Environmental Health Engineering and Management Journal. 2025;12:1389
http://ehemj.com
doi 10.34172/EHEM.1389
Environmental Health Engineering and Management Journal
Original Article
Open Access Publish Free

Microplastics occurrence in gills and digestive tract tissues of blue crabs collected from the Persian Gulf coast

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Abstract
Background: Increasing usage of plastics for various goals has led to the microplastics (MPs) enhancement in different environments, especially the marine environment. Crab is known as a seafood type, which is easily gained and often consumed by humans.
Methods: Abundance of MPs and their features in the gills (G) and digestive tract (DT) tissues of 44 blue crabs (*Portunus pelagicus*) collected from the coast of the Persian Gulf in Bushehr port were investigated in this study. Physical features of MPs (including size, shape, and color) and their chemical combination were identified through a binocular microscope and Micro-Raman, respectively.
Results: The mean abundance of MPs in the G and DT tissues was 0.89 and 0.38 items/g, respectively. The MPs levels were significantly different ($P < 0.01$) among the G and DT tissues. The highest number of MPs in the G and DT tissues was related to the size range of 20-50 µm. The highest dominant color and shape of MPs in the G and DT were fiber and white/transparent, respectively. Nylon and polystyrene (PS) in tissues both tissues were the dominant polymer types of detected MPs.
Conclusion: The results of the present study displayed that high levels of MPs in the seafood, such as crabs, may pose a negative effect on this species as well as a high exposure risk for humans.
Keywords: Blue crab, Nylons, Plastics, Polymers, Risk assessment
Citation: Moshtaqzadeh M, Rahmani A, Dobaradaran S, Asgari G, Khazaei M, Mohammadi A. Microplastics occurrence in gills and digestive tract tissues of blue crabs collected from the Persian Gulf coast. Environmental Health Engineering and Management Journal. 2025;12: 1389. doi: 10.34172/EHEM.1389.

Article History:
Received: 20 July 2024
Revised: 11 November 2024
Accepted: 4 December 2024
ePublished: 19 August 2025

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Introduction

Global production of plastic materials is growing and has increased from 1.5 million tons in 1950 to 359 million tons in 2018 (1,2). About 80 percent of the plastic waste manufactured worldwide enters marine environments due to improper waste management (3,4). Microplastics (MPs) are specified as plastic particles with a diameter smaller than 5 mm (5), which are classified into primary and secondary MPs. Primary MPs are directly released into the environment in micro-sized and secondary MPs originate from the fragmentation of larger plastic debris into smaller pieces (6,7). MPs are quickly dispersed in the surrounding environment due to their lightweight (8). MP particles, especially small-sized MPs, can affect marine and human life and pose environmental and health risks (8,9). MPs can cause different harmful effects on marine organisms, such as oxidative damage, intestinal blockage and internal abrasion, liver stress, inflammation, and growth decline (8). MPs are extensively found in all ecosystems, including land, rivers, oceans, and lakes (10).

Coastal areas, as a common border between dry environment and sea, are affected by plastic contamination and causing the accumulation and transfer of MPs from the ground into the sea (11). MPs are confused with food and consumed as bait by different aquatic organisms, including fish, shrimp, shellfish, and mollusks (12-15). The

MPs' ingestion by aquatic organisms may lead to adverse effects, for example, reproductive failure, gastrointestinal obstruction, reduced growth, and even death due to accumulation in tissues (16). There are many routes for human exposure to MPs, but seafood consumption is one of the main routes (17). The contamination of marine animals by MPs and their consumption as a human food source has raised concerns about the entry of these contaminants into the human food chain (8). The MPs' existence has been investigated in aquatic environments, such as seawater (18-20), marine sediments (21-23), fish (14,19,24), and crabs (8,25,26). Crabs are one of the main commercial aquatic species and are important due to their nutritional value (8,13). Crabs have different feeding habits, often due to living in various habitats and also food resources (27).

Bushehr port is known as an appropriate environment for MPs study because of adjacent to the Persian Gulf, which is an important fishing and commercial center in the Middle East (28,29). Different factors such as land-based contamination, quick industrialization, extraction of oil and gas, great traffic of marine, coastal development, and overfishing can influence the Persian Gulf contamination (30). The MPs presence in various environmental matrices, including air (31), indoor dust (32), personal protective equipment (33-35), water (36,37), coastal sediment (38), runoff (39), landfill leachate (40), organic solid waste (41), mollusks (12), fish (42), shrimp (43), and crabs (*Portunus armatus*) (44) was investigated in the Persian Gulf region. But no previous study has yet assessed the MPs contamination in the blue swimming crabs (*Portunus pelagicus*) collected from the Persian Gulf coast. Thus, the objectives of the present research were to 1) Determine the MPs abundance in different tissues of blue crabs (*Portunus pelagicus*) collected from the Persian Gulf coast in Bushehr port; 2) Investigate the MPs features including shape, size distribution, color, and polymer type in different tissues of the blue crabs (*Portunus pelagicus*).

Materials and Methods

Research Area and Sampling

The crab samples (*Portunus pelagicus*) were collected from the coastal area of Bushehr port, along the Persian Gulf (28°94′21″N, 50°77′50″E), in August 2022 (Figure 1). A total of 44 crab samples with approximately the same weight (141.32 ± 35.4 g) were randomly collected. Then, the crab samples were frozen at -20°C before analysis and dissected within one week.

