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Microplastic pollution in coastal ecosystem off Mumbai coast, India

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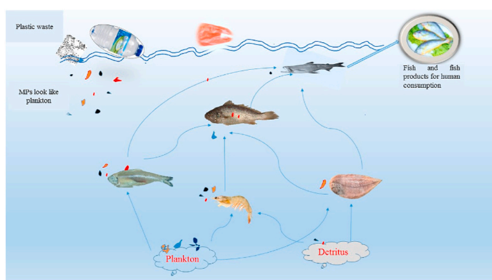
HIGHLIGHTS

- Microplastics were observed in all the studied water, sediments and biota samples.
- MP abundance was relatively higher in pelagic carnivorous species.
- The smaller size MPs (<250 μm) were dominantly observed in GI tracts of marine biota.
- Fish processing interventions to be followed prior to consumption for reducing the health risks.

GRAPHICAL ABSTRACT



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ABSTRACT

Microplastics (MPs) are anthropogenic pollutants which can adsorb toxic substances from surrounding water and absorb into the fish body. During the present study, MPs were observed in water, sediment, and gastrointestinal tracts of marine biota samples collected from the coastal waters of Mumbai, India. The mean abundances of MPs recorded in water samples 372 ± 143 items/liter and 9630 ± 2947 items/kg dry weight (DW) in sediment samples. The mean abundance of MPs in pelagic fish species varied from 6.74 ± 2.74 to 9.12 ± 3.57 items/individual and in the demersal species the values ranged from 5.62 ± 2.27 to 6.6 ± 2.98 items/individual. Shape-wise, four type of MPs were observed in the surface waters, sediments and all studied species, predominantly fibers, followed by fragments, pellets/beads, and films. Seven different colors of MPs (red, blue, black, translucent, brown, green, and yellow) were observed from studied samples. MPs of size below 250 μm formed the dominant size in the surface water, sediments, and biota samples except Bombay duck and Malabar sole fish. Based on Raman spectroscopy analysis, eleven types of plastic polymers identified from all studied samples. Thus, presence of MPs in studied biota indicates the transfer of MPs through interlinked food chain/web to higher trophic levels and the occurrence of MPs in the fish gut underlines the necessity of more studies on processing interventions for reducing the microplastic contamination in fish for human consumption.

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1. Introduction

Globally, plastic production has reached to 359 million metric tons in 2018 (Plastics Europe, 2019). Plastic pollution has become a serious environmental concern. However, breaking down larger plastic items into minute fragments (<5 mm-microplastics) has posed severe risk (Andrady, 2015). Recently, microplastics (MPs) have been identified as a significant emergent global issue that troubles the life under the sea as well as human health (Wang et al., 2019). These MPs are the persistent addition in the aquatic systems and potentially biomagnified in the living organisms due to non-degradation by microorganisms (Yoshida et al., 2016). Among all the aquatic faunas, fishes are most affected by accidental ingestion of MPs. Generally, ingestion of MPs occurs through direct consumption of MPs at the lower trophic level and reach higher trophic levels via food chain (Nelms et al., 2018). Therefore, ingestion of these tiny particles can lead to different abnormalities in the fish body, such as false hunger satisfaction, physiological stress, reduced enzyme production, pseudo satiation, reproductive complications, oxidative stress, and slow growth rate (Espinosa et al., 2017; Jovanović, 2017).

MPs can also adsorb lethal and toxic substances from surrounding seawater which can enter into the fish body (Reisser et al., 2014). The ingestion of these particles leads to blockage of the digestive tract which causing apart from other toxicity in the organisms (Jovanović, 2017). Keeping in mind the detrimental effect of MPs on aquatic life and humans, scientific research related to impact of MPs on the ecosystem has become central issue of research (Shim and Thomposon, 2015). Thus many reports have been published on the ingestion of MPs by pelagic, demersal, estuarine, and freshwater biota (Lusher et al., 2013; Zhu et al., 2019; Gurjar et al., 2021a). Every year, India generates 3.8 million tons of domestic plastic waste materials (Ministry of Housing and Urban Affairs, 2019). The Mumbai coast has been undergoing substantial changes due to rising population, development in coastal areas, and anthropogenic activities such as industrial and sewage discharge, municipal solid wastes, tourism, waste from fishing activities (Takar et al., 2020). In earlier reports, authors have conferred the MPs in beach sediments golden anchovy and shrimp species along the studied region (Jayasiri et al., 2013; Gurjar et al., 2021a, 2021b).

The widespread pressures of plastics, especially MPs in natural habitats and trophic food chains have required regulatory and government agencies to gadget targeted activities to mitigate and control plastic pollution (Galgani et al., 2013). Since commercially exploited fishes form the main route of MPs transfer from the ecosystem to humans, an assessment of the rate of microplastic ingestion by the diverse aquatic biota will help to understand the threats of microplastic pollution on the ecosystem services and consumers. Along the studied region small size fishes and shrimps are also consumed in dried form without removing the gut and hence the availability of MPs in the gut and their further involvement in the human food is worth reporting. Further, the knowledge about the concentration of MPs is essential to assess threat to the marine environment and aquatic organisms. Along the studied region, limited studied has been performed on the microplastic pollution in coastal beaches and fishes and even still no studies has been carried out on MPs pollution in coastal sediments and waters. In view of these facts, the present study was conducted to generate baseline information on the site-specific microplastic pollution in the coastal waters, sediments, and commercial fishes and shellfishes, in order to the intensity of the impacts of microplastic pollution on the ecosystem and coastal biota of the North eastern Arabian Sea, India.

2. Materials and methods

2.1. Study area and sampling procedure

To conduct the present study, coastal areas of Mumbai were selected, which receive a huge load of plastics waste through industrial and sewage discharge, fishing activities, aqua tourism, and untreated domestic wastewater (Takar et al., 2020). For the study, pelagic species (Bombay duck, *Harpodon nehereus*, and White sardine, *Escualosa thoracata*) and demersal species (Belanger croaker, *Johnius belangerii*; Malabar sole fish, *Cynoglossus macrostomus*, and Kadal shrimp, *Metapenaeus dobsoni*) were harvested using a mechanized trawler (Institute's fishing research vessel) from the studied areas at depths up to 20 m during September 2019 to February 2020 (Fig. 1). All collected samples were kept in an icebox during transportation to the laboratory where samples were stored in a deep freezer at −20 °C for further analysis. Feeding type, habitat, and trophic level for studied species were collected from the published literature and online data resource FishBase (Froese and Pauly, 2019).

