*Microplastics Characteristics in Water and Sediment From Three Ecosystems on Sari Ringgung Beach, Pesawaran Regency, Lampung Province

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Abstract. Plastic waste that pollutes the ocean will lead a degradation process until it becomes small particles measuring less than 5 mm called microplastics. The durability and microscopic properties of microplastics can have a harmful effect on mangrove, seagrass, and coral reef ecosystems. The purpose of this study was to analyze the microplastics characteristics that found in the water and sediment of the three ecosystems. The study was conducted in August 2024 at Sari Ringgung Beach, Pesawaran Regency, Lampung Province. Samples of water and sediment were taken from three stations representing three ecosystems. According to the results that the mangrove ecosystem had the highest microplastics abundance, namely in water 410 particles/m3, and in sediment 466.67 particles/Kg. Microplastics abundance in the water from seagrass ecosystem was 203.33 particles/m3, and in sediment 360 particles/Kg. Microplastics from the water of coral reef ecosystem had an abundance 283.33 particles/m3, and in sediment 160 particles/Kg. The microplastic contamination found was in the form of fibers, films and fragments. The size of microplastics is dominated by small sizes (<1 mm), except in sediments in the mangrove ecosystem which are mostly large sizes (1-5 mm). The dominant microplastics colors are black, blue, red and brown. Data and information related to the characteristics of microplastics that pollute Sari Ringgung Beach are needed so that they can be managed more optimally and sustainably.

Keywords: microplastics, ecosystems, mangrove, seagrass, coral reefs

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1 INTRODUCTION

The phenomenon of marine pollution from plastic waste is increasing and has become a global issue that must be addressed immediately. Based on Jambeck et al. (2015), 8 million tons of plastic trash enters the sea through surface runoff, river flow and drainage. Plastic waste will go through several processes such as mechanical abrasion, fragmentation, photodegradation, and biological, physical, and chemical interactions to produce microplastics with particle sizes smaller than 5 mm during the process [1]. The very small size of microplastics makes it easy for currents and waves to carry them to remote locations [2]. Microplastics that have a higher density than seawater tend to settle in sediments on the seabed, and microplastic particles with lower densities tend to float in the column or on the surface of the water [3].

Microplastics come in various shapes, colors, and sizes. Some forms of microplastics include films, fibers, fragments, granules, and foam. Each form of microplastic has different characteristics. For example, microplastics in the form of fragment pieces that have strong synthetic polymers come from plastic products such as beverage bottles, leftover jars, and gallons [4]. In general, microplastics are black, blue, red, brown, yellow, green, and white. Microplastics are divided into two groups according to size, large microplastics (1–5 mm) and small microplastics (<1 mm) [5]. The primary determinant of microplastics impact on living things is their size [6].

Detected a large number of microplastic impacts in mangrove sediments, and found that the movement process of plastic waste was hampered by mangrove roots during transportation [7]. Through leaf or root absorption, microplastics can accumulate in mangrove plants and affect their morphology, physiology, and metabolism. The marine biota's consumption of plastic can be significantly increased when microplastics are present in seagrass habitats [8]. A number of earlier studies have been discovered microplastic particles in digestive tract of marine biota that associated with seagrass [9]. The complex interactions between coral reef ecosystems and plastic particles with different characteristics can have negative impacts on corals in different ways through attachment, feeding habits, and covering of coral reef body parts [10].

Mangrove ecosystems, seagrass beds, and coral reefs have an ecological function bond between one another. Therefore, research related to the characteristics of microplastics that pollute the three ecosystems is important to do. This study aims to analyze the characteristics of microplastics found in water and sediment from three ecosystems in the coastal area of Sari Ringgung Beach, Pesawaran Regency.

2 RESEARCH METHODS

2.1 Sampling

This study was conducted in August 2024 on the coast of Sari Ringgung Beach, Pesawaran Regency, Lampung Province. Microplastics from mangrove, seagrass, and coral reef environments were sampled by taking sediment and water sample. Sampling time was in the morning when the weather was sunny to avoid a significant increase in the number of microplastics due to runoff from land carried by rain [11]. Each station representing the three ecosystems had three sampling points with a distance of 10 meters each for repetition. The sampling technique was carried out using the static method. Water samples were taken as much as 100 liters and then filtered using a plankton net until 200 ml of water samples were obtained [12]. Sampling of sediment was carried out using a tube sampler as much as 200 grams of sediment [13].

