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Dried fish more prone to microplastics contamination over fresh fish – Higher potential of trophic transfer to human body

Jabed Hasan [a], Evana Yesmin Dristy [a], Anjumanara [a], Pronoy Mondal [b], Md Sazedul Hoque [b], Kizar Ahmed Sumon [a], Mostafa Ali Reza Hossain [c], Md Shahjahan [a,*]

[a] Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
[b] Department of Fisheries Technology, Patuakhali Science and Technology University, Dumki, Patuakhali 8602, Bangladesh
[c] Department of Fish Biology and Genetics, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

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ABSTRACT

Globally, microplastics (MPs) contamination in aquatic organisms is emerging as an alarming phenomenon. In the present study, we investigated MPs in three commercially important fishes (Bombay duck *Harpadon nehereus*, ribbon fish *Trichiurus lepturus* and hairfin anchovy *Setipinna phasa*) in fresh and dried conditions collected from two sites (Chattogram and Kuakata) of the Bay of Bengal. It was evident that fresh *T. lepturus* ingested highest amount of MPs through the gills (6.41 mps/g) from Chattogram followed by in the gastrointestinal tract, GIT (6.20 mps/g) and in the muscle (1.20 mps/g) from Kuakata. Among the fresh fishes, *H. nehereus* from Kuakata accumulated highest amount of MPs (0.21 mps/g), while *S. phasa* from Kuakata contained the least amount of MPs (0.06 mps/g). On the other hand, among the dried fishes, *T. lepturus* from Kuakata contained highest amount of MPs (46.00 mps/g), while *S. phasa* from Kuakata retained lowest amount of MPs (2.17 mps/g). Strangely, all the dried fishes showed significantly higher amount of MPs compared to fresh fishes from both the locations. Fiber was the most dominant type of shape of MPs which accounted 66 %, followed by fragment (27.38 %), microbeads (3.59 %), film (1.48 %), foam (1.31 %) and pellet (0.25 %). Size-wise, the major portion (39.66 %) of MPs was present to be in size range less than 0.5 mm followed by 37.67 % in the size range of 0.5–1.0 mm group and rest 22.67 % within 1.0–5.0 mm. Red (41.55 %) colored MPs was the most prominent, followed by brown (22.11 %), blue (16.32 %), pink (11.69 %), purple (5.10 %), and green (2.25 %). Among polymer types, low-density polyethylene (LDPE) was the most common (38 %), followed by polystyrene (PS-22 %), polyvinyl chloride (PVC-16 %), polyamide (PA-13 %) and ethylene-vinyl acetate (EVA-9 %). The present study confirms high occurrence of MPs in the dried fishes over the fresh fishes from the Bay of Bengal, with high potential of trophic transfer to the human body.

1. Introduction

Microplastics (MPs) are particles derived from large plastic components used in a range of mechanical and photo oxidative procedures which are less than 5 mm in size (Arthur et al., 2009). Large amounts of non-degradable and hazardous solid waste have been distributed in the aquatic ecosystem due to extensive uses of plastics which is increasing the accumulation rate severely over the past decades (Selvam et al., 2021). The methodical cohesion of bigger plastics traces are broken down through biological, physical and chemical activities that transform into microscopic particles afterwards (Rahman et al., 2020). It is estimated that around 93–268 kilotons of MPs are streaming along the ocean at present (Aliko et al., 2022; Jambeck et al., 2015; Sebille et al., 2015). MPs are denser than sea water such as acrylics pile up in the ocean floor those lead to a significant quantity of MPs accumulation in the deep sea and pass through the food webs of marine species eventually. These plastics are eventually causing the presence of MPs in various tissues of marine organisms including commercially important species such as mollusks, crustaceans and fishes (Alimba et al., 2021; Prokić et al., 2021; Hossain et al., 2019; Mak et al., 2019; Hossain and Olden, 2022). MPs may transfer from marine organisms to the human body and can lead as potential hazards to human health (Crew et al., 2020; Sunitha et al., 2021).

The Bay of Bengal is a good source of numerous aquatic organisms

* Corresponding author.
E-mail address: mdshahjahan@bau.edu.bd (M. Shahjahan).

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and shares major marine production of Bangladesh which has a great economic importance of the country's national gross domestic product (Hossain et al., 2015b; Rahman, 2017). However, MPs contamination in the Bay of Bengal has been identified in a number of studies (Hasan et al., 2022b; Rakib et al., 2021; Woodall et al., 2022). The three major rivers - Padma, Jamuna and Meghna and their numerous tributaries transport MPs to the Bay of Bengal, from Bangladesh and a number of neighboring countries, making the Bay highly vulnerable to MPs pollution (Napper et al., 2021). Moreover, the world's longest sea beach along the coast of Bay of Bengal, the main tourist spots of Bangladesh is visited by approximately 2 million tourists also passage MPs to the bay (Hossain et al., 2021). Enormous amounts of plastic waste are being produced from the beachside hotels, restaurants and other tourist activities and all are disposed into the bay. MPs are also pass through the beach sediments or water column from primary and secondary sources in the Bay of Bengal (Hossain et al., 2021; Hasan et al., 2022a).

The present study was intended to study the occurrence of MPs in three commercially important fishes (Bombay duck *Harpadon nehereus*, ribbon fish *Trichiurus lepturus* and hairfin anchovy *Setipinna phasa*) from the Bay of Bengal. The Bombay duck, *H. nehereus* inhabit deep water offshore on sandy mud bottom for most of the year, but also gathers in large shoals in deltas of rivers to feed during monsoons (Frimodt, 1995). The ribbon fish, *T. lepturus* lives near the bottom and mid-waters and also near the ocean surface. They are extensively distributed in warm and temperate waters at various regions, where the maximum depth is around 350 m. This fish is ranked in the sixth place of landing capacity globally for commercial capture, mostly in the Asia Pacific, China and Japan. The hairfin anchovy, *S. phasa* is one of the significant food fish commercially (Sarma, 2015) due to the presence of high content of nutrients (Chaubey et al., 2021). This fish species is pelagic and amphidromous (Riede, 2004). These fishes are commonly consumed as fresh and dried conditions.

The dried fish sector of Bangladesh has long been playing a key role in the food, nutrition, employment generation and economy (Hossain et al., 2015b). Every year, a significant amount of capture fisheries both freshwater and marine are processed as dried, salted and fermented fish products (Belton et al., 2018). In particular, marine fish drying dominates and is carried out along the entire coast of Bangladesh, predominantly in the east coast – the different sub-districts of Cox's Bazar. It is estimated that nearly half of the total marine catch is dried, with 80 % production occurring during October to March - the winter season in Bangladesh (Hossain et al., 2015b). These dried fish products are not only in high demand at national level, but are also exported to overseas markets, particularly among the Bangladeshi diaspora living in UK, USA, Malaysia, Saudi Arab and other Middle Eastern countries. Belton et al. (2014) studied the pattern of dried fish consumption in Bangladesh and found that the contribution of the products to the total fish consumption dominated disproportionately in the low-income consumer groups making the dried fish very important for food and nutrition security for the groups.

