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Research article

Assessment of microplastics contamination in selected coral species from Kuantan coastal waters off the South China Sea

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Abstract

Microplastics, defined as plastic particles less than 5 mm in size, pose a significant environmental threat and have been detected across various terrestrial and marine ecosystems. This study explores the abundance, types, and potential impact of microplastics in corals from the coastal waters of Kuantan, Malaysia. Using Fourier Transform Infrared (FTIR) spectroscopy, three coral species – *Acropora*, *Montipora*, and *Porites* – were collected from two locations, Pulau Ular and Cherok Paloh, to identify and quantify the microplastics contamination. A total of nine samples underwent a digestion process to isolate and analyze microplastics from both external and internal structures. The results revealed that *Acropora* species exhibited the highest microplastics abundance, while *Montipora* and *Porites* showed similar but comparatively lower contamination levels. The identified polymers included polyacrylamide, polyvinyl, polyethylene, polyamide, styrene, polypropylene, methyl vinyl ether, and polystyrene, with polyacrylamide being the most prevalent, constituting 33.33% of the total microplastics detected. These findings align with previous studies and underscore the potential adverse effects on coral feeding mechanisms, energy intake, and overall health. This study highlights the significance of ongoing research to refine microplastic identification methods and to develop targeted strategies to mitigate their impact on marine ecosystems.

Keywords: Microplastics, coral species, coastal waters, polymer identification

Introduction

The pervasive presence of microplastics in the world's oceans has become a critical environmental concern due to their adverse impacts on marine ecosystems. Microplastics, defined as plastic particles smaller than 5 mm, originate from the breakdown of larger plastic debris and direct industrial emissions. These pollutants are nearly invisible to the naked eye and persist in the environment, undergoing slow degradation through processes such as biodegradation, photodegradation, and hydrolysis (Saliu et al., 2019). Once in the marine environment, microplastics are readily ingested by various organisms, spreading contaminants throughout the food chain (Avio et al., 2017).

Coastal regions are particularly vulnerable to microplastic pollution due to the concentration of human activities such as tourism, aquaculture, shipping, fisheries, and dense coastal populations. Shorelines often accumulate significant amounts of plastic waste, exacerbating the problem. Malaysia, ranked as the 4th most polluted country globally in terms of marine debris, faces substantial risks to its coral reefs, which are crucial to its coastal waters. The country's role as a prominent importer of plastic waste, coupled with challenges in waste management due to rapid urbanization, further intensifies these risks (Moh & Abd Manaf, 2014; Lechner et al., 2020). As a biodiversity hotspot with some of the most diverse coral reefs, addressing plastic pollution in Malaysia is essential to safeguarding these sensitive marine ecosystems (Cros et al., 2014).

Coral reefs, in particular, are susceptible to microplastic pollution in the water column. As filter-feeders, corals capture food using their tentacles, during which they can unintentionally ingest microplastics. Hall et al. (2015) indicate that certain hard coral species (*Scleractinia*) in Australia can consume up to 50 µg of plastics, which are typically expelled within 48 hours. However, the potential internal damage and long-term effects remain uncertain. Malaysian coastal corals, especially those in regions impacted by sedimentation, tourism, and coastal development, are at a heightened risk of exposure to higher concentrations of microplastics (Tan et al., 2022).

This study aims to investigate the spatial variation of microplastics between two sites, Pulau Ular and Cherok Paloh, and to identify the types of microplastics found in three coral species: *Acropora*, *Montipora*, and *Porites*. It is hypothesized that the concentration of microplastics in these corals will differ between sites and coral species, resulting in either significant or non-significant variations in contamination levels.

