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# Microplastic Contamination in Key Crustaceans and Molluscs from Bandar Abbas Coastal Waters, Persian Gulf

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**Abstract**

**Introduction:** Microplastic contamination poses significant challenges to aquatic life and human health. This study aimed to assess the presence, frequency, and characteristics of microplastics in the Blue Swimmer Crab (Portunus armatus), Banana Prawn (Penaeus merguiensis), Bivalve Mollusc Oyster (Amiantis umbonella), and Razor Shell (Solen roseomaculatus) from the coastal waters of Bandar Abbas, Persian Gulf, Iran, which provides a comprehensive analysis of microplastic contamination in these species within this area.

**Methods:** Five research stations along the Bandar Abbas coast, representing varying levels of urbanity, were chosen for sampling. After collecting biological samples, we isolated microplastics using a digestion procedure and flotation method. The characteristics of microplastics, including shape, color, size, and type, were analyzed with microscopy and Fourier-transform infrared spectroscopy (FTIR). Matrix-spiked (MS) samples were prepared to validate method accuracy and recovery rates. Identified microplastic forms included fibers, fragments, and films, with fibers being the most common.

**Results:** The particles were categorized into three size ranges: 0.45-25 µm, 25-250 µm, and 250-500 µm. Sixty-six percent fell within the 0.45-25 µm range, predominantly in black and blue colors. Common polymers included polyethylene, polypropylene, polyethylene terephthalate, polystyrene, and polyamide. The average microplastic frequency was 2.57±1.2, 4.9±1.95, 3.27±1.2, and 4.05±1.9 particles/g for Blue Swimmer Crab, Banana Prawn, Bivalve Mollusc Oyster, and Razor Shell, respectively. Correlation analysis indicated a significant positive relationship between microplastic frequency in soft tissues and body size.

**Conclusion:** This study highlights the presence of microplastics in key marine species in Bandar Abbas waters, posing risks to aquatic ecosystems and human health.

**Keywords:** Microplastics, Ecosystem, Persian Gulf, Crustaceans, Molluscs

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## Introduction

Escalating concerns about plastic particles in marine and freshwater ecosystems have intensified awareness of their potential hazards to environmental integrity and human health (1). Microplastics and nanoplastics have been documented to cause numerous adverse impacts on marine ecosystems, representing one of the most pressing environmental challenges of the present era (2). Globally, the manufacture and use of plastics have surged, often without adequate consideration of their harmful environmental impacts (3). From 1950 to 2013, global plastic production increased approximately 200-fold, from 1.7 to 299 million tons, with an estimated 5 to 13 million tons entering marine ecosystems annually (4). The versatility of plastic products has led to their widespread application worldwide (5). Characteristics such as low density, exceptional durability, and resistance to corrosion have further facilitated their extensive adoption across various industries (6,7).

Upon entering the environment, macroplastic debris undergoes a range of biotic and abiotic processes, progressively fragmenting into smaller particles referred to as microplastics (8). By definition, microplastics are plastic particles smaller than 5 mm in diameter. In specific contexts, particles that pass through a 500 µm sieve but are retained on a 67 µm sieve are also categorized as microplastics (9). These particles are generally classified into two categories: primary and secondary microplastics. Primary microplastics are released directly from manufactured products, such as synthetic textiles, plastic packaging,

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and vehicle tires. Secondary microplastics are formed through the fragmentation of larger plastic items due to environmental factors including ultraviolet radiation, mechanical abrasion, and chemical degradation (10).

Weathering processes on beaches cause the formation of microcracks on plastic surfaces, ultimately leading to the generation of microplastic particles, which can be transported into aquatic environments by natural forces such as wind and waves (11). Plastic degradation in marine environments involves both physical disintegration and significant chemical alterations, markedly reducing the average molecular weight of constituent polymers. Since mechanical strength and structural integrity are closely linked to polymer molecular weight, extensive degradation severely compromises material stability (12). As plastics become increasingly fragile, they readily disintegrate into smaller particles during transport. The characteristics of microplastic particles, including size, shape, and polymer composition, play a critical role in determining their toxicity and bioavailability to living organisms (13).

Studies have identified various forms of microplastics, including fibers, fragments, granules, foams, and films, with fibers reported as the most prevalent type. The wide range of fiber colors—such as blue, purple, green, and red—indicates their predominantly anthropogenic origin. These fibers are commonly composed of synthetic polymers such as polyester and nylon (14). Numerous studies have demonstrated that microplastics are widely distributed throughout the world's oceans, contaminating water columns, sediments, and marine biota (8).

The ubiquity of microplastics in aquatic ecosystems is evident from their detection even in deep-sea sediments at depths ranging from 1,100 to 5,000 m (15). A variety of anthropogenic activities contribute to the introduction of plastic debris into marine environments, either directly or indirectly, including recreational and industrial fishing, coastal tourism, aquaculture operations, offshore oil platforms, and increasing coastal urbanization (16,17).

