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Original Research

First Evidence of Microplastics Presence in Corals of Jepara Coastal Waters, Java Sea: A Comparison Among Habitats Receiving Different Degrees of Sedimentations

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Abstract

Even though the research on the richness and diversity characteristics of microplastics in coral reef ecosystems has received great attention, however, understanding the occurrence, fate, and impact of microplastics in corals remain still poor. The study reported here was aimed to observe the microplastic abundance and distribution on selected life-form corals from habitats receiving different degrees of sedimentation in the Jepara Coastal Waters, Java Sea. Microplastics were sampled from four different locations representing a different level of sedimentations. Four coral life-forms (massive, submassive, folious, and branching) were sampled with two replications at each location in July 2020. In the laboratory, microplastics were extracted and enumerated under fluorescent microscopy. The study demonstrated that the means of microplastics were found to reach 16.00±7.5, 14.25±3.8, 14.80±7.9, and 9.50±3.6 particles kg^{-1} in the Awur Bay, Kartini Coast, Panjang Island, and Bandengan Coast, respectively. The Awur Bay, the location with the highest sedimentation rate, has the highest microplastic abundance. Statistically, however, there were no significantly different among site locations ($F_{(3,13)}$ = 1.27, p-value = 0.327>0.05). It is indicating that there was no spatial variation in microplastic abundance across sampling site locations. While the means of microplastics in the coral life-forms of massive, submassive, folious, and branching corals were 9.75±6.6, 9.50±3.3, 11.50±4.5, and 17.75±2.3 particles kg^{-1}, respectively. One-way ANOVA statistical analyses showed that there was no significant difference in microplastic abundance among coral life-forms ($F_{(3,10)}$ = 2.12, p-value = 0.161>0.05). Even there was no significant difference among coral life-forms, however, microplastics on the branching coral lifeform showed a strong tendency to increase. The black microplastics were the primary color, and the fiber shape is the dominant type of microplastics found in all locations. This study contributes novel information on microplastic occurrence and composition in different coral life-forms. Besides,

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our results provide insights on the role of environmental filters in governing the distribution, abundance, and diversity of microplastics on habitats receiving different degrees of sedimentation.

Keywords: microplastics, sedimentation, coral reef, coral life-form, Java Sea

Introduction

Indonesia as the second-largest contributor to marine plastic waste in the world has promised to reduce 2/3 of the total pollution of plastic waste in the sea in 2025, as declared on Indonesia's Plan of Action on Marine Plastic Debris [1]. A serious obstacle to the ultimate target of marine plastic reduction in Indonesia is the high population of coastal communities who live on the beach and their activities at sea [2]. In Indonesia, approximately 1.29 out of 3.2 million tonnes of plastic waste produced enter annually in the marine environment [3]. These plastic wastes can be degraded physically, mechanically, hydrolysis, and biologically result in various shapes, types, sizes, and different chemical compositions (Song et al., 2017; Soares et al., 2020). Plastic debris that has a length between 1-5 mm is categorized as microplastic [5]. Although the appearance of microplastics is not as clear as macroplastics, however microplastics are at higher risk to the environment than macroplastics [6]. The scientific publication reports evidence from laboratory studies that coral eats microplastics and their effects such as necrosis and bleaching [7]. Moreover, the total microplastic mass in nature is estimated to be several hundred times greater than the microplastic mass [8]. Due to their abundance and persistence in nature, microplastics are gaining increasing attention and studied intensively in the freshwaters and seawaters for their toxicity in the living organisms and their environment [9]. However, only a few pieces of information are documented on the abundance, distribution, composition, and concentration of microplastic in the corals [10].

Indonesia's coral reef is considered the most diverse in the world is approximately 18% of the world's total coral reef area. These ecosystems are crucial due to support the live necessity of Indonesian communities and provide a pivotal role in participating in the national building economy. It is expected that the positive effect of Indonesian healthy corals in coastal fisheries, jobs, and tourism sectors could provide tens of billion US dollars to the economic development [11]. However, only less than 5% of Indonesia's reefs remain in excellent condition [12]. Corals are delicate and susceptible to anthropogenic damages such as anthropogenic activities, global warming, pollutions, disease, and sedimentation [13]. Sediments are considered to be the main sinks of microplastics [14]. The microplastic accumulation in sediments could threaten the corals due to their ability to associate with toxic pollutants [15]. Besides, the growth rates of corals will be decreased due to increased sedimentation as a consequence of lowered light levels [16].