2.2. Gastrointestinal (GI) tracts digestion and filtration

In the laboratory, specimens were thawed; length and weight of individual specimens were noted and dissected. The gastrointestinal tracts of all studied samples were carefully dissected out, weighed and stored in labeled tubes. For the digestion or remove of the organic matter, samples were kept for 24 h at room temperature after addition of 25–30 ml of 30% hydrogen peroxide (H_2O_2) into each glass tube, if natural organic material is visible, add another 20 ml of 30% H_2O_2 and keep it back for 12 h to complete the digestion of organic materials (Masura et al., 2015). After digestion, 4.4 M NaI solution was added into suspension to increase the density of the aqueous solution and kept back for 24 h to allow MPs to float. The clear and supernatant solution was sieved through nitrocellulose filter paper having a pore size of 0.45 μm under vacuum filtration and subsequently filtered samples were kept in individual Petri dishes with lids and dried at room temperature for further analysis.

2.3. Water and sediment sampling and analysis

During the study period, monthly water and sediment samples were randomly collected from three different locations along the studied region (Fig. 1). Barrows et al. (2017) observed that the water sample collected surface grab sampling has more MPs than the neuston net tow sampling because during the sampling procedure the small sized MPs passed through the mesh of neuston net (333 μm). Therefore, 30 L of surface water (up to 50 cm depth) was collected using through iron sling with a stainless steel bucket. The collected water was immediately sieved through an iron mesh sieve (mesh size 5000 μm) in a steel drum and covered. At the laboratory, three subsamples of water (each of 1 L) were taken and filtered through 0.45 μm pore size nitrocellulose filter paper and filtered materials were kept for digestion of organic matters using the 30% H_2O_2. After digestion solutions were filtered through 0.45 μm pore size nitrocellulose filter paper under a vacuum filtration. Thereafter, filtered samples were subsequently kept in individual Petri dishes with lids and dried at room temperature for further analysis.

Sediments were sampled to a depths up to 20 m using a sediment grab sampler from the study area. Further, a subsample of 500 g wet weight was collected from each location, and mixed. The mixed sample was dried in the oven at 60 °C. From the dried sediment three subsamples each of 10 g were transferred into separate glass bottles and 30 ml of potassium metaphosphate (5.5 g/L) was added it and mixed for 30 min at a speed of 1000 RPM, using a stir bar to break up the clods (Masura et al., 2015). Latter, the sediment solution was sieved through 5 mm sized mesh sieves and washed with filtered distilled water. In the sieved materials, 4.4 M NaI solution was added for the density separation of MPs, treated with hydrogen peroxide, and filtered as described previously.

2.4. Identification of microplastics

The materials retained on the filter papers were observed using an Olympus stereo zoom microscope (SZX16 Model, India). The visual

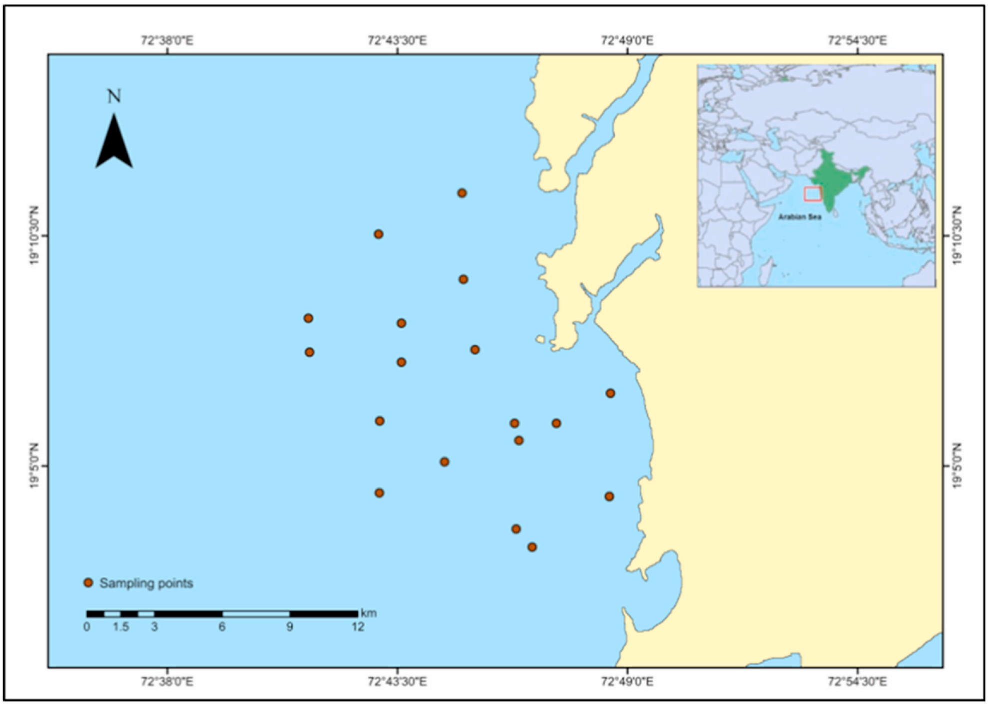


Fig. 1. Map showing the sampling locations in north eastern Arabian Sea.

assessment of MPs was made according to the shape, colour, and size of the material, and the images were captured (Li et al., 2015; Gurjar et al., 2021b). Raman spectroscopy was used to efficiently evaluate the MPs polymer (Gurjar et al., 2021b; Dong et al., 2020a). Further, the suspected particulates, on the filter paper were analyzed using laser Raman spectroscopy to confirm the functional groups of plastic polymer.

2.5. Contamination control

During the experimental field sampling, glass bottles containing filtered distilled water were kept open as blank field samples at each sampling location. Altogether, eighteen blank field samples were used to quantify the potential contamination during the field sampling procedure. Two MP items were recorded from the eighteen field blank samples, which was negligible as compared to the total number of MP items recorded in the present study. A total of 36 laboratory blanks without seawater, sediment, and gastrointestinal tract samples were used to know the procedural contamination. To minimize the chance of MPs contamination in the laboratory, all glass wares were rinsed twice with ultrapure water, wore nitrile gloves and personnel cotton lab coat and the samples were covered with aluminum foil to prevent air-borne contamination during the entire process. The extraction of MPs from all samples was performed under a fume hood and remained covered with aluminum foil to prevent air-borne contamination during the laboratory procedure. All the used chemicals and mixtures were filtered through a filter paper having a pore size of 0.45 μm (Gurjar et al., 2021a).

2.6. Statistical analysis

The obtained data were analyzed using the EXCEL (2013 version, Microsoft) and SPSS software (version 20.0). One-way ANOVA was performed to know the difference in size-wise microplastic abundance between the studied marine species. Pearson correlation was used to check the associations between microplastic abundance and the total length, total weight, GI tract weight of studied samples.