Certain plastics, such as polyethylene and polypropylene, are lightweight and easily transported by seawater, allowing them to disperse far from their original sources. In contrast, denser plastics like polyvinyl chloride tend to settle on the seabed near their points of entry; however, they may still be redistributed by ocean currents (18).

Each year, hundreds of marine organisms—including whales, dolphins, sea turtles, and seabirds—die as a result of ingesting plastic debris or suffering from physical obstruction and suffocation (6,19,20). A major concern associated with microplastics is their capacity to act as vectors for persistent organic pollutants and other contaminants (8,21). Due to their relatively high surface-area-to-volume ratio compared with larger plastic debris, microplastics can efficiently adsorb persistent organic compounds and heavy metals (6).

In recent years, the coastal waters of Bandar Abbas City, located at the strategic entrance of the Persian Gulf in southern Iran, have been subjected to multiple environmental pressures, including overfishing, oil pollution, habitat degradation, invasive species introduction, and the overexploitation of marine resources. The discharge of untreated sewage, along with domestic and industrial waste, has further intensified these challenges. Consequently, growing concern has emerged among researchers and environmental professionals regarding the increasing prevalence of microplastic pollution along the Persian Gulf shoreline. Microplastics pose a dual threat by endangering marine biodiversity and presenting potential risks to human health (22).

Addressing these challenges requires a comprehensive understanding of microplastic pollution in aquatic environments, particularly within the Persian Gulf. This includes quantifying the occurrence and frequency of microplastics in coastal sediments and resident marine organisms. Given the ecological and economic importance of the Persian Gulf's coastal regions, the present study investigates microplastic contamination in the Banana Prawn (Penaeus merguiensis), a widely consumed seafood species in Bandar Abbas City. The novelty of this research lies in its multi-species approach, focusing on economically important crustaceans and molluscs that have not been extensively studied in this region.

## Materials and Methods

This study examined microplastic contamination in the coastal waters of the Persian Gulf along the shores of Bandar Abbas City, southern Iran. This region is characterized by a wide range of industrial activities, including shipbuilding and aluminum and zinc production. Additionally, several utilities, such as power generation plants, petrochemical refineries, and multiple water desalination facilities, are currently operational in the area. These industrial activities, which are both directly and indirectly dependent on marine resources, have significantly contributed to the degradation and pollution of the marine environment.

Sampling was conducted at five strategically selected stations surrounding Bandar Abbas City along the Persian Gulf coast (Figure 1). This systematic approach was designed to provide comprehensive insight into the extent of microplastic contamination in local marine ecosystems, with a particular focus on crustaceans and molluscs inhabiting these waters.

### *Sampling*

A total of 160 samples (40 for each species) were collected from four species: the Banana Prawn (Penaeus merguiensis) and Blue Swimmer Crab (Portunus armatus) from the crustacean group, and the Razor Shell (Solen roseomaculatus) and Bivalve Mollusc Oyster (Amiantis umbonella) from the mollusc group in March 2023. Sampling was conducted at five research stations along the Persian Gulf coast near Bandar Abbas City, southern Iran. The sampling strategy addressed two core objectives:

1. Assessing microplastic contamination in species of high economic and nutritional value that play pivotal roles in the local food web. Selection criteria included

