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RESEARCH ARTICLE

Abundance Analysis of Microplastics and Community in Batik Mussels *(Paphia undulate)* in Water Regions of East Java, Indonesia

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ABSTRACT

Microplastics are plastic waste degraded by sunlight into small particles < 5 mm in size. Batik mussels (*Paphia undulata*) have filter feeder properties, few detoxification enzymes, and are sedentary animals; therefore, they are very likely to be contaminated with microplastics. This study aimed to determine the abundance of microplastics and the level of community consumption of batik mussels (*Paphia undulata*) in the waters of Banyuurip and Ujungpangkah, Gresik Regency, East Java. The research stage consisted of primary and secondary data collection. Mussle samples were collected using purposive sampling at two locations: Banyuurip and Ujungpangkah. For complementary data, direct interviews were conducted with communities in the field. Data analysis was carried out descriptively based on the data obtained. The results of this study showed that there were 3 forms of microplastics found in this research, there are fiber, fragments, and filaments the dominant form is fiber with a total of 100 particles/head. Fiber is caused by the activities of fishermen and is a form that easily accumulates during the digestion of biota. Blue was the dominant color found in all locations. The microplastic particles ranged in size from 0.083 to 4.619 mm. The highest abundance of microplastics was found at location 2 with 0.78 particles/head. The results of interviews with 30 respondents indicated that the local community consumed batik mussels at a weekly frequency of 15 people, with an average consumption of < 50 g/day for 18 people and > 50 g/day for 12 people.

Introduction

Microplastics are a new pollutant in Indonesian waters with the potential to harm aquatic ecosystems significantly. Because of a lack of awareness and proper waste management and processing, the use of materials containing plastic elements has resulted in the accumulation of plastic waste in water. Plastic waste is a long-lasting material that is difficult to decompose. However, plastic waste can be degraded by ultraviolet light, microbes, and physical and chemical properties over time, resulting in smaller particle sizes, known as microplastics [1]. The majority of plastic waste is generated by human activities, both individual consumption and industrial or commercial activities, and it is estimated that approximately 500 billion plastic materials are used annually, and 13 million tons end up in water areas, threatening and killing 100,000 aquatic ecosystems [2]. Microplastic investigations in Indonesia have been reported, one of which is profiling the abundance of microplastics in mangrove ecosystems that have been contaminated with microplastics and several types of polymers in the Jakarta and Surabaya areas [3,4]. The process of microplastic movement before entering the downstream (sea), investigations were carried out on water and sedimentation samples in the Surakarta River with the composition of Polystyrene, Silicone polymer, Polyester, Polyamide [5].

Microplastics are small particles of plastic waste that have been degraded by sunlight and have a size limit of < 5 mm, with an unknown lower size limit [6]. Owing to their small size, microplastics can be consumed by aquatic biota, such as fish, mollusks, and crustaceans, allowing microplastics to enter the food chain system. Microplastics are classified into several types based on their shape, including fibers, films, fragments, foams, and pellets [1]. Microplastics in aquatic biota are found in animals of the Bivalvia class, specifically batik clams

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(*Paphia undulata*). Microplastics in shellfish pose a new threat to Indonesia's food security because shellfish are high in protein and amino acids, both of which are beneficial to the body and are widely consumed by people. Shellfish can be easily contaminated by microplastics because they have filter feeder properties, namely filtering and absorbing whatever is around them, and have few detoxification enzymes compared to vertebrate animals, so contaminants that enter their bodies tend to accumulate and have slow movement activity or are often referred to as sedentary animals, so they may be unable to avoid contaminants around them [7].