3. Results and discussion

3.1. Abundance of microplastics in water and sediments

MPs were observed in all the studied water and sediments samples collected from Mumbai coast, where the abundances of MPs ranged from 165 to 547 items/liter in water and 4900–14,500 items/kg dry weight (DW) in sediments. The MP items observed in sediments during the present research, are in accordance with earlier findings (Bauerlein et al., 2020; Leslie et al., 2017). In Dutch marine sediments, MPs ranged from 479 to 13,931 items/kg DW (Bauerlein et al., 2020); 100 to 3600 particles/kg dry sediment were recorded from the Dutch North Sea coast (Leslie et al., 2017). The Amsterdam urban canal water and sediment contained 48–187 per liter and 68–10,500 particles/kg DW, respectively (Leslie et al., 2017). The raw sewage influents collected from municipal wastewater treatment plants in the Netherlands contained microplastic concentrations of 68–910 particles/liter (Leslie et al., 2017). Dong et al. (2020b) also recorded the higher abundance of MPs 7707 items/kg in sediment collected from an urban lake in Wuhan city. MPs in the size fraction between 63 and 5000 μm have been recorded in the sediment of rivers Rhine and Main in ranged from 228 to 3763 and 786–1368 items/kg DW, respectively (Klein et al., 2015). The very high numbers of MP with 75,000 particles/kg were recorded in the sediment of river Mersey/Irwell (Hurley et al., 2018). Kim et al. (2015) studied MPs distribution in surface water of Soya Island, South Korea, and found, on average, 46,334 ± 71,291 items/m^2. The abundances of MPs were recorded in water (334–1058 items/m^3) and sediments (508–3987 items/kg DW) with the dominance of fiber in Fengshan river, Taiwan (Tien et al., 2020). All these studies show that throughout the world, sediments and waters of the sea, rivers, and lakes are contaminated with microplastic pollution. Similarly, present study revealed that studied region also polluted with MPs due to its huge population and various anthropogenic activities such as abrasion of tires, fishing activities, industrial and sewage discharge into the coastal waters.

3.2. Characteristics of microplastics in water and sediments

In the present study, smaller MPs less than 100 μm and 250 μm was comparatively higher appeared in the coastal water than sediments, while MPs with size groups of greater than 250 μm was higher in coastal sediments than water (Fig. 2). Small sized MPs generated from the degradation of large plastic debris or direct discharge of primary MPs after using related products (Cole et al., 2011; Wang et al., 2017; Lin et al., 2018). As plastic marine debris on coastal beaches and floating in coastal water is exposed to solar UV radiation, it undergoes extensive weathering and progressively degrades it into smaller particles (Cooper and Corcoran, 2010; Yakimets et al., 2004). Frei et al. (2019) observed a higher abundance of MPs with decreasing the particle size.

During the present study, four different morpho-types of MPs such as fibers, fragments, pellets/beads, and films were recorded from the surface water and sediment samples (Fig. 3). Fibres were most dominant in the coastal water and sediments of studied region, followed by fragments, pellet/beads and films (Fig. 4). Globally, fiber-shaped MPs represent the highest abundance of plastic in marine environments (Walkinshaw et al., 2020). The more availability and distribution of fiber-shaped MPs shown a close association to the various anthropogenic activities such as waste generated during washing of clothes, rope material used in the fisheries sector and textile fibres from domestic wastewater discharge, and other activities by the local human in the studied region (Takar et al., 2020; White et al., 2018; Andrady, 2011). The fragments might result from the degradation of larger plastic products due to abrasion and weathering (Karthik et al., 2018). In contrast, film originates from mismanaged single-use plastic packaging materials that are easily carried by winds and riverine discharge (Robin et al., 2020). On the other hand, pellets/beads resulted from the use of microbeads in cosmetic and personal care products and accidental or intentional spillage and disposal during their manufacture (White et al., 2018; Mintenig et al., 2017).

In the present study, seven different MPs colors (red, blue, black, translucent, brown, green and yellow) were recorded with predominant black color in coastal water and sediment samples (Fig. 5). The color of MPs is imperative in source detection (Veerasingam et al., 2016; Koongolla et al., 2018) and is an important ingestion cue for few organisms that visually detect food (Maharana et al., 2020). Similar to the present study, the proportion of black color MPs were abundantly recorded in the coastal water and sediments of Goa (Saha et al., 2021) and southwest coast of India (Robin et al., 2020). The black MPs mainly might have come into the environment due to abrasion of tires on the road surfaces as regular wear and tear (Wik and Dave, 2009). Colored microplastic particles are commonly used in packaging, clothing, and several other applications (Wang et al., 2017).

3.3. Abundance of microplastics in biota

During the present study, 1725 MP particles were collected from the gastrointestinal tracts of 250 specimens of pelagic (Bombay duck, *Harpodon nehereus* and White sardine, *Escualosa thoracata*) and demersal species (Belanger croaker, *Johnius belangerii*; Malabar sole fish, *Cynoglossus macrostomu*, and kadal shrimp, *Metapenaeus dobsoni*) and MPs were found in all the studied samples (Table 1). The results of the present study may not be directly comparable to other studies from different parts of the world due to methodological variations; however, similar results on occurrence of MPs in all fishes was reported from the Adriatic Sea (Anastasopoulou et al., 2018), R'ıo de la Plata estuary (Pazos et al., 2017) and Shanghai market (Jabeen et al., 2017). Comparatively lower ingestion was observed in fishes from the different part of the globe such as Adriatic sea (Pellini et al., 2018), Tokyo Bay (Tanaka and Takada, 2016); Mediterranean Sea (Nadal et al., 2016; Güven et al., 2017; Fossi et al., 2018; Giani et al., 2019), Kerala (Daniel et al., 2020), North Pacific Central Gyre (Boerger et al., 2010), southwest coast of India (Robin et al., 2020), south east Bay of Bengal (Karuppasamy et al., 2020), south east coast of India (James et al., 2020). In the present study, MPs abundance was found to be positively correlated ($p < 0.01$) with the total length, total weight and GI tract weight of individuals (SI Table 1), which suggests that the larger size of individuals contained the more MPs than smaller ones (Gurjar et al., 2021b).

MPs were found in both pelagic and demersal species, but the MP abundance was relatively higher in pelagic species, possibly due to insignificant weight of these particles allowing them to restrict to pelagic realm and feeding behaviors of fishes. Thus, among the fishes studied, an average higher abundance of MPs (9.12 ± 3.57 items/specimen) was recorded in *Harpadon nehereus*, a pelagic species and lower in *Cynoglossus macrostomus* (5.62 ± 2.27 items/individual), a benthic species. As compared to benthic species, pelagic fishes required