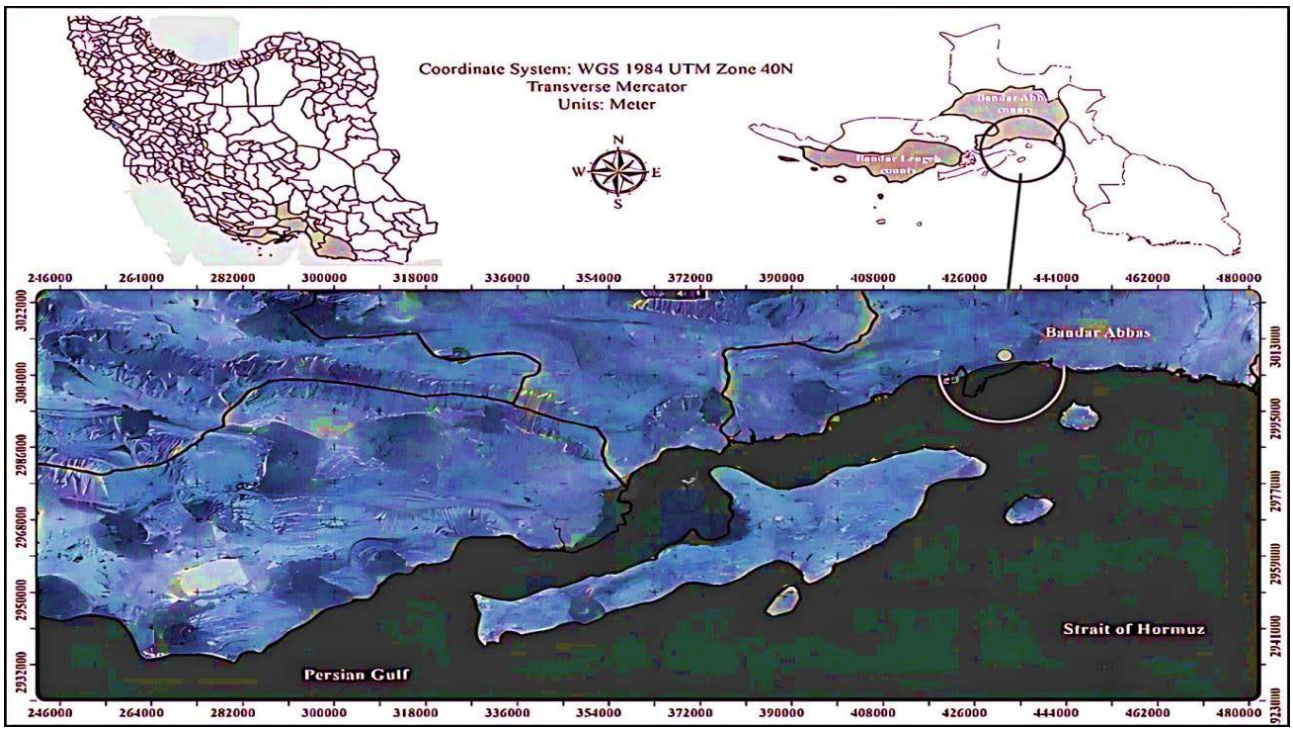



**Figure 1.** Location of study area

abundance, nutritional profile, ease of collection, and substantial local consumption.

2. Evaluating overall pollution loads at the sampling locations, which, based on historical water quality data and environmental assessments, had been previously identified as polluted sites (22,23).

### *Preparation of samples*

The samples were promptly wrapped in aluminum foil and labeled with markers. They were saved in an ice-filled container and transported to the laboratory as quickly as possible. In the lab, samples were maintained at -20 °C. Before analysis, each sample was rinsed three times with cold distilled water to eliminate any slime, sand particles, and algae. Subsequently, biometric measurements were conducted. Specimens were immediately wrapped in aluminum foil, labeled, placed in ice-filled containers, and rapidly transported to the laboratory. In the laboratory, samples were stored at −20 °C until further processing. Before analysis, each sample was rinsed three times with cold distilled water to remove slime, sand, and algae. Biometric measurements were then performed.

- For *P. armatus* (Blue Swimmer Crab), carapace width and carapace length (from the anterior tip of the frontal spine to the midpoint of the posterior margin) were measured using a caliper accurate to ± 0.1 mm.
- For *P. merguiensis* (Banana Prawn), the measured parameters included rostrum length (from the eye socket to the carapace end) and total body length (from the rostrum tip to the end of the telson).
- For *A. umbonella* (Oyster), total shell length and shell height were recorded.
- For *S. roseomaculatus* (Razor Shell), dorsal–ventral and anterior–posterior shell lengths, as well as shell diameter, were measured.

Body weight was recorded using a digital scale with an accuracy of ± 0.01 g. For soft tissue mass determination, the hard exoskeleton was manually removed, and the tissue was separated using a spatula, placed in individual Petri dishes for weighing, then stored in sealed plastic bags with proper labeling (24).

### *Digestion method for samples*

For acid digestion, soft tissues were placed into 150 mL glass beakers previously rinsed with distilled water. Each sample was analyzed in triplicate. To digest organic matter, 10 mL of hydrogen peroxide (30% $H_2O_2$, Product No: 106005, Merck KGaA, Germany) was added per gram of soft tissue. Beakers were labeled and incubated in a shaker (Model: GFL 3033, GFL Gesellschaft für Labortechnik mbH, Germany) at 65 °C for 24 h with a rotation speed of 80 rpm. Samples were then left at room temperature for an additional 24–48 h, depending on digestion progress. This method follows the procedure described by Pfeiffer et al. (2020) (25). To isolate microplastics, a saturated sodium chloride (NaCl) solution was used for density separation. Approximately 800 mL of NaCl solution was added to each beaker, stirred with a glass rod, and allowed to settle for 24 h. The supernatant was subsequently filtered through an Erlenmeyer flask using cellulose nitrate membrane filters (0.45 µm pore size, 47 mm diameter; Whatman). This pore size ensured retention of microplastic particles within the 0.45–25 µm range, consistent with previous marine biota studies (8). Filters were rinsed with distilled water to remove residual salt, transferred to covered glass Petri dishes, and air-dried overnight at room temperature for further analysis. The use of NaCl solution represents a cost-effective and efficient method for microplastic

isolation (25).

