Analysis of types, forms and abundance of microplastics in the mangrove forest area of pusong island, langsa city

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Abstract. Pollution of mangrove waters by microplastic particles is coastal plastic waste pollution which has become a major water pollution problem in developing countries. However, this pollution problem, both qualitatively and quantitatively, has not yet been discussed comprehensively. Therefore, it is necessary to analyse the level of microplastic presence and identify the types of microplastics of each size found in the water in the mangrove forest area of Langsa City-Aceh. The aim of this research is to analyse the presence, shape and dominance of microplastic particles in the mangrove waters of Langsa City. The research method was carried out by taking water and river sediment samples based on SNI 03-7016-2004 and the samples were the result of a combination of places (integrated samples). Separation of microplastics is carried out by filtering, destroying organic compounds, separating based on specific gravity and filtering using vacuum. Identification of the type, shape and abundance of microplastics is carried out using a microscope. The analysis results show that microplastics in water are generally of the fragment and fibre type with a density of between 7 - 13 particles per Liter with an average size of 200 μm.

1 Introduction

Pusong Island is a coastal area located in Gampong Telaga Tujuh, West Langsa District, Langsa City, Aceh Province. Pusong Island is six miles from the port of Kuala Langsa. Access to this island requires a ferry boat about 30 minutes from Kuala Langsa port. Nearly 80% of the livelihood of Pusong Island residents is as fishermen who use this water access, the rest work as traders, salted fish processors, ferry service providers and others.

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As an estuary area that is still influenced by river flows, Pusong Island is thought to carry a lot of plastic waste which is generally produced by the community [1]. Around 80% of plastic waste comes from land, while 20% comes from the sea [2]. This is exacerbated by the input level being greater than the degradation time, especially for plastic waste which dominates ¾ of marine waste and 10% of which is newly produced waste [3], [4]. The distribution of microplastics is also influenced by wind movements, the movement of marine biota, currents and the characteristics of the polymers that make up the plastic [5]. Coastal areas, especially industrial areas, are hotspots for microplastic accumulation [6], [7].

Microplastic waste can be found on the surface, columns and bottom of waters (substrate), beaches, rivers and estuaries [8]. Microplastics found in sea water come from river flows, as the main route for microplastics from terrestrial sources [9]. Microplastics can also come from community activities around rivers and coasts [10]. Microplastics have an impact on the environment [11] because of their size, microplastics are susceptible to being consumed by organisms in waters by accidentally swallowing them and mistaking microplastic particles for food [7]. Microplastics cause various negative impacts on fish that consume them, such as internal organ infections, blockages, carcinogenesis, endocrine disruption, physical damage (resulting from accumulation, translocation, shape, egesting, population level effects, transfer to the food chain), changes in lipid metabolism and behavioural changes as well as toxicity [6], [12].

Several reports of fishing nets being abandoned/untied and becoming ghost fishing, causing fish to die due to entanglement and it is feared that the consumption of microplastics by fish will cause bioaccumulation and biomagnification in the food chain[13]. In addition, microplastics not only impact the marine environment and organisms, but can also impact humans as final consumers through transfer to the food chain [6]. The presence of microplastic pollutants in aquatic biota consumed by humans can pose a food safety risk, because it has an impact on health [14]. Exposure to microplastics can cause inflammation, oxidative stress, cell poisoning, while the chemicals in them cause digestive and reproductive disorders and trigger an immune response. Inhaled microplastics will cause respiratory problems and inflammation [15].

Coastal areas are the most vulnerable areas to microplastics, this is because coastal areas are dynamic areas and are influenced by tides, so the presence of microplastics will spread throughout the mangrove forest area [16]. Mangrove roots and other natural processes will increase the mechanism for trapping microplastics [17].