2.2 Sample Preparation

Water and sediment sample preparation was carried out at the Aquatic Environmental Productivity Laboratory, Aquatic Resources Study Program, Faculty of Agriculture, University of Lampung. In 200 ml of filtered water samples, the sample analysis activity began with filtering the sample water using Whatman paper No. 42, then rinsed using 20 ml of 30% H_2O_2 solution to destroy organic matter [14]. Density separation using 6 grams of NaCl per 20 ml of sample solution, then heated on a magnetic stirrer at a temperature of 60ºC for 15 minutes [15]. After being allowed to cool, the sample was filtered again using Whatman paper No. 42, then placed in a cup and covered with aluminum foil.

In sediment samples, the analysis began with drying using an oven at a temperature of 60ºC for 48 hours [16]. Then the dried sample was filtered using a sieve shaker measuring 2 mm, 1 mm, 0.6 mm and 0.45 mm [17]. A sample of 50 grams was taken and a 30% NaCl solution was added with a ratio of 3:1 for density separation. Destruction of organic matter using 20 ml of 30% H_2O_2 and heated at a temperature of 60ºC for 15 minutes to accelerate the reaction. After cooling, the sample was filtered using Whatman paper No. 42 and placed in a cup for further observation.

2.3 Identification of Microplastic Particles

Identification of microplastic samples was carried out at the Plant Protection Laboratory, Faculty of Agriculture, University of Lampung. Identification was carried out visually using a stereo microscope to analyze the microplastics characteristics from their size, form and color. The size of microplastics will be divided into two categories, namely large size microplastics (1-5 mm) and small size microplastics (<1 mm). According to their shape, microplastics will be classified into five forms, including fiber, film, fragments, pellets and foam. According to their color, microplastics can be seen from where the plastic waste comes from.

3 RESULTS

3.1 General Condition of Research Location

Sari Ringgung Beach is located in Sidodadi Village, Teluk Pandan District, Pesawaran Regency, Lampung Province. Geographically, the coast of Sari Ringgung Beach is between 05º33'S and 105º15'E, as shown in Figure 1. This coastal area has three interrelated supporting ecosystems, namely, mangrove ecosystems, seagrass beds and coral reefs. Human activities that take place in the coastal area of Sari Ringgung Beach include tourism activities, fishing and aquaculture using floating net cages. Fishing activities and tourist activities will have an impact on the three ecosystems with the potential for mutually supporting and diverse biological resources.

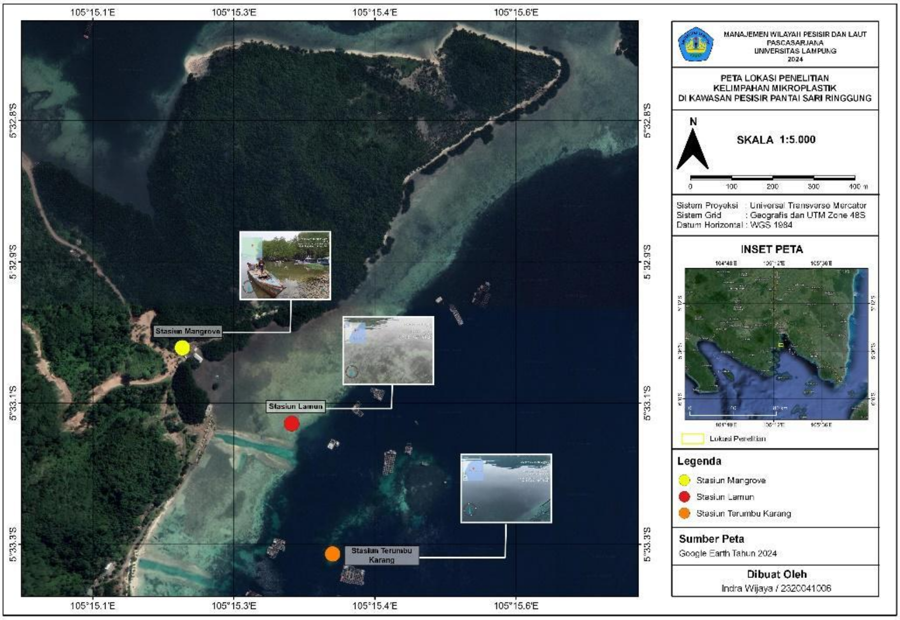

Fig. 1. Research location

According to the results of measurements from the physical and chemical parameters of the waters at Sari Ringgung Beach, it is known that the current speed is included in the slow category ranging from 0.1 m/sec. The difference in tides reaches 2 meters calculated from the highest tide and the lowest ebb. The dynamics of salinity changes in these waters are also low, ranging from 28 to 30 ‰. The pH of the water tends to be stable and normal, with a value of 6.6 -7.7. The water temperature ranges from 28.4 °C to 30.4 °C. This shows that the coast of Sari Ringgung Beach is a good habitat for the growth of mangrove and seagrass vegetation.