Samples Processing

The extraction of MPs from the crab samples was performed based on the previous study with a few corrections (8). The crabs were first washed three times with distilled water to remove foreign bodies. The gills (G) and digestive tracts (DT) of crab samples were carefully separated by a surgical knife and scissors and weighed (with mean ± SD levels of 5.86 ± 2.31 and 6.5 ± 3.74 g, respectively). Then, the samples were transferred to the glass containers and covered with aluminum foil. The digestion of samples was done by 60 ml of KOH (10%, v/v) (Merck, Germany) in

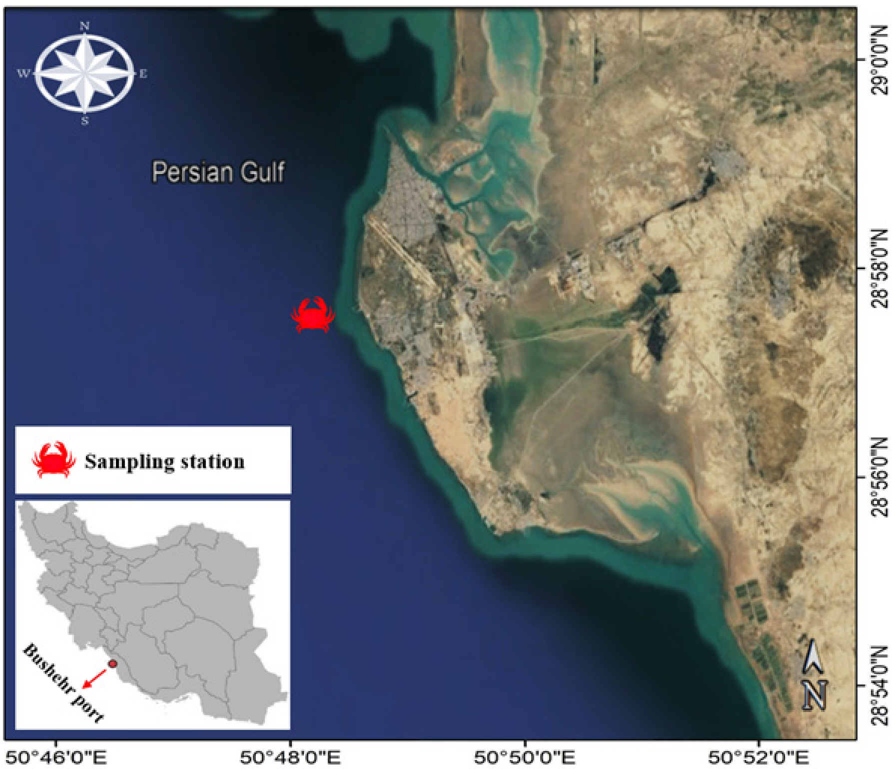

Figure 1. The location of the sampling area

the incubators (Aqualytic- Lovibond, Germany) at 40°C for 48 h. After digestion, the supernatant was filtered by vacuum filtering through a polytetrafluorethylene (PTFE) membrane filter (Whatman, Maidstone, Kent, UK) with a pore size of 0.45 µm after digestion. Finally, the filter papers were put in a Petri dish, washed with distilled water, and dried at room temperature for MPs analysis. Figure 2 illustrates the different steps of the sample processing and MPs detection.

Detection of MPs

In the first stage, MP particles were identified through a binocular microscope (A. KRÜSS Optronic, Germany) with up to 40X magnification. All MPs' characteristics, including color, size, and form, were visually evaluated and classified (45,46). Furthermore, it was needed the usage of the hot needle test in some cases to help distinguish among MP particles and other crystalline structures, for assurance. Probe diameter used to determine the longest part of each observed MPs and noted. The observed plastic particles were categorized into four forms, including fibers, film, angular, and fragments (47). Micro-Raman (Lab Ram HR, Horiba, Japan) was utilized to recognize the chemical composition of the observed MP particles in addition to the visual method. The source of stimulation was a laser, which irradiated at 785 nm. Moreover, the spectrum of Raman was gained within 3500-500 cm^{-1}. Eventually, by comparing the obtained spectra with the plastic particles spectral libraries for the Raman microscope, the polymer type of particles was specified.

Quality Control (QC)/Quality Assurance (QA)

Before sampling and MP analysis, to prevent contamination during the study, the equipment and workplace were cleansed with paper and ethanol. To avoid plastic contamination from entering the work environment during the experiments, only glass dishes were used. All used material was washed three times with distilled water. Cotton coats, nitrile gloves, and face masks were used in all analytical procedure steps. The surface of the samples was covered with aluminum foil in all preparation and extraction stages. The vacuum pump was also covered by aluminum foil when it was not in use. A control sample was used to account for airborne MPs contamination in the laboratory for a batch of samples. Also, blank samples were provided, like the experimental samples. In the blank samples, a few numbers of MPs were identified, and these values were applied to correct all samples.

Data Analysis

The Microsoft Excel 2016 and SPSS 20 software were utilized for analysis. To analyze MP particles in the G and DT tissues of crab samples, descriptive statistics were used to analyze MPs in the G and DT tissues of crab samples. After determination of the data normality, normality was tested by the Kolmogorov-Smirnov test that all variables had a normal distribution. Thus, a sample t-test analysis was applied to identify the difference among the levels of MPs in the G and DT tissues of crabs. Statistical significance was accepted at $P < 0.01$.