Microplastic pollution has been found on the sea surface, bottom waters, water column, beaches, rivers, estuaries, bays and open seas in polar and equatorial regions, including the Arctic and Antarctic seas [8]. As much as 330 million metric tons of plastic waste is produced globally per year [18]. According to [19], the volume of input of plastic waste from the East Asian continent into the surrounding seas is the largest in the world. The presence of microplastics is also found in Indonesia with an estimate of 0.48 to 1.29 million metric tons per year and this is considered the second largest contributor of plastic waste to the sea in the world after China [20].

2 Material and Methods

The material in this research is water from the waters of the mangrove forest area of Pusong Island in Langsa City, Aceh Province. The method used in sampling is the purposive sampling method. Purposive sampling was taken at four representative stations (**Figure 1**), namely water areas and mangrove forest areas closest to residential areas, water inflow from coastal waters to the estuary, mangrove forest areas with low levels of mangrove density and areas with high levels of mangrove forests. the mangrove density is high. Water samples were taken at the top of the surface, but before taking the water samples, environmental quality measurements were carried out at the four stations, namely measuring temperature, salinity, pH and ocean currents.

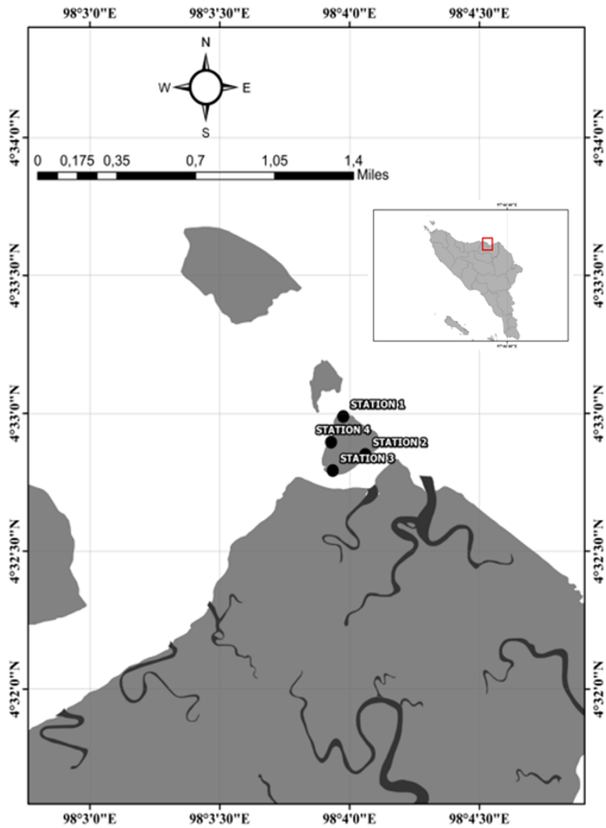

Fig. 1. Map of study area and the location of sampling

Fish acclimatization was carried out individually in transparent containers for one week (Photoperiod 12:12 hours light: dark; DO: 6.2 mg O^2/L; temperature: 25 C; PH: 7.5 and turbidity: <1 NTU). To avoid stressful conditions due to interactions between fish, each side of the acclimatization container was lined with opaque paper. Feed in the form of silk worms was given twice a day (09.00 and 16.00 WIB) ad libitum [6]

2.1 Water Sampling Method

Water samples were taken using a water sampler, then filtered using a plankton net with a diameter of 30 cm and the mesh size is 200 µm. The water samples that have been taken were then put into a 600 ml sample bottle and stored in a storage box to avoid contamination. Next, the separation was carried out using a floatation tool, where the process of separating water from microplastics was carried out in stages by adding 200 ml of sample water every time (3 repetitions) which is then added with filtered sea water to the limit of the floatation tool. Next, the samples were stirred evenly for 5 minutes and let sit for 10 minutes. The sample at the top of the floatation device were poured into a 100 ml sample bottle with every 50 ml of sample water which were separated into a different sample bottle and were labelled. To the 50 ml water sample of microplastics, a 23 ml of 70% ethanol solution was added and to the remaining 50 ml water sample of microplastics no ethanol solution was added to see the differences between the two samples. Ethanol helps to discolour organisms and brightens the colour of plastic [21].