Nearly all the fish and shellfishes that are caught in the Bay of Bengal coast are dried and used either for human consumption or for fish meal preparation to be used as the key ingredient for manufacturing animal feed. Bombay duck (*H. nehereus*, or loitta in Bangla), ribbon fish (*T. lepturus*, or churri) and hairfin anchovy (*S. phasa* or phaissa) are the most important marine fish species when abundance and popularity are considered among all the aquatic organisms dried in Bangladesh (Belton et al., 2014; Jahan et al., 2019). In the year 2020–21, the contribution of Bombay duck (0.072 million MT) was 10.56 % of the total marine fish catch (0.68 million MT) and 1.56 % of the total fish production (4.621 million tonnes) of the country (FRSS-DoF, 2022). In a study conducted in the largest dried fish wholesale market of Asia (Asadgong in Chottogram), Faruque et al. (2012) observed that nearly half (47%) of the sale accounted for Bombay duck (25 %) and ribbon fish (22 %) of the total sold product. The hairfin anchovy also contributes significantly to commercial fishery in the coastal Bangladesh round the year and is consumed in fresh, dried and fermented condition (Kamal et al., 1999; Hossain et al., 2013; Mehedi et al., 2020).

Although a number of studies evidenced MPs in fish (Hossain et al., 2019; Ghosh et al., 2021), shrimp (Hossain et al., 2020) and beach sediment (Banik et al., 2022; Hossain et al., 2021; Rahman et al., 2020) in the Bay of Bengal, still it warrants MPs study in the fish which are commercially important and consumed by millions of people. Recently we reported high abundance of MPs in two dried fishes from the Bay of Bengal (Hasan et al., 2022b). The objective of the present study was to analyze MPs in three most commercially important edible fish species, *H. nehereus*, *T. lepturus* and *S. phasa* in fresh and dried conditions.

2. Materials and methods

2.1. Sampling sites

Fishery ghat, Chattogram (22.31942°N, 91.83879°E) and Mohipur Landing Center nearby Kuakata, Patuakhali (21.8198°N, 90.1104°E) were selected for sampling (Fig. 1). Fishery ghat is the largest marine fish landing center and whole sale market in north-east coast of the Bay of Bengal. Mohipur Fish Landing Center nearby Kuakata is also one of the largest fish markets in the southwest coast of the country and supply marine fish round the year.

2.2. Sample collection

A total of 240 individual (20 of each) fresh and dried Bombay duck, ribbon fish and hairfin anchovy were collected from the sampling sites between October and December, 2021. Fishes were wrapped in pre-cleaned aluminum foil and labeled by their scientific names and sampling locations, accordingly. Immediately, the wrapped fishes were preserved in an ice box and transported to the Laboratory. Collected samples were stored in a refrigerator at − 20 °C in the laboratory for further analysis without any delay. Care was taken during the sampling and transportation to prevent contamination and alleviate physical damage of the fishes. The mean length (cm) and weight (g) of sampled fresh and dried fishes are presented in Table 1.

2.3. Chemicals

For MPs extraction, various chemicals like sodium lauryl sulfate (SLS; $CH_3(CH_2)_{11}NaSO_4$; molar mass 288.372 g/mol; density 1.01 g/cm^3; laboratory grade; white color) powder (Research-Lab Fine Chem Industries, India), potassium hydroxide (KOH; molar mass 56.11 g/mol; density 2.12 g/cm^3; JP, BP; white solid appetence) pellet (E. Merck, Germany), 30 % hydrogen peroxide (H_2O_2; molar mass 34.0147 g/mol; density 1.11 g/cm^3 (30 % (w/w) solution); laboratory grade; very light blue liquid appearance) (Schlarlau, Spain), sodium chloride (NaCl; molar mass 58.443 g/mol; density 2.17 g/cm^3; ACS, ISO; colorless cubic crystals appearance) (Baker Ltd. Dangenham, England) and 99 % ethanol (C_2H_6O; molar mass 46.069 g/mol; density 0.78945 g/cm^3 (at 20 °C); ACS, ISO, Reag. Ph Eur; colorless liquid appearance) and sartorius cellulose nitrate (CN) filter 0.45 μm pore size (sterilized, readily usable and individually packed) (Sartorius Stedim Biotech GmbH, made in Germany) were procured from scientific instrument and chemical shops located at Dhaka city of Bangladesh.

2.4. Microplastics extraction

First, fresh fish samples were thawed in cleaned metal tray at the room temperature in the laboratory. Fishes were dissected then carefully and the gills, gastrointestinal tract (GIT) and muscle were carefully separated. Weights of these organs were taken individually and the values were recorded. Following, gills, GIT and muscle (5 g) were transferred to 500 mL glass beaker and marked the beaker by species name, number and organ name. For isolation of MPs, we performed a

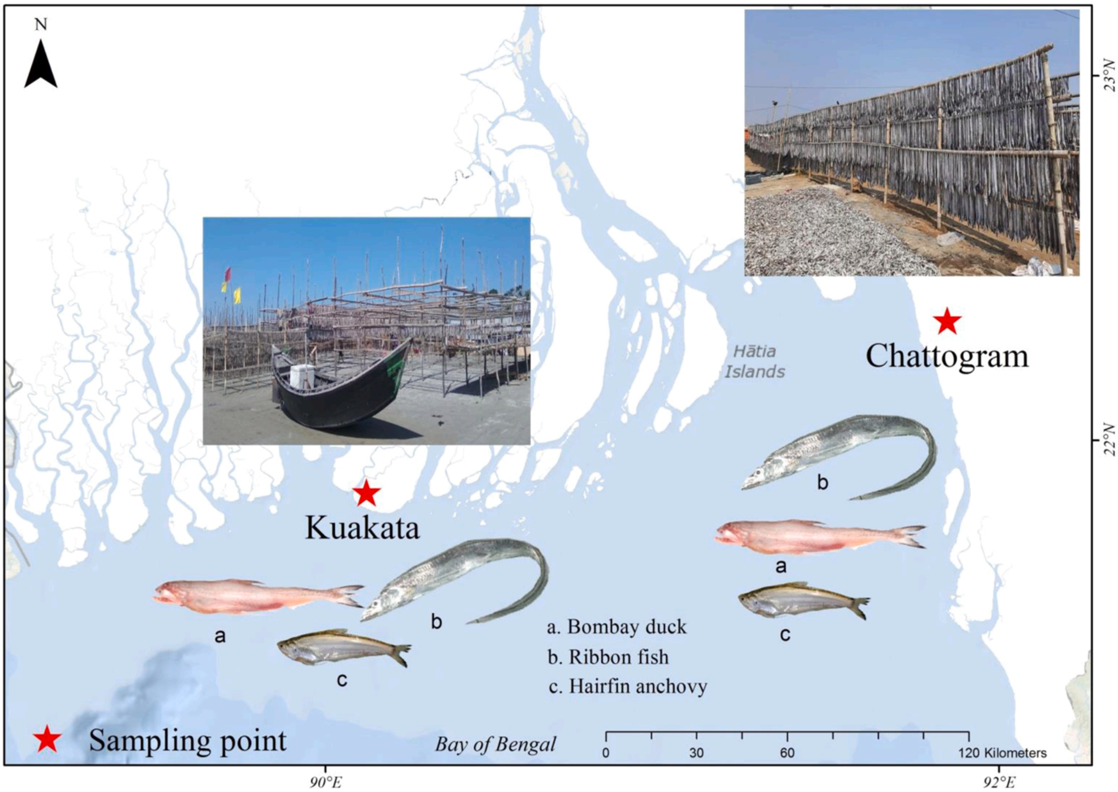

Fig. 1. Location of fishing grounds in the Bay of Bengal and drying yards of collected fish samples at Chattogram and Kuakata in Bangladesh.

Table 1
Mean length (cm) and weight (g) of sampled fresh and dried fishes (N = 20).

