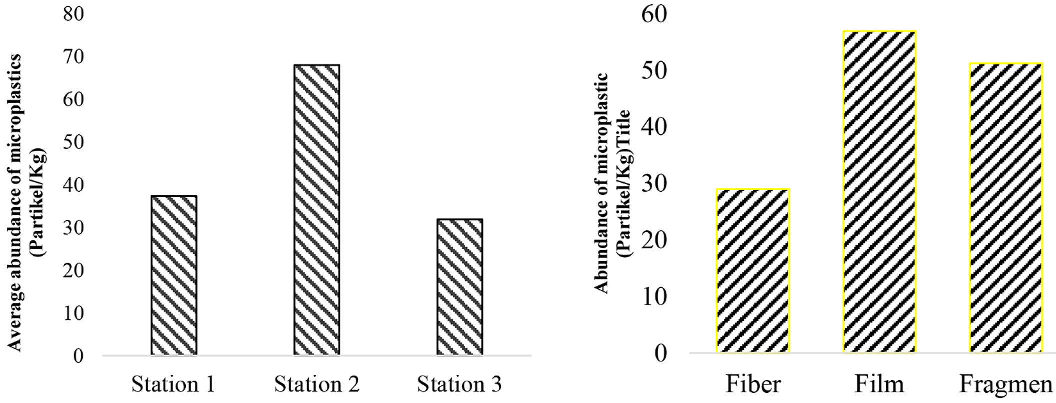

Figure 2. Microplastic abundance in coral reef sediment by (a) stations and (b) microplastic type

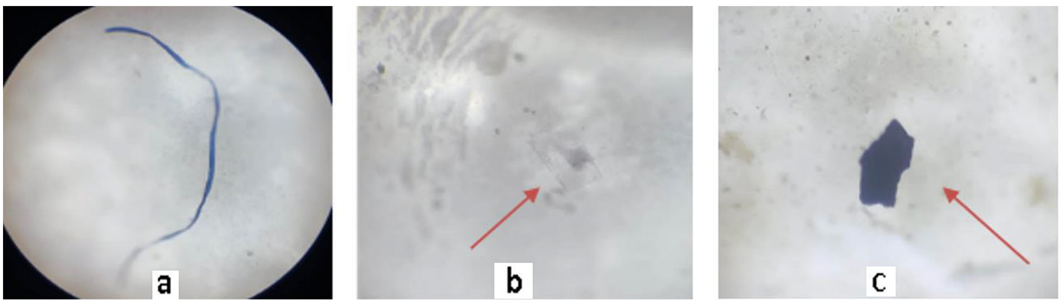

Figure 3. Microplastic particles found in study sites, Ujong Pancu Waters (magnification 10×/0.25), (a) fiber, (b) film and (c) fragment

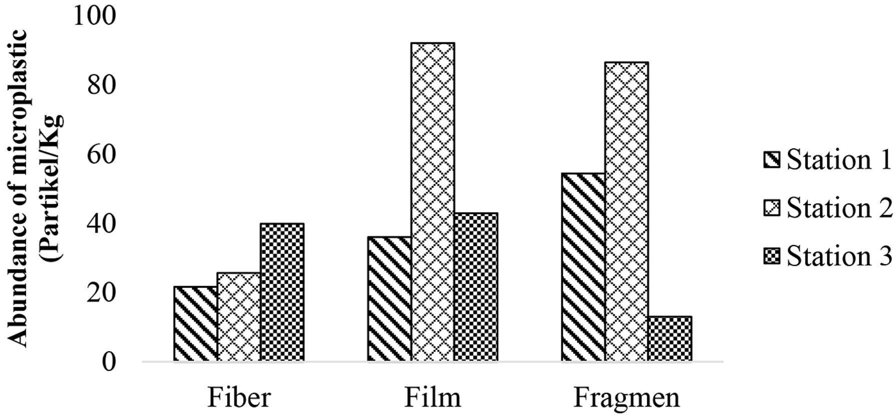

Figure 4. Abundance of microplastic species

Table 2. Microplastic abundance study sites at Ujong Pancu Waters

Station	Point station	Number of microplastics unit type			Microplastic abundance (particles/kg)
		Fiber	Film	Fragment	
Station 1	St 1.1	8	24	24	75
	St 1.2	9	5	12	35
	St 1.3	6	5	4	20
	St 1.4	0	8	9	23
	St 1.5	4	3	19	35
Station 2	St 2.1	11	33	55	132
	St 2.2	1	3	8	16
	St 2.3	6	24	26	75
	St 2.4	4	46	12	83
	St 2.5	10	9	7	35
Station 3	St 3.1	18	18	4	53
	St 3.2	0	12	0	16
	St 3.3	9	4	0	17
	St 3.4	9	10	4	31
	St 3.5	10	7	6	42