Methods

Sample sites

This study was conducted in the coastal waters of Kuantan, focusing on two locations: Pulau Ular and Cherok Paloh. Pulau Ular is a small island located 34 km north of Kuantan, between Cherating and Balok in the South China Sea, while Cherok Paloh is situated approximately 8 km south of Kuantan. At Pulau Ular, two distinct sampling sites were selected, named Pulau Ular 1 and Pulau Ular 2, to capture potential variations in microplastic abundance within different areas of the island. These sites were differentiated based on their coordinates and slight environmental variations. In contrast, a single sampling site was chosen at Cherok Paloh to serve as a representative location for that area.

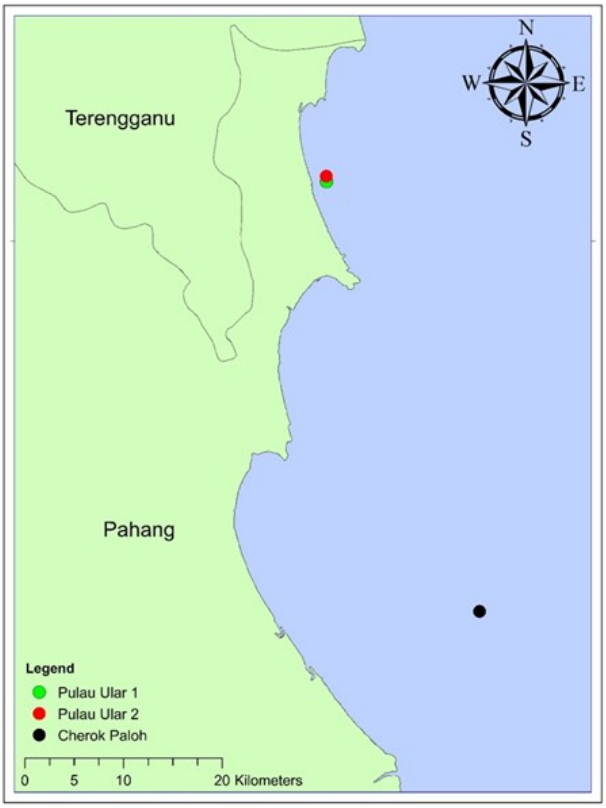

Figure 1. Sampling sites in Kuantan coastal waters.

Figure 1 provides a visual representation of the locations while Table 1 presents detailed information on the coordinates, sampling dates and depths of each site. Coral samples were collected using a boat and diving equipment. At each site, samples of three coral species (*Acropora*, *Montipora*, and *Porites*) were carefully extracted using a hammer and chisel, ensuring minimal damage to the coral structures. Approximately 150 grams of each coral species were collected per site and immediately placed in iceboxes for transportation to the laboratory, where they were stored in a freezer until further analysis.

Microplastics digestion

To isolate and analyze microplastics from the coral samples, a two-step digestion process was performed targeting both external and internal microplastics. For the extraction of surface microplastics, each coral skeleton was submerged in a saturated sodium chloride (NaCl) solution in a glass beaker covered with aluminum foil to minimize contamination. The

Table 1. Detailed information on sampling sites.

Site	Coordinates	Sampling date	Depth (meters)	Coral species collected
Pulau Ular 1	4°03.250'N 103°24.577'E	7th August 2023	8	*Acropora, Montipora, Porites*
Pulau Ular 2	4°03.548'N 103°24.570'E	7th August 2023	8	
Cherok Paloh	3°39.732'N 103°32.946E	15th Aug 2023	18	

samples were then sonicated at room temperature using 200W of power for five minutes to detach any surface-bound microplastics. After sonication, the solution was allowed to settle for 24 hours before being decanted and filtered through a 0.7 µm pore size, 47 mm diameter glass fiber membrane. To extract microplastics embedded within the coral skeleton, approximately 10 grams of each coral sample from the first step was dissolved in 15% hydrochloric acid (HCl) for 30 minutes. The resulting HCl solution was then diluted with Milli-Q water and passed through the same glass fiber membrane. Any remaining undissolved skeleton fragments were thoroughly rinsed with Milli-Q water, combined with the previously filtered HCl solution, and filtered again. The membranes from both digestion steps were then dried and stored for further analysis.