Species		Chattogram		Kuakata	
		Length (cm)	Body weight (g)	Length (cm)	Body weight (g)
Bombay duck (loitta) *Harpadon nehereus*	Fresh	26.30 ± 0.89	82.02 ± 6.21	26.87 ± 1.59	80.82 ± 3.07
	Dried	28.92 ± 1.42	32.21 ± 3.69	29.30 ± 2.10	34.31 ± 3.95
Ribbon fish (churii) *Trichiurus lepturus*	Fresh	59.60 ± 4.96	91.31 ± 4.72	55.58 ± 2.29	85.77 ± 2.92
	Dried	64.75 ± 2.24	69.34 ± 5.38	60.35 ± 4.91	65.28 ± 5.35
Hairfin anchovy (phaissa) *Setipinna phasa*	Fresh	19.17 ± 1.50	31.10 ± 4.50	15.65 ± 0.77	32.99 ± 2.46
	Dried	13.68 ± 0.44	12.71 ± 1.50	13.93 ± 0.61	9.40 ± 1.27

All values are expressed as mean ± SD.

combined extraction procedure with some modification following several previous studies (Hasan et al., 2022b; Hurt et al., 2020; Masura et al., 2015; Rochman et al., 2015) showed in Fig. 2. Digestion was carried out through KOH (1 M) and SLS (0.5 % w/v [Ca. 5 g L^{-1}]), allowing the samples to submerse in 60 and 30 mL ratio respectively. The beakers were covered with aluminum foil and transferred to digital constant temperature water bath at 50 ^{o}C for 72 h. Then the beaker was gently shaken several times during the incubation period. After incubation, 6 g NaCl was thoroughly mixed with 30 mL of 30 % H_2O_2 and added to the samples and waited for 12 h at room temperature to allow digestion of remaining organic materials from the samples. When the solution caused excessive foaming, 100 mL distilled water was added to settle down the overflow. Then the sample was filtered through 0.45 µm cellulose nitrate filter (Sartorius, Germany) using glass filtration unit (Duran, Germany) by a vacuum pump (Rocker 300). Hereafter, filter paper was carefully transferred to petri dish to prevent contamination and labeled accordingly and stored for further analysis.

MPs from dried fishes were extracted using the method previously used by Hasan et al. (2022b). In brief, the whole fish was minced in a mincer machine (Miyako, Japan) and minced sample was reweighted. For digestion, 1 g of homogenized minced sample of dried fish was transferred to a cleaned 500 mL beaker and submerged by adding in 60 mL of 1 M KOH and 30 mL of Sodium lauryl sulfate ($C_{12}H_{25}NaSO_4$) (0.5 % w/v [Ca. 5 gL^{-1}]). The beaker was incubated at 50 °C for 72 h in water bath and shaken the beaker smoothly for several times. For oxidation, 6 g NaCl and 20 mL of 30 % H_2O_2 was added to the beaker and left for 12 h at room temperature. The sample was then filtered through a 0.45 µm cellulose nitrate filter (Sartorius, Germany) by glass vacuum filtration unit (Duran, Germany) using a vacuum pump (Rocker 300, Taiwan). After filtration, the filter membrane was immediately covered with a petri dish to prevent contamination and labeled and stored.

2.5. Characterization and quantification of microplastics

Visual identification and quantification were carried out based on their morphological characteristics according to the previous studies (Hasan et al., 2022b; Hidalgo-Ruz et al., 2012; Masura et al., 2015; Norén, 2007). In a short, filter paper was examined under a sophisticated microscope (Daffodil MCX100, Micros Austria) ranged between 40 and 1000X. Clean tweezers were used to transfer the filter paper from petri dishes and positioned under the microscope. Few drops (2–3) of glue were directly applied to the filter edges for the curved filter paper where needed and the grid was viewed from left to right, shifted down one row, and read from right to left and data from each sector of the grid was recorded in turn however, slightly discolored white, and gridded filter paper ensured the counting and was easily distinguishable for the light colored perimeter of the filter and particles were persisted within the perimeter.

MPs were categorized in six types or groups namely fibers,

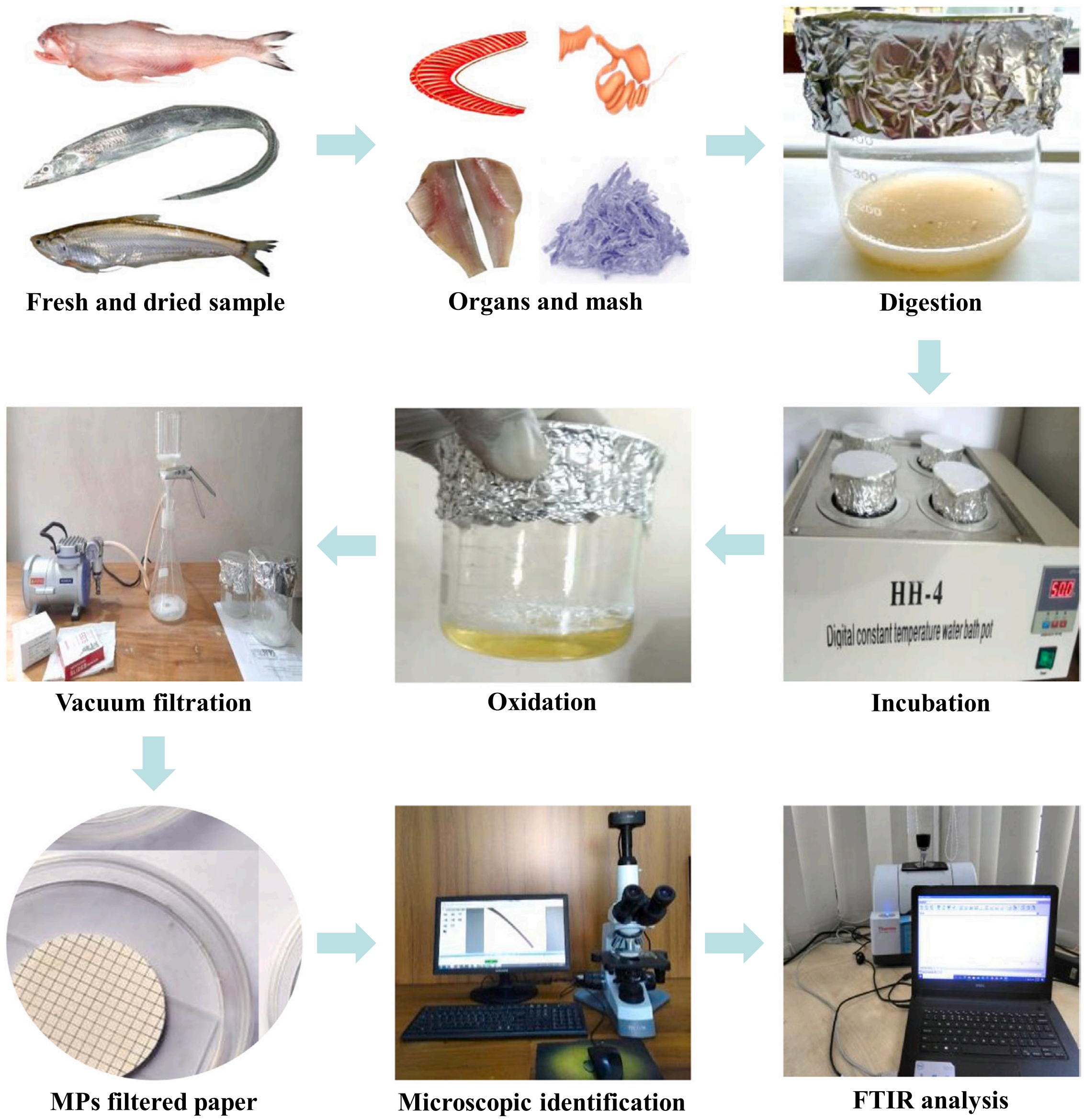

Fig. 2. Sample preparation, digestion and analytical procedures for detecting microplastics in fresh and dried fishes.

fragments, films, foams, pellets, and microbeads and classified in three size groups like < 0.5 mm, 0.5–1.0 mm and 1.0–5.0 mm according to their lengths. Color count was deployed by the naked observation. Each microplastic was photographed by AmScope camera mounted with the microscope. A hot needle test was performed as an alternate identification method for 10 % of the particles to ensure positive identification by distinguishing between plastic bits and organic components.