Jepara regency (6°34'49.79"S-110°40'44.34"E) is located in the northeastern coastal region of Central Java, bordering the Java Sea in the north and west. It covers an area of 1,004.13 km^2 and had a population of 1,257,912 in 2019 [17]. The Jepara regency was undergoing rapid economic growth, which increased the release of microplastic particles into the sea. With a coastline length of 72 km, Jepara coastal waters are mainly originated from corals and include Panjang island (1.5 nautical miles in distance from the shoreline). Edinger and Risk [13] reported that the high sedimentation rate is the primary threat to the coral ecosystem of Jepara coastal waters because of flooding and river flows. The microplastic pollution in Jepara corals has never been studied. Hence, the objective of this research was to examine the abundance, distribution, and composition of microplastics in corals of Jepara coastal waters. Further contributing novel information on microplastic occurrence and composition in different coral life-forms. Our results provide insights on the role of environmental filters in governing the distribution, abundance, and diversity of microplastics on habitats receiving different degrees of sedimentation rate along Jepara coastal waters.

Material and Methods

Establishment of the Study Area

The sampling was conducted in Jepara coastal waters, Java Sea, Central Java, Indonesia. Four sampling site locations were established in the study area included Awur Bay (110°38'53.14"E, 6°36'36.82"S), Kartini Coast (110°38'15.12E, 6°35'30.13"S), Panjang Island (110°37'24.01"E, 6°34'23,43"S), and Bandengan Coast (110°38'55.32"E, 6°32'59.28"S) as shown in Fig. 1. These locations have received different degrees of sedimentation rates as shown in Table 1 [18]. These site locations are also representing locations with specific geographical characters as follows:

The Awur Bay is the highest sedimentation rate characterized by a densely populated residential area and high agriculture intensity. Followed by Kartini coast, the high tourism activity and surrounded by shrimp's brackish water. Bandengan coast, an agricultural farm dominated by paddy-rice fields. Panjang Island is the lowest sedimentation rate, a tourist area characterized by high tourist activities, such as swimming, snorkeling, diving, fishing, and ship line routes.

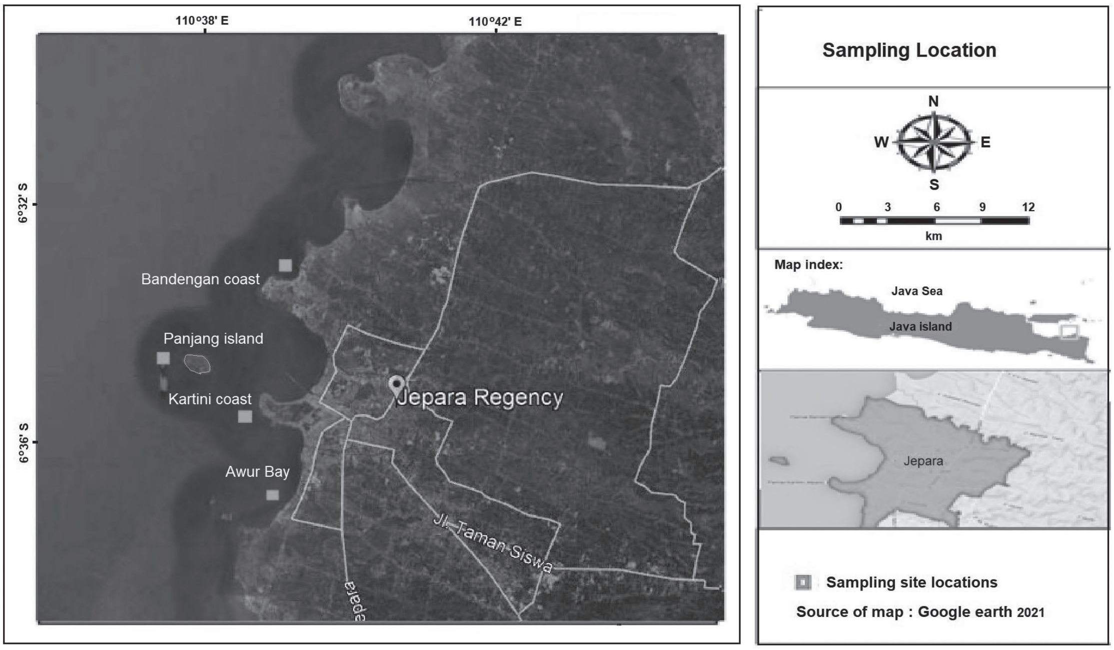

Fig. 1. Sampling site locations of Jepara coastal waters (Google Earth, 2021).