2.2 Extraction of Microplastic Samples

The extraction process was carried out at the Marine Chemistry Laboratory, Faculty of Marine and Fisheries of Syiah Kuala University. On a sample of 50 ml of water, the 20 of 30% H_2O_2 was added using a dropper pipette and stirred with an iron spatula to homogenize the sample. Next, place the sample on a hot plate stirrer at 30 ºC for 10 minutes with 150 ml of saturated NaCl solution added for density separation. The density separation process was carried out for 20 minutes and the sample was poured into an Erlenmeyer flask then covered with aluminium foil to leave for 12 hours. The results of this sample extraction were then taken as much as 20 ml for each water sample. The sample that has been extracted was then poured into a funnel with filter paper at the top to filter the sample and then dried for 48 hours (2 days). After the sample was visibly dry, the filter paper on a petri dish was palced and put it in the incubator machine to completely remove the water content on the filter paper at a temperature of 40 ºC for 8 hours. After the extraction process is complete, observations was made using a stereo microscope [22].

2.3 Identify Type, Colour and Size of Microplastics

Identification of micro plastics was done by classifying six types of microplastic, namely films, fragments, fibers, foam, pellets and granules [23]. Identification of microplastic types was also carried out based on type, color and size using a stereo microscope (Olympus SZ61) with 10x-40x magnification with an attached software camera [24]. Microplastic particles were counted in a “zigzag” pattern from left to right. The data was processed using Microsoft Excel and displayed in the form of tables and images which were analyzed descriptively [22].

2.4 Calculating the Abundance of Microplastics in Water

Calculation of microplastic abundance can be calculated using the equation:

$$K = \frac{n}{v}$$

Information:
K = Abundance of microplastics (particles/m^3)
n = Number of Microplastics (Particles)
v = Sample volume (m^3)

3 Result and Discussion

Before collecting microplastic data, environmental parameters are first measured. The results of measuring these parameters can be seen in **Table 1**. The location of station 1 is the point closest and directly facing the settlement of the Pusong Island population, of course this will not have a big influence on the current if seen from the results of the environmental parameter measurements that have been carried out. This is different from station 2, which is the entry point for free coastal waters into the estuary. This point is the entry point for fishermen who want to go to sea to find fish. Currents and salinity also greatly influence this station point, this is proven by the strong currents and high waves that make the condition of the mangrove ecosystem at station 2 not very fertile and relatively low. Meanwhile, at station 3, even though it is adjacent to station 2, the condition of the mangrove ecosystem in this area is fertile because of the good and sufficient supply of nutrients. Many fishermen use this location as a place-to-place crab traps (bubu) which proves that the influence of the current is not that big. Fishermen in this area can maintain their fishing gear. The salinity and temperature measurement data shows that it is suitable for the habitat of mangrove crabs. At station 4, the measurement results show that the condition of the mangrove ecosystem is lower but better at station 4 compared to station 2. However, the condition of the water environment is almost the same as station 1, namely the current, temperature and salinity are relatively low.

Table 1. Results of environmental parameter measurements at sampling stations

Parameters	**Station 1**	**Station 2**	**Station 3**	**Station 4**
PH	7.1	7.4	7.2	7
Température	31.3^0C	35.6^0C	31.1^0C	35.5^0C
Salinity	32	33	32	33
Curent speed	28.25 m/s	7.70 m/s	18.22 m/s	25.18 m/s
Direction	North-East	East	North-East	North-East

3.1 Microplastic Abundance

The highest abundance of microplastics was found in water samples without ethanol, namely 0.275 particles/m³ and the lowest abundance was found in water samples that had added ethanol solution, namely 0.174 particles/m³ (**Table 2**). The high concentration value of microplastics on the surface of the water can be caused by the low mass of microplastics and microplastics being released in seawater with a high salt content, making the microplastics continue to float [25].