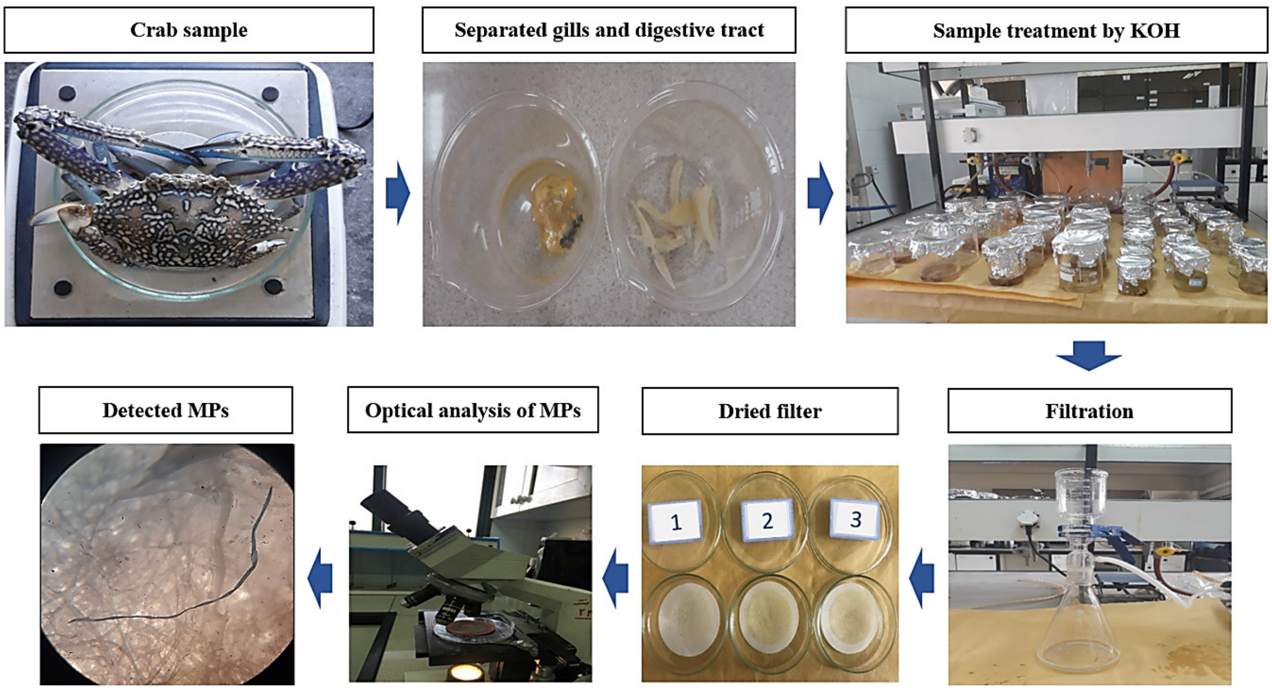

Figure 2. Crab sample, sample processing, and detection steps of MPs

Results

The Abundance of MPs in the Crabs' Tissues

MP particles were found in the G and DT tissues of the blue crab samples gathered from the Persian Gulf coast in Bushehr port. In total, 339 plastic particles were observed in the 44 crab samples. The abundance of MPs in both tissues of the crab samples, including G and DT, is shown in Figure 3 and Table 1. As seen in Figure 3 and Table 1, the mean levels of MPs in G and DT of crab samples were 0.89 and 0.38 items/g, respectively. The G tissues had more MP abundance than the DT. Also, the mean level of MPs in the studied tissues of crabs was 0.64 items/g. As presented in Table 1, a significant difference ($P < 0.01$) was detected among the MP particle abundance in the G and DT tissues. The comparison of MPs abundance and their features in the present study and other studies is illustrated in Table 2.

Physical Features of MPs

The MP particles detected in the different tissues of crab samples were classified into five size categories, as seen in Figure 4 (a). The size distribution of detected MPs ranged from < 50 to 1000-5000 µm. The size classes of identified MP particles in the G samples were below: 20-50 µm (42.17%), 50-250 µm (31.3%), 250-500 µm (10.86%), 1000-5000 µm (10.43%), and 500-1000 µm (2.21%). Also, the size categories of MPs in the DT samples were as follows: 20-50 µm (33.96%), 50-250 µm (33.02%), 1000-5000 µm (14.67%), 250-500 µm (12.84%), and 500- 1000 µm (5.5%).

The distribution and quantity of detected MP particle shapes in the G and DT tissues of crab samples are shown in Figure 4 (b). The MPs shapes were categorized into fiber, angular, fragments, and film. The detected MPs forms in the samples of G were fibers (67.39%), irregular fragments (26%), angular fragments (5.21%), and films (1.3%). While the identified MPs shapes in the samples of GT were fibers (85.32%), irregular fragments (12.84%), and angular fragments (1.83%). The predominant shape of identified MPs in both tissues was fibers.