Table 1. Sedimentation rate in sampling site locations.

Location	Sedimentation rate (mg cm^{-2} d^{-1})
Awur Bay	27.31±1.2
Kartini Coast	18.82±0.5
Panjang Island	9.01±1.6
Bandengan Coast	14.73±1.6

Source: (Sabdono et al., 2021)

Sample Collection

Coral samples, massive, submassive, folious, and branching coral life-forms, were collected from 4 sampling site locations with two replications on July 2020 (Fig. 2). A purposive random sampling method was used in this study. Coral fragments were sampled by the SCUBA set at a depth of 2-3 meters. The coral fragment was taken ±100 g by hammer, chisel and stored in double zip-lock plastic containers. All samples

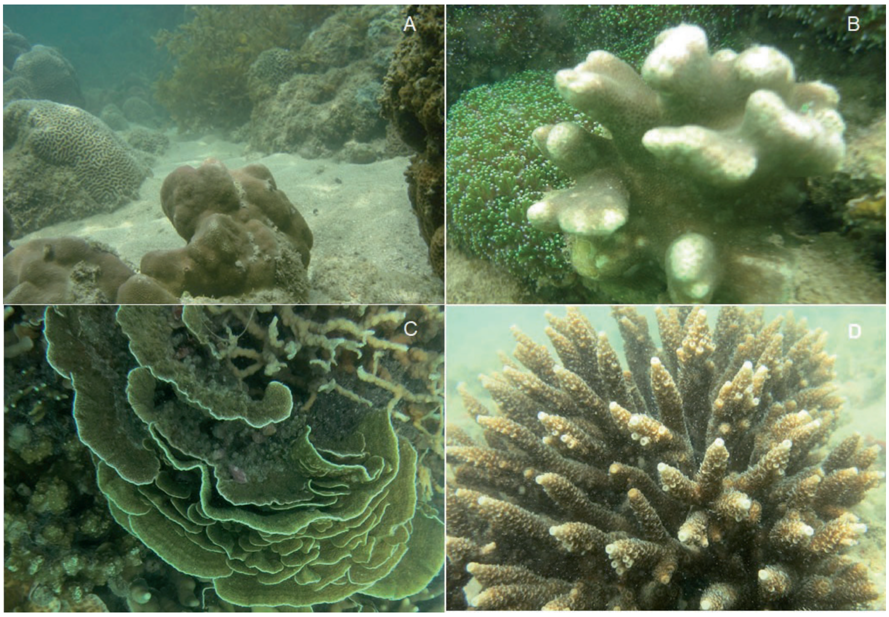

Fig. 2. Coral life-forms. Note: A = Massive (*Porites lutea*); B = Submassive (*Galaxea fascicularis*); C = Folious (*Montipora foliosa*); D = Branching (*Acropora aspera*).

were then analyzed for microplastics in the Tropical Marine Biotechnology laboratory, FPIK, UNDIP.

Microplastic Analysis

Preparation of microplastic analysis on coral samples refers to the microplastic extraction method by Cordova et al. [19] with slight modification. This method is a combined modification of the sediment microplastic extraction method by Thompson et al. [20], Claessens et al. [21], and Nor and Obbard [22]. The difference is in the breaking method of coral samples for extraction microplastic. The process began with breaking coral fragments into granules with a stainless-steel hammer. All the processes did in sterile conditions due to avoid contamination. The final form of coral fragments was granule. The coral samples were dried at 74ºC in an oven for 24 hours. The dried coral samples were added with 30% hydrogen peroxide (H_2O_2) and re-oven at a temperature of 80-90ºC, this addition aims to remove organic material contained in the coral. The coral samples that come out of foam were removed, then added with saline water (1.18 g L^{-1} NaCl + Aquades) and let stand for 24 hours. After that, the filtering process by a vacuum pump with Whatman Filter Cellulose filter paper (pore size 0.45 µm) was carried out.