Table 3. Average percentage of live coral cover per station

Station	Station point	% Live coral cover	Average (%)
1	St 1.1	27	34
	St 1.2	35	
	St 1.3	30	
	St 1.4	43	
	St. 1.5	35	
2	St 2.1	67	65
	St 2.2	67	
	St 2.3	36	
	St 2.4	80	
	St 2.5	74	
3	St 3.1	45	49
	St 3.2	76	
	St 3.3	73	
	St 3.4	36	
	St 3.5	14	
Total average			49

Relationship between microplastic abundance and live coral coverage, and environmental parameters

Cluster analysis was based on the similarity of data on microplastic abundance, % coral cover, % gravel, % sand, temperature, current velocity, pH, and salinity. The results of the cluster analysis showed that each station point has a significant similarity level with the highest similarity level of 9.7% at station points 3.2 and 3.3, and an insignificant similarity level is at station points 1.1 and 2.1, namely 55. 82%.

The characteristics of microplastic abundance, percentage of live coral cover, percentage of sand, percentage of gravel, water quality parameter values (temperature, brightness, current speed, pH, salinity) which have an influence on all observation stations 85.01% (Fig. 6). Station points 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5 were characterized by microplastic abundance, temperature, brightness and salinity values. Station points 3.1, 3.2, 3.3, 3.4, 3.5 were characterized by current velocity and pH values. Station points 1.3, 1.4, 1.5 were characterized by the percentage of gravel.

DISCUSSION

The abundance of microplastics in Ujong Pancu waters were differently at each station, this caused by the characteristics of different research locations/stations. The highest abundance of microplastics was at station 2 in the northwestern part of Pulau Tuan with 68 particles/kg (Figure 2a). In contrast to the research by Nugroho *et al.* (2018) regarding the abundance of microplastics in the waters of Benoa Bay, Bali Province, where the average abundance of microplastics can reach to 85 particles/kg. The high abundance

Table 4. Life form of coral in Ujong Pancu waters

Life from coral	% Coral cover			Average (%)
	Station 1	Station 2	Station 3	
Acropora digitate (ACD)	5.01	0.00	0.00	1.67
Acropora tabulate (ACT)	0.07	0.00	0.00	0.02
Acropora branches (ACB)	1.34	1.90	37.19	13.47
Coral branching (CB)	0.70	0.00	3.68	1.46
Coral encrusting (CE)	0.80	0.00	0.03	0.28
Coral massive (CM)	6,78	2.84	0.33	3.32
Coral *millepora* (CME)	8.85	8.28	4.51	7,21
Submassive coral (CS)	10,42	51.90	2.64	21.65
Coral foliose (CF)	0.00	0.00	0.47	0.16
Average	3.77	7,21	5.43	

Table 5. Results of water quality measurements in Ujong Pancu waters

Station	Temperature (°C)	Brightness (cm)	Current speed (m/s)	pH	Salinity (‰)
1	32	7	0.08	7	38
2	32	8	0.06	7	38
3	30	6	0.14	8	35

of microplastics at station 2 is suspected because station 2 is close to Ujong Pancu beach which is a tourist spot and also close to residential areas. The study of microplastic abundance in the Karimunjawa Marine National Park, Muchlissin *et al.* (2020) stated that the abundance of microplastics in the area was influenced by the activities of visiting tourists. Anthropogenic waste generated from household and tourist activities, such as toiletries, snack packaging, and plastic bottles, is thought to have been carried away by currents and waves that swept the coast into the waters. Hidalgo-Ruz *et al.* (2011) stated that plastic-based wa can be fragmented into microplastics in various forms such as fragments, films, fibers, pellets, and granules. These microplastics can settle in sediments due to the *biofouling activity* of microorganisms (Lusher *et al.,* 2017).

Station 1 in the southern part of Tuan Island found the second highest abundance of microplastics after station 2, as many as 37 particles/kg (Figure 2a). Station 1 is close to the pier and small harbor where fishing boats parked and trade, plastic waste produced from fishing activities can be fragmented into microplastics. This is in accordance with Dewi *et al.* (2015) which states that plastic waste can be generated from port activities, for example plastic bags for wrapping fish and fishermen's fishing gear.