The distribution and quantity of detected MP colors

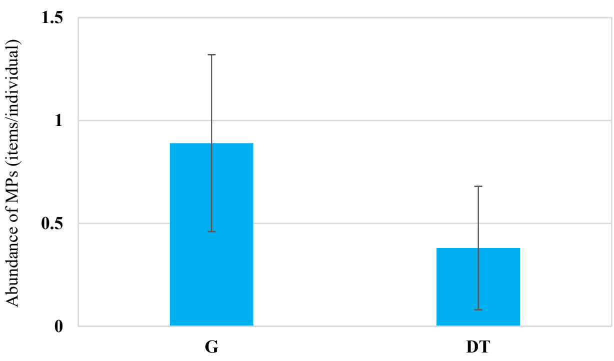

Figure 3. The abundance of detected MPs in the gills (G) and digestive tract (DT) of crab samples collected from the Persian Gulf coast. Error bars illustrate standard deviation (SD)

Table 1. MPs abundance (items/individual) in the gills and digestive tract of crab samples collected from the Persian Gulf coast

Sample. No	Gill (items/individual)	Digestive tract (items/individual)
S_1*	0.68	1.23
S_2	1.37	0.00
S_3	0.85	0.15
S_4	1.88	0.15
S_5	0.85	0.31
S_6	1.02	0.15
S_7	0.68	0.31
S_8	0.17	0.00
S_9	0.17	0.15
S_{10}	0.34	0.62
S_{11}	2.05	0.15
S_{12}	0.68	0.15
S_{13}	0.34	0.31
S_{14}	0.85	0.15
S_{15}	0.34	0.46
S_{16}	0.68	0.46
S_{17}	1.02	0.15
S_{18}	0.34	0.31
S_{19}	0.85	0.31
S_{20}	0.85	0.15
S_{21}	1.02	0.46
S_{22}	1.19	0.00
S_{23}	0.68	0.15
S_{24}	1.88	0.46
S_{25}	0.17	0.77
S_{26}	0.68	0.46
S_{27}	1.02	1.08
S_{28}	1.02	0.31
S_{29}	1.54	0.31
S_{30}	0.85	0.15
S_{31}	0.85	0.46
S_{32}	1.02	0.31
S_{33}	1.02	0.15
S_{34}	1.54	0.15
S_{35}	1.19	0.46
S_{36}	0.85	0.15
S_{37}	0.85	0.46
S_{38}	1.19	0.62
S_{39}	1.02	1.23
S_{40}	0.68	0.46
S_{41}	1.02	0.15
S_{42}	0.51	0.92
S_{43}	0.51	0.46
S_{44}	0.85	0.92
Mean (± SD)	0.89 (± 0.43)	0.38 (± 0.3)
Total mean (± SD)	0.64 (± 0.26)	
P-value	0.001	

[a] Difference between various tissues.**Significant at *P*-value < 0.01.

Table 2. Abundance, characteristics, extraction protocols, and identification of MPs in the crabs reported worldwide

Location	Crab type	Tissue	MPs abundance	Dominant size range	Major shapes	Major polymer type	Major color	Digestion	Identification of MPs	Ref
Chukchi Sea, China	Chionoecetes opilio	-	0-0.6 (0.09*) items/ individual	0.87 mm	Fragments	PVA[1]	White	10% KOH	μ-FTIR	(5)
Beibu Gulf, China	-	Gills-Gastrointestinal	0.39-4.96 items/ individual	20-100 μm	Pellets-Fibers	PE[2]	White	30% H_2O_2	Raman microscope	(25)
Yellow Sea and East China Sea, China	Portunus trituberculatus, Charybdis Japonica, Dorippe japonica, Matuta planipes	Gills - Muscles-Gut	0.8-22.71 (5.17*) items/g	0-500 μm	Fibers	Cellophane	Black-gray and Blue-green	10% KOH	μ-FTIR	(8)
Corpus Christi Bay, Texas	Callinectes sapidus	Stomach	0.44–0.72 (0.87*) items/ individual	-	Fibers	Cellulose/ Rayon	Blue	30% H_2O_2	μ-FTIR	(48)
California beaches, United States of America	Mole crab	Digestive tracts	0.65* items/ individual	-	Fibers	-	-	-	Micro FTIR	(49)
Baltic coastal waters, Poland	Eriocheir sinensis	Stomach	-	-	Balls-Strands	-	Transparent	-	-	(50)
Northern Adriatic coast, Italy	Carcinus aestuarii	Gastrointestinal tracts	1-117 items/ individual	100-500 mm	Fibers	PES[3]	Red	10% KOH	FTIR	(51)
Nassau bay, Chile	Southern king crab	Stomach	-	-	Fibers	-	Blue	10% Formaldehyde	-	(52)
Isla Espiritu Santo and San Pedro de Vice mangrove, Mexico and Peru	Ucides occidentalis	Gills-Digestive tract	-	<250 μm	Fibers-Films	PP[4]	Transparent	10% KOH	FTIR	(53)
Bahía Blanca Estuary SW Atlantic, Argentina	Neohelice granulata	Gills-Digestive tract	-	-	Fibers	-	Blue	30% H_2O_2	-	(54)
Kune-Vain Lagoonary Complex, Albania	Carcinus Aestuarii, Carcinus sapidus	Gut	10.75-12.5 (11*) items/g	100-500 μm	Fibers	HDPE[5]	Black	10% KOH	FTIR	(26)
Indian River Lagoon system, India	Panopeus herbstii	Gills-Digestive tract	2.7-25.8 (4.2*) items/ individual	-	Fibers	-	Blue	30% H_2O_2	-	(55)
Persian Gulf, Iran	Portunus armatus	Gills - Muscles	0.25-0.86 items/g	1-5 mm	Fibers	-	Black	10% KOH	-	(44)
Persian Gulf, Iran	Portunus segnis	Digestive system	0.83* items/g	500-1000 μm	Fibers	PE and PP	Black	10% KOH	FTIR	(56)
Persian Gulf, Iran	Portunus pelagicus	Gills-Digestive tract	0-2.05 (0.64*) items/g	20-50 μm	Fibers	Nylon and PS[6]	White/ transparent	10% KOH	Raman microscope	This study