2.6. FTIR analysis

The chemical composition of MPs was determined using Fourier Transform Infrared (FTIR) (Nicolet iS5 FT-IR, Thermo Scientific Inc., USA). Individually, randomly selected extracted particles were placed on the surface crystal of an Attenuated Total Reflectance (ATR) (iD7, Thermo Scientific Inc., USA). The chemical composition of the sample was determined after capturing the sample spectrum and combining it with the Omnic polymer reference Spectra library (Thermo Fisher Scientific Inc., USA). The level of similarity between the samples and the reference spectra was set at 80 %. Isopropanol was utilized to clean the crystal surface of ATR before each sample was placed.

2.7. Prevention of contamination and quality assurance

All the chemical solutions and distilled water were filtered through 0.45 μm cellulose nitrate filter prior to use. Working areas and utensils were cleaned before and after using. Dissection was done on a clean metal tray and dissecting tools were cleaned continuously after a while with pre-filtered distilled water. Laboratory coat and latex gloves were worn during the experiment. Beakers were kept covered with aluminum foil. All experimental equipment, glassware, metal tools were rinsed three times with filtered distilled water prior to use for each sample. Whole laboratorial process was executed in a laminar flow hood and in a non-ventilated low traffic room.

2.8. Statistical analysis

ImageJ software was used to measure the length of the isolated MPs using a calibration slide (Japan) as a reference length in millimeter. The recorded data was organized in excel spread sheet and analyzed using SPSS software (version 22). Two way analysis of variance (ANOVA) was deployed to know the significance level between the fresh and dried fish samples by sampling sites.

3. Results

3.1. Occurrence and abundance of MPs in fresh fishes

Ingested MPs from the gills, GIT and muscle of the three fresh fishes were counted separately (Table 2). It was clearly evident that *T. lepturus* ingested highest amount of MPs in the gills (6.41 mps/g) from Chattogram followed by in the GIT (6.20 mps/g) and in the muscle (1.20 mps/g) from Kuakata. Overall lowest amount of MPs (0.09 mps/g) were found in the muscle of *S. phasa* from Kuakata. MPs abundance of gills and GIT were significantly ($p < 0.05$) higher than muscle in all fishes from both locations. Except gills and GIT of *T. lepturus*, there was no significant difference in abundance of MPs in individual tissues between the two locations. Overall, abundance of MPs per gram tissue weight of different fish species in fresh condition from two sampling sites is shown in Table 3. Among the fresh fish species, *H. nehereus* from Kuakata accumulated highest amount of MPs (0.21 mps/g), while *S. phasa* from Kuakata contained lowest amount of MPs (0.06 mps/g).

3.2. Occurrence and abundance of MPs in dried fishes

Overall abundance of MPs per gram body weight of different fish species in dried condition from two sampling sites is shown in Table 3. Among the dried fishes, *T. lepturus* from Kuakata contained highest amount of MPs (46.00 mps/g), while dried *S. phasa* from Kuakata retained lowest amount of MPs (2.17 mps/g). All the dried fishes showed significantly ($p < 0.05$) higher amount of MPs compared to fresh fishes from both the locations. Additionally, there was a significant difference ($p < 0.05$) in MPs abundance between the locations except the *S. phasa*.

3.3. Shapes of MPs

Isolated MPs particles of the fresh and dried fishes from both the locations were photographed by Amscope camera attached with the microscope. Microscopic images of the relevant shapes of MPs are shown in Fig. 3. Percent portion of MPs of the fresh and dried fishes from both the locations is shown in Fig. 4. Fiber was the most dominant shape of MPs of the total isolated particles from the fresh and dried fish species from the two sampling sites which accounted 66 %, followed by fragment, microbeads, film, foam and pellet 27.38 %, 3.59 %, 1.48 %, 1.31 %, and 0.25 % respectively. Highest portion of fiber was found in fresh *H. nehereus* from Chattogram which was 84 %. All the samples (100 %) contained fiber and fragment, however fresh *H. nehereus* from Chattogram, Kuakata; fresh *T. lepturus* from Kuakata; fresh and dried *S. phasa* from Chattogram and Kuakata did not show any other types of MPs except fiber and fragment. Dried *H. nehereus* and *T. lepturus* from Kuakata only showed all the six categories of MPs types.

Table 2
Abundance of microplastic items (mps/g) in different tissues of sampled fresh fishes.

Species	Sampling point	Tissues		
		Gills	GIT	Muscle
H. nehereus	Chattogram	$2.47 \pm 1.03^{a,1}$	$2.00 \pm 1.31^{a,1}$	$0.13 \pm 0.10^{b,1}$
	Kuakata	$2.21 \pm 1.18^{a,1}$	$4.00 \pm 1.63^{a,1}$	$0.10 \pm 0.11^{b,1}$
T. lepturus	Chattogram	$6.41 \pm 1.22^{a,1}$	$3.15 \pm 1.25^{ab,1}$	$0.93 \pm 0.58^{b,1}$
	Kuakata	$3.73 \pm 1.22^{a,2}$	$6.20 \pm 0.79^{ab,2}$	$1.20 \pm 0.45^{b,1}$
S. phasa	Chattogram	$1.09 \pm 0.58^{a,1}$	$1.15 \pm 0.80^{a,1}$	$0.11 \pm 0.10^{b,1}$
	Kuakata	$0.81 \pm 0.55^{a,1}$	$1.20 \pm 0.69^{a,1}$	$0.09 \pm 0.07^{b,1}$

Values with different alphabetic and numeric superscripts indicate significance difference ($p < 0.05$) among tissues and between locations respectively (Duncun's multiple range test). All values are expressed as mean ± SD.

Table 3
Abundance of microplastics items (mps/g body) in sampled fresh and dried fishes.

Species		Chattogram (Cox's Bazar)	Kuakata
H. nehereus	Fresh	$0.13 \pm 0.00^{a,1}$	$0.21 \pm 0.04^{a,2}$
	Dried	$28.50 \pm 5.54^{b,1}$	$41.33 \pm 3.44^{b,2}$
T. lepturus	Fresh	$0.20 \pm 0.04^{a,1}$	$0.12 \pm 0.02^{a,2}$
	Dried	$34.17 \pm 8.52^{b,1}$	$46.00 \pm 7.51^{b,2}$
S. phasa	Fresh	$0.08 \pm 0.04^{a,1}$	$0.06 \pm 0.03^{a,1}$
	Dried	$2.33 \pm 1.37^{b,1}$	$2.17 \pm 0.98^{b,1}$

Values with different alphabetic and numeric superscripts indicate significance difference ($p < 0.05$) between fresh and dried species, and locations respectively (Duncun's multiple range test). All values are expressed as mean ± SD.