Identification and analysis of microplastics

Following the digestion process, all filtered samples were initially observed under a stereoscopic microscope to identify potential microplastics based on their visual characteristics such as shape, color, and size. Particles exhibiting typical features of microplastics were isolated and subjected to further analysis using Fourier Transform Infrared (FTIR) spectroscopy. This technique provides a molecular fingerprint of each particle, allowing for precise polymer identification. The FTIR spectra of each suspected microplastic particle were compared against a reference database to confirm the polymer type. Identified polymers included polyacrylamide, polyvinyl, polyethylene, polyamide, styrene, polypropylene, methyl vinyl ether, and polystyrene. Quantification was achieved by counting the number of microplastic particles of each type, providing insights into the overall distribution and prevalence of specific polymers in the samples.

Quality control

Stringent quality control measures were implemented throughout the study to minimize contamination and ensure data integrity. All glassware, including conical flasks and beakers, were thoroughly rinsed at least three times with filtered distilled water before use. To reduce airborne contamination, all solution preparations and biological dissections were carried out in a semi-enclosed space, and containers were consistently covered with aluminum foil when not in use. Laboratory personnel wore nitrile gloves and cotton lab coats during all procedures to avoid introducing contaminants. To further ensure accuracy, the Ge crystal used in Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy was meticulously cleaned with 100% filtered ethanol after each sample analysis. Additionally, procedural blanks were included in every batch of samples to monitor and account for any potential contamination introduced during the laboratory processes.

Statistical analysis

Data collected from the experiments were analyzed using SPSS software to calculate the mean values and standard deviations for each coral species and sampling site. The standard deviation was used to represent the variability of microplastic concentrations within each group. The analysis focused primarily on descriptive statistics to illustrate the observed trends in microplastic contamination across different coral species (*Acropora*, *Montipora*, and *Porites*) and sampling sites (Pulau Ular 1, Pulau Ular 2, and Cherok Paloh).

Results

Coral sample masurement

Figure 2 displayed coral samples that found in all sites. The biological parameters of the coral species *Acropora*, *Montipora*, and *Porites* were measured across three sampling sites: Pulau Ular 1, Pulau Ular 2, and Cherok Paloh. The mean weight of each coral species was calculated at each site, along with the corresponding standard deviations, as shown in Table 2. The consistency in sample weights across the sites ensured reliability in subsequent analyses of microplastic contamination.

Microplastic abundance

A total of 36 coral samples were collected, with microplastics isolated from both the external and internal regions of the coral skeletons. Of these samples, 20 were found to contain microplastics, accounting for 55.56% of the total. The procedural blanks indicated no contamination, confirming the reliability of the sample processing method. Table 3 presents

Table 2. Mean weight of coral species (*Acropora*, *Montipora*, and *Porites*) at different sampling sites.

Sites	Species	Weight (g)
Pular Ular 1	*Acropora*	10.38 ± 0.186
	Montipora	10.27 ± 0.160
	Porites	10.35 ± 0.321
Pular Ular 2	*Acropora*	10.15 ± 0.030
	Montipora	10.31 ± 0.287
	Porites	10.25 ± 0.182
Cherok Paloh	*Acropora*	10.13 ± 0.144
	Montipora	10.41 ± 0.141
	Porites	10.46 ± 0.324

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Figure 2. Coral samples found in (a) site Pulau Ular 1 (b) Pulau Ular 2, and (c) Cherok Paloh with the sequence of *Acropora*, *Montipora* and *Porites* from left to right.

the distribution of microplastics within each coral species across the three sites. The results showed that the number of microplastics detected varied among species and sites, with *Acropora* generally exhibiting a higher number of microplastic items compared to *Montipora* and *Porites*.

Physical characteristics of microplastics found in samples

Upon examining the microplastics retrieved from the coral samples, three predominant shapes were identified: fragments (3 items), fibers (25 items), and films (2 items), constituting 10%,

Table 3. Number of microplastic items found in coral species (*Acropora*, *Montipora*, and *Porites*) at different sampling sites.