Table 2. Abundance of Microplastics at Each Station

Sample	**Type of Microplastic**	**St 1**	**St 2**	**St 3**	**St 4**	**Average (particle/m³)**
Water + Ethanol	Fiber/Line	0,08	0,06	0,08	0,1	0,08
	Fragment	0,08	0,08	0,08	0,1	0,085
	Film	0	0,02	0,02	0	0,01
	Foam	0	0	0	0	0
	Pellet	0	0	0	0	0
Total		**0,16**	**0,16**	**0,18**	**0,2**	**0,175**
Water - Ethanol	Fiber/Line	0,14	0,06	0,12	0,1	0,105
	Fragment	0,26	0,06	0,2	0,06	0,145
	Film	0,02	0	0,02	0,04	0,02
	Foam	0	0	0,02	0	0,005
	Pellet	0	0	0	0	0
Total		**0,42**	**0,12**	**0,36**	**0,2**	**0,275**

As shown in **Table 2**, there were differences in abundance between water samples that had ethanol added and those that had not been added. This proves that the ethanol solution influences the microplastic samples. Kim *et al.*,[26] said that if there are different methods for adding ethanol solution, it can remove several types of microplastic pollutants.

Based on the analysis results, the highest abundance of microplastics was found at station 1 at 0.35 particles/m³ (**Figure 2**), where this station is the point closest to people's homes. According to [27] that high population density can influence the distribution and concentration of the abundance of microplastics found. One of the factors causing the dominance of microplastics in the environment is household activities [4]. Waste from human activities can be leftover clothing threads that come from washing clothing fabrics and plastic ropes that have undergone a degradation process [28]. Furthermore, the second highest abundance of microplastics was at station 2, with a total abundance of 0.28 particles/m³ (**Figure 2**). The high abundance of microplastics at station 2 could be caused by it being a place where sea waters enter the estuary. Apart from that, Station 2 is also a route for Pusong Island fishermen who want to catch fish in the sea. Based on research by [29], the source of microplastics can come from the fragmentation of plastic that enters the environment, either through river flows, run off, tides, carried by the wind, or from the sea such as passing ships. as well as fishing gear

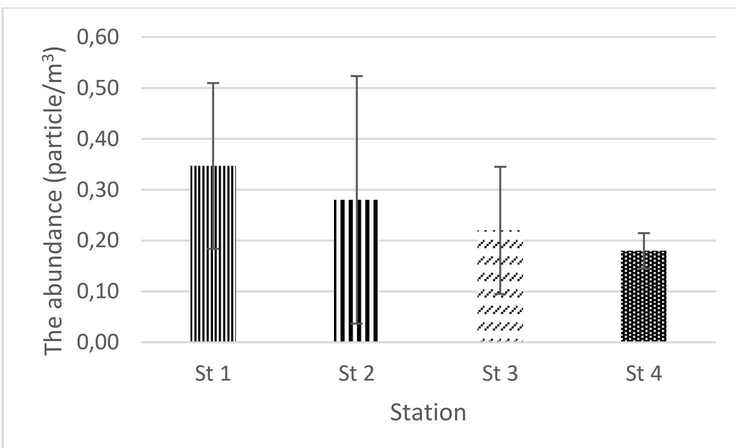

Fig. 2. The abundance of microplastics in Pusong island

The abundance of microplastics at station 2 automatically influences the abundance of microplastics next to it, namely station 3, which has the third highest abundance of microplastics at 0.22 particles/m³ (**Figure 2**). This could be caused by sea currents and winds which carry microplastic particles to this station. According to [11] that repeated movements of currents and gravity can be a factor causing the movement of microplastics in the water column to other places so that the amount of microplastics tends to be different at each station.

At station 3 there is also a river flowing into the sea estuary. River water flow is one of the main routes for microplastics to enter the marine environment [30]. This could be the main factor in the high abundance of microplastics at this station. Meanwhile, the lowest abundance of microplastics was at station 4, namely 0.18 particles/m³. Station 4 is between station 3 and station 1, each of which is only 10 meters away. It is thought that currents will transport microplastic particles in the water column to move them to other places [29].