### *Identification of microplastics*

Visual identification was used to classify microplastic particles based on physical characteristics. After 24 h of air-drying, filters were examined under an Olympus CX31 optical microscope (10×–40×magnification) using a Z-shaped scanning pattern. Larger particles (>20 µm) were visually documented, while smaller particles (<20 µm) were confirmed using FTIR spectroscopy for polymer identification. Particular attention was paid to the edges of Petri dishes, where microplastics tend to accumulate. Filters were kept covered to minimize airborne contamination.

Particles were identified using tweezers and heated needle tests; those that bent or dented without breaking were classified as microplastics. Additionally, particles lacking cellular or tissue structures and exhibiting uniform coloration were classified as microplastics (26). Identified particles were categorized by morphology and color. Particle size (µm) was measured using ImageJ software and classified into three size classes: 0.45–25 µm, 25–250 µm, and 250–5000 µm. In this study, "fiber" refers to elongated particles, "film" to thin sheet-like particles, and "fragment" to irregular plastic pieces not classified as fibers or films (27).

### *Test Method*

Matrix spiked samples were used to validate analytical accuracy. Each sample was deliberately spiked with 12 microplastic particles, which were then extracted and analyzed. Recovery rates were measured as follows: polypropylene (PP) – 98%; polyethylene (PE) – 100%; polyethylene terephthalate (PET) – 99%; polyamide (PA) – 97%; and polystyrene (PS) – 95%. Fourier Transform Infrared Spectroscopy (FTIR) was used for polymer identification. The FTIR optical aperture was set at 2 mm, with 32 spectral accumulations per sample to optimize accuracy. Acquisition time per spectrum was 30 seconds. Spectrum One software (PerkinElmer) was used to compare acquired spectra with reference libraries to confirm polymer types.

### *Quality Assurance/Quality Control (QA/QC)*

To ensure the reliability and reproducibility of the results, several quality assurance and quality control (QA/QC) measures were implemented. All glassware and equipment were thoroughly cleaned and rinsed with distilled water before use to prevent contamination. Blank samples were processed alongside the actual samples to monitor for any potential contamination during the extraction and analysis phases. The spiking procedure involved adding known quantities of microplastic particles to assess recovery rates, ensuring that the analytical method was performing within acceptable limits. Regular calibration of the FTIR instrument was conducted before analysis, and standard reference materials (SRMs) were utilized to validate the results effectively.

### *Statistical Analysis*

Statistical analyses were carried out using SPSS 22. A Mann Whitney U test was employed to compare mean microplastic frequencies among species collected from five research stations along the Bandar Abbas coastline. Kruskal Wallis tests were used to assess differences among species—Penaeus merguiensis (Banana Prawn), Portunus armatus (Blue Swimmer Crab), Amiantis umbonella (Bivalve Mollusc Oyster), and Solen roseomaculatus (Razor Shell). When significant differences were detected, Mann-Whitney U tests were applied for pairwise comparisons at a 0.05 significance level. Spearman's rank correlation was used to analyze relationships between microplastic ingestion and organism size (length and weight).

## Results

The biometric measurement results of the studied biological species are presented in Table 1.

The recognized types comprised fibers, pieces, and sheets, with fiber microplastics being the most prevalent and film microplastics the least common among the examined biological organisms, respectively (Figure 2 and Figure 3).

The morphological and polymeric characteristics of microplastic particles identified in the examined biological species based on microscopic observation and FTIR spectra is in Table 2.

Microscopic and spectroscopic assessment of the extracted particles demonstrated a coherent pattern between the physical appearance and chemical identity of microplastics detected in the studied marine organisms. Fibrous structures dominated the dataset, exhibiting strong correspondence with polyethylene and polypropylene spectra confirmed by FTIR analysis. the morphological diversity and polymeric heterogeneity of microplastics reflect complex input pathways rather than a single pollution source. The simultaneous presence of PE, PP, PS, PET, and PA suggests mixed origins from terrestrial runoff and marine debris.

The identified microplastic particles were classified into three size categories: 0.45–25 µm, 25–250 µm, and 250–500 µm. A significant majority of the particles (66%) fell within the 0.45–25 µm size range, with black and blue being the predominant colors observed. The analysis revealed that polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), and polyamide (PA) were the most prevalent polymers detected in the study area. In terms of microplastic contamination in the sampled organisms, the average frequency of microplastics was quantified as follows: Banana prawn (Penaeus merguiensis) exhibited an average of 2.57 ± 1.2 particles/g of soft tissue, Blue Swimmer Crab (Portunus armatus) had 4.9 ± 1.9 particles/g, Bivalve mollusc oyster (Amiantis umbonella) presented 3.27 ± 1.2 particles/g, and Razor shell (Solen roseomaculatus) recorded 4.05 ± 1.90 particles/g. The microplastic frequencies across species are presented in Figure 4.