Sites	Species	Number of item	Total
Pular Ular 1	*Acropora*	6	8
	Montipora	1	
	Porites	1	
Pular Ular 2	*Acropora*	4	11
	Montipora	3	
	Porites	4	
Cherok Paloh	*Acropora*	5	11
	Montipora	1	
	Porites	5	

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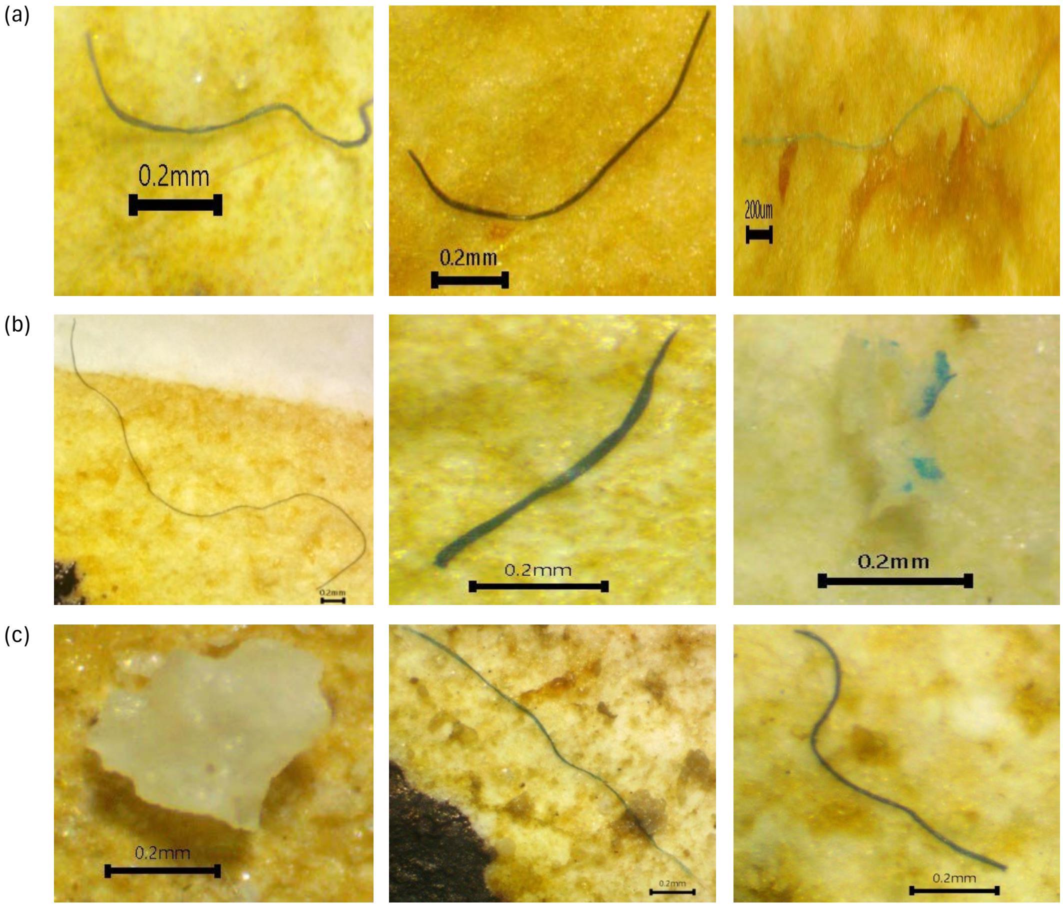

Figure 3. Examples of microplastics found at different sampling sites: (a) Pulau Ular 1, (b) Pulau Ular 2, and (c) Cherok Paloh. These images highlight the diverse physical characteristics of the collected microplastics.