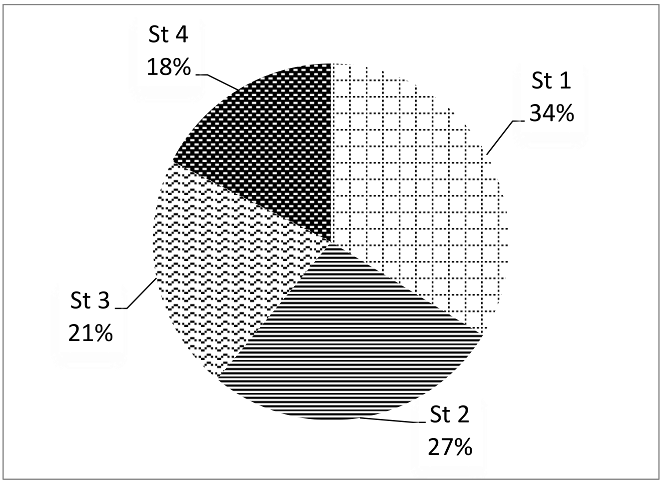

Fig. 3. Percentage of Microplastic Abundance on Pusong Island

Based on the analysis results in **Figure 3**, the highest percentage value of microplastic abundance is at station 1, namely 34%, while the lowest percentage abundance is at station 4, namely 18%. Therefore, the results of this analysis are in accordance with what has been found by several previous researchers in areas with the same characteristics as the findings in this study.

3.2 Type of Microplastic

According to [31] the types of microplastics commonly found on water surfaces are fragments, fibres and films. Based on observations of the water on Pusong Island (**Figure 4**), the highest percentage density of microplastics is the fragment with the value of 49%. Furthermore, the second highest is the fibre at 41% and followed by the film at 7%. Meanwhile, the lowest density percentage is the type of foam, at 2% and pellets are only 1%. Fragment type microplastics are produced from waste such as bottles, jars, and small pieces from Parallon pipes. The high abundance value of microplastic fragment types can be caused by the dominance of the amount of waste on riverbanks, such as plastic bottles or other household plastic waste. The process of fragmentation and size reduction of macro-sized polypropylene plastic waste will occur if the plastic waste flows in river flows and becomes fragmented microplastic waste.

The distribution of fibre-type microplastics can be influenced by fishing activities, fishing nets or abandoned nets which then undergo a monofilament degradation process [10]. According to [28] fibre type microplastics can originate from waste resulting from human activities which enter river flows until they settle and accumulate in sediment. Waste from human activities can be leftover clothing threads that come from washing clothing fabrics and plastic ropes that have undergone a degradation process [28].

As a result of observations of microplastics in water samples on Pusong Island, five forms of microplastics were found, including fragments, fibres, films, foam and pellets (Figure 5). Fragment type microplastics have a rough surface and jagged edges. Fragmented microplastics were the most frequently found in water samples at all observation stations. This has an impact on the high use of solid textured plastic items such as household utensils and beverage bottles. Apart from that, the fibre-shaped microplastics identified in this study were the second most frequently found. Fiber-shaped microplastics were found at all observation stations. Microplastic fibre comes from fishing activities and household activities [2], of course this is in line with the facts on the ground that Pusong Island has a high population density with the majority of the population working as fishermen. Meanwhile, film-shaped microplastics were also found at all observation stations, although not too many, but this indicates that there are plastic bags and other plastic packaging that have experienced degradation and fragmentation due to waste that is not managed properly [32]. Meanwhile, microplastics in the form of foam and pellets were only found at a few stations, and the number found was the lowest compared to the other three forms of microplastics, this was due to their lower or lighter density so they tended to be easily carried away by currents or easily transported [29].