Microplastic contamination has been found in the waters of Banyuurip Village, Ujungpangkah Subdistrict, and the Gresik Regency. Several previous studies on the presence and abundance of microplastics in Banyuurip waters have been conducted [8,9]. Many microplastics with fragments equal to 22.89 x 10^2 particles/m^3 found in mangroves predominate in Banyuurip waters. Domestic waste and anthropogenic activities contribute to the fragmentation of microplastics [8]. While the research results from Samantha et al. [9] showed that samples of blood clams (*Tegilarca granosa*), tofu clams (*Meretrix meretrix*), and sediments in Banyuurip waters were dominated by microplastic fiber types, namely as many as 5.5 items/individual in blood clams, as many as 5.4 items/individual in tofu shells which are also commonly found in mangroves, and 73.5 items/g in sediments which are most commonly found in pond areas. Fishing activities, particularly in Banyuurip Village, produce fiber-type microplastics. Researchers have used batik shells (*Paphia undulata*) as an indicator of the presence of microplastics in Banyuurip waters because batik shells are commonly consumed and traded by locals.

The objective of this study was to determine the abundance of microplastics in Banyuurip and Ujungpangkah waters and the level of public consumption of batik shells (*Paphia undulata*) in the Gresik Regency. The abundance of microplastics in the Banyuurip waters is primarily the result of the activities of fishermen and the surrounding community. The government of Banyuurip Village and the community must play an urgent role in reducing the accumulation of plastic waste, which can eventually degrade into microplastics. The government of Banyuurip Village can begin educating the community on how to recycle waste, particularly plastic waste, which has economic value, in addition to preventing waste piles. Village governments can also implement policies to reduce the use of plastic bags and provide personal containers when shopping. The community's role is not to throw garbage in the form of plastic waste, fishing nets, or washing water.

Material and Methods

Material

The raw material used in this study was batik mussel obtained from Banyuurip waters. Other research materials include 70% alcohol, aquades, ice, H_2O_2 30% and H_2SO_4 30%, NaCl. The tools used in this research were GPS, *coolbox,* digital caliper, microscope, camera, digital scales, microscope camera, petri dish, measuring cup, funnel, wattman paper, spatula, and glass jar.

Study Area

This study was conducted in Banyuurip Village, Ujungpangkah Subdistrict, Gresik Regency from September 2022 to May 2023. The collection of batik mussels (*Paphia undulata*) was carried out in two locations: the first location in Banyuurip Waters and the second location in Ujungpangkah waters. The first location is adjacent to petroleum drilling, while the second location is located around the mangrove area (Figure 1).

Data Collection

The research used in this study is descriptive. Primary and secondary data sources were used. Primary data were obtained from interviews and laboratory tests, while secondary data were in the form of supporting information about the abundance of microplastics and the level of community consumption of mussels obtained from previous studies. Purposive sampling was used in mussel sampling. Samples of batik mussels (*Paphia undulata*) were taken from as many as 33 mussels in three size groups: group one 30–35 mm, group two 35–40 mm, and group three 40–45 mm at each location. However, the sampling technique used in the community involves accidental sampling. The data collection techniques used in this study were interviews by going directly to the field, documentation to complement the research of data, and laboratory test results related to the abundance of microplastics in batik mussels (*Paphia undulata*).

Data Analysis

Data analysis was conducted based on the results of laboratory tests related to the abundance of microplastics in batik mussels (*Paphia undulata*) and the characteristics of microplastics, including color, shape, and size. The shape of microplastics can be observed using a microscope, the size of microplastics can be observed using the *ImageJ* application, and the color of microplastics can be observed visually. The consumption level was analyzed based on the results of interviews using the Food Frequency Questionnaire (FFQ) semi-quantitative form submitted to the community in Banyuurip Village. The abundance of microplastics can be calculated using the formula [10]:

$$\text{Microplastic concentration } \frac{item}{head} = \frac{number\ of\ microplastics\ in\ mussels}{number\ of\ individual\ mussels} \quad (1)$$