3.2 Microplastics Abundance

The microplastics abundances found in water and sediment from mangrove, seagrass and coral reef ecosystems is presented in Table 1.

Table 1. Microplastics abundance

Characteristics	Mangroves	Seagrass	Coral Reefs

Abundance in water (particles /m3)	410.00	203.33	283.33
Abundance in sediment (Particles/Kg)	466.67	360.00	160.00

The microplastics abundances mostly in water comes from the mangrove ecosystem at 401 particles/m^3. The lowest microplastics abundances is in the seagrass ecosystem with 203.3 particles/m^3. In the coral reef ecosystem, the microplastics abundances is 283.33 particles/m^3. The highest microplastics abundances in sediment from the mangrove ecosystem reaches 466.67 particles/Kg, while in the seagrass ecosystem it is only 360 particles/Kg. The lowest abundance is in the coral reef ecosystem with a value of 160 particles/Kg.

3.3 Microplastic Forms

Based on the results of research on water and sediment from mangrove ecosystems, seagrass beds and coral reefs, it shows that microplastic pollution has occurred on the coast of Sari Ringgung Beach. From the three ecosystems, three forms of microplastics were found, namely fiber, fragments and films, as shown in Figure 2.

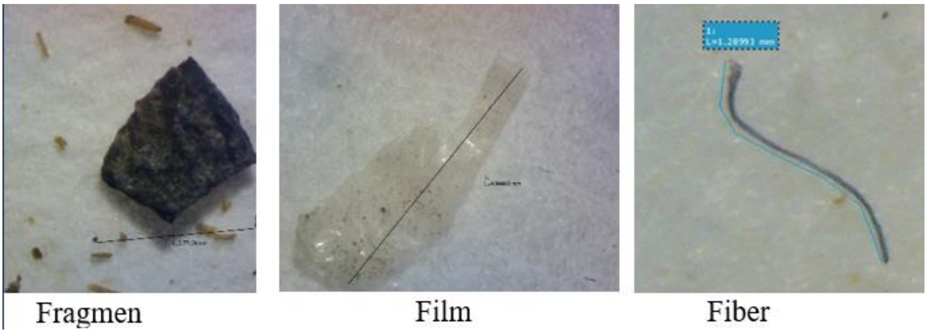

Fig. 2. The types of microplastics found in the samples consisted of three forms

The form of microplastics in Sari Ringgung is dominated by fibers, films, and fragments with small sizes, below 1 mm. While the form of microplastics in sediments is dominated by fibers, films, and fragments with large sizes (1-5) mm.

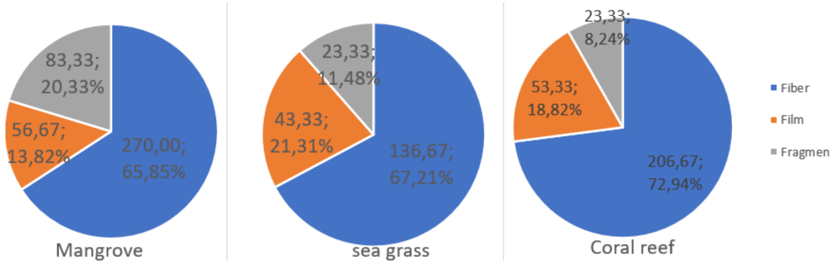

Fig. 3. Microplastics abundance in water based on their shape

The characteristics of microplastics in water according to their shape show that the fiber form dominates with a percentage of up to 70% compared to the film and fragment forms. microplastics abundance in the form of fibers dominates the mangrove ecosystem with an amount reaching 270 particles/m^3, this is equivalent to the of the microplastics abundances comparison in the mangrove ecosystem which is higher than the seagrass and coral reef ecosystems. The lowest microplastics abundances according to their shape in water samples is microplastics fragments form that found in the seagrass and coral reef ecosystems. As seen in Figure 3, the abundance values for each of the two ecosystems are 23.33 particles/m^3. Meanwhile, the highest level of microplastics abundance from seawater in the form of films is found in the mangrove ecosystem at 56.67 particles/m^3, and the lowest in the seagrass ecosystem with an abundance of 43.33 particles/m^3.