83.33%, and 6.66% of the total, respectively. As shown in Figure 3, the majority of microplastics retrieved across all three sites were characterized by a fiber shape, with fragments and films being less prevalent. Notably, fragments and films were primarily located in Porites specimens collected from site 2 of Pulau Ular and Cherok Paloh. Figure 4 illustrates examples of microplastics found at different sampling sites, highlighting their diverse physical characteristics: (a) Pulau Ular 1, (b) Pulau Ular 2, and (c) Cherok Paloh.

Figure 5 categorizes microplastics into five size classes: < 0.2 mm, 0.2 mm – 0.4 mm, 0.41 mm – 0.6 mm, 0.61 mm – 0.8 mm, and > 0.8 mm. The most abundant size range observed was 0.2 mm – 0.4 mm, with a total of 12 items (40.0%). In contrast, the largest size class, exceeding 0.8 mm, had the fewest items, with a total of 3 (10.0%). The distribution of the remaining size classes included 6 items (20.0%) within < 0.2 mm, 5 items (16.67%) within 0.41 mm – 0.6 mm, and 4 items (13.33%) within 0.61 mm – 0.8 mm.

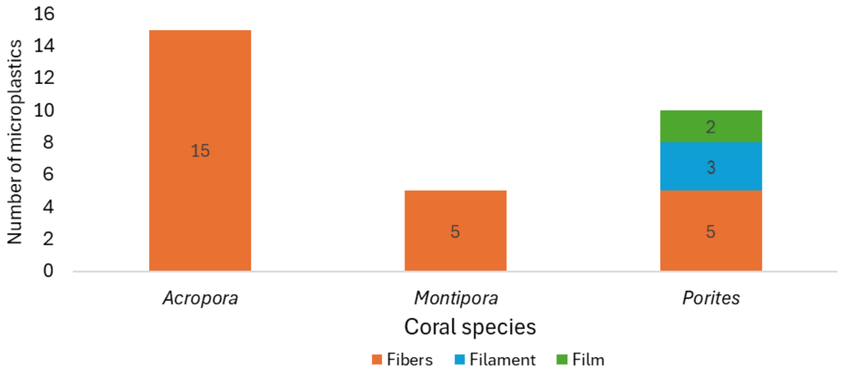

Figure 4. Abundance of microplastics according to their shape in different coral species.

The colors observed during the experiment exhibited a predominant prevalence of black, with 16 items, while green, red, and brown were less common, with 9, 3, and 2 items respectively. This distribution corresponds to the following percentages: 53.33% for black, 30% for green, 10% for red, and 6.67% for brown. The prominence of black microplastics, accounting for over half of the observed items, indicates their notable prevalence in the experimental findings, while the other colors contribute to a diverse but less frequent spectrum (Figure 6).

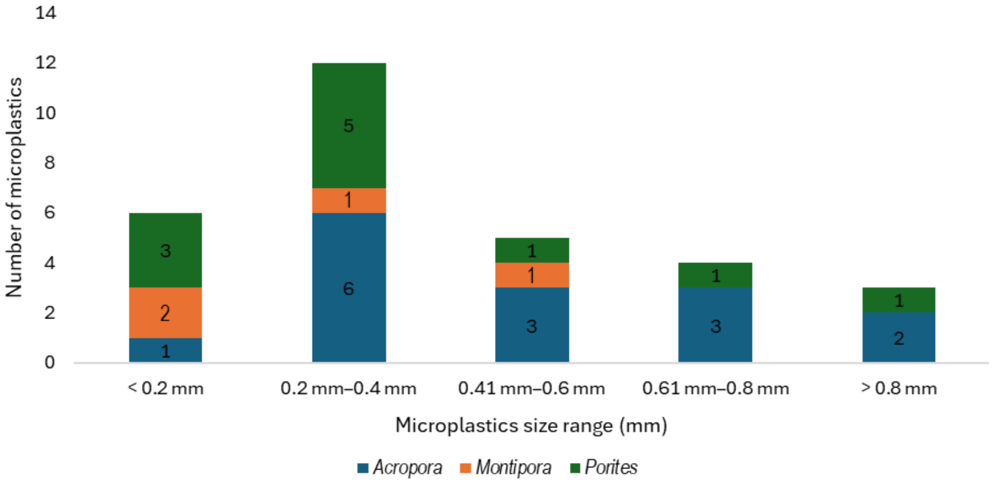

Figure 5. Distribution of microplastic sizes found in the coral species *Acropora*, *Montipora*, and *Porites*.