* Mean level of MPs. 1: Polyvinyl alcohol; 2: Polyethylene; 3: Polyether sulfone; 4: Polypropylene; 5: High-density polyethylene; 6: Polystyrene.

in the crab's samples in both types of tissues (G, DT) are displayed in Figure 4 (c). The colors of identified MP particles in the samples of G were as follows: white/transparent (54.78%) > black (30.86%) > green (11.73%) > red/pink (2.6%). Also, in the DT, the colors of identified MPs were as follows: white/transparent (41.28%) > black (37.61%) > green (15.59%) > red/pink (3.66%). The dominant colors of detected MP particles in both tissues were white/transparent (51.03%) and black (33.03%), respectively.

Polymer Types of MPs

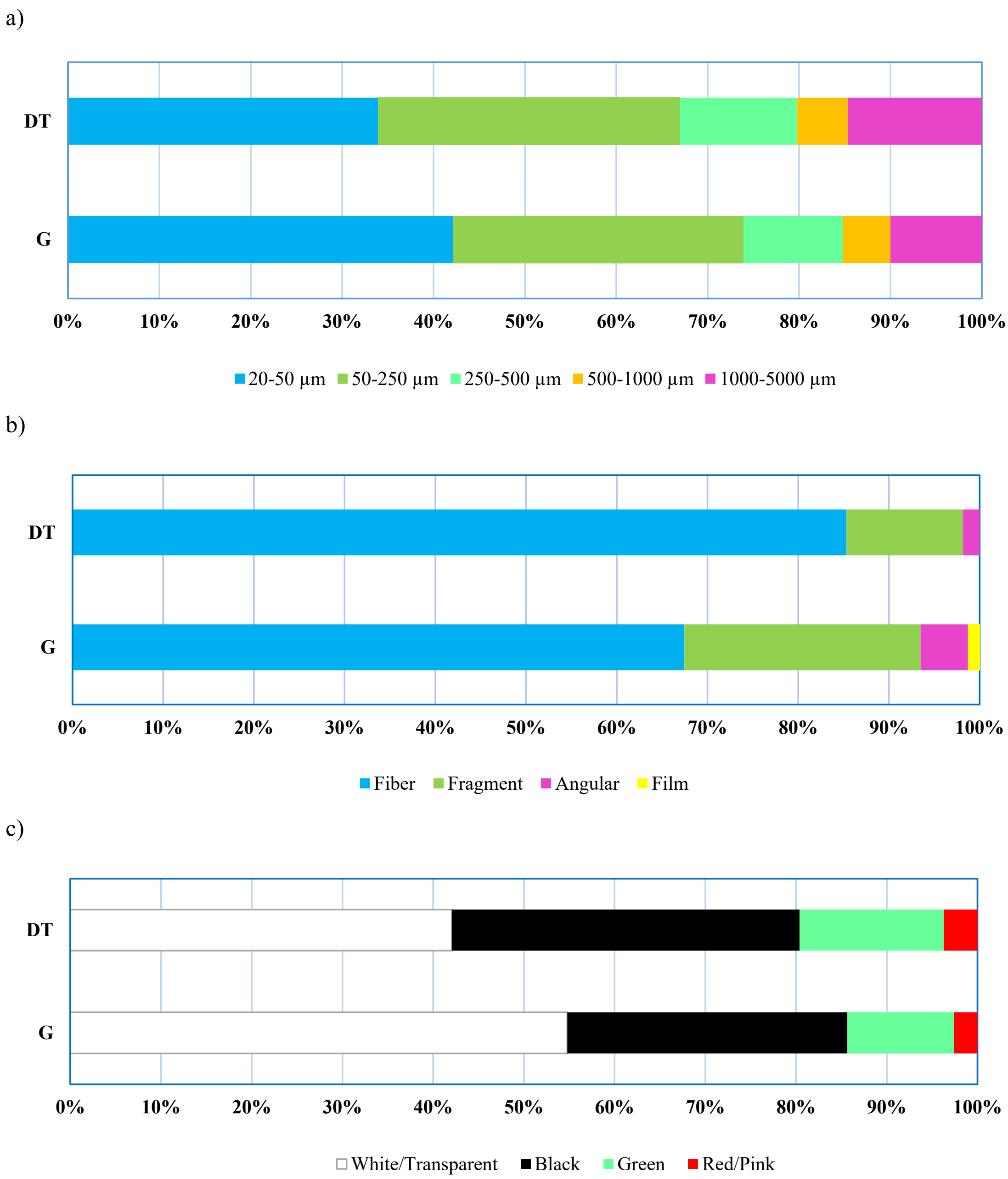

Figure 4. Size distribution (a), shape (b), and color (c) of detected MPs in the gills (G) and digestive tract (DT) of crab samples collected from the Persian Gulf coast

The polymer type of 19 MP particles (11 particles for G samples and 8 particles for DT samples) was determined by Raman spectroscopy randomly. Polymer type percentages of identified MPs in both tissues of crabs (G and DT) are shown in Figure 5. The Raman spectra of some detected polymers of MPs in the crab's tissue samples are also presented in Figure 6. In total, three polymer types, including nylon (53.09%), PS (36.87%), and low-density polyethylene (LDPE) (10.02%), were detected in the G and DT tissues of crabs. In the G samples, the identified polymer types were nylon (73.91%), PS (20.43%), and LDPE (5.65%). The detected types of polymer in the DT samples were PS (71.55%), LDPE (19.26%), and nylon (9.17%). The most prominent polymer type of MPs in the G samples was nylon, while the dominant type of polymer in the DT samples was PS.