3.4. Color of MPs

The total isolated MPs from the fresh and dried *H. nehereus, T. lepturus, and S. phassa* of different location showed red as the prominent color (41.55 %), followed by brown (22.11 %), blue (16.32 %), pink (11.69 %), purple (5.10 %), green (2.25 %) and others (black and transparent) (0.97 %). Percentage of color combination of the isolated MPs separated by species, species types and location is shown in Fig. 5. Green color was totally absent in fresh and dried *H. nehereus* from Chattogram and Kuakata.

3.5. Size of MPs

We categorized MPs into three size groups < 0.5 mm, 0.5–1.0 mm and 1.0–5.0 mm. Size categories of extracted MPs from the fresh and dried fish species from Chattogram and Kuakata is shown in Fig. 6. Of the quantified MPs, the major portion (39.66 %) was present to be in size range less than 0.5 mm. Following the largest portion, 37.67 % of the quantified MPs persisted into size range from 0.5 m to 1.0 mm group and rest 22.67 % accompanied into 1.0–5.0 mm size range group accordingly.

3.6. Polymer composition of MPs

A total of 120 visually identified MPs (10/species/site) were analyzed for polymer identification using ATR-FTIR (Fig. 7). Five polymer types were found to be present in the selected MPs and few MPs did not match the polymer composition thus grouped into unidentified group (Table 4). Overall, low density polyethylene (LDPE) was the most common type of polymer found in all the fresh and dried fish species from the different geographical location of the Bay of Bengal (38 %), followed by polystyrene (PS-22 %), polyvinyl chloride (PVC-16 %), polyamide (PA-13 %), ethylene vinyl acetate (EVA-9 %) and unidentified (3 %). However polymer composition was varied with species and location of sampling (Table 4), LDPE and PS was present in all species within the location basis and the highest portion of LDPE and PS was 50 % in dried *H. nehereus*, and *S. phasa*, and fresh *T. lepturus* from Chattogram, and 40 % in fresh *T. lepturus* from Kuakata respectively. Additionally, PA was totally absent in fresh and dried *S. phasa* from the locations.

4. Discussion

The present study confirms the occurrence of MPs in both the fresh and dried fishes collected from the Bay of Bengal. Globally, many studies reported the ingestion of MPs in fin fishes (Hossain et al., 2019; Karuppasamy et al., 2020; Siddique et al., 2022; Hossain and Olden, 2022) and shrimp (Hossain et al., 2020). In this study, all the fish species were contaminated with MPs from the two sampling sites. Varying abundance of MPs in different tissues like gills and GIT of the collected fresh fishes

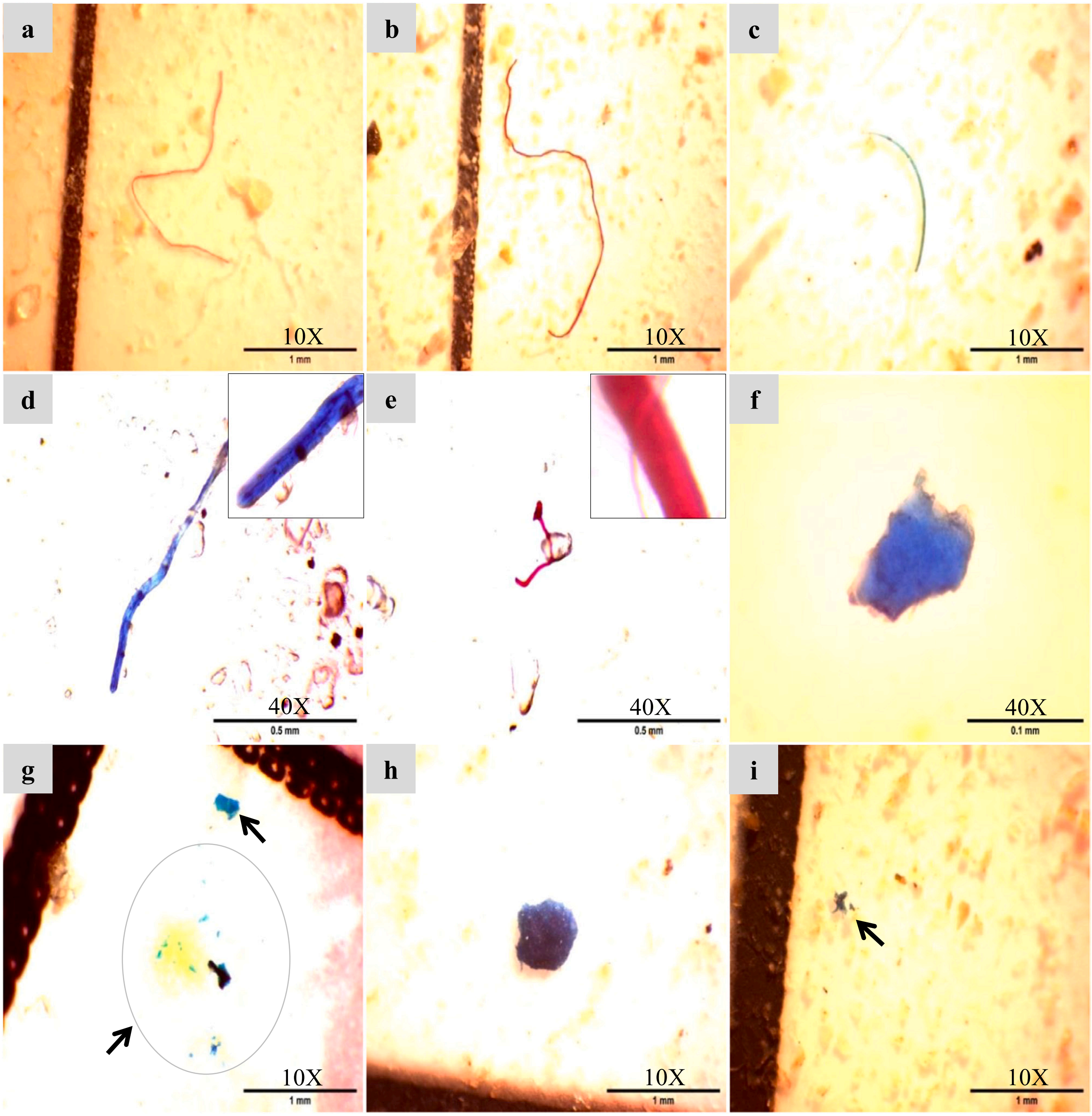

Fig. 3. Microscopic images of selected microplastics: a, b, c, d & e- fiber; f & g- fragment; h- foam; and i- film.

were reported in the present study. It has been reported that organ specific abundance and difference of MPs differs as organs structure, weights, and morphology varies among species (Jabeen et al., 2017). *T. lepturus* having benthopelagic and predatory characteristics usually aggressive feeding on fish, squid and crustaceans (Chiou et al., 2006) may influence the higher MPs ingestion rate. *H. nehereus* is also a benthopelagic fish found on the offshore water and gathers in river mouths and their unique body and depressible teeth helps in aggressive feeding on shrimp and fishes (Balli et al., 2006). The *S. phasa* is a pelagic and amphidromous fish (Riede, 2004). Therefore, occurrence of MPs in these three species may be influence by their feeding habits, MPs accumulation and escalated by different anthropogenic activities and morphological characteristics of the MPs in the marine environment.