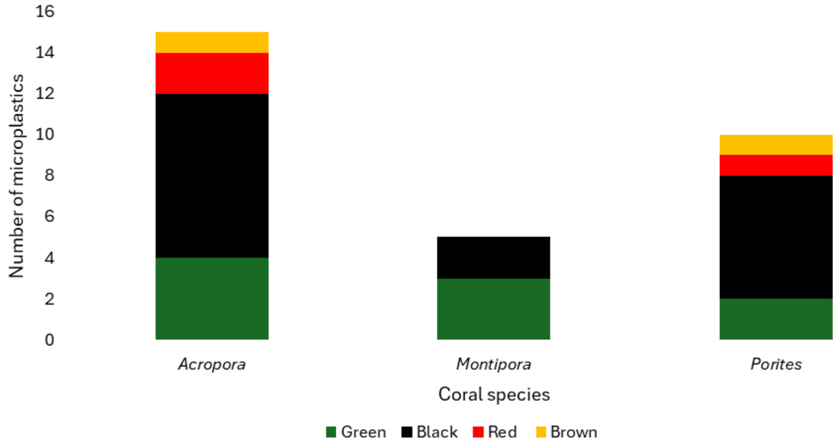

Figure 6. Distribution of microplastic colors identified in three coral species: *Acropora*, *Montipora*, and *Porites*.

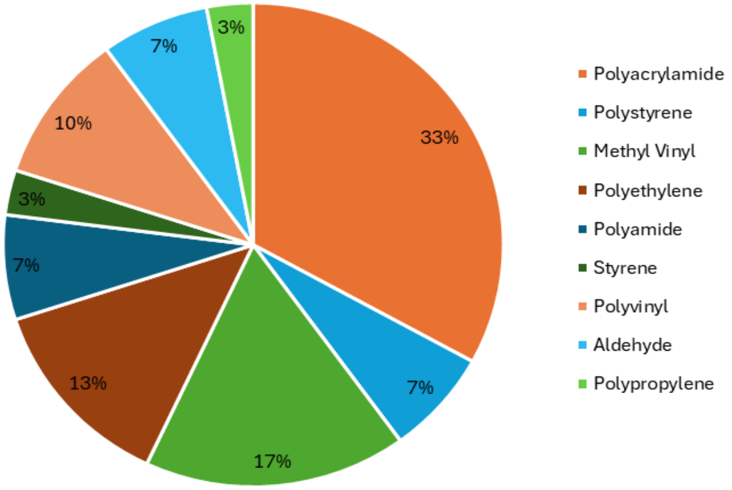

Figure 7. The percentage distribution of different polymer types found in coral samples collected from three study sites.

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Polymer identification

The FTIR analysis revealed polyacrylamide as the most common polymer, comprising 33.33% of the total microplastics detected (10 items). Methyl vinyl ether was the second most frequent polymer, with 5 items (16.67%), followed by polyamide with 4 items (13.33%), polyvinyl with 3 items (10%), and polystyrene, polyethylene, and aldehyde with 2 items each. Styrene and polypropylene were the least commonly identified polymers, each represented by 1 item. Polypropylene was only found at site 2 of Pulau Ular, while styrene was only detected at Cherok Paloh. Figure 7 presents the percentage distribution of different polymers identified from the coral samples within three sites. The data shows a high presence of polyacrylamide, followed by other polymers in varying proportions.