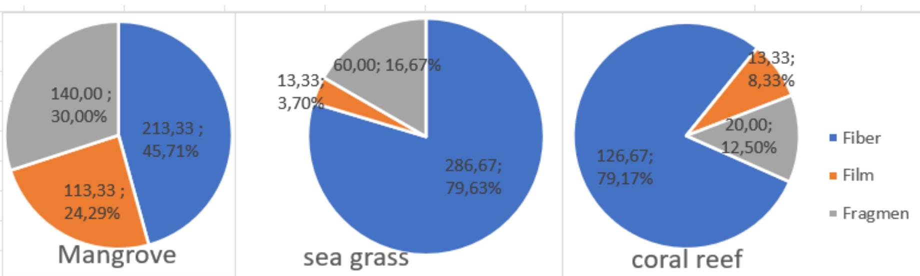

Fig. 4. Microplastics abundance in sediment samples based on their shape

Based on Figure 4, the excees of microplastics in sediment samples is dominated by fiber forms reaching almost 80% compared to fragment and film forms. The greatest number of fibers abundance in sediments is from seagrass ecosystem, reaching 286.67 particles/m^3. Microplastics in film form are the type least found in sediment samples in seagrass and coral reef ecosystems, each amounting to 13.33 particles/m^3. In general, the abundance of fiber-type microplastics dominates from water and sediment samples.

3.4 Microplastic Size

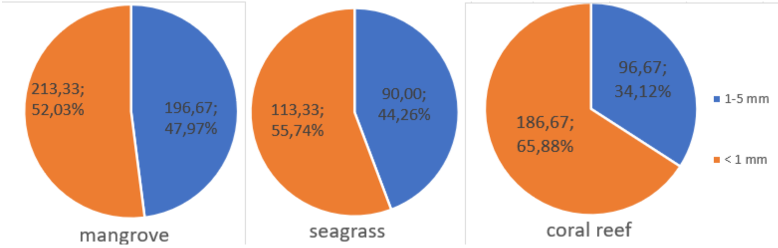

Fig. 5. Microplastics abundance in water samples based on size

As shown in Figure 5, microplastic pollution in water from mangrove ecosystems have two size categories, which is named large microplastic particles (1-5 mm) as many as 196.67 particles/m^3 and small microplastics (<1 mm) as many as 213.33 particles/m^3. The lowest number of particles is found in seagrass ecosystems with an abundance of large microplastics as many as 90 particles/m^3 and small microplastics as many as 113.33 particles/m^3. In coral reef ecosystems, the abundance of large microplastics found was 96.67 particles/m^3 and small ones as many as 186.67 particles/m^3.

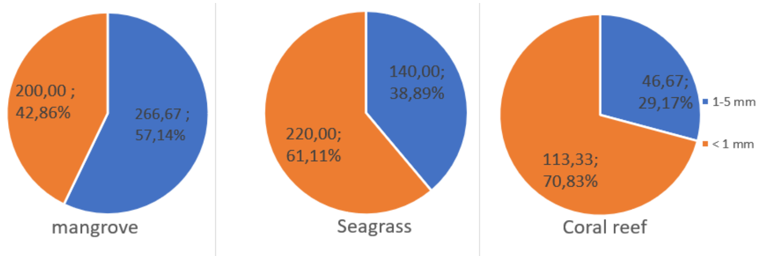

Fig. 6. Microplastics abundance in sediment samples based on size

According to its size, the microplastics abundances in mangrove sediments is dominated by large sizes (1-5mm), which is 266.67 particles/Kg, while small sizes are 200 particles/Kg, as shown in Figure 6. This can be caused by the large amount of macroplastic waste trapped in the mangrove ecosystem, so that the mangrove ecosystem is the first place where the plastic waste is degraded. This case is different from seagrass and coral reef ecosystems where the microplastics are abundant in sediments which have been dominated by small particles.