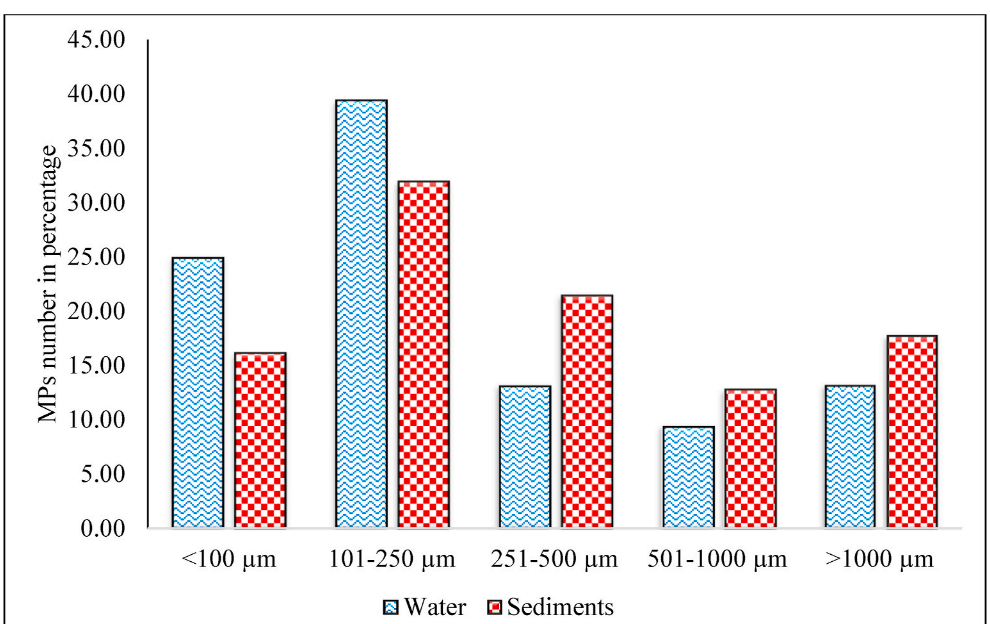
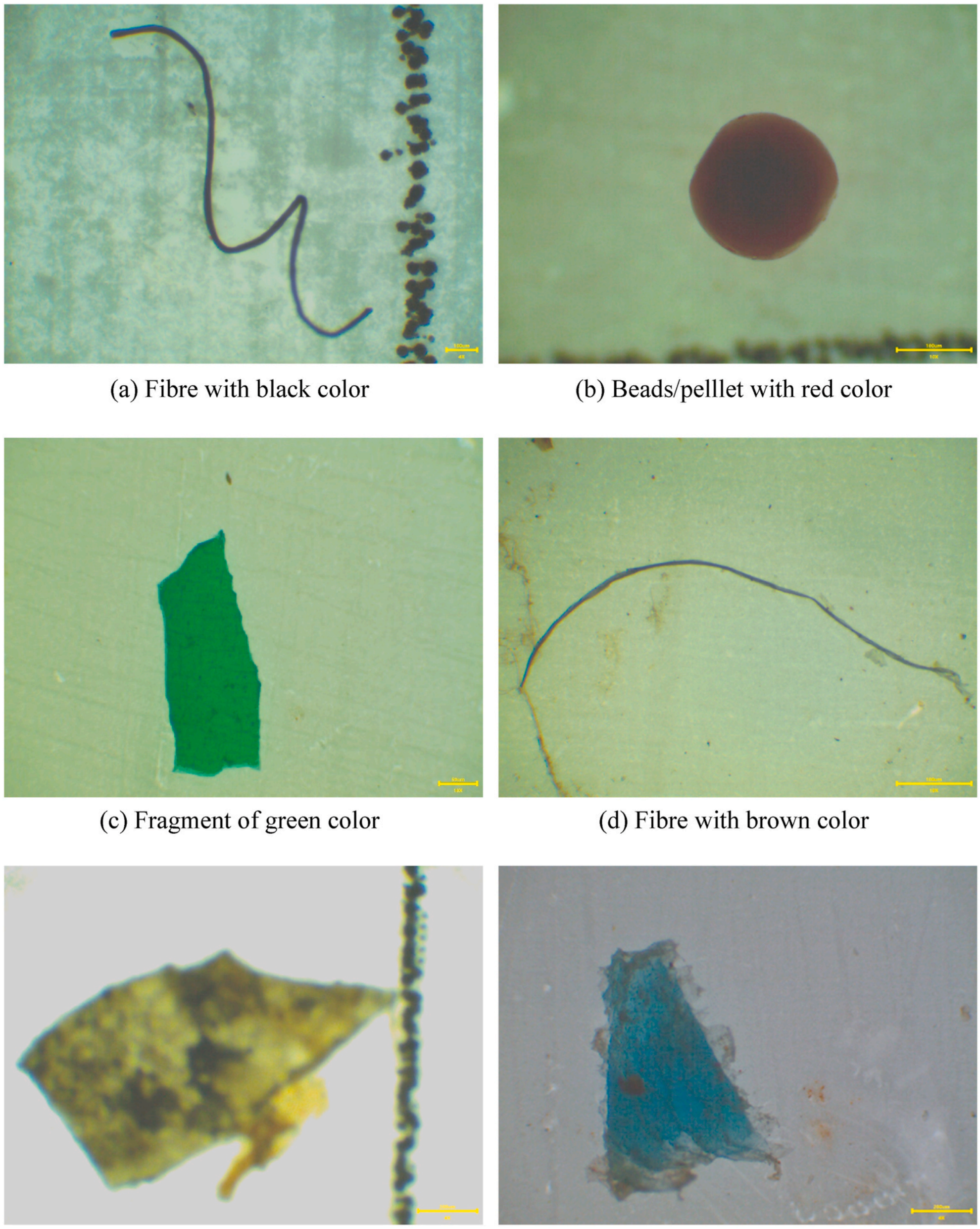


Fig. 2. Size wise MPs observed in the water and sediment samples.



(a) Fibre with black color
(b) Beads/pelllet with red color
(c) Fragment of green color
(d) Fibre with brown color
(e) Fragment with yellow color
(f) Film with blue color

Fig. 3. Different types and color of MPs recorded from studied samples. (a) Fibre with black color (b) Beads/pelllet with red color (c) Fragment of green color (d) Fibre with brown color (e) Fragment with yellow color (f) Film with blue color.

more energy to swim; therefore, to get more food they mistakenly feed upon MPs that look similar to their prey items. James et al. (2020) also reported higher abundance of MPs in pelagic species than demersal species from the south east coast of India. In the current study, the average number of MPs varied from 6.74 ± 2.74 to 9.12 ± 3.57 items/individuals in pelagic species and 5.62 ± 2.27 to 6.6 ± 2.98 items/individuals in demersal species, which is relatively greater than most of the earlier investigations conducted from different parts of the globe (Nadal et al., 2016; Fossi et al., 2018; Herrera et al., 2019; James et al., 2020). Further, the marine fishes inhabiting the shallow coastal waters would have a higher chance of MPs ingestion than those living within the deep-sea environment because anthropogenic activities along shore areas lead to higher MPs concentrations in shallow areas (Pozo et al., 2019). While compared with the present investigation, higher MPs abundance were recorded in *Chelon auratus* (9.5 items/fish) of the Adriatic Sea and *Solea solea* (7.3 particles/fish) from the Mediterranean Sea (Anastasopoulou et al., 2018). Hossain et al. (2019) also recorded 8.72 ± 1.54 and 5.80 ± 1.41 particles/individuals in the gut of *Harpadon nehereus* and *Harpadon translucens,* respectively from the Bay of Bengal.