The filtered cellulose, then, was stored in sterile disposal Petri and wrapped with parafilm/wrap to avoid contamination. Observation of identification and quantification of microplastics was conducted by using an OLYMPUS CX23 microscope with a magnification of 40X. Identification of microplastics was carried out based on Matsura et al. [23] data were observed based on the number, shape, type, and color of microplastics. Particles were identified as microplastics with size criteria between 0.3-5 mm. For particles in doubt whether or not they were microplastic, a hot needle test [24] was performed. The mean values and relative standard deviation of the replicates were compared by 1-way ANOVA analyses using SPSS version 26.0.

Results and Discussion

Microplastics on Coral Habitats with Different Level of Sedimentation Rate

In this study, microplastics in coral samples were quantified for their abundance and distribution. The results showed that the means of microplastics were found to reach 14±7.04, 13±3.56, 12±6.2, and 9.7±4.11 particles kg^{-1} in the Awur Bay, Kartini Coast, Panjang Island, and Bandengan Coast, respectively. Statistically, there were no significant difference of microplastic abundance among site locations ($F_{(3,13)}$ = 1.27, p-value = 0.327>0.05). The Awur Bay, the highest sedimentation rate, was the highest relative abundance (RA) of microplastics. As shown in Tables 1, 2, and Fig. 3, the Awur Bay, with the highest sedimentation rate, was the highest relative abundance of microplastics. Similarly, Panjang Island, a location with the lowest sedimentation rate, also showed a high relative abundance. It is indicating that there was no spatial variation in microplastic abundance among site locations. By comparing to some previous studies, the abundance of microplastics in this study (5-22 particles kg^{-1}) was lower. Ding et al. [25] reported that the microplastic abundance in Xisha Islands's corals was 20-1300 particles kg^{-1}. The different investigations by Oldenburg et al. [26] reported that the abundance of microplastics in Sapodilla Cayes (296±SE 89 particles kg^{-1}) and Drowned Cayes (75±SE 14 particles kg^{-1}).

In contrast to our earlier assumptions, Panjang Island, the location with the lowest sedimentation, have also a high microplastic relative abundance. It seems that sedimentation is not the only factor that contributes source of microplastic agents in Jepara coastal waters. In this study, it is hypothesized that microplastic distribution patterns can be approximated by patterns of sedimentary rates. The selected sites are representative of different levels of sedimentation rates range from low to high sediment rates. Data on sediment grain size distribution and composition were not available. Other factors like the high

Table 2. The mean and Sd of microplastic (particles/kg) in four locations.

Coral Life-form	Sampling Site Locations:				Total	Mean±Sd
	Teluk Awur	Kartini Coast	Panjang Island	Bandengan Coast		
Massive	22	8	5	5	40	$10.0\pm7.^{0}$a
Sub-massive	7	15	7	9	38	9.5 ± 3.2^{a}
Foliose	7	nd	16	nd	23	$11.5\pm4.^{5}$ a
Branching	20	16	20	15	71	$17.75\pm2.^{3}$ a
Total Particles	56	39	48	29	172	
Mean±Sd	14 ± 7.0^{4}a	13 ± 3.56^{a}	12±6.2a	9.7 ± 4.11^{a}		

**nd: no data; ^{a}: the same alphabet means no significant difference

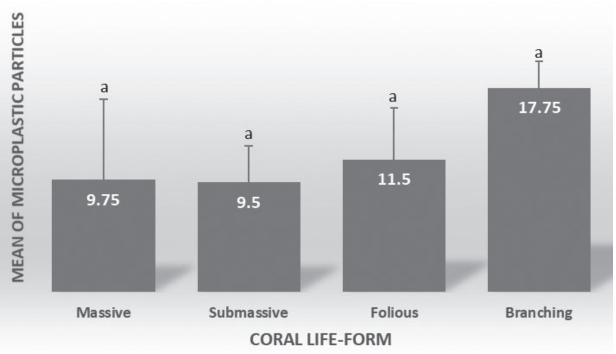

Fig. 3. Relative abundance (%) of microplastics in different sampling locations.