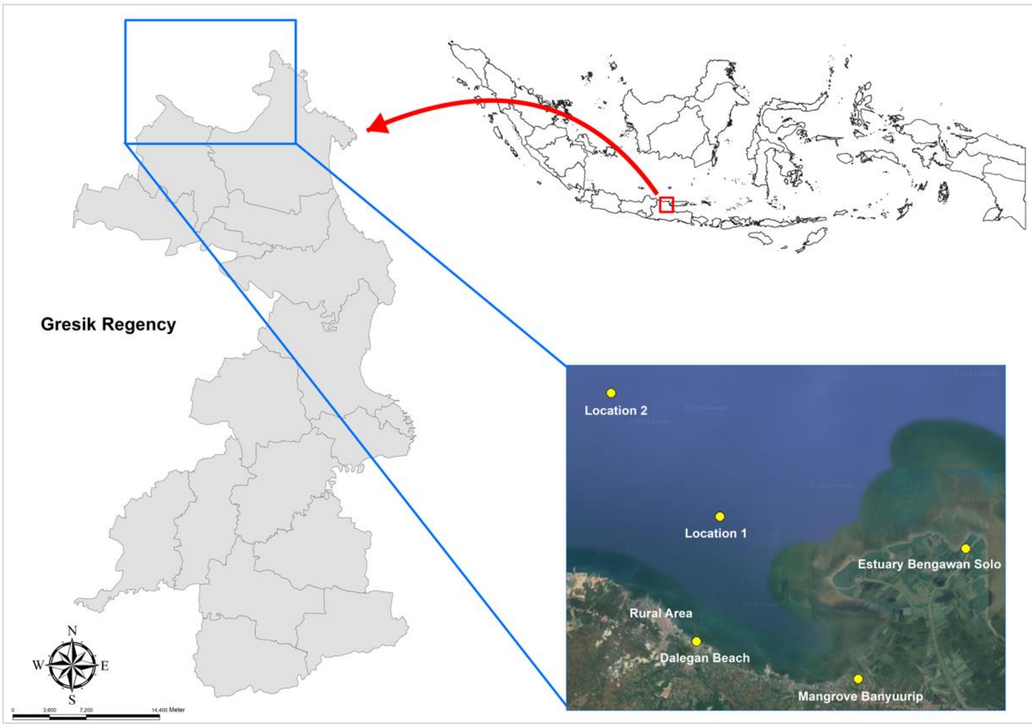

Figure 1. Study area.

Results and Discussion

Microplastic Characteristics

Shape of Microplastics

Sampling of batik mussels (*Paphia undulata*) in Banyuurip Waters on March 15, 2023. Sampling of batik mussels (*Paphia undulata*) was carried out at two locations, the first in Banyuurip waters, and the second in Ujungpangkah waters with a depth of approximately 25–30 cm. The shapes and amounts of microplastics found in this study are listed in Table 1. Based on table 1, the sampling of batik mussels (*Paphia undulata*) was carried out at two different locations with a total of six samples, and the presence of microplastic particles consisting of three types: fiber, fragments, and filaments was found. The dominant form of microplastics found among all sampling locations and size groups was fiber, with a total of 100 particles/head. The amount of fiber found could be caused by the high activity of fishermen at location 2. Fibers have a shape similar to long fibers that can also come from synthetic fibers such as clothing, rope, and the results of washing activities either from the mass industry or from households. Leaning boat ropes are also a source of fiber-shaped microplastics because the rope experiences friction in tidal areas, which then breaks down into small plastic particles [11]. The fragments have an elongated, irregular, solid, and flake-like shape. Fragmented microplastics also come from bottle caps, buckets, and pipes [12]. Filaments have a transparent sheet-like shape that comes from the same plastic waste as fragments, such as plastic bottles, bags, and disposable plastic cups that have degraded in water [13].

Table 1. The shape and amount of microplastics.