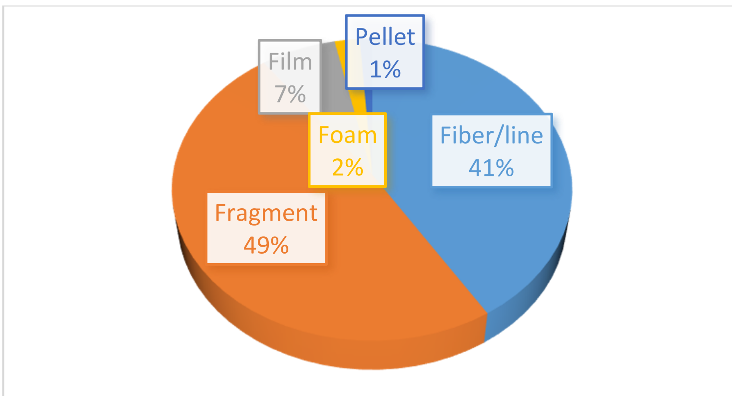

Fig. 4. Percentage Density of Microplastic Types on Pusong Island

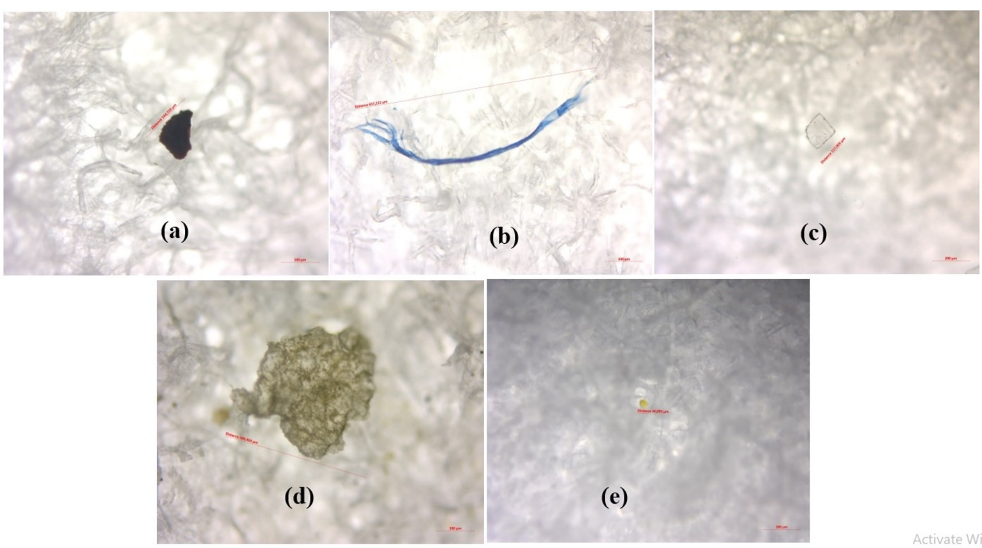

Fig. 5. Forms of microplastics found on Pusong Island (a). Fragments, (b). Fiber, (c). Film, (d). Foam and (e). Pellets

3.3 Type of Microplastic

The colours of microplastics found at all stations were white, black, red, yellow, blue and brown (Figure 6). The most dominant colours of microplastics were black and brown with a total of 41 particles each, while the colour that was least found was green with a total of 5 particles. The differences in the colour of microplastics vary greatly due to the length of time the microplastics are exposed to sunlight so that the polymer undergoes oxidation which results in colour changes in the microplastics themselves [33].