3.4. Microplastics in gastrointestinal tracts

3.4.1. Size of microplastics

In the present study, MP items were classified into four different size categories, i.e., <100 μm, 101–250 μm, 251–500 μm, 501–1000 μm, and >1000 μm. The size-wise percentages of MPs in all studied species are presented as follows (Fig. 6). The size wise number of MPs was found significantly different within the studied species and the number of MPs with a size of <100 μm was highest in white sardine and shrimp followed by Belanger croaker, Bombay duck, and Malabar sole fish (Table 2). In *Cynoglossus macrostomus,* size-wise (<100 μm) number of MPs was observed significantly lower as compared to all other species,

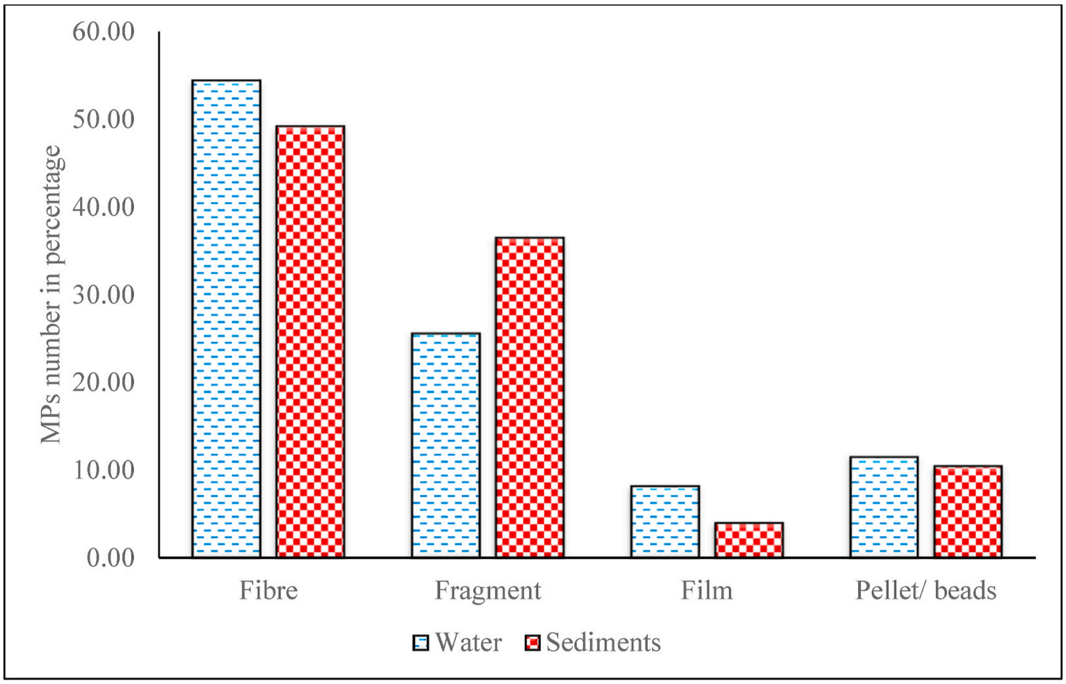


Fig. 4. Morpho type composition of MPs recorded in the sediment and water samples.

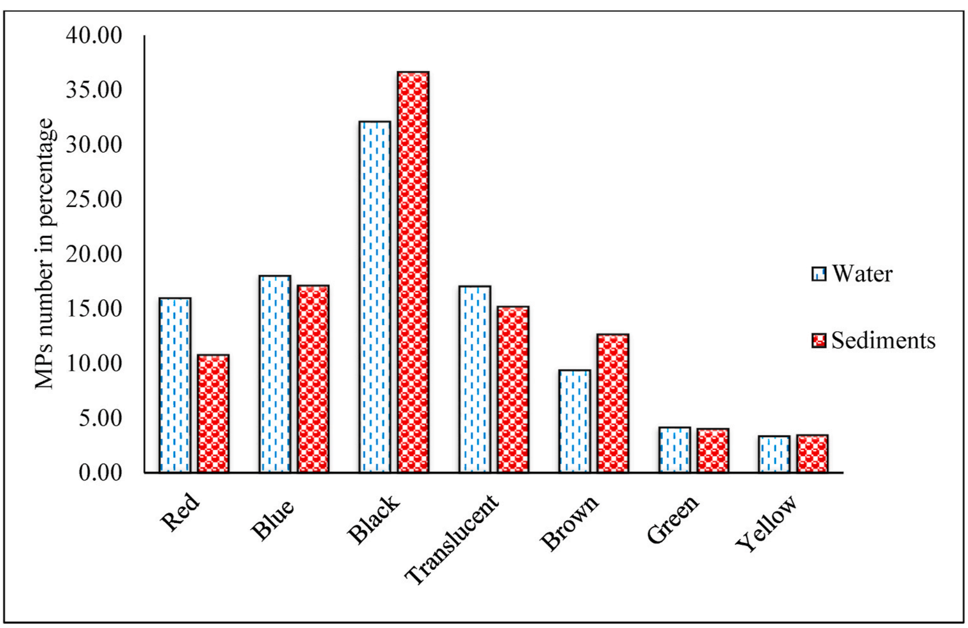


Fig. 5. Color wise composition of MPs recorded in the water and sediments. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

which might be due to differences in their preferred habitat and feeding types. A higher number of small size MPs (<100 μm) recorded in white sardine and shrimp might be due to their smaller body size, limited choice of food items, and microplastic particle size similar to their prey size (Hossain et al., 2019; Cole et al., 2013). The number of MPs with the size of 251–500, 501–1000 and > 1000 μm were significantly ($P < 0.05$) higher in Bombay duck, which may be due to their larger size of mouth, body, and feeding behavior, which agreed with earlier findings of Hossain et al. (2019). The number of MPs with the size of 501–1000 μm did not show a significant ($P > 0.05$) difference between white sardine, croaker, and sole fish.

3.4.2. *Shape of microplastics*

Concerning the characteristics, four different morphotypes of the MPs were observed in the studied samples. The most common shape of MPs was categorized as fiber, followed by fragments, pellet/beads, and film (Fig. 3). In *Cynoglossus macrostomus,* fragments were dominantly recorded while fiber types were dominant in all other species compared to other MPs shapes (Fig. 7). The results of the present study align with the result of earlier reports from the Mediterranean sea (Nadal et al., 2016) and Bohai Sea (Dai et al., 2018), where different species of shrimps and fishes dominantly ingested fibers (Gurjar et al., 2021b; Hossain et al., 2020; Jabeen et al., 2017; Sathish et al., 2020). Globally, fiber-shaped MPs are present in the highest abundance in the marine

Table 1
Feeding characteristics, trophic level and occurrence of microplastics in marine biota and environments.