Remarkably, we found high abundance of MPs in the dried fishes compared to the same fishes in fresh condition. The high concentrations of MPs presence in dried fish and other dried marine products have also been evident from a number of earlier studies - in Greenback mullet *Chelon subviridis*, Belanger's croaker *Johnius belangerii*, Indian mackerel *Rastrelliger kanagurta* and Spotty-face anchovy *Stolephorus waite* (Karami et al., 2017) and dried seaweed nori *Pyropia* spp. (Li et al., 2020). This phenomenon can be explained as depending on the species used, 2–6 kg of fresh fish is required to produce 1 kg of dried fish. In a study, Hossain et al. (2015a) found that to produce 1 kg of the respective dried fish products, nearly 6 kg of fresh Bombay duck and 3 kg of fresh ribbon fish were required. Thus, the higher amount of accumulated raw materials may consequences higher MPs of the resulted dried fish. Moreover, the fishes may be contaminated by MPs during drying process in the drying yards. Usually, fishes are dried in an open air condition for several days placing on the ground spreading polyethylene sheet, mat made of split bamboo, and in bamboo pole and bar. Thus they are more susceptible to contact with the beach sediments by continuous traffic movement and handling by the workers and visitors along the yards. Several studies

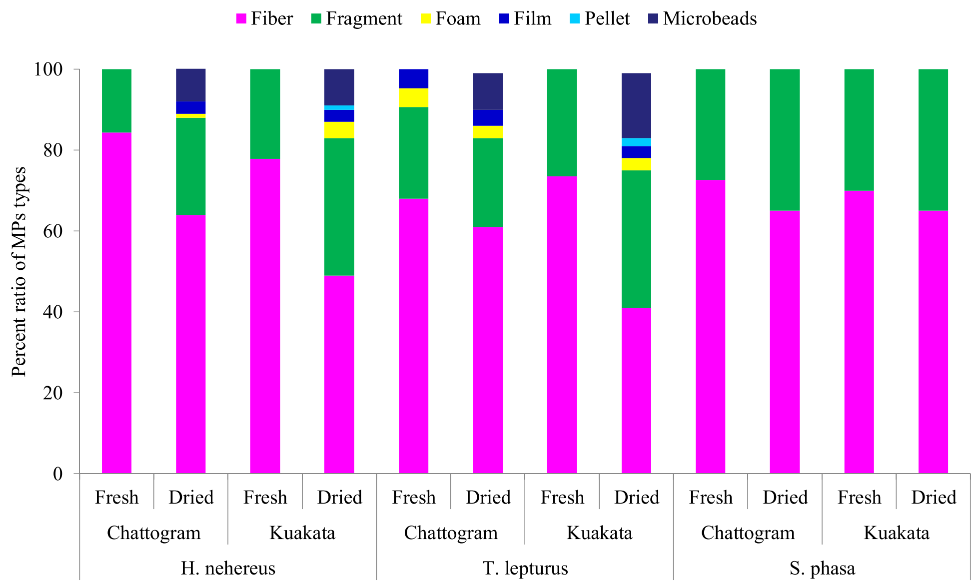

Fig. 4. Distribution of types of microplastics found in fresh and dried fishes from Chattogram and Kuakata.

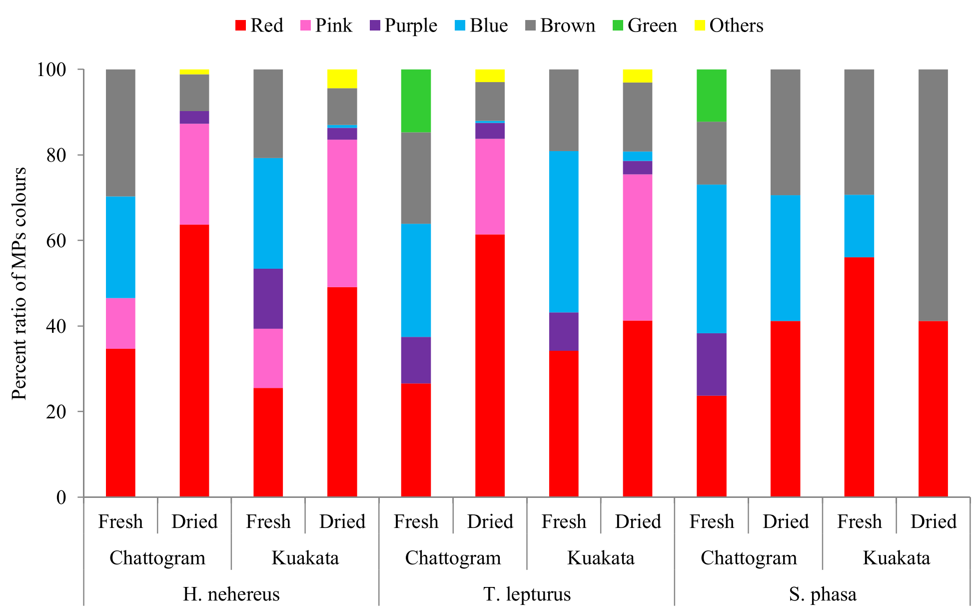

Fig. 5. Distribution of microplastics found in fresh and dried fishes from Chattogram and Kuakata, by colors.

have been reported MPs abundance in the beach sediment from Kuakata (Banik et al., 2022), and Cox's Bazar (Hossain et al., 2021; Rahman et al., 2020).

The morphological characteristics of MPs, including types, color and size were detected in all of the samples isolated from the three species in fresh and dried conditions of the both locations. Of the sample identified in this study, fiber (66 %) was the dominant types of MPs. Similar proportion of fibers (66 %) has been reported in fishes of Portuguese coast (Neves et al., 2015). Another study reported fibers (70 %) as dominant types of MPs in epipelagic and mesopelagic fishes of Southeast coast of India (Sathish et al., 2020). Fibers in commercial marine fish from Malaysia, accounted for 80 % has been reported in another study (Jaafar et al., 2021). Microfibers are also the most dominant types over 75 % has been reported (Taghizadeh Rahmat Abadi et al., 2021). Besides numerous studies on dried fish and fishery products have been reported the dominant types of MPs in their studied samples were fibers (Akhbarizadeh et al., 2020; Piyawardhana et al., 2022). However, some studies reported the fragments as the dominant types of MPs extracted from the fish samples (Cordova et al., 2020; Devi et al., 2020; Li et al., 2020; Mistri et al., 2022). Possible sources of these fibers in coastal waters might be fishing equipment like nets and ropes, urban, and laundry waste (Browne et al., 2011; Claessens et al., 2011). High number of garment industries in Bangladesh, may also contribute to the high abundance of microfibers in aquatic ecosystems and species. Besides, commonly used daily amenities like beauty and health products, and other industrial products, such as toothpastes and cleansers may be the possible source of microfibers as well.