Discussion

The Abundance of MPs in the Crabs' Tissues

MP particles were found in the G and DT tissues of the blue crab samples gathered from the Persian Gulf coast in Bushehr port. In total, 339 plastic particles were observed in the 44 crab samples. The mean levels of MPs in G and DT of crab samples were 0.89 and 0.38 items/g, respectively (Figure 3 and Table 1). The MPs abundance and their characteristics in the present study and other studies are reported in Table 2. The result of this study is consistent with the results of a study in the Bahía Blanca Estuary, Atlantic South America, as the MPs abundance in gill tissue had the highest level compared to the digestive tract

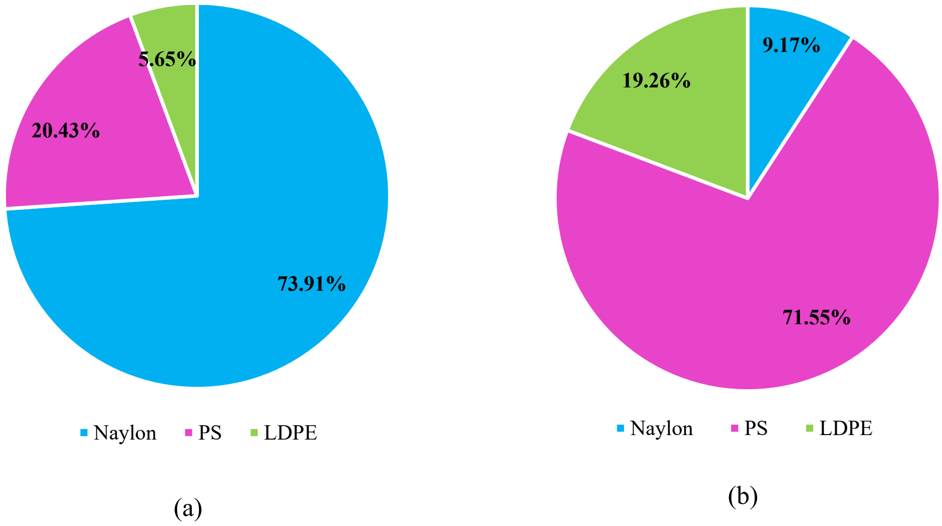

Figure 5. Polymer type of MPs in the gills (a) and digestive tract (b) of crab samples collected from the Persian Gulf coast

(54). A study conducted in the Yellow Sea and East China Sea, China, reported a mean concentration of 5.17 items/g in the gills, muscles, and gut of crab samples (8). Also, the MPs level in the crabs (*Portunus pelagicus*) sample of the present study was approximately similar to the MPs abundance in the crab samples (*Portunus armatus*) gathered from the Persian Gulf, Iran, ranging from 0.25 to 0.86 items/g (44). In another research, the mean value of MPs in the digestive systems of crabs (*Portunus segnis*) was 0.83 items/g (56). In the nature reserve lagoonary complex of Kune-Vain, Albania, the mean level of MPs in the gut of crabs was reported 11 items/g (26). The MPs abundance in this study was higher than the presented level in the crab samples collected from the Chukchi Sea, China, ranging from 0 to 0.6 items/individual with the mean level of 0.09 items/individual (5). Differences in the abundance of MPs can be due to differences in the sampling location, specific traits of species, and analyzed tissues, as well as analytical parameters (57).

This study was done in the Persian Gulf coast in Bushehr as a fishing and commercial port, where the fishing gear, nets, buoys, and plastics shedding are the major MP particle sources in this region. In the Musa Estuary, Persian Gulf, the greatest number of detected MPs in various tissues of fish and prawn were related to the digestive tissue (42). This can reflect changes in the amount and food eaten by different species. High MP particle numbers in the G and DT tissues of crab samples can be due to entering the MP particles via breathing (58) and feeding, respectively (8). In a study on onshore crab samples from the River Exe estuary, Devon (UK), it was reported that both ventilation and nutrition pathways are important in absorbing MPs (59). The nutritional behavior is one of the major reasons for the accumulation of MPs in the DT tissue of crabs (60). MPs ingestion has some negative impacts on crabs, such as a false sense of satiety, scratching or blocking the DT, and transport of smaller MPs from the intestine to other tissues (61,62). The major secondary absorption route of MPs in aquatic organisms is through the G tissue (59). During crabs breathing, MP particles in the seawater can stick to the gills of the crab, which may affect the crab's breathing intensity and the capability to regulate osmotic pressure (63). Thus, MPs in crabs can damage their growth and health (64). The MPs uptake by crabs as lower trophic organisms can lead to the transfer of MPs in the maritime food chain (65) and consequently enter the human body and finally cause potential human health risks (66). It is worth noting that the entry of many rivers, near-shore fishing operations, and the petrochemical industry are the major plastic contamination sources in the Persian Gulf (56). Therefore, more attention should be paid to reducing plastic contamination, especially MPs contamination, in the Persian Gulf and subsequent aquatic organisms.