density of coastal settlements, maritime transport, and tourism activities are also contributing to plastic debris accumulation in the coastal environment by *in-situ* waste [27]. It could be proven by the interest of tourists visiting Jepara remains high, even though it is currently in the midst of the red zone category for the spread of COVID-19 [28]. Panjang Island as one of the tourist destinations is attracted domestic and foreign visitors for enjoying fishing, swimming, snorkling, and scuba diving. Consequently, these human activities are likely other sources of marine microplastic pollution that increased plastic disposal into the coastal waters. Some evidence showed that tourism and recreational activities are the major sources of marine and coastal plastic accumulation into the marine ecosystems [29-31].

Microplastics on Different Coral Life-Forms

Microplastics can easily enter the tissue and accumulate in organs due to their very small size [4]. Nonetheless, no efforts were made to widely study the fate and distribution of microplastics in corals. To date, only limited publications were reported on the occurrence and distribution of microplastics on corals [25, 26, 32]. This study explores the influence of reef architectural forms on microplastics by comparing the relative abundance, size, and shape of microplastics on four coral life-forms represented by four different coral species namely massive (*Porites lutea*), submassive (*Galaxea fascicularis*), folious (*Montipora foliosa*) and branching corals (*Acropora aspera*) (Fig. 2). The three coral species, *P. lutea, M. foliosa,* and *A. aspera* represent a coral with a small polyp while *G. fascicularis* have a large polyp [33]. As shown in Table 2 and Fig. 4, the means of microplastics in the coral life-forms of massive, submassive, folious, and branching corals were 10.0±7.0, 9.5±3.2, 11.5±4.5, and 17.75±2.3 particles kg^{-1}, respectively. One-way Analyses of Variance (ANOVA) statistical analyses resulted in no significant difference of microplastic abundance among coral life-forms ($F_{(3,10)} = 2.12$, p-value = $0.161>0.05$). Even there was no significant difference among coral life-forms, however, microplastics on the branching coral lifeform showed a strong tendency to increase. To our knowledge, no previous study has investigated microplastic abundance among coral life-forms. The detailed understanding of coral response to microplastics is still limited. However, since coral branching *A. aspera* was the highest amount of microplastics among the other life-form species, it is needed to study further their mechanism and response to microplastic exposure.

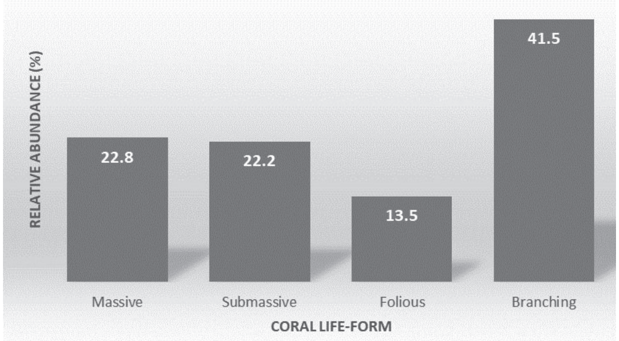

Fig. 4. Relative abundance (%) of microplastics in different coral life-forms.

Some present studies reported that scleractinian coral could remove microplastics from the water suspension through ingestion and adhesion mechanisms [34-36]. While, Martin et al. [34] showed that *Goniastrea retiformis*, which presents a massive form with a highly rugose surface and larger polyps and septa, demonstrated the highest trapping microplastic particles compared to branching coral *Acropora hemprichii* and *Pocillopora verrucose*. In this study, the unexpected results showed that the highest abundance of microplastics was found in *A. aspera* represent a branching coral with a small polyp, it was not found in *G. fascicularis* submassive coral with a large polyp. It seems that the polyp size might be not the significant factor in microplastic trapping due to the most abundant microplastics in small size (Fig. 5). Furthermore, Martin et al. [34] demonstrated that adhesion is better than that of ingestion of microplastics in removing microplastics from the water column. In the most recent study, de Smit et al. [36] stated that coral species with a more complex aboveground architecture is better than that of less architecturally complex organisms in the microplastic particle trapping. Accordingly, it could be attributed to the fact that in this study corals with a complex architecture and rough surface like *A. aspera* trap the number of microplastics higher than corals with simple architectural life-forms (*G. fascicularis, P. lutea, M. foliosa*). However, this study only gives introductory knowledge about coral-microplastic-interactions. A detailed study is needed to understand their relationship mechanism.