Sample details	Habitat	Trophic level value	Feeding type	Total length range (mm)	Total weight range (g)	MP number/fish (Mean ± SD)	Occurrence (%)
White sardine (*Escualosa. thoracata*)	Pelagic	3.16 ± 0.08	Planktivore	73–108	5.8–13.54	6.74 ± 2.74	100
Bombay duck (*Harpodon nehereus*)	Pelagic	4.10 ± 0.74	Carnivore	135–270	9.78–101	9.12 ± 3.57	100
Belanger croaker (*Johnius belangerii*)	Demersal	3.27 ± 0.32	Carnivore	72–195	4.5–92.81	6.42 ± 2.65	100
Kadal shrimp (*Metapenaeus dobsoni*)	Demersal	3.50 ± 0.50	Omnivore	81–171	5.2–53.30	6.60 ± 2.98	100
Malabar sole (*Cynoglossus macrostomus*)	Demersal	3.30 ± 0.32	Omnivore	100–170	5.03–23.48	5.62 ± 2.27	100
Water (MPs items/liter)	–	–	–	–	–	372 ± 143	100
Sediment (MPs items/kg DW)	–	–	–	–	–	9630 ± 2947	100

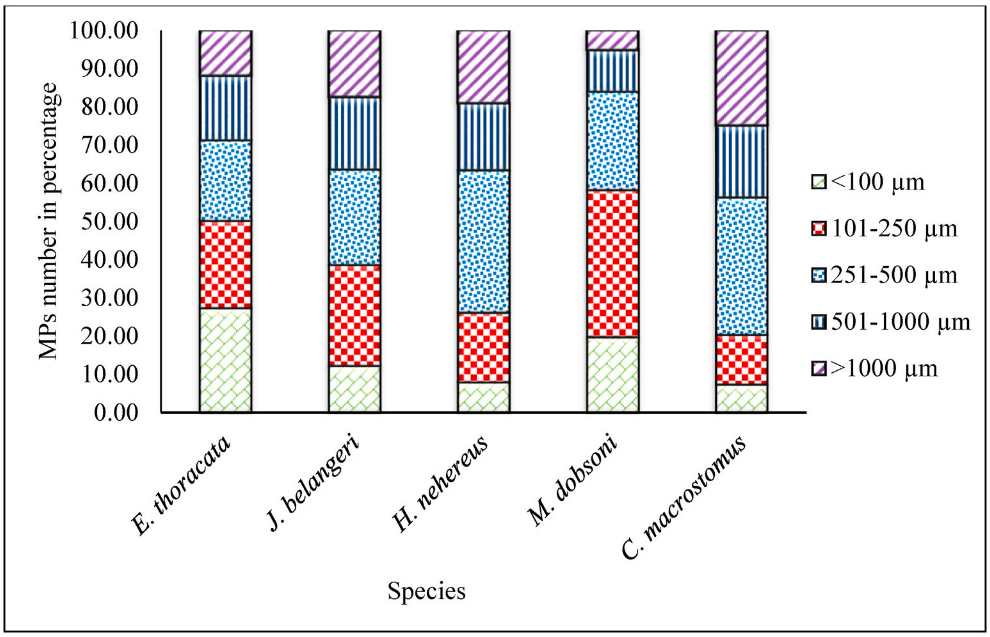


Fig. 6. Size wise ingestion of MPs recorded in the GI tracts of studied species.

Table 2
Size-wise variation in abundance of microplastics in different marine biota.

Size of MPs	Numbers of MPs				
	Escualosa thoracata	*Johnius belangerii*	*Harpodon nehereus*	*Metapenaeus dobsoni*	*Cynoglossus macrostomus*
<100 μm	1.84 ± 0.13^{d}	0.90 ± 0.12^{b}	0.72 ± 0.10^{ab}	1.30 ± 0.12^{c}	0.42 ± 0.08^{a}
<100–250 μm	1.54 ± 0.12^{b}	1.82 ± 0.11^{b}	1.66 ± 0.12^{b}	2.54 ± 0.18^{c}	0.84 ± 0.09^{a}
251–500 μm	1.42 ± 0.13^{a}	1.48 ± 0.09^{a}	3.40 ± 0.23^{c}	1.70 ± 0.13^{ab}	1.98 ± 0.14^{b}
501–1000 μm	1.14 ± 0.13^{b}	1.18 ± 0.11^{b}	1.60 ± 0.11^{c}	0.72 ± 0.09^{a}	1.02 ± 0.11^{ab}
>1000 μm	0.80 ± 0.12^{b}	1.04 ± 0.13^{bc}	1.74 ± 0.15^{d}	0.34 ± 0.07^{a}	1.36 ± 0.13^{c}

Values are expressed as mean ± SE; n = 50 each; Mean value in the same row with different superscripts are significantly different ($P < 0.05$).

environments (Walkinshaw et al., 2020). The more availability and distribution of fiber-shaped MPs shown a close association to the various anthropogenic activities such as fisheries activity, packaging of food products, aqua tourism, domestic wastewater discharge, use of microbeads in personal care products, waste generated during washing of clothes and other activities in the studied region (Browne et al., 2011; Takar et al., 2020).

3.4.3. Color of microplastics

In the current study, seven colors of MPs (red, blue, black, translucent, brown, green and yellow) were recorded from the studied samples. The black color MPs were predominantly recorded in shrimp (33.03%), Bombay duck (30.48%), and Malabar sole fish (29.54%), while blue color was dominant in white sardine and Belanger croakers. The green and yellow colors of MPs were observed only in the GI tracts of Malabar sole fish, Belanger croaker and Bombay duck (Fig. 8).

Daniel et al. (2020) recorded six different colors (red, blue, green, transparent, white, black) of MPs from inedible tissue (gills and viscera) of pelagic fishes. Similar to findings of the present study, different colors of MPs were recorded in different pelagic and demersal fishes from other parts of the globe (Boerger et al., 2010; Daniel et al., 2020; Lusher et al., 2013; Ory et al., 2017). Hossain et al. (2020) recorded five colors of MPs

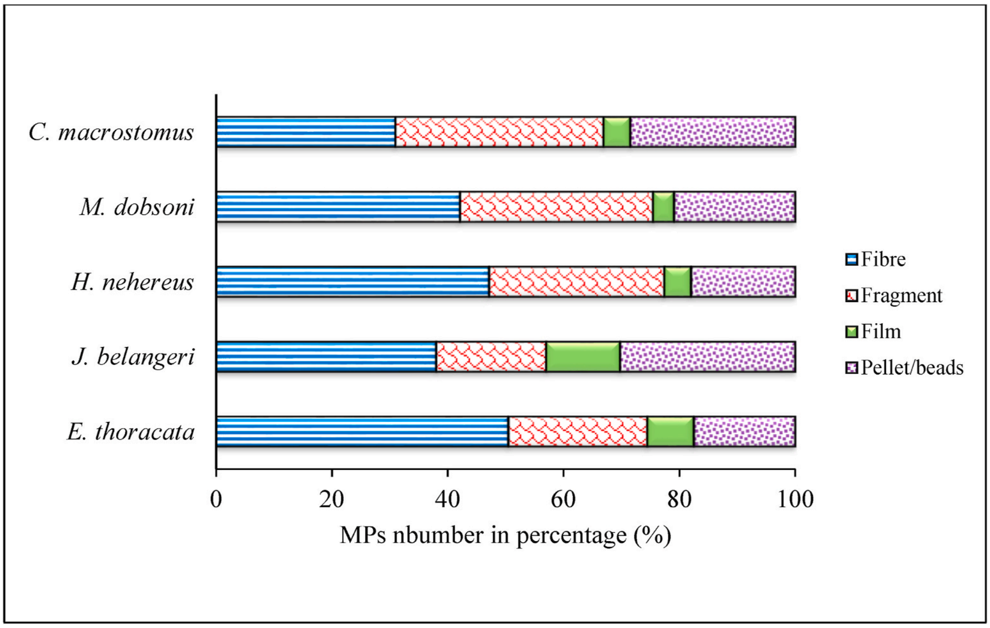


Fig. 7. Morpho type composition of MPs recorded in the GI tracts of studied species.