Number	Sample code	Types of microplastics (Particle/head)			Amount (Particle/head)
		Fibers	Fragments	Filaments	
1	A1	11	0	2	13
2	A2	17	0	11	28
3	A3	7	0	1	8
4	B1	23	2	3	28
5	B2	25	0	1	26
6	B3	17	0	6	23
Total		100	2	24	126

When conducting observations and sampling, the researchers found that in the Banyuurip waters there are many fishing boats that search for mussels and fish in the sea. Many use nets and fishing ropes when looking for fish. This activity is thought to affect the presence of microplastic particles in the form of fibers in Banyuurip water. Fibers are also the most common and widespread form of microplastics in the ocean, making it easy for them to accumulate in the digestive system of biota. In addition, to indicate the origin of plastic waste, the shape of microplastics can also provide information about human activities that can contribute to the presence of microplastics in the area [14]. The shapes of the microplastic fibers, fragments, and filaments are shown in figure 2.

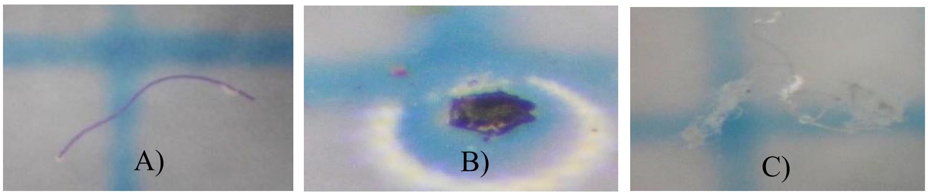

Figure 2. A) fibers, B) fragments, C) filaments.

Color of Microplastic

The results of laboratory testing of batik mussel (*Paphia undulata*) samples related to the color and number of microplastic particles are shown in Table 2. Table 2 shows that in the batik mussel (*Paphia undulata*) samples taken from the two locations, there is a diversity of colors and amounts. The colors found in each microplastic particle are 7 colors consisting of blue, red, black, grey, purple, orange, and transparent. Blue and transparent were the dominant colors found in batik mussels (*Paphia undulata*). The total microplastic particles were found in the whole range from location, size group, and shape of microplastics with blue color 58, red color 14, black color 3, gray color 3, purple color 1, orange color 1, and transparent color 46. The difference in color is thought to be caused by the origin of the color of the waste or the synthetic material itself, the result of anthropogenic activities, and degradation by continuous sunlight [15].

Table 2. Color and number of microplastic particles.

Color	Location				
	1		2		
	Fibers	Filaments	Fibers	Fragments	Filaments
Blue	18	9	26	1	4
Red	5	1	8	-	-
Black	2	-	-	1	-
Grey	2	1	-	-	-
Purple	1	-	-	-	-
Orange	1	-	-	-	-
Transparent	6	3	31	-	6

Blue and red colors can originate from anthropogenic activities, residual laundry water, clothing threads, and as a result of the degradation process by sunlight [15,12]. Transparent colors are often associated with *polypropylene* and *polyethylene* plastic polymers, typically used as food wrappers. Microplastics with transparent colors can also originate from plastic waste that has long faded and degraded by sunlight [13]. The orange color also indicates the photooxidation and weathering of microplastics [16]. Black and dark colors (gray and purple) indicate the number of contaminants absorbed into microplastics and other organic particles. Black microplastics can also absorb large amounts of pollutants and affect the texture of microplastics [17]. The color of microplastics can also affect the preference of marine biota to consume small plastic particles. Generally, some marine biota, such as microplastics, have shapes similar to their prey's. Marine biota tends to be more attracted to microplastics with bright colors, such as blue and transparent because it is easier to distinguish them than the natural environment's colors. Microplastic colors are generally derived from synthetic dyes that leach into the environment and can pose a risk to marine biota, such as batik mussels (*Paphia undulata*) [16].