The lowest abundance of microplastics was found at station 3 of the Lhok Mata Ie coast with 32 particles/kg (Figure 2a). Lhok Mata Ie beach is quite far from residential areas and less of human activity in that location. This is in accordance with Manalu (2017) which states that fewer human activities with low abundance of microplastics, but the presence of microplastics at station 3 is thought to result from visiting tourists and fishing activities at that location. Ayuningtyas (2019) states that the abundance of microplastics in a waters can be caused by fishing activities at that location. Abundance of films and fragments were found at station 2 in the northwestern part of Tuan Island with values of 92 particles/kg and 86.4 particles/kg respectively (Figure 2b). Station 2 which is close to the beach, residential areas and the pier. The large number of activities in the area has a high probability of dumping waste in the coastal area which then flows into the sea. Film type microplastics come from the degradation of plastic bags and food packaging which tend to be transparent (Claessens *et al.*, 2011) and according to Sari (2015) states that household plastic waste is the biggest source of fragment type microplastics. The abundance of fiber type microplastics was found at station 3 on Lhok Mata Ie beach as much as 40 particles/kg (Figure 4). This may be due to the relatively high fishing activity marked by the large number of remnants of fishing equipment such as fishing line and nets found at that location. This is in accordance with Kurniawan *et al*. (2021) who stated that fiber microplastics come from fragmentation of plastic waste in the form of fishermen's nets or fishing lines.

The temperature of Ujong Pancu waters was in the range of 30–32 °C (Table 5), is still considered good for coral growth. Zurba (2019) states that coral can survive at a maximum temperature of 36 °C. The brightness of Ujong Pancu waters (Table 5) meets the quality standards for marine biota according to Government Regulation No. 22 of 2021, namely > 5 m. The current speed in the Ujong Pancu waters ranges between 0.06–0.14 m/s. The current speed is still good for coral growth. The degree of acidity (pH) in Ujong Pancu waters meets the quality standards for marine biota according to Government Regulation No. 22 of 2021, namely 7–8. The salinity of Ujong Pancu waters is in the range of 35–38‰ (Table 5), this value is not in accordance with Government Regulation No. 22 of 2021 for coral growth of 33–34‰. This condition can be influenced by the weather when measuring salinity, hot weather can increase evaporation or evaporation on the sea surface resulting in an increase in water salinity, but rainy weather will cause low salinity (Moira *et al.*, 2020).

Cluster analysis of Ujong Pancu waters had the highest equation of 9.7% at station points 3.2 and 3.3. The percentage values of coral reefs at the two station points were not much different, namely 76% and 73% (Figure 5) with lower microplastic abundance values of 16 particles/kg and 17 particles/kg. The good condition of coral reefs with low microplastic abundance is thought to be caused by the location of station 3 which is far from residential areas and have low human activity at that location, this is in accordance with Assuyuti et *al.* (2018) settlements with high human activity can affect the condition of coral reefs. The lowest similarity was 55.82% in station *clusters* 1.1 and 2.1, where at both station points the microplastic abundance values were much higher, namely 75 particles/kg and 132 particles/kg (Table 1) compared to the percentage of live coral cover, which was 27%. and 67% (Figure 4, 5). This is thought to be caused by station points 1.1 and 2.1 which are close to residential areas and the large number of human activities at these locations such as household activities, tourists, and fishing, as well as being locations for ships or fishing boats to cross, so that waste production, especially plastic waste, is more tall.

Based on principal component analysis (PCA) (Figure 6) station points 1.1 and 2.1 were affected by the values of microplastic abundance, temperature, brightness, and salinity may cause the percentage of coral cover at stations 1.1 and 2.1 to be lower with a percentage cover of 27% and 67% (Figure 5). Environmental factors that greatly influence the high abundance of microplastics at stations 1.1 and 2.1 are temperature, brightness and salinity. Barnes *et al*. (2009) stated that mechanical damage to plastic is caused by degradation due to water temperature (thermal degradation), temperature can help degrade