**Table 1**. Biometric measurement results of the species

| Species | Biometry | Number | Minimum | Maximum | Average | Standard Deviation |
|---|---|---|---|---|---|---|
| Banana prawn (Penaeus merguiensis) | Total weight (gr) | 40 | 6.91 | 34.64 | 19.57 | 6.71 |
| | Soft tissue weight (gr) | 40 | 4.21 | 20.68 | 11.59 | 3.84 |
| | Length (cm) | 40 | 3.88 | 7.10 | 5.85 | 0.77 |
| | Width (cm) | 40 | 11.81 | 18.12 | 15.10 | 1.80 |
| Blue Swimmer Crab (Portunus armatus) | Total weight (gr) | 40 | 101.6 | 356.27 | 213.13 | 81.97 |
| | Soft tissue weight (gr) | 40 | 36.58 | 156.71 | 9.27 | 36.85 |
| | Length (cm) | 40 | 5.91 | 10.36 | 7.67 | 1.16 |
| | Width (cm) | 40 | 11.17 | 16.15 | 13.91 | 1.25 |
| mollusc oyster (Amiantis umbonella) | Total weight (gr) | 40 | 50.36 | 89.32 | 67.37 | 11.46 |
| | Soft tissue weight (gr) | 40 | 10.23 | 25.11 | 16.78 | 4.8 |
| | Length (cm) | 40 | 5.04 | 6.93 | 6.02 | 0.65 |
| | Width (cm) | 40 | 4.02 | 6.13 | 4.97 | 0.61 |
| Razor shell (Solen roseomaculatus) | Total weight (gr) | 40 | 4.19 | 29.41 | 17.32 | 7.35 |
| | Soft tissue weight (gr) | 40 | 2.83 | 18.46 | 10.87 | 4.78 |
| | Length (cm) | 40 | 6.50 | 11.85 | 9.90 | 1.45 |
| | Width (cm) | 40 | 0.80 | 2.86 | 1.65 | 0.47 |



**Figure 2.** Examples of microplastic particles observed through a microscope include fiber particles, pieces, and films

To further investigate the potential correlation between microplastic frequency and the physical characteristics of the studied organisms, a correlation test was employed to assess the correlation between the frequency of microplastics, body weight, and body length (Table 3). The results indicated a statistically significant correlation

**Table 2.** Morphological and polymeric characteristics of microplastic particles identified in the examined biological species based on microscopic observation and FTIR spectra

| Microplastic size range (µm) | Dominant colors | Common shapes | Major polymer types detected (by FTIR) | Relative abundance (%) |
|---|---|---|---|---|
| 0.45–25 µm | Black, blue, red, yellow | Fibers (dominant), small fragments | Polyethylene (PE), Polypropylene (PP) | 66 |
| 25–25 µm | Blue, white | Fragments, films | Polyethylene terephthalate (PET), Polystyrene (PS) | 24 |
| 250–500 µm | Transparent, white | Films and large fragments | Polyamide (PA), Polyethylene (PE) | 10 |