Size of Microplastic

Microplastics are plastic fractions that degrade into smaller particles with a size of less than 5 mm. The results of microplastic testing of batik mussel (*Paphia undulata*) samples are shown in Figure 3 with a boxplot diagram. Based on Figure 3, shows that from 3 groups of mussel shell lengths with sampling in 2 different locations, microplastic particles of various sizes were found in three groups of mussel shell lengths. The size range of microplastic particles in group 1 location 1 (A1) was 0.356–3.908 mm, group 2 location 1 (A2) was 0.469–4.536 mm, group 3 location 1 (A3) was 0.379–1.907 mm, location 2 group 1 (B1) was 0.083–4.619 mm, location 2 group 2 (B2) was 0.356–3.908 mm, and location 2 group 3 (B3) was 0.444–2.502 mm. Overall, the microplastic particles were less than 5 mm in size. The range of values is the result of the minimum and maximum values of microplastic sizes obtained based on laboratory test results. The results of the boxplot diagram also show the existence of extreme values, and there are outliers and data distributions that are not symmetrical or skewed, which is indicated by the median value that is not in the center, and one of the whiskers is longer than the others. According to Rochman et al. [18] in his research stated that microplastics have a variety of different sizes. The most mentioned size is less than 5 mm, as defined by the National Oceanographic and Atmospheric Association. However, in general, there is no lower limit for the determination of microplastics. The difference in the size of microplastics has led to many other studies reporting microplastics of various sizes. The different sizes of microplastics found were due to differences in size groups and locations of the batik mussel (*Paphia undulata*) collection.

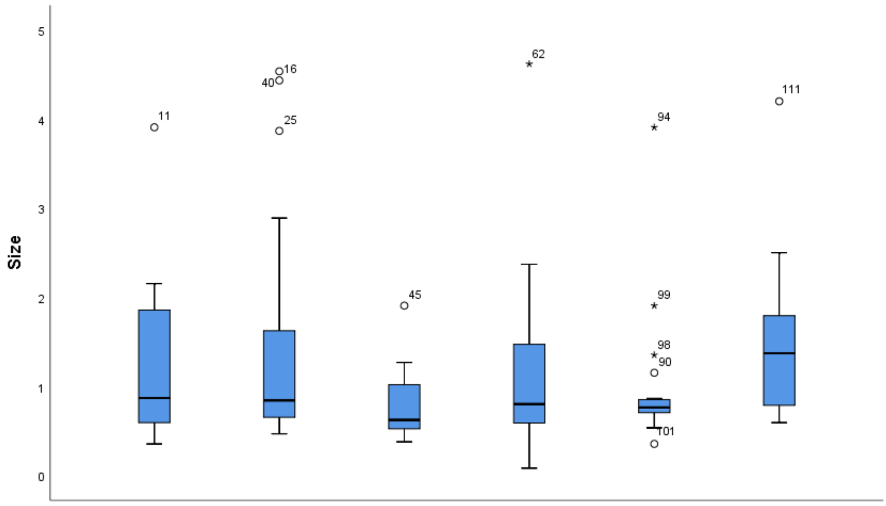

Figure 3. Microplastic size at each location in each sample group.

Microplastic Abundance

Sampling activities for batik mussels (*Paphia undulata*) in Banyuurip Waters were carried out in two different locations: the first location in Banyuurip waters, precisely around the mangrove area, and the second location in Ujungpangkah Waters, precisely in the petroleum drilling area. The following are the results of the comparison of microplastic abundance in batik mussels (*Paphia undulata*) from 2 locations which can be seen in table 3. Table 3 shows the highest abundance of microplastics from the batik mussel (*Paphia undulata*) sampling at location 2 at 0.78 particles/head, which is precisely in the Ujungpangkah waters or petroleum drilling area. Microplastics' high and low abundance depends on the mussel's size and location. The presence of microplastics in water can threaten water biota, which accidentally eat microplastics because it can cause toxic effects on these biotas. If this condition occurs for a long time, it can affect the food chain and public health [19]. One of the biotas that are easily contaminated with microplastics is Bivalve animals such as batik mussels (*Paphian undulata*), which are included in filter feeder organisms or absorb all objects, including microplastics that are nearby both from sediment and water [20].

Table 3. Comparison of microplastic abundance.