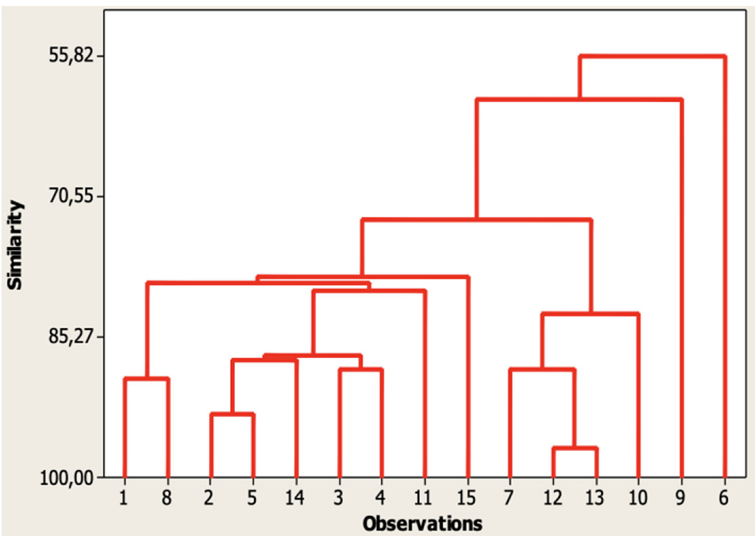

Figure 5. Dendogram of station points at level of similarity

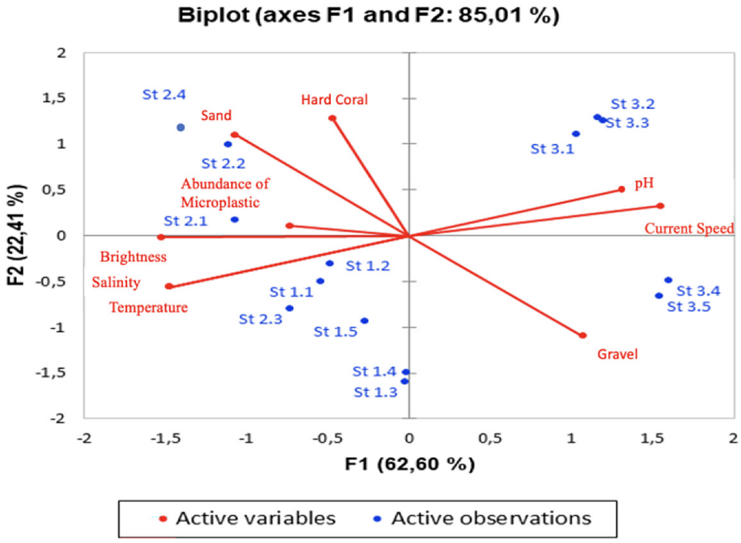

Figure 6. PCA graph

plastic into small-sized particles (microplastics), so that higher temperatures lead to higher abundance of microplastics. Apart from temperature, salinity also helps the fragmentation process of plastic. Higher salinity will cause higher density. Teuten *et al.* (2009) stated that the level of plastic fragmentation in seawater depends on the density value of the plastic. Plastic which has a higher density than sea water will easily settle to the bottom of the water compared to microplastic which has a lower density which will float on the surface of the water. Brightness also affects the abundance of microplastics. Febri *et al.* (2020) stated that the factor that influences the distribution of microplastics is the level of transparency of the water column. Water that has low brightness is indicated to have a lot of suspended particles, both dead and alive, such as plankton and bacteria. Bacteria can help the plastic degradation process (Hamuna *et al.,* 2018).

Station points 3.2 and 3.3 were influenced by the pH value and current speed (Figure 6). The pH value at stations 3.2 and 3.3 has the same value, namely 8 (Table 4). The pH value is still good for coral growth. The current velocity values at station points 3.2 and 3.3 also have the same value, namely 0.14 m/s. The pH value and current velocity at station points 3.2 and 3.3 are still at the threshold for coral growth. This is thought to have caused the percentage of coral cover at station points 3.2 and 3.3 to be still relatively high with a cover percentage value of 76% and 73% (Figure 6).

A different thing is shown at station point 2.4 where the percentage values of coral reefs with microplastic abundance at these station points are not much different, namely 80% and 83 particles/kg. Muchlissin *et al.* (2020) stated that damage to coral reefs caused by microplastics is only 3–5%. The research results from Ulfah *et al.* (2021) damage to coral reefs on Tuan Island increased in 2018. This was caused by the discharge of aquaculture pond waste into the waters and the increase in *Achantaster planci. Acantaster planci* is an organism that eats coral polyps making it the most dangerous coral predator. Pond waste contains organic materials such as protein, carbohydrates and inorganic materials such as nitrogen, phosphorus and ammonia. This waste can damage corals and can cause coral death. Ulfah *et al.* (2021) in the results of their study stated that high wave intensity in the waters of Ujong Pancu, especially Lhok Ketapang and Lhok Mata Ie, caused coral damage. Lhok Mata Ie is dominated by coral Acropora branching (ACB) with a coverage percentage of 37.19% is very easily broken due to high waves.

CONCLUSIONS

The presence of microplastic contaminants has been a critical issue on coral reef ecosystem. In Ujong Pancu waters, Aceh Province, it was found various types of microplastics trapped in the sediments of the coral reef ecosystem, namely fiber, film, and fragments. The average abundance of microplastics at each station was 37 particles/kg, 68 particles/kg, and 32 particles/kg. Meanwhile the condition of coral reefs in Ujong Pancu waters is in the moderate category with an average percentage of live coral cover of 49%. Although, the strong relationship between the abundance of microplastics and the percentage of live coral cover and environmental parameters were not observed at all studied stations, a significant similarity level of 97% was monitored at station 3. It suggests that the coverage of live coral was affected by the existence of microplastic mainly driven the fishing activities and environmental parameters. As this area located around the marine protected area of Aceh Besar regency, the further studies of the biological impact of microplastic on coral reel productivity as well as the chemical leaching of microplastic on coral reef life cycle are needed.

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