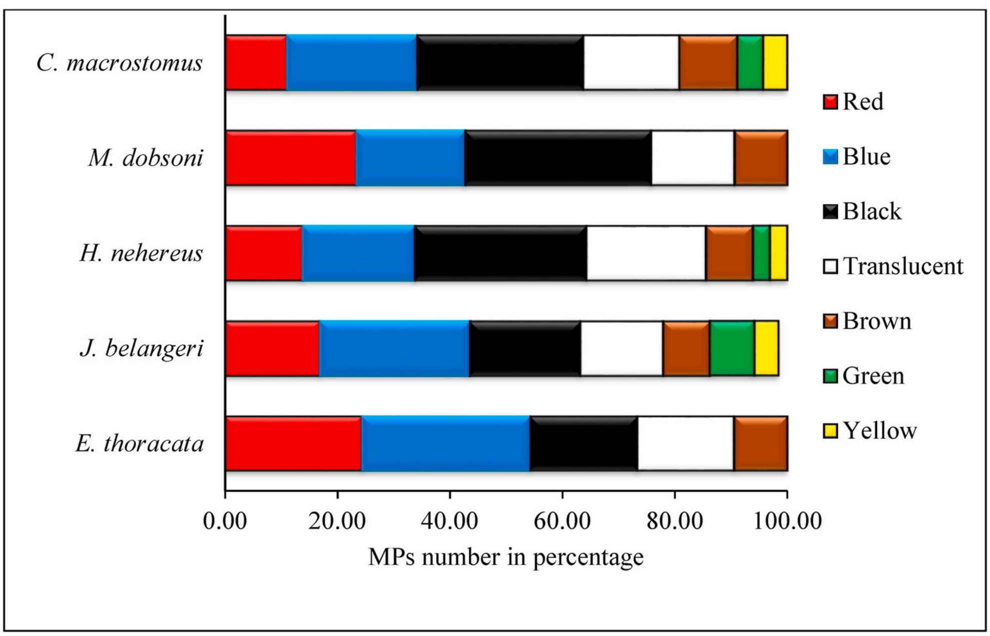


Fig. 8. Colour wise composition of MPs recorded in the GI tracts of studied species. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

(black, white, green, blue and red) in the gut of *P. monodon* dominant with black color (48%). Plastic particles, particularly yellow/pale-yellow colored pellets with irregular outer surfaces, may imitate a certain degree of photo-oxidative weathering (Maharana et al., 2020) and the clear and translucent colors of MPs are formed presumably due to weathering and fading of plastic substances in the environment (Herrera et al., 2019). Due to filter-feeding habits, fishes move near to the surface of the water, where they ingest free-floating MPs mistakenly, as they are visually similar to their prey items (Renzi et al., 2018). The black and blue colors were selected through the feeding strategies of European anchovy because they feed on the dark prey items (Renzi et al., 2018). The blue colour is extensively used for manufacturing fishing rope and nets to catch fishes (Sathish et al., 2020). The color of plastic items affects their bioavailability because they look similar to their prey items such as species of blue copepod (Ory et al., 2017).

3.5. *Plastic polymer in water, sediment and marine biota*

The suspected microplastic particles were randomly selected and analyzed using the Laser Raman Spectroscopy to validate polymer functional groups. A total of eleven different plastic polymers was identified from the studied samples of water, sediment, and biota (Fig. 9). Among the biota samples, nine plastic polymers such as polypropylene, polyethylene, polystyrene, polyamide, nylon, polycarbonate, polymethyl methacrylate, polyester, polyethylene terephthalate were