Physical Features of MPs

Based on Figure 4 (a), the MPs with the size category of 20-50 µm were the most abundant in the G and DT tissues. The MPs percent with a size class of lower than 50 µm in both tissues was 39.5% of the total MP particles. As shown in Table 2, the most abundant size classes of MP particles in former studies in the Yellow Sea and East China Sea, China (8), Beibu Gulf, China, (25), Kune-Vain Lagoonary Complex, Albania (26), and the Persian Gulf, Iran (44) were reported as 0-500 µm, 20-100 µm, 100-500 mm, and 1-5 mm, respectively. The size of MPs as an important metric has the highest effect on the organisms (67). Although MP particles greater than 150 µm cannot be absorbed in the digestive track of organisms, MPs smaller than 150 µm are absorbed in their digestive track and accumulated in various tissues (68). Smaller MP particles in the marine environment are easily swallowed by maritime organisms as prey (22,69,70). Small MP particles are ingested by crabs through feeding activities and can be transported

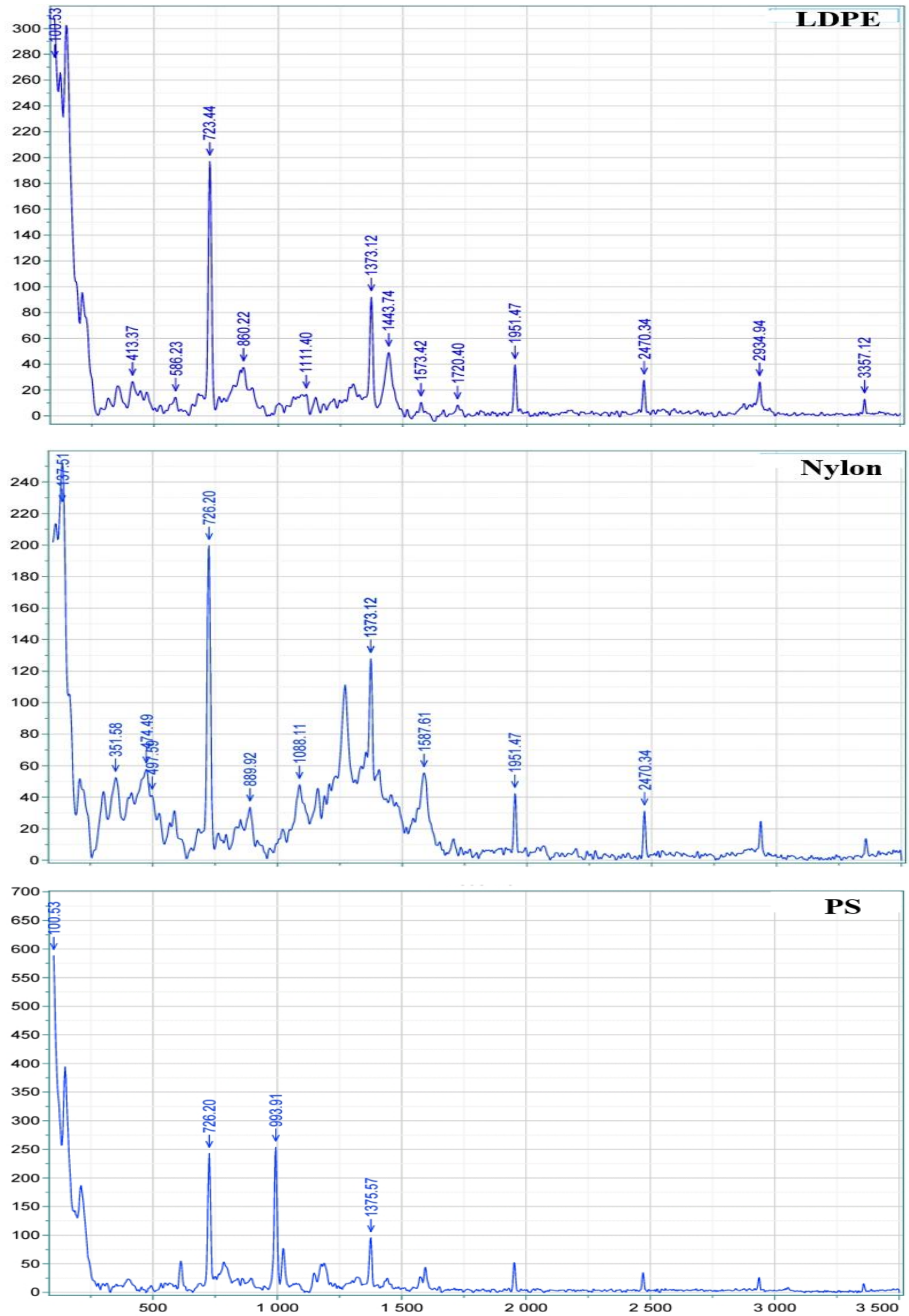

Figure 6. Spectra Raman of some polymers identified in the gills and digestive tract of crab samples collected from the Persian Gulf coast

to different tissues, and may cause adverse effects (71). MPs with smaller sizes are hazardous to crabs due to the effect on survivability, growth, reproduction, nutritional damage, physiology, and metabolism (72).