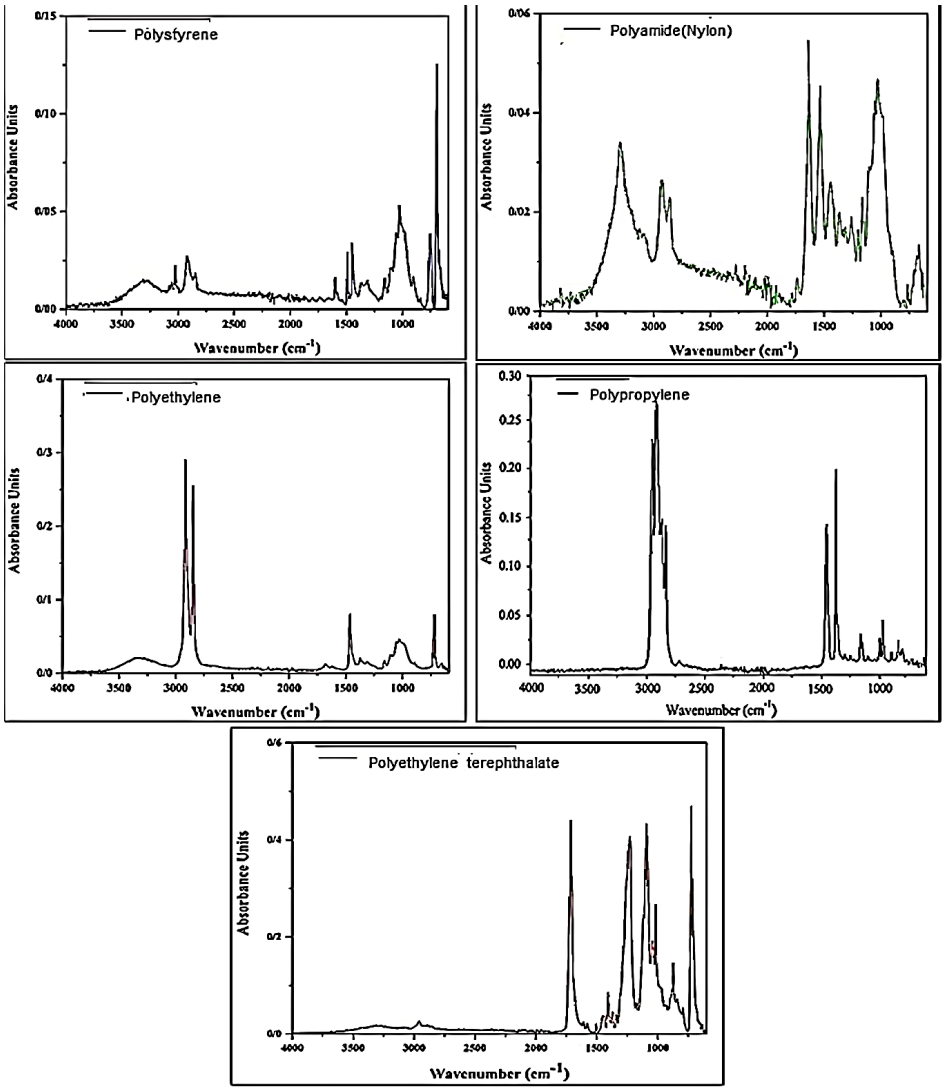



**Figure 3.** FTIR spectrum of polymers identified in the examined biological species

between the frequency of microplastics in the soft tissue of the examined species and their body size (both weight and length) at a significance level of 0.01 ($P<0.05$). This suggests that larger organisms accumulate higher quantities of microplastics, which may have implications for understanding the ecological risks associated with microplastic pollution in marine environments(28).

The findings from the non-parametric Kruskal-Wallis analysis indicated that a notable variation existed in the mean occurrence of microplastic particles among the four biological species examined ($P<0.05$) (Table 4).

The results of the Mann-Whitney U test confirmed significant differences in the frequency of microplastic particles among the studied species. Specifically, the average frequency of microplastic particles was found to be significantly higher in Blue Swimmer Crab (Portunus armatus) compared to both Banana Prawn (Penaeus merguiensis) and the other two bivalve species, indicating that this species is more susceptible to microplastic accumulation. Furthermore, a notable difference was observed in the frequency of microplastics between Razor Shell (Solen roseomaculatus) and both Banana Prawn (Penaeus merguiensis) and Bivalve Mollusc Oyster (Amiantis umbonella) ($P>0.05$). The data indicated that Razor Shell accumulated a greater quantity of microplastic particles than both of these species. Additionally, a statistically significant difference was found between the mean frequency of microplastic particles in Bivalve

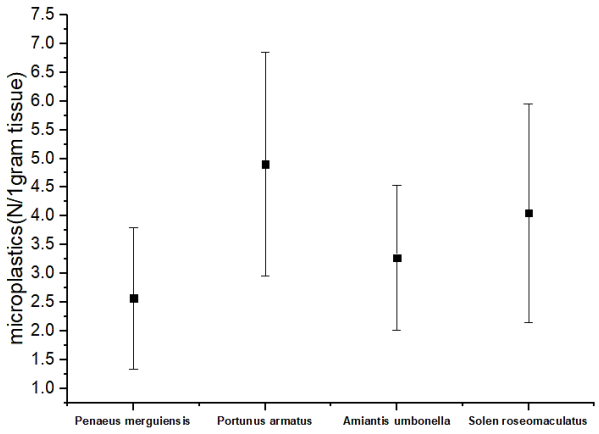



**Figure 4.** Microplastic frequencies across species

Mollusc Oyster (Amiantis umbonella) and Banana Prawn (Penaeus merguiensis) ($P<0.05$), with Bivalve Mollusc Oyster exhibiting a higher mean frequency of microplastics than Banana Prawn (Penaeus merguiensis).