Among the three size group categorized in this study, smaller size less than 0.5 mm (39.66 %) was the dominant group among all isolated MPs from the samples. Similarly, the mean size of MPs both in water and fish samples around Nanxun Reef in Nansha Islands, South China Sea was less than 0.5 mm (Nie et al., 2019). It was found less than 1 mm size MPs in the stomachs of thirteen deep sea fishes from South China Sea (Zhu et al., 2019). Size distribution of isolated MPs of different fish

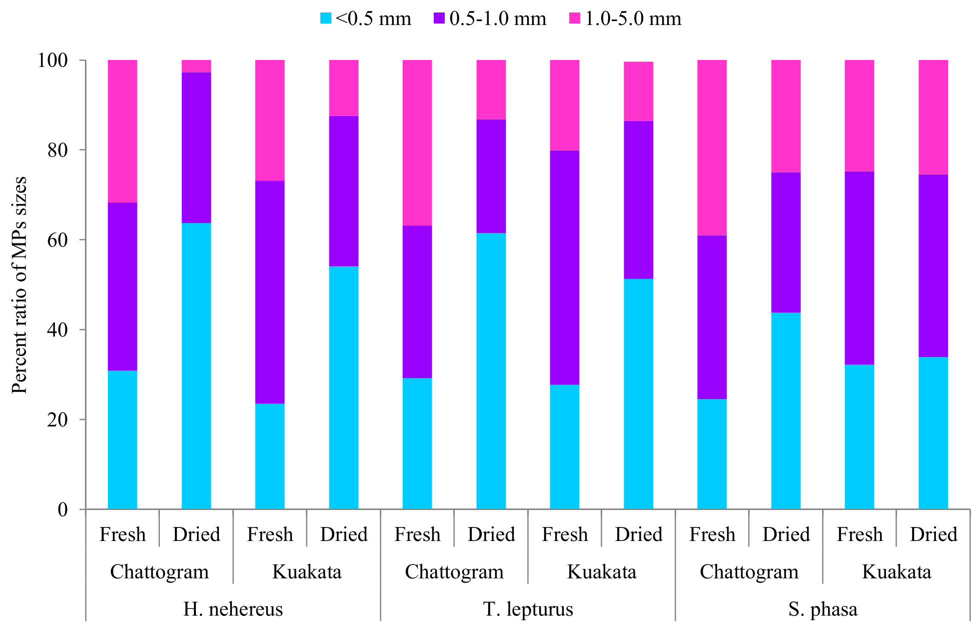

Fig. 6. Distribution of microplastics found in fresh and dried fishes fish from Chattogram and Kuakata, by particle sizes.

species have been reported from different regions ranging from 0.05 mm to 0.77 mm in pelagic and demersal fishes from Adriatic Sea (Mistri et al., 2022), 0.1–5.0 mm in dolphin fish from Eastern Pacific Ocean (Li et al., 2022), 10–5000 μm in Atlantic horse mackerel from Northeast Atlantic Ocean (Prata et al., 2022), 0.04–4.73 mm in fishes from Vembanad Lake, India (Nikki et al., 2021), 0.89–4.85 mm in Alien fish Pirapitinga from Ramsar site, Vembanad Lake, India (Devi et al., 2020) and 0.33–2.58 mm in demersal and pelagic fishes from Thailand (Klangnurak and Chunniyom, 2020). Additionally, size distribution in fishery products have also been reported ranging from 10 to 8000 μm in canned fish (Akhbarizadeh et al., 2020), 2–5 mm in seaweed (Gao et al., 2020), and 195–4780 μm in fish products from different countries (Piyawardhana et al., 2022). However, there was no significant difference between the size classes of ingested particles by different species caught in the North Sea (Foekema et al., 2013). Moreover, the relationships between the feeding types and abundance, shape, and size in fish are still not properly evaluated. The present study found more < 0.5 mm MPs in the dried species compared to fresh ones. It may be due to assimilation process of the ingested food and retention in the organs for short or longer periods. Being most of the isolated MPs from the smaller size groups (<1 mm), this study implies that fish had preferentially ingested these smaller MPs. Fish contaminated with these smaller MPs upon ingestion by preferentially or unintentionally may pose serious threats and further monitoring of toxicological effects should be needed.

Regardless the isolated MPs from different species and locations, red was the most dominant color, accounting for 41.55 %. It has been reported that 39.4 % red color dominated the fragments of isolated MPs in marine sediments from the Montenegrin coast (Bošković et al., 2022) and 26.26 % red color of MPs examined from three commercial fish from the coast of Lima, Peru (De-la-Torre et al., 2020). In *H. translucens*, from the Bay of Bengal, 32 % extracted MPs were red colored (Hossain et al., 2019). The dominant color of screened MPs in demersal fish (31.03 %) and in pelagic fish (28.57 %) was red (Klangnurak and Chunniyom, 2020). However, most of the study reported the dominant color as blue (Garcés-Ordóñez et al., 2020; Nie et al., 2019; Pereira et al., 2020). Small aquatic animals are drawn to the sight of colored MPs that mirrors their natural prey items, making them dangerous to marine life (Cózar et al., 2014; Ory et al., 2018). Color of MPs seems similar to the color of planktons, small fish and crustaceans persists in the aquatic environment increases the chance of preferential ingestion by fish and other aquatic organisms (Hodkovicova et al., 2022; Wieczorek et al., 2018).

Chemical composition analysis of MPs provides vital sources of contamination (Galgani et al., 2015). In this study, ATR-FTIR analysis of the isolated particles confirmed the highest presence of plastic polymer LDPE (38 %), followed by PS (22 %), PVC (16 %), PA (13 %), EVA (9 %) and unidentified (3 %). Many studies predominately reported the presence of PE (Mistri et al., 2022; Park et al., 2022), PS (Cordova et al., 2020; Maghsodian et al., 2021), PVC (Chan et al., 2019; Nikki et al., 2021; Renzi et al., 2019), PA (Borges-Ramírez et al., 2020; Devi et al., 2020; Klangnurak and Chunniyom, 2020; Prata et al., 2022; Savoca et al., 2019; Wu et al., 2020) and EVA (Garcés-Ordóñez et al., 2020; Goswami et al., 2020). Some other studies also reported various types of polymer in fishes and shrimp (Hasan et al., 2022b; Hossain et al., 2020) and in water and sediments of the coast or beaches from the Bay of Bengal (Dhineka et al., 2021; Sunitha et al., 2021). These pollution indicating different sources like river and waste water discharge, precipitation, plastic litter, tourists, fishery, and residential activities (Tiwari et al., 2019). Increased accumulation of PA in fishes may arise from fishing nets, baskets/bags, ropes, and floats in the marine waters (Hossain et al., 2019; Thushari et al., 2017). PE commonly used in bags, packages, ropes, bottles, and daily amenities, while PA are used in textiles, clothes, furniture and ropes (Tien et al., 2020). high concentration of PE particles in this area may be attributed to intense tourism, fishing activities on a regular basis, waste disposal for instant plastic bottles, bags, packaging materials, cosmetics, and ropes, fishing gears, and other products, high traffic on maritime routes and increased urbanized coastal areas (IDCL, 2019). PS is the raw material used in plastic products such as baskets, nets, and packaging might have the chance of mixing up with fishes during transportation or storage and processing (Wu et al., 2019).