Location	Coordinate point	Sample code	Microplastic abundance (Particles/head)	Average abundance (Particles/head)
Location 1	6050'31"S	Lok 1, A1	0.39	0.49
	112028'29"E	Lok 1, A2	0.85	
		Lok 1, A3	0.24	
Location 2	6047'38"S	Lok 2, B1	0.81	0.78
	112025'56"E	Lok 2, B2	0.79	
		Lok 2, B3	0.7	

Location 1 is a batik mussel (*Paphia undulata*) sampling site not far from the fishing boat dock area and mangrove tourism. This location is also a traffic area for fishing boats, mussels, and catching fish, although not many fishermen take mussels and fish at that location. Location 2 is where most mussels and fish are caught, because they are located in the middle of the sea. although this location is quite far from community activities, much garbage is still found in the middle of the sea due to shipments from the Bengawan Solo River. The highest average abundance of microplastics at location 2 is thought to be due to the many activities of fishermen who catch mussels and fish; therefore, fiber is the most common form of microplastics found at location 2. Based on the size group of the batik mussel (*Paphia undulata*) shell length, the abundance of microplastics was highest in the small size group, which was in groups 1 and 2 with sizes of 30 to 35 mm and 35 to 40 mm.

The absorption of microplastics in mussels can be influenced by the filtration rate. The filtration rate increased as the growth rate of the mussels increased. The filtration rates of large- and small-sized mussels are different. Small mussels tend to have a higher filtration rate than large mussels. This is because small mussels absorb more food than larger mussels. Similar to the filtration rate of mussels against microplastics, small mussels tend to contain more microplastic particles than large mussels [12].

Community Consumption Level

Batik mussels (*Paphia undulata*) are a mussel widely consumed by the Banyuurip community, especially during the season. According to the local community, this type of mussel is delicious compared with other types of mussels. Table 4 shows the results of interviews with 30 respondents who live around the Banyuurip waters, in the Bondot Hamlet, Ujungpangkah Subdistrict, Gresik Regency, regarding the frequency and average consumption of batik mussels (*Paphia undulata*).

Table 4. Community Consumption Frequency on Batik Mussels *(Paphia undulata).*

Number	Consumption frequency	Amount (people)	Percentage (%)
1.	> 3 times/day	1	3.33
2.	1 time/day	1	3.33
3.	3–6 times/week	5	16.67
4.	1–2 times/week	10	33.33
5.	2 times month	13	43.33
Total		30	100.00

Table 4 shows the respondents who consumed batik mussels (*Paphia undulata*) with a daily frequency of two people, weekly 15 people, and monthly 13 people. The average consumption (gr/day) was obtained from the data processing results using the FFQ semi-quantitative interview form. Daily nutrient intake was calculated by converting the number of batik mussels (*Paphia undulata*) consumed by the community into units of days. The frequency of consumption in the form of units of days is then multiplied by the number of batik mussels (*Paphia undulata*) that have been converted into grams so that the average amount of consumption of batik mussels (*Paphia undulata*) in a day can be obtained. The average amount of community consumption was then divided by two to obtain the average value range of community consumption of batik mussels (*Paphia undulata*). The average community consumption of batik mussels (*Paphia undulata*) is shown in table 5.

Table 5. Average community consumption of batik mussels *(Paphia undulata).*

Number	Average consumption (gr/day)	Amount (people)	Percentage (%)
1.	< 50	18	60
2.	> 50	12	40
	Total	30	100

Table 5 shows that respondents who consumed batik mussels (*Paphia undulata*) with an average consumption of <50 g/day were 18 people. Those who consumed >50 g/day were 12 people, measured using a household scale before being converted into gram units. These results suggest that communities that consume batik mussels (*Paphia undulata*) >50 g/day have a higher risk of microplastic contamination than those that consume batik mussels (*Paphia undulata*) <50 g/day. One of the main sources of microplastics that can enter the human body is ingestion or consumption of food previously contaminated with microplastics. Mussels are animals that are consumed by eating all parts of their body, so it has a higher risk of microplastic contamination compared to other biota that are removed first from the contents of the stomach or digestive tract. Given the high human consumption of mussels worldwide, it is inevitable that humans have been contaminated by microplastics at some level [21].