## Discussion

Numerous studies have demonstrated a relationship between population density and microplastic prevalence, with higher concentrations in marine ecosystems correlating with population growth and coastal activities (29,30). Urban development around the coastal areas of the Persian Gulf coastal zones, along with untreated sewage, fishing debris, tourism, industrial activities, oil spills, and river waste, has degraded its environment. In this study, the average microplastic frequencies were measured as 2.57 ± 1.23 particles/g in Blue Swimmer Crab (Portunus armatus), 4.9 ± 1.95 particles/g in Banana Prawn (Penaeus merguiensis), 3.27 ± 1.26 particles/g in Bivalve Mollusc Oyster (Amiantis umbonella), and 4.05 ± 1.90 particles/g in Razor Shell (Solen roseomaculatus), indicating variable ingestion levels among species. Nouri et al. (2018) found that microplastics in Pinctada radiata bivalves from Bandar Lange were predominantly microfibers. This aligns with our study's finding of fiber-type microplastics in Banana Prawn (Penaeus merguiensis). Similarly, Zakeri et al. (2019) reported that fiber-type microplastics were prevalent in white fish (Rutilus frisii kutum) from the Caspian Sea. The Persian Gulf's semi-closed nature makes it particularly vulnerable to pollutants; microplastics can persist and be ingested by aquatic organisms. The high prevalence of microplastics in these creatures is closely related to pollution levels in their habitats (27).

Various marine species, including crustaceans and mollusks, widely consume plastic particles (31,32). Further investigation is warranted to elucidate the potential impacts of microplastics on these groups, as they may be disproportionately susceptible (33). Our study indicates a significant diversity in microplastic consumption among different biological species. Specifically, a higher prevalence was observed in Portunus armatus (4.9 ± 1.95 particles/g) and Solen roseomaculatus (4.05 ± 1.90 particles/g), while lower levels were found in Penaeus

**Table 3.** Results of the correlation test between the frequency of microplastics, body weight, and body length

| Spearman's correlation | Total microplastics | Body weight | Body_length |
|---|---|---|---|
| Total microplastics | 1 | | |
| Body weight | **0.58 | 1 | |
| Body length | **0.63 | 0.06 | 1 |

**Significance at the 0.01 level

**Table 4.** The results of the Kruskal-Wallis test, comparing the frequency of microplastics found in the body of the understudy species in the studied sites of Bandar Abbas city coasts

| Microplastic particles | Coefficient | Sig |
|---|---|---|
| fiber | 6.50 | 0.15 |
| film | 0.65 | 0.93 |
| piece | 1.31 | 0.84 |
| Total microplastics | 2.15 | 0.70 |

merguiensis (2.57 ± 1.23 particles/g) and Amiantis umbonella (3.27 ± 1.26 particles/g). This suggests species-specific differences likely arising from feeding strategies and the distribution patterns of microplastics (25,34). Aquatic organisms under dietary pressure may consume more microplastics due to their feeding habits (34).

While several studies have examined the prevalence of microplastics in mollusks and crustaceans globally(35), methodological differences pose challenges for direct comparison with our findings. For instance, Penaeus merguiensis typically consumes fewer microplastics than are present in the environment. Increasing sample sizes in future research could potentially reveal a greater abundance of microplastics in this species.

Our study also identified a significant correlation between the amount of ingested microplastics and the average weight and length of the studied species, with a significance level of 0.01 ($P<0.05$). This suggests that larger individuals may consume more microplastics due to their larger mouth size, which aligns with findings by . Dowarah et al. (2020) and Daniel et al. 2020 (2020) (36,37). All studied species are omnivorous and have diverse diets that include zooplankton and algae. Research conducted by Abbasi et al. (2018) (20) and Akhbarizadeh et al. (2019) (38) has reported the presence of microplastics in the tissues of Penaeus merguiensis and Penaeus semisulcatus. Abbasi et al (2018) documented 36 microplastic particles in the muscle tissue of green shrimp (20), while Akhbarizadeh et al. found an average of 0.36 particles per gram in Penaeus semisulcatus (38). Additionally, Devriese et al. (2015) reported an average of 0.64 microplastic particles per gram in brown shrimp (39), although Daniel et al (2020). Did not identify any microplastics in shrimp tissues. The differences in findings may stem from species-specific variations or local pollution levels. The retention time of microplastics in the digestive system also affects their presence in tissues; longer retention may lead to increased fragmentation and a higher likelihood of transfer to edible tissues(37). Fabra et al. (2021) observed that higher concentrations

of microplastics existed in the digestive tract compared to muscle tissue. Unlike organochlorines and mercury, microplastics are less likely to biomagnify(40).

FTIR analysis revealed that the samples included several polymers: polypropylene (PP), polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET), and polyamide (PA). A significant majority of the identified microplastic particles (66%) fell within the 0.45–25 μm size range, with black and blue being the predominant colors observed. Previous research has documented these polymers in sediments and waters of the Persian Gulf, with Kor and Mehdinia (2020) highlighting PE, PP, and PS as the most common (24). Keshavarzifard et al. (2021) identified PET, PS, and PP as the predominant types in the northwestern region (41). Naji et al. (2017) reported high levels of PE, nylon, and PET in coastal sediments of Bandar Abbas, while Najafi et al. (2018) found similar results in mollusks from the northern Persian Gulf, corroborating our findings (23). Saeed et al. (2020) identified microplastics such as PP, PE, PS, and nylon in the marine environment of Kuwait (42), reinforcing evidence from several previous studies (28,32,37,43-45).