It is alarming that millions Bangladeshi people living in the country and in the overseas regularly consume dried fishes. On the other hand the country's production of MPs is increasing alarmingly with days. The country has more than 3000 plastic manufacturing installations. Due to high population growth and ever-increasing urbanization, both plastic use and pollution are rising at an alarming rate in Bangladesh. Over the just fifteen years, per capita plastic consumption in urban areas of the country reached three times higher, from 3.0 kg in 2005 to 9.0 kg in 2020 (World Bank, 2021). Bangladesh has been ranked 10th out of the top twenty plastic polluting countries in the world. Plastic has been contributing 8 % of the country's waste, which is equivalent to 800,000

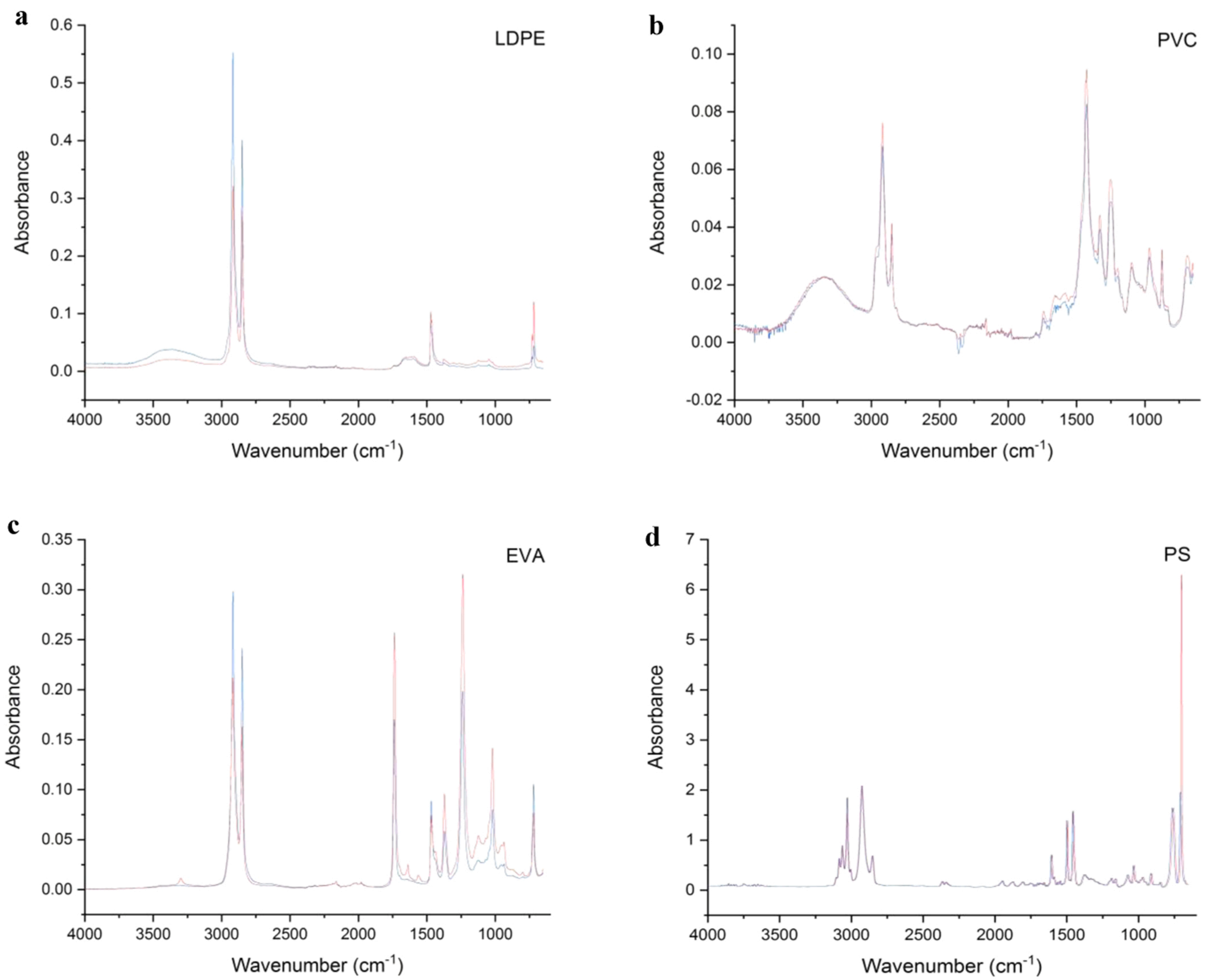

Fig. 7. ATR- FTIR spectra shows: a. low-density polyethylene (LDPE); b.; polyvinyl chloride (PVC); c. ethylene-vinyl acetate (EVA) and d. polystyrene (PS). Blue and red line indicates reference and sample spectra respectively.

tones, of which around 200,000 tones go into the ocean and rivers (Hossain and Shams, 2020). In a river and floodplain dominated country like Bangladesh where both annual and flash floods are frequent, the plastic waste accumulation eventually enter into the marine ecosystems and affects the biota of the Bay of Bengal. Mehedi (2018) documented 6705 pieces of debris from the Cox's Bazar beaches with 63 % of plastic particles. Already high and increasing population density and growing waste production coupled with untreated release turn Bangladesh highly vulnerable to plastic pollution. It is assumed that the density of MPs in oceans and rivers would increase in coming years (Napper et al., 2021). The dried fish (85 % from marine sources) produced in Bangladesh are either consumed by local people or exported to overseas for affluent non-resident Bangladeshis living mainly in Europe and USA and poor labor community working in the Middle Eastern and East Asian countries (Hossain et al., 2015b). Millions of people of Bangladesh are fond of dried fish and have been regularly eating the products. The effects of consumption of MPs with dried fish on regular consumers are unknown. People in general seem to be unaware of the potential risks and the government has not been monitoring MPs in the food products. In this backdrop, the presence of high level of MPs detected in the fish in the present study warrants all the relevant government departments to work in a coordinated way to pinpoint sustainable solutions to the potentially grave risks posed by the increasing presence of MPs in fish and all other food products.

5. Conclusion

The results of this study strongly underscore the high occurrence of MPs in the dried fishes over the fresh fishes from the Bay of Bengal. The fishes might be contaminated by MPs during drying process as fishes are dried in an open air condition on the ground spreading polyethylene sheet. The fishes contaminated with MPs in the Bay of Bengal and the likely health concern of the consumers should prompt the proper measures by the authorities to start removing plastics from the inland and marine waters and careful monitoring the ways of fishing, post-harvest processing and consumption. Finally, future research across a wider range of species and habitats must be considered in order to understand the potential effects of MPs in the estuarine and marine ecosystems of the Bay of Bengal.

CRediT authorship contribution statement

Jabed Hasan, Evana Yesmin Dristy, Anjumanara and Pronoy Mondal: Sample collection and preparation, finalization of extraction protocol, extraction and analysis of MPs, table and graph preparation, preparation of the first draft of the manuscript. **Md Sazedul Hoque,**

Table 4
Polymer types (percent ratio) of microplastic items in sampled fresh and dried fishes.

Species	Types	Chattogram (Cox's Bazar)		Kuakata	
		Fresh	Dried	Fresh	Dried
H. nehereus	LDPE	30	50	20	40
	PS	20	20	30	30
	PVC	30	-	30	-
	PA	-	30	-	30
	EVA	10	-	20	-
	Unidentified	10	-	-	-
T. lepturus	LDPE	50	40	20	40
	PS	10	10	40	20
	PVC	30	-	20	-
	PA	-	50	-	40
	EVA	10	-	10	-
	Unidentified	-	-	10	-
S. phasa	LDPE	40	50	40	30
	PS	10	20	30	20
	PVC	20	20	20	20
	PA	-	-	-	-
	EVA	20	10	10	20
	Unidentified	10	-	-	10

LDPE; Low-density polyethylene, PS; Polystyrene, PVC; Polyvinyl chloride, PA; Polyamide and EVA; Ethylene-vinyl acetate.

Kizar Ahmed Sumon and Mostafa Ali Reza Hossain: Technical oversight to the manuscript, review & editing. **Md Shahjahan:** Conceptualization, funding acquisition, visualization, supervision, data analysis and final approval. All authors read the final version and approved the manuscript.

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.

Data availability

No data was used for the research described in the article.

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