Discussion

Relationship between plastic and coastal waters

The presence of microplastics in coastal areas is influenced by various physical and chemical processes, including transport via currents and wind, as well as degradation through weathering (Yu et al., 2016). In this study, microplastics were predominantly characterized as fibers (83.33%), suggesting that environmental factors such as UV radiation and mechanical abrasion from waves are contributing to the fragmentation of larger plastic debris. Research suggests that sandy beaches can act as temporary or permanent reservoirs for microplastics, accumulating them over prolonged periods due to environmental factors such as UV irradiation and physical abrasion from waves (Cozar et al., 2015). However, the process of fragmentation is slower in ocean environments, attributed to lower temperatures, reduced UV intensity, and diminished mechanical abrasion (Veerasingam et al., 2016).

As observed in this study, the coastal zones of Kuantan are particularly vulnerable due to their proximity to industrial activities and the extensive maritime operations at nearby port. The results suggest that coastal zones, which serve as primary sources of plastic pollution and receivers of marine environmental impacts, exhibit complex dynamics that require a deeper understanding of the fundamental aspects of microplastic behavior in these regions. For instance, the presence of diverse polymer types like polyacrylamide, polyvinyl, and polyamide points to multiple pollution sources, including industrial discharges and consumer products.

Most studies on microplastics focus on factors like abundance, chemical composition, and ecological threats, with fewer analyses exploring their physical properties (Chubarenko et al., 2018). This study highlights the need for more research into the physical characteristics of microplastics, such as size, shape, and color, to better understand their ecological implications. External effects like chemical or biological pollution are often linked to unintended consequences of human activities (Ho & Goethals, 2022). Lin et al. (2021) emphasized that microplastics in the environment are influenced by diverse sources, including industrial, agricultural, anthropogenic, and personal care products, which were all likely contributors to the findings in this study.

The findings of this study underscore the urgent need to address marine plastic pollution in Malaysia’s coastal zones. Rapid economic development has led to a yearly 4% rise in waste generation (Moh & Abd Manaf, 2014), and a significant portion of this waste is expected to enter waterways and oceans. With a coastline spanning 4,675 km and a rich marine ecosystem, proactive measures are essential to mitigate the detrimental impacts of microplastics on coastal and marine ecosystems.

Microplastic ingestion by corals

The results of this study validate findings from other research, indicating that coral species can ingest microplastics (Hall et al., 2015; Reichert et al., 2018) and highlight this study areas for further investigation. Coral species such as *Acropora*, *Montipora*, and *Porites* exhibit both phototrophic and heterotrophic feeding strategies. They obtain nutrition through the translocation of photosynthetic products produced by their symbiotic zooxanthellae. Despite this reliance on internal sources, corals depend on external food sources to fulfill their nutritional requirements, constituting approximately 15–35% of their daily energy needs. Acting as passive suspension feeders, corals capture plankton and other particles passing over their tentacles. Unfortunately, this feeding mechanism also allows small debris such as microplastics to become entrapped and ingested by the coral polyps (Hall et al., 2015).

Variations in feeding rates among coral species are not solely attributed to measurement techniques but rather signify differences in feeding effort. This observation aligns with previous studies, which emphasized the species-specific nature of coral feeding behavior and capacity (Hall et al., 2015). Additionally, the buoyancy of microplastics reduces the likelihood of particles sinking away from coral polyps, making them more accessible during active feeding. The buoyant properties of microplastics likely contribute to the disparities observed among colonies in terms of ingestion rates. As biofilm and biofouling develop on microplastics, their buoyancy decreases, posing an even greater risk to corals by increasing their chances of ingestion (Feng et al, 2020).

Some coral species employ a filter-feeding strategy, stretching their specialized polyp structures to catch microscopic particles suspended in the water. Due to their small size, microplastics can be inadvertently ingested during this feeding process. Moreover, sedimentation poses additional risks to coral communities, as microplastic particles may settle on coral colonies, impairing nutrient exchange and gas diffusion. Corals are stationary organisms, remaining in the same locations, which makes the adverse effects of sedimentation and microplastic accumulation more pronounced.