Artificial fibers in the environment are often linked to local fishing gear, as demonstrated by Martin et al. (2017) (46); fishing equipment typically includes PP, PE, PVC, PS, and PA (47). The abundance of these polymers in the study could be related to residual fibers from fishing activities. PE and PP constitute a major part of global plastic production, comprising 62% of plastic demand (25). A significant portion of the microplastics in marine samples—water, sediments, and organisms—consists of PE and PP, likely due to their mass production, low density, and transportability (28). These traits enable PE and PP to persist in the water column and be carried to less contaminated areas (29,48).

The microplastics in this study are mainly polypropylene, indicating significant use in aquaculture (28). According to Waite et al. (2018), (29) and Cho et al. (2019), (28) most fiber particles come from ropes, fishing nets, and nylon/PP clothing. PE and PP also derive from various sources like packaging, automotive parts, and cosmetics (37). These plastics are common in urban development, food packaging, and agriculture, leading to a notable presence in aquatic ecosystems (5,17,32). Polyethylene particles (0.4 to 80 μm) can be ingested by biological species, causing inflammatory responses and lysosomal destabilization (5). Crustaceans can identify living versus non-living particles, yet small crustaceans ingest both algae and polystyrene microplastics in marine environments (33). Polystyrene, used in appliance insulation and disposable cutlery (28), has a higher density than polyethylene, allowing it to exist in both water and sediment, thereby threatening aquatic organisms. Conversely, lower-density polyethylene microplastics are primarily found in the water column (29). However, biofilm formation can alter polymer density, affecting accessibility for aquatic organisms (33). Additionally, polyethylene terephthalate (PET) is a significant polymer in plastic waste.

Polyethylene terephthalate (PET) is widely used in textiles, plumbing, electronics, personal care, and food packaging due to its mechanical properties and performance (48,49). It is also common in the medical field for orthopedic bandages, sutures, and artificial tendons (36). Despite bans in countries like Canada and the U.S. in 2017 on PET in sanitary products, its durability continues to encourage its use in food packaging and textiles, increasing environmental prevalence (50). Significant PET quantities were found in coastal regions, likely due to beach tourists discarding bottles and plastic bags. The density of PET (1.33 g/cm$^3$) and nylon (1.14 g/cm$^3$) exceeds that of seawater (1.02 g/cm$^3$), causing them to sink and accumulate in sediments (37). Nylon, used in fishing lines and nets, contributes to the formation of marine microplastic particles (5,49,51). Fishing activities along the Persian Gulf coasts likely increase nylon microplastic presence in these environments.

## Conclusion

This study highlights the widespread issue of microplastic pollution in aquatic ecosystems, particularly in the coastal areas of Bandar Abbas, Iran. The lack of access to historical data on microplastic pollution levels in the coastal waters of Bandar Abbas made it difficult to conduct a more precise analysis of temporal trends.

Given the average abundance of microplastics observed in these species, our results indicate an urgent need for continuous monitoring and assessment of microplastic pollutants in this area. The digestion and separation methods employed demonstrated the ability to extract microplastic particles from biological samples, revealing the diversity of shapes, colors, and types. Notably, the prevalence of fibers in our samples indicates a direct link to pollution sources such as textile fiber shedding and the degradation of larger plastic waste. This study emphasizes the importance of identifying and reducing specific sources of microplastic pollution to protect marine ecosystems and their resident organisms.

Our analysis also showed a clear relationship between the abundance of microplastics in soft tissues and the size of the organisms. This relationship indicates that larger specimens may accumulate more microplastics, which could negatively impact their health, growth, and reproductive functions. The consequences of this accumulation also extend to the food chain, as these contaminated organisms are a significant part of the diet for various marine species and human consumers. In conclusion, this research not only contributes to the existing body of knowledge on microplastic pollution but also emphasizes the urgent need for comprehensive strategies to reduce plastic waste and ensure a healthier marine environment. Collaboration among governmental, scientific, and local community entities is essential to effectively address this global challenge.

Future studies should employ advanced analytical techniques to quantify microplastic types and their potential toxicological effects on marine organisms.

Additionally, long-term monitoring of microplastic concentrations across various seasons and environmental conditions is essential to better understand their dynamics in marine ecosystems.

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**Competing Interests**
The authors declare that they have no competing interests.

**Ethical Approval**
The data presented in this manuscript are original and collected during the entire period of study. No data have been published or never will be published again.

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