3.5 Microplastic Colors

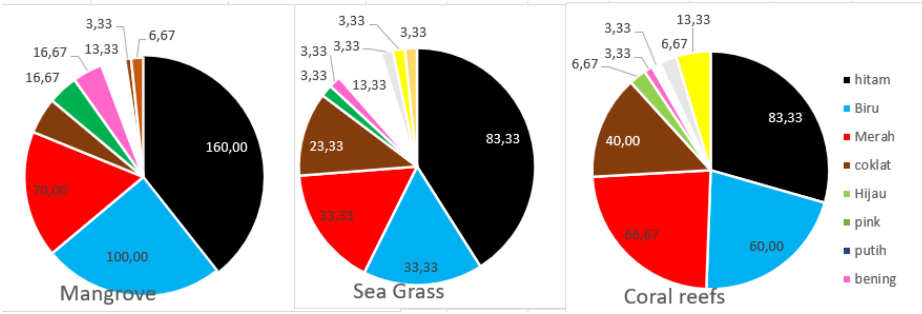

Fig. 7. Microplastics abundance in water samples based on color

Based the analysis results on the microscope, twelve colors were found in the water samples on the Sari Ringgung beach, including: black, blue, red, brown, green, pink, white, clear, orange, gray, yellow and gold. There are four colors of microplastics that are often found in water samples, namely black, red, blue and brown. The dominant color found in mangrove water is black with an abundance of 160 particles/Kg, as shown in Figure 7.

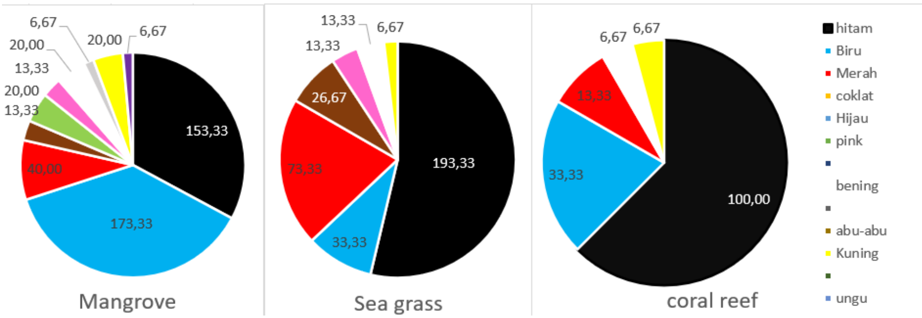

Fig. 8. Microplastics abundance in sediment samples based on color

In Figure 8, we can see that the dominant color found in mangrove sediment is blue with an abundance of 173.33 particles/Kg. The large number of blue microplastics is most likely due to anthropogenic activities both on land and at sea, such as mangrove ecosystems that are used as mooring and ship repair locations. Meanwhile, sediments in seagrass and coral reef ecosystems are dominated by black microplastics with an abundance of 193.33 particles/Kg and 100 particles/Kg.

4 DISCUSSION

The comparisons of the microplastics abundances obtained from water samples in mangrove, seagrass and coral reef ecosystems show that the highest amount of microplastics is found in the mangrove ecosystem. The density of mangrove ecosystem vegetation has more potential to capture waste that enters the waters [18]. The distance of the mangrove ecosystem that is closer to residential areas will also be positively correlated with the abundance of plastic waste [19]. Surface currents and waves are known to be the main driving forces for sending marine-based waste into the mangrove ecosystem [20]. The mangrove ecosystem is more likely to be polluted due to the large amount of plastic waste caught in the trunks and roots of mangrove trees [21]. The lowest abundance in the seagrass ecosystem, this can be seen during observations, where the seagrass ecosystem environment is clean from plastic waste. The time of sampling was also carried out when the Sari Ringgung coast was at its lowest ebb, so that the mass of water carrying microplastics in the seagrass ecosystem was greatly reduced. The microplastics abundances in the water from coral reef ecosystems is quite high, thought to be due to direct contact with floating net cage fisheries cultivation activities.