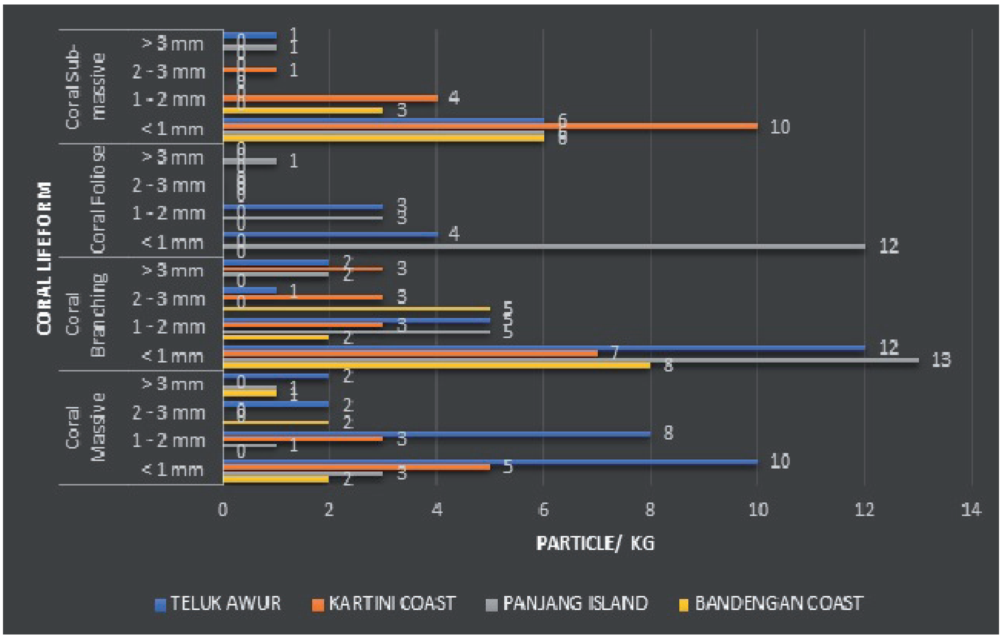

Fig. 5. The size of microplastics in the corals of Jepara coastal waters.

Physical Characterizations of Microplastics

The origins use, and particular source sectors of microplastic particles could be identified more precisely based on morphology composition [37]. In this study, the physical properties of microplastics such as size, shape, and color were observed. As shown in Fig. 5, microplastics found in all sampling site locations were classified into three classes: small (<1 mm), medium (1-3 mm), and large (>3 mm) microplastics. The small class (microplastic with size less than 1mm) found at the most abundance. Similar to many other previous observations the smaller sized microplastics (<1 mm) were dominant [10,38]. Interestingly, Ding et al. [25] reported that corals contained similar amount of microplastics between 500-1000 µm (28.6%) and 20-330 µm (25.8%). Unlike in the surface water and sediments, microplastic abundance in the corals are difficult to quantify due to lack of a relatively standardized unit or enough available data [39]. Rotjan et al. [32] found that concentrations of microplastic abundance in the wild coral was 112 particles polyp^{-1}. In Fig. 6 showed that microplastics detected in all samples were categorized into fibers, films, rubbers and fragments. The dominant type of microplastic classes was fibers (63.8 %), followed by rubber (23.05 %), fragments (7.0 %), and films (6.17 %). Microbeads had a very small contribution, while pellets and coats were absent. In the present analysis, microbeads, pellets, foam, and coats were considered as fragments. The fiber shape was the most dominant of microplastics in Jepara coastal waters. Some previous physical characterizations of microplastics were reported. Rotjan et al. [32] found that the most microplastic abundance in coral colonies from Rhode Island was fibers. Besides, Oldenburg et al. [26] also found that microfibers were the most abundant in morphological shape in corals. Meanwhile, Ding et al. [25] reported that fibers were the major shape of microplastics in seawater, fish, and coral. In this study, there was significant variability of coral colors (Fig. 7). This figure demonstrated that nine colors of microplastic particles namely green, black, red, orange, purple, brown, blue, transparent, and white, were detected in corals. The black color was the most abundant, followed by red, orange, purple, brown, blue, transparent, and white.