The major MPs shape in the both tissues of crab samples were related to the fibers (Figure 4 (b)) that is in agreement with the similar studies in China (8,25), United States of America (49), Italy (51), Argentina (54), India (55), as well as the Persian Gulf, Iran (44), as shown in Table 2. Fibers and fragments are the main MPs shapes usually identified in various aquatic organisms (73). Fiber shape in the gills may be associated with the anatomical structure of the gill. The gills can gather more MPs fibers because of their shoulder-like structure. The consumption of fiber MPs as target food of aquatic organisms can be a reason for the high proportion of fibers in the DT (74). The fiber sources in the water environments are mostly from the domestic sewage, textile industries, and fishing (43,75,76). Most of the fishing nets are fibrous and may enter the crab tissues via different exposure routes, such as eating and breathing, during the fishing (77). High utilization of plastic fishing gear, for example, ropes and fishing nets, in the Persian Gulf can cause a greater abundance of fibers compared to other shapes (78). Moreover, crabs utilize their large paws to cut fishing nets for evasion. The fragmented fishing nets are mostly in fiber shape and can be eaten by the crabs, and consequently enter their body (8).

The dominant colors of identified MPs in both tissues were white/transparent and black, respectively (Figure 4 (c)). The findings of this research are consistent with the results of similar research in China, where the predominant color of MP in the crabs was white (5,25) (Table 2). However, in a study on the northern Adriatic coast, Italy, red was reported as the most predominant color (80%) of detected MPs in crabs (51), as shown in Table 2. The white/transparent color sources can be fishing equipment, packaging materials, and fishing nets (79,80). A similar study found that juvenile fish that live on plankton can eat MPs with white rust instead of bait (81). The color of MPs is the main factor that increases the ingestion chance by organisms due to the similarity to their prey (26). Because of the lack of light penetration in benthic environments or even in shallow water, crabs may accidentally ingest MP particles by mistakenly taking them for their prey (61).

Polymer Types of MPs

According to Figure 5, the dominant polymer types of MPs in the G and DT samples were nylon and PS, respectively. Figure 6 shows the Raman spectra of some detected polymers of MPs. In a former research in China, polyethylene (PE) was the predominant polymer type of detected MPs in the crab samples (63). In another study in Australia, polyolefin, PS, and PE were the identified MP particles in the samples of crab (57). The dominant polymer type of plastic particles in the omnivorous crabs samples collected from the Northern Adriatic coast, Italy, was reported polyether sulfone (PES) (51). In the south of the Caspian Sea, Iran, nylon was the most common type of MP particles in the important commercial fish samples (82).

The buoyancy, type, and shape of plastic can affect the type of detected MPs. Nylon, as a synthetic polymer type, is mainly applied in the production of fishing gear, fabrics, apparel, fibers, plastic bags, and packaging materials (83,84). PS polymer is extensively applied in the production industries, for instance for instance medical and packaging, electrical and optical media, plastic cups, disposable cutlery, fast food trays, egg cartons, and clothes hangers (84). LDPE is widely used in single-use plastics, for example, bottles, bags, and fishing nets (85). Due to low density, PS and LDPE have more floating and are predominantly detected in the surface water. While nylon tends to settle in water depth and often on surface sediments. Crabs can feed from the food found in the water column and on top of the sediment. Thus, the determination of detected polymer type can be related to their density (26). The polymer type of detected MPs in the aquatic organisms, such as crabs, can be due to fishery and commercial activities (24).

A basic subject in the detection of MPs is the lack of a standard method that may affect the analyses of MP particles. The methods applied for identifying MPs are various, which greatly reduces the comparability between different studies. The usual method for quantifying MPs can specify the MPs number. While the quantification of MPs mass can provide adequate details to perceive the MPs levels in the crabs. In this study and similar studies, due to the high number of detected MPs, determining all polymer types of MPs by Raman spectroscopy was not feasible. This issue can cause some degree of uncertainty. Thus, the mentioned limitations should be considered in future research.

Conclusion

The levels of MPs and their characteristics in the G and DT tissues of crab samples gathered from the Persian Gulf coast in Bushehr port were quantified in the present study. MP particles were generally detected in the G and DT tissues of crabs, and their abundance in the G was significantly higher than in the DT. MPs in the size class of 20-50 μm were the most abundant in both tissues of the crab samples. The dominant shape of MPs observed in the studied tissues was fiber. Additionally, nylon and PS were the most detected polymer types in the G and DT samples, respectively. Based on the results, the major source of MPs contamination in the aquatic organisms of the Persian Gulf, especially crabs, is fishing and commercial activities. Thus, further researches is required to identify the distribution and accumulation of plastic particles in different seafood tissues, especially crab tissues, the MPs contamination sources in the marine environment, and consequent seafood, the contaminants adsorbed on MPs in the seafood, and potential health effects of MPs and related contaminants. Moreover, providing effective regulatory solutions is immediately required to reduce the plastic contamination of the marine environment.

Acknowledgements

This study was conducted as a student dissertation (Master of Science in Environmental Health Engineering) by Masoumeh Moshtaqzadeh. The authors appreciate the Deputy of Research and Technology of Hamadan University of Medical Sciences for providing research materials, equipment, and funding (project code: 14010220959). Also, the authors would like to express their sincere gratitude for the support of the laboratory of the Systems Environmental Health and Energy Research Center, the Persian Gulf Biomedical Sciences Research Institute, throughout the research process.

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Competing interests

The author declares that there is no conflict of interests.

Ethical issues

This study was approved by the Research Ethics Committee of the Hamadan University of Medical Sciences (Ethical code: IR.UMSHA.REC.1401.003). The guidelines for conducting the research, as outlined by the committee, were strictly followed.

Funding

No external funding was received.

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