Harmful effects of microplastics on corals

It has been shown that corals can experience various adverse effects due to microplastics (Soares et al., 2020). These impacts include reduced growth, significant decreases in detoxifying and immunity enzyme activities, increased antioxidant enzyme activity, increased mucus production, lower fitness, and negative effects on the connections between corals and their symbiotic algae. Additionally, tissue necrosis has been linked to the presence of microplastics, which can affect skeletal growth and calcification in corals, alter metabolite profiles, elevate energy expenditures, reduce fertilization success rates, and lead to coral bleaching incidents.

Instances of lower food intake and feeding performance, as well as changes to photosynthetic efficiency, have also been documented due to increased exposure to contaminants, pathogens, and harmful compounds. Research investigating the effects of microplastics on photosynthetic activity has shown disrupted performance in two coral species (*Amphiroa verrucosa*), while for *Porites lutea* and *Pocillopora damicornis*, no such alterations were observed (Reichert et al., 2018). At varying depths, these impacts are particularly detrimental to species that are more susceptible to stress and depend on the type of microplastic ingested. For instance, studies have demonstrated that low-density polyethylene (LDPE) negatively affects *Acropora* coral polyps by interfering with photosynthesis, leading to necrosis and bleaching in the staghorn coral, which primarily inhabits tropical shallow-water reefs (Syakti et al., 2019).

Corals can also experience indirect effects from microplastics that increase their exposure to viruses, chemical contaminants, and bacteria. Hydrophobic organic contaminants and aqueous metals, including antibiotics, phthalic acid esters, and other chemicals, often adsorb to microplastics (Saliu et al., 2019). Some coral species, such as *Pocillopora damicornis*, have shown impaired immune systems and reduced anti-stress capacities due to microplastic exposure. Additionally, microplastics can serve as substrates for pathogenic microorganisms, leading to biofilm formation (Curren & Leong, 2019). These biofilms provide new surfaces on which specific dominant bacteria, not naturally present in seawater, can thrive. Notable examples include families such as *Vibrionaceae*, *Rhodobacteraceae*, and *Flavobacteriaceae* (Wu et al., 2022), which have been linked to coral tissue damage. *Vibrio* species, in particular, are the primary pathogens associated with coral bleaching. Furthermore, microplastic biofilms can harbor harmful *Pseudomonas* and *Vibrio cholerae* (Feng et al., 2020), increasing the likelihood of coral diseases and mortality.

Conclusions

The study provides critical insights into the spatial variation and impact of microplastics on coral species in the Kuantan coastal waters. The findings underscore the urgent need for effective waste management strategies and pollution control measures to mitigate the influx of microplastics into the marine environment. Further research is essential to explore the long-term effects of microplastic ingestion on coral health and to develop targeted interventions to protect these vital ecosystems. The study's detailed analysis of microplastic characteristics, distribution, and ingestion by corals offers a comprehensive understanding of the extent and impact of microplastic pollution, contributing to the broader efforts to preserve marine biodiversity and ecosystem health.

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Authorship contribution

Fuad Miskon: Conceptualization, project leadership, methodology, writing – original draft preparation, writing – review and editing. **Shamin Amarul Sharulnizam**: Laboratory analysis, data collection, writing – original draft. **Intan Noor Munira Ghazali**: Laboratory methodology testing, quality control of analytical procedures, writing – methodology section. **Muhammad Faiz Mohd Hanapiah**: Coral species identification, expert consultation on coral-related aspects, writing – review and editing. **Muhammad Khairulanwar Rosli**: Coral sampling methodology, field data collection, writing – methodology section. All authors reviewed and approved the final manuscript and are responsible for the integrity and accuracy of the work.

Data availability

Datasets generated during and/or analysed throughout the present study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

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