Base on study from Smith [22], The contaminant microplastic (MPs) with their implementation for human health were two path way consist with physical and chemical. The microplastics and nutrients were combined and entered the muscle and remained on the side. Microplastics have been reported to have an impact on human surgical procedures. MPs can enhance the bioaccumulation of water-soluble toxins such as the antibiotics oxytetracycline (OTC) and florfenicol (FLO). MPs act as carriers and are then absorbed into marine biota such as clams, thereby increasing the accumulation of these antibiotics. This poses a risk of antibiotic resistance to human health [23]. The vector effect of MPs on other contaminant substances is influenced by several factors such as their interactions, particle size, and exposure time. Changes in toxicity occur in samples containing microplastics and other contaminants, resulting in an 18% increase in the toxicity of the other contaminants [24]. A similar study revealed that exposure to a combination of Pb and MPs in crabs increased the bioaccumulation of Pb in the samples. MPs pose the risk of becoming potential vectors for heavy metals and other exposures that may result in more severe effects [25]. Several studies have reported direct health effects in experimental mice. Exposure to MPs of 1–10 μm and 50–100 μm significantly impaired both the repair and post-injury muscles in mice [26].

The very small microplastics can be easily ingested by marine biota, so they can be potentially harmful if they accumulate in the human body and other biota. Most responses of the body contaminated with microplastics at the cellular level can be oxidative stress, metabolic shifts, and activation of inflammation at the systemic level. In the long term, it can cause inflammation, metabolic dysregulation, and oxidative stress, which can later manifest as clinical disorders of chronic toxicity [27]. Another impact of microplastics on human health is that they can be carcinogenic, mutagenic, and endocrine disruptors because plastics contain monomeric materials derived from various other additives. Microplastics can also cause changes in amino acid and bile acid metabolism, ion channel function and ion homeostasis, disruption of intestinal iron transport and cellular uptake, decreased liver ATP levels, disrupted energy metabolism, autophagy, cell death, and decreased catalase activity. Microplastics that have been absorbed into the stratum corneum and human body can interact with various target cells, depending on several factors, such as size, surface chemistry, and biological charge. Microplastic exposure's long-term impact in humans requires further research and investigation. It is especially important to understand the degradation of microplastics after ingestion under acidic conditions in the gut or cell lysosomes, because it can affect human health [28]. Furthermore, there is currently not enough information available to comprehend the direct implications for cases of illness caused by microplastics [29]. For now, contamination of microplastics in food of marine biota can be regarded as a form of unintentional contamination [30].

Conclusion

Microplastic particles in batik mussels (*Paphia undulata*) found in Banyuurip waters, Ujungpangkah Subdistrict, and Gresik Regency have different shapes, colors, and sizes. The shapes of microplastics include fibers, fragments, and filaments. The microplastic particles were of seven colors, namely blue, red, black, grey, purple, orange, and transparent. The microplastic particles also had a variety of sizes, ranging from

0.083 to 4.619 mm. The abundance of microplastics in batik mussels (*Paphia undulata*) from the two sampling locations showed different results. The highest abundance of microplastics was located at location 2 in Ujungpangkah waters, with an average of 0.78 particles/head. This condition is caused by the high activity of fishermen in catching batik mussels (*Paphia undulata*); therefore, microplastics are found in the fibers. The length groups of mussels with the highest abundance of microplastics were groups 1 and 2, with shell sizes of 30–35 mm and 35–40 mm. Community consumption levels were calculated using the semi-quantitative FFQ method over daily, weekly, and monthly periods. Two respondents consumed batik mussels (*Paphia undulata*) daily were 2 people, of weekly were 15 people, and 13 had an average consumption of <50 g/day by 18 people and >50 g/day by 12 people. This research can serve as a study material for addressing plastic waste issues, both at the national level in Indonesia and globally. As a result, we are concerned with managing and optimizing plastics for production and recycling.

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