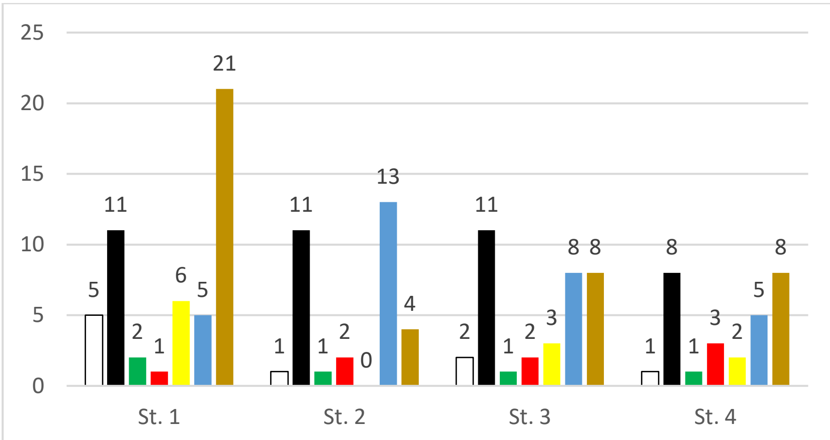

Fig. 6. Microplastic abundance separated by color

As shown in **Figure 6**, not only black, brown and green can be found at all observation stations, but blue, white and red are also found. Yellow is not found at station 2, however, it is found at the other three stations. As for station 1, the colour most found is brown, while at station 2 it is blue. This is different from station 3 which is dominated by black and then station 4 has the two colours that are most found, namely black and brown. According to [34] observing the colour of microplastics will be useful to find out the source of the pollutant. Fragment type microplastics have various colours such as red, green, blue, orange and brown [35]. Fiber is shaped like thread with various colours such as blue, red and black [10]. Fiber comes from fishing lines and net fishing equipment and can also come from clothing that is no longer used and experiences friction so that it breaks down into very small plastic particles, or fabric fibres left over from washing clothes that are carried by currents into the water [36]. The red, blue, and black colours are believed to come from clothing threads and wastewater from washing. The microplastic film type is black and white (grey) like plastic sheets, while the foam type is white and green with a rubbery texture, and the pellets are black, orange, and grey. The presence of colour or transparency makes it possible for marine biota to accidentally eat it [37]. The white or transparent colour is thought to come from plastic bags and Styrofoam that are thrown away carelessly. Red and blue are artificial colours from anthropogenic results or colours that have been degraded by sunlight (UV), while black can be indicated by the large number of contaminants absorbed in microplastics and other organic particles. If the colour of the microplastics found is still dark, it indicates that the microplastics have not undergone significant discolouring.

3.4 The Size of Microplastic

Based on the results of observations of microplastics using a stereo microscope, the sizes of the microplastics found in each type of sample, both sediment and seawater samples, have different sizes.

Microplastics are composed of irregular fibres to round and long fibres [10]. Based on **Table 3,** microplastics in the form of fragments have various sizes in water samples. The smallest fragment size was 17.6 µm and the largest fragment size was found at 611 µm. Of all the sizes of microplastics found, fibre was the largest in all water samples, compared to the sizes of other microplastics. The fibre shape is always elongated, even reaching a size of 1755.5 µm in water without ethanol and the smallest size, namely 31.3 µm in water samples with ethanol added, this result is almost the same as that found by [38]. Meanwhile, for film-form microplastics, the smallest size found was 71.5 µm in seawater samples without ethanol and the largest size was 197 µm found in sediment samples. Meanwhile, the size found in the foam form was 577 µm and the pellet form was 23.4 µm in the water sample without ethanol.

Table 3. Size of microplastics in water samples on Pusong Island

Sample	Type of Microplastics	Size (µm)
Water with Ethanol	Fragment	33,2 - 611 µm
	fibber	31,3 - 828,4 µm
	film	197 µm
Water without Ethanol	Fragment	17,6 - 416,5 µm
	fibber	63,3 - 1755,5 µm
	film	71,5 - 136 µm
	foam	577 µm
	Pellet	23,4 µm

The size differences in microplastics are influenced by the length of the microplastic fragmentation process in waters. The microplastic fragmentation process can also be influenced by ultraviolet radiation and strong mechanical forces from waves and sea currents [11]. Small-sized microplastics show a long fragmentation process, until the plastic particles are broken down into smaller sizes (Hebner and Maurer-Jones, 2020). Many smaller microplastics are buried in deeper layers of sand or sediment before being transported by ocean currents [39].