The mechanism of microplastic entry into this fragile but valuable ecosystem can also be through its buoyancy [22]. Microplastic particles will remain floating in the waters until they finally enter the ecosystem [23]. Microplastics with a density less than seawater (<1.02 g/cm3) have a tendency to float on or near the sea surface, whereas high-density microplastics will settle and collect in sediments [24]. Based on data of the microplastics abundances found in sediments from each ecosystem, it can be seen that the amount of microplastics in the mangrove ecosystem is greater than that found in seagrass and coral reef ecosystems. This can also be caused by the type of sediment in the mangrove ecosystem in the form of fine sand and mud (clay) which contains a lot of organic matter, making it easy for microplastics to be trapped and accumulated in it [25]. There is a definite correlation between the amount of microplastics found in mangrove sediments and the volume of fish farming activity in the vicinity, regardless of where the sediment samples are taken (within or outside the mangrove zone) [26]. The types of sediment in seagrass and coral reef ecosystems are almost the same, namely sand and gravel originating from coral fragments and shells that are susceptible to movement influenced by ocean currents. Sediments with coarse material and larger pores make microplastics more easily carried by currents [27]. The movement of microplastic particles from the ocean to the coast is also influenced by tidal mechanisms and sea waves [13]. However, in seagrass ecosystems, there are a number of *Enhalus acoroides* habitats, making microplastics more retained in seagrass sediments compared to conditions on coral reefs.

Microplastic characteristics are generally associated with the size, shape, and color of the particles found [28]. Microplastic sizes are divided into two categories, namely, large microplastics (1-5 mm) and small microplastics (<1 mm). Large microplastics usually come from the fragmentation of larger plastic waste, or what is commonly called secondary microplastics. Small microplastics usually come from secondary microplastics and primary microplastics, namely, microplastics that enter the waters already in micro sizes such as soap, agricultural and industrial waste. Small microplastics are more dangerous because they are easily swallowed or captured by marine biota [29]. The division of microplastic sizes is correlated with the level of danger or impact on marine biota and coastal vegetation. The smaller the size of the microplastic, the more worried the threat is because it is easier to enter the pores of the body of marine biota. Microplastics of a certain size can even enter human body tissue.

Microplastics found in the coastal waters of Sari Ringgung consist of fibers, films, and fragments. The large number of microplastics in the form of fibers indicates that there are fishing activities in the coastal area [30]. Fiber-type microplastics are usually produced from anthropogenic activities related to marine fisheries [31]. Fibers come from fishing nets or nets in floating net cages that degrade into smaller fibers [32]. This type is widely found in water because its shape is like fiber and is usually made of low-density polymer materials that have buoyancy properties [33]. Fish farming activities in the adjacent sea are also considered to be a major contributor to microplastics in Qinzhou Bay and Dongzhaigang mangrove sediments, this is because throughout the cultivation process, a lot of equipment made of polystyrene (PS), polypropylene (PP), and PE plastics is used [34].

Other forms found in sediments are fragments with thick, hard and irregular shapes. Fragments generally come from secondary microplastics produced from the fragmentation process of larger plastic waste such as beverage bottles, plastic household appliances and pipe pieces over a long period of time [35]. The longer the degradation process, the smaller the particles produced [36]. Sources of microplastics in the form of fragments can also come from aquaculture activities that use plastic materials as buoys and tourist waste that uses disposable consumption equipment. A longer degradation process in waters can be characterized by microplastics that are getting smaller in size [37]. Degradation may happen because of mechanical pressure on the seabed or the activity of microorganisms such as bacteria and fungi that can break down microplastics. Meanwhile, the form of microplastic that is rarely found in sediments on the coast of Sari Ringgung Beach is microplastic in the form of a film. This microplastic has characteristics like a thin and transparent plastic sheet. Films are usually resulting from the deterioration of plastic packaging from both tourists and household activities [38]. Film-type microplastics are more entangled in muddy sand-type sediments [39].

Microplastics with a dominant number of colors have a higher chance of being consumed by aquatic biota because it is difficult to distinguish between microplastics and food [39]. The diversity of microplastic colors can be an indication of the number of contaminant sources that pollute a body of water [40]. Differences in the concentration of microplastic color can also indicate differences in the time of the photodegradation process of a type of microplastic in water. White and clear (transparent) colors indicate the bleaching and fading process considering the duration of the microplastic has been in the ocean [41]. The large number of blue microplastics is most likely due to human activities both on terrestrial and marine, such as mangrove ecosystems that are used as mooring and ship repair locations [25]. Colorful microplastics are susceptible to being ingested by marine biota because some biota are attracted to their colors. Marine biota generally ingest brightly colored microplastics that are similar to their natural food. Fish larvae, copepods, and zooplankton consume blue, green, red, and black microplastics [42]. Consumption of microplastics by marine biota can be dangerous because it will cause death and reduced biodiversity in the mangrove ecosystem.

5 CONCLUSION

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