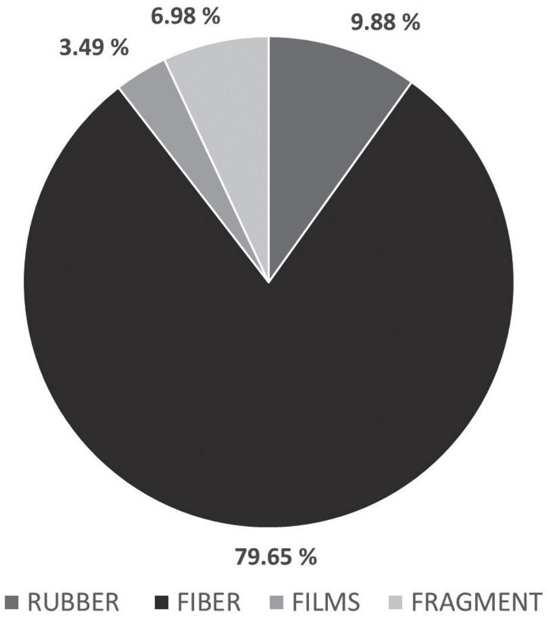

Fig. 6. The shapes of microplastics found in the corals of Jepara coastal waters.

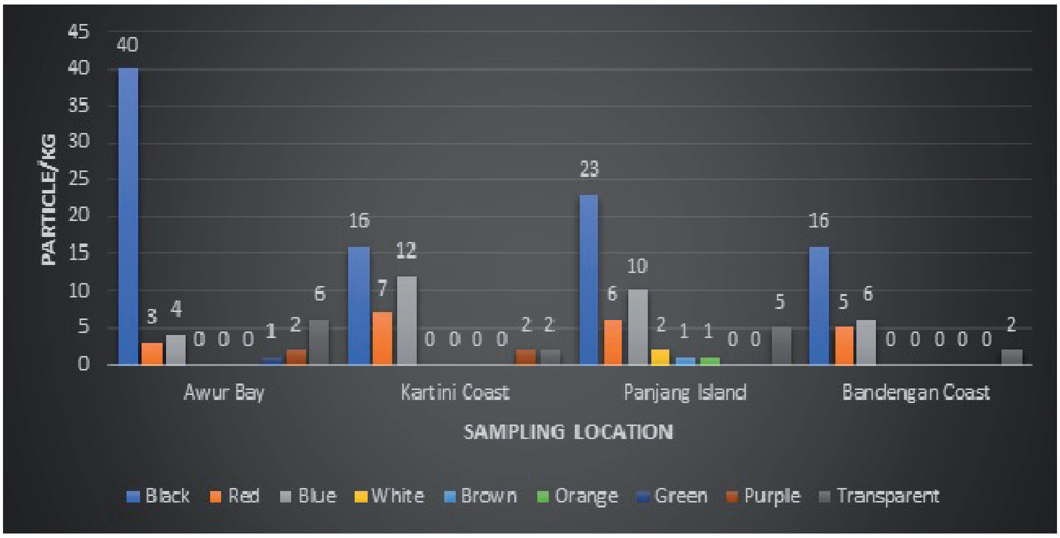

Fig. 7. The color of microplastic in the coral of Jepara coastal waters.

Conclusion

In this study, microplastic content in the coral reefs of Jepara coastal waters was found to be present in relatively low quantities (ranging from 40±4 particles Kg^{-1} to 610±11 items/kg), with distinctive shapes, sizes, and colors. There was no spatial variation in microplastic abundance across sampling site locations with different levels of sedimentations. Also, there was no significant difference in microplastic abundance among coral life-forms, even microplastics on the branching coral lifeform showed a strong tendency to increase. The detailed understanding of coral response to microplastics is still limited. However, since coral branching *A. aspera* was the highest amount of microplastics among the other life-form species, it is needed to study further their mechanism and response to microplastic exposure. Besides, microplastics with small size (<1 mm) was the most abundance hence they could not be ignored. Since the most common shape was fibers, the source of microplastics might come from the discharge of textile or fishing.

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Conflict of Interest

The authors declare no conflict of interest.

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