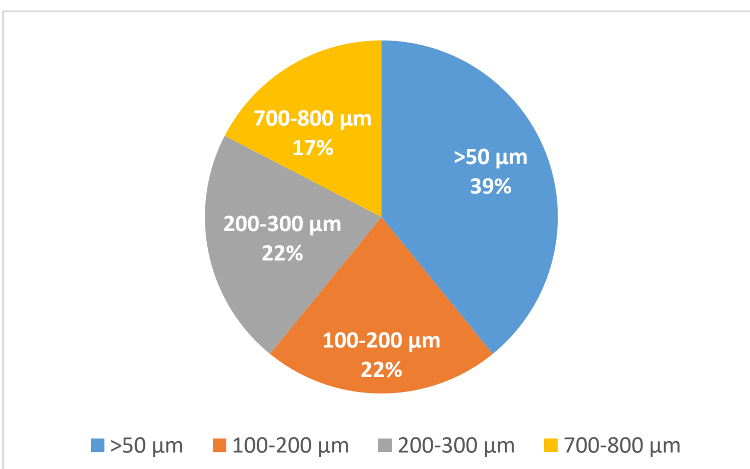

Fig. 7. Percentage of microplastic size in seawater samples added with ethanol

In seawater samples added with ethanol (**Figure 7**), it was found that the most found microplastic size was >50 µm in size at 39%, while the smallest size found was 700-800 µm in size, namely only 17%. In contrast to the size obtained in sediment samples, the size of seawater samples with ethanol added was larger, even reaching 700-800 µm, although only 17%.

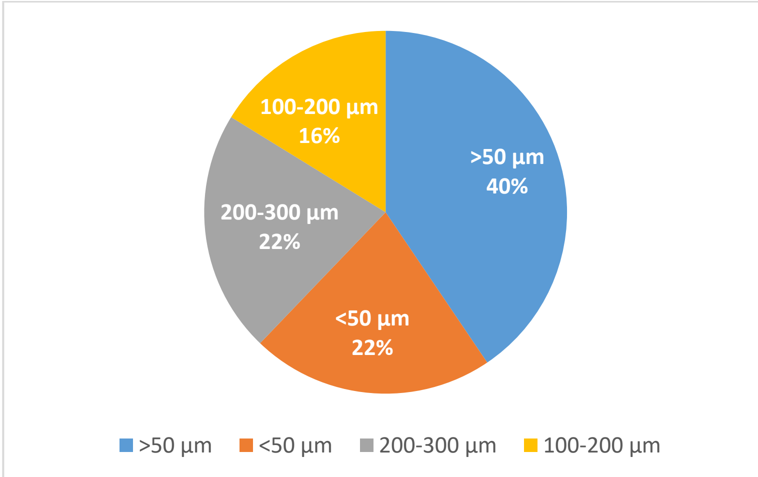

Fig. 8. Percentage of Microplastic Size in Seawater samples without Ethanol

Meanwhile, in seawater samples without ethanol (**Figure 8**), the largest percentage of microplastics was found in sizes <50 µm, namely 40%, while the smallest size found was 100-200 µm, which was only 16%. Of the three samples, both sediment samples and seawater samples, the most dominant size was found to be the same. According to [11,40], the time for plastic to fragment is largely determined by the physical conditions of the environment. The presence of microplastics in an aquatic ecosystem will have the same influence on the surrounding waters [9].

4 Conclusion

The highest abundance of microplastics found on Pusong Island was 0.35 particles/m³ at station one, while the lowest abundance was at station 4 with a total of 0.18 particles/m³. The types of microplastics found on Pusong Island consisted of 5 types, namely fragments (49%), fibber (41%), film (7%), foam (2%) and pellets (1%). Meanwhile, the colours of microplastics found at all stations were white, black, red, yellow, blue and brown. Meanwhile, for the size of the microplastics found based on observations using a stereo microscope, the smallest fragment size was 17.6 µm and the largest fragment size was 611 µm, while for the type of fibber that is always elongated, the largest size was around 1755.5 µm. and the smallest size is 31.3 µm. Meanwhile, for the film type the smallest size was found to be around 71.5 µm and the largest size reached 197 µm and for the size of foam type microplastics it was only found with a size of 577 µm and the same thing with the pellet type was found at 23 .4 µm.

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