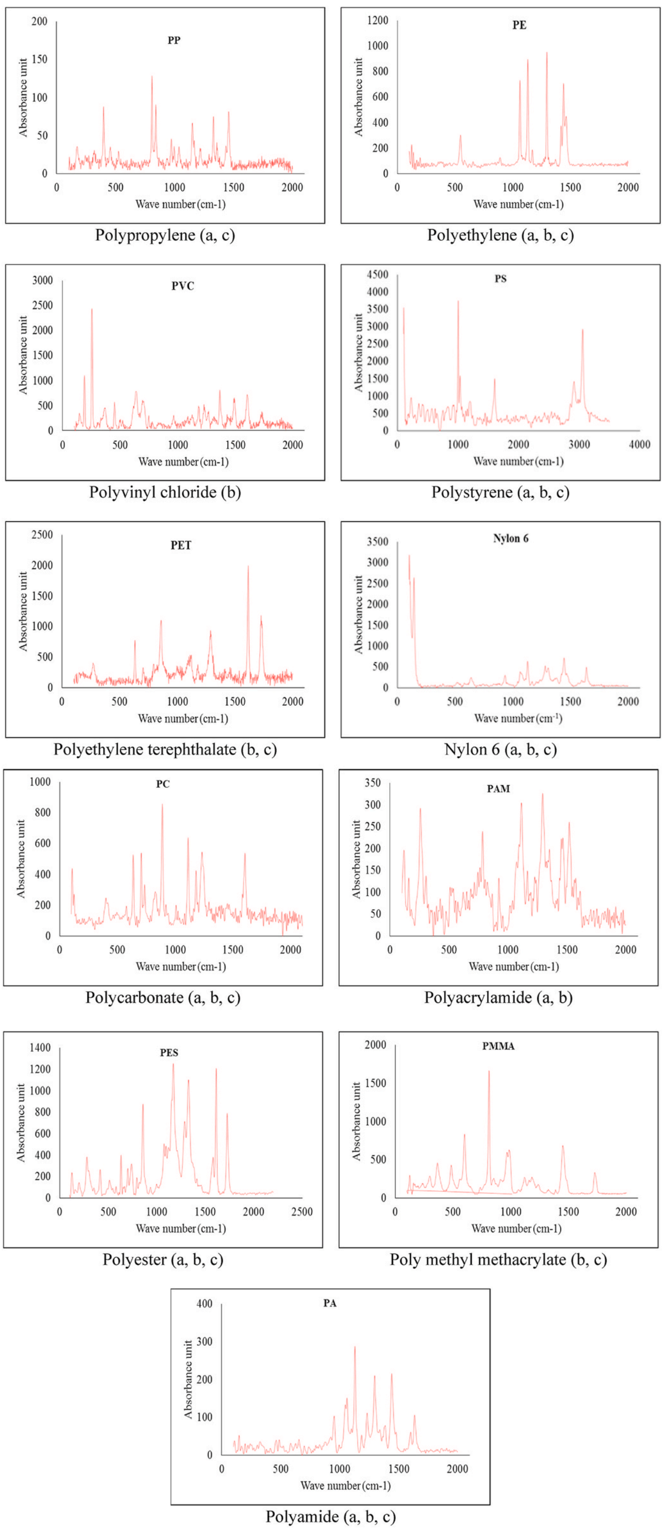


Fig. 9. Raman spectroscopy results of microplastics obtained from the studied (a) water, (b) sediment and (c) biota samples. Polypropylene (a, c) Polyethylene (a, b, c) Polyvinyl chloride (b) Polystyrene (a, b, c) Polyethylene terephthalate (b, c) Nylon 6 (a, b, c) Polycarbonate (a, b, c) Polyacrylamide (a, b) Polyester (a, b, c) Poly methyl methacrylate (b, c) Polyamide (a, b, c).

recorded from GI tracts of the studied samples. Similar to the results of the current study, ten plastic polymers were observed from the gut contents of commercial fishes caught from of the Bohai sea (Wang et al., 2021).

The polymer analysis of water samples revealed the eight types of MPs polymers such as polypropylene, polyethylene, polystyrene, polyamide, polyester, nylon, polycarbonate, polymethyl methacrylate. However, from sediments samples, ten MPs polymers were recorded except polypropylene. Similar to the present results, eleven types of plastic polymer (polyethylene, polypropylene, α-cellulose, polyethylene terephthalate, cellulose acetate, polyamide, polybutene, polymethyl methacrylate, cellophane, polyurethane, and ethylene/ethyl acrylate) were reported in water and sediment samples collected from the Yangtze Estuary, China (Li et al., 2020). In the present study, MPs denser than water such as polyamide, polyester, nylon, polycarbonate, polymethyl methacrylate were also recorded from water samples. A possible reason is that high-density particles can again enter the water column by resuspension of bottom soils (Lambert and Wagner, 2018). Influenced by offshore tides and nearshore circulation, the sediment resuspension in tidal estuaries contributes to exchanging materials between water and sediment phases (Shi et al., 1996). Thus, in this study, low-density microplastic (polyethylene) was also observed in the sediment samples, which could be due to change in densities with biofouling and weathering in the aquatic environment (Long et al., 2015).

3.6. Ecological significance of MPs

The white sardine feed on small planktonic organisms such as copepods, cladocerans, fish larvae, mysids, diatoms, polychaete larvae, which are the common prey items for various fish and shellfish species (Froese and Pauly, 2019; Gurjar et al., 2017). Kadal shrimp feeds on (diatoms, detritus, small crustaceans and polychaetes); Belanger croaker feeds upon (shrimp and fishes); sole fish feeds on (diatoms, algae, bivalve remains, gastropod remains, polychaetes, fish eggs, mysids, copepods, and other crustacean) (Froese and Pauly, 2019) and Bombay duck feeds on shrimps, small size fishes, sciaenids, and juveniles of fish and shellfishes (Froese and Pauly, 2019; Balli et al., 2006). In the present study, based on feeding behaviors, MPs were observed in planktivorous (white sardine), carnivorous (Bombay duck and Belanger croaker), and omnivorous species (kadal shrimp and Malabar sole fish). Thus, MPs in water, sediment, fishes (pelagic and demersal) and different feeding types of fishes showed a chance of transfer of MPs to higher trophic levels in the aquatic ecosystems.

Copepods, common food items for many aquatic organisms are reported to ingest MPs (Botterell et al., 2019). Accidental ingestion and consuming the microplastic contaminated prey items were observed in marine biota (Renzi et al., 2018; Gurjar et al., 2021a), probably leading to transfer and accumulation at different trophic levels, a phenomenon called trophic transfer (Welden et al., 2018). In the present study, it has been observed that the carnivore species, Bombay duck have more MPs than other carnivores (*J. belangarii*), plankton feeder (*E. thoracata*), and omnivores species (*C. macrostomus* and *M. dobsoni*), while plankton feeder species *E. thoracata* have more MPs than carnivores (*J. belangarii*), and omnivores species (*C. macrostomus* and *M. dobsoni*). The findings of the present study are similar to the results obtained for six fish species exhibiting three different types of feeding habits from the coastal waters of the southeast coast of India (Sathish et al., 2020) and eleven fish species with four different kinds of feeding behaviors observed from the South America waters (Pazos et al., 2017).

Trophic transfer of microplastic to upper the trophic level of the food chain has been observed in several aquatic organisms (Nelms et al., 2018). The availability of MPs in the plankton feeder fish has a chance of MPs transfer to the higher trophic predators (Boerger et al., 2010). Thus, Romeo et al. (2015) noted biomagnifications in the bluefin tuna, albacore, and swordfish along the Mediterranean Sea. The trophic transfer of MPs has also been evidenced from Atlantic mackerels, *Scomber scombrus* to gray seals, *Halichoerus grypus* (Nelms et al., 2018). The present study observed that studied biota are inter-linked in the food web, so there are increased chances of MPs transfer from one trophic level to another. Generally, fish are consumed in fresh condition, while Bombay duck, white sardine, croakers, and shrimps are also consumed in dried form (Bharda et al., 2017). Along with the studied region, Bombay duck, white sardine, croakers, and shrimps are used for drying without removing the digestive tract and therefore, the chance of trophic transfer of MPs is more.

4. Conclusion

The present study assessed the microplastic concentration in the water, sediment and marine organisms, revealed that MPs were found in both pelagic and demersal species, but the MP abundance was relatively higher in pelagic species. This illustrates that species inhabiting the shallow coastal waters are more prone to ingestion of MPs because anthropogenic activities along shore areas leading to higher MPs concentrations in coastal areas. The smaller size of MPs (<250 μm) was dominantly observed in guts of studied species, suggested that need of consumption of deveined and degutted shrimp and fish species. Even though studies on trophic transfer of MPs have been accomplished but the reports are limited; therefore especially site specific studies will facilitate in a better understanding that will form baseline information for an effective management of microplastic pollution in coastal habitats.

CRediT author statement

Udai Ram Gurjar: Data investigation, Writing the initial draft preparation K.A. Martin Xavier: Conceptualization Supervision- Reviewing and Editing Satya Prakash Shukla: Advisor in sampling Geetanjali Deshmukhe: supervision of microscopic analysis Ashok Kumar Jaiswar: Gut analysis and reviewing Binaya Bhusan Nayak: Project administration supervision I also declare that all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chemosphere.2021.132484.

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