Microplastic Ingestion by Fishes from Jamuna River, Bangladesh

H.M. Shahnewaz Khan[*] and Shamsunnahar Setu

Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh

ARTICLE INFO

Received: 23 Aug 2021
Received in revised: 19 Nov 2021
Accepted: 29 Nov 2021
Published online: 24 Jan 2022
DOI: 10.32526/ennrj/20/202100164

Keywords:
Microplastic/ Plastic pollution/ Gastrointestinal tract/ River/ Bangladesh

*** Corresponding author:**
E-mail:
Shahnewaz14037@gmail.com

ABSTRACT

Microplastics (MP) have been an evolving global concern by dint of the escalation of plastic pollution in the aquatic environment. However, few data document MP ingestion and accumulation in freshwater fauna as compared to marine organisms. This study investigates the prevalence of MPs in the gastrointestinal tracts (GIT) of 45 individuals belonging to seven commonly found Bangladeshi freshwater fish species with different feeding types (herbivore, carnivore, and omnivore). A total of 81 MP items of varying shapes were detected in 76% of individuals investigated, with an average abundance of 1.80±1.65 items/individual. Of these, fiber was identified as the most prevalent ingested MP type (70%) followed by film (14%), line (10%), fragment (4%), and foam (2%). Black-colored MPs were the most dominant (27%) followed by white (26%), blue (24%), red (17%), and green (6%). The results demonstrated a higher number of MPs in the carnivore (1.95 items/individual) and omnivore (1.85 items/individual) fish species as compared to herbivore fish species. Among carnivores, *Wallago attu* registered the highest amount of ingested MP items (3.5 items/individual), while *Anguilla bengalensis* registered the highest amount of ingested MP items (2.14 items/individual) among the omnivores. The amount of ingested MPs was significantly correlated ($P<0.05$) with body size, body weight, and gut weight, while an insignificant correlation ($P>0.05$) was found between the number of consumed MPs and trophic fractions. The results provide valuable insights into the prevalence of MPs in freshwater fish in Bangladesh and associated bioaccumulation through trophic transfer.

1. INTRODUCTION

Plastics are recognized as artificial substances composed of synthetic or semi-synthetic natural polymers manufactured from petro-based chemicals that are cost-effective, lightweight, durable, and corrosive resistant (Boucher and Friot, 2017; Denuncio et al., 2011). Plastic production has been increased about 43% over the last decade. According to data from the Association of Plastic Europe, worldwide plastic production hit 322 million tons during 2015 (Plastics Europe and EPRO, 2016), 335 million tons in 2017 (Lahens et al., 2018), and demand is presumed to increase to 1,000 million tons by 2050 (Lusher et al., 2017). Freshwater ecosystems are the primary destination of many pollutants delivered in the watershed since aquatic environments are generally situated in valleys and low-height landscapes. Plastic discarded inaccurately (e.g., roads, streets, and open landfills) are conveyed by pluvial flows to water bodies (Faure et al., 2015). Upon reaching freshwaters, plastics may get entangled by streambed structures (e.g., riverbanks, shrubs, trees, and cliffs), carry with the current to floodplains, or become entrained in adjacent sediments (Azevedo-Santos et al., 2021). In Brazil's Amazonian ecosphere, plastic comprises 15.7% of total solid waste and it is precisely estimated that 182,085 metric tons of plastic are dumped yearly, which is potentially transported by the Amazon River to the Atlantic Ocean, presently the world's second most plastic-polluted river, trailing only China's Yangtze River (Giarrizzo et al., 2019). Rivers currently dump 1.15 to 2.41 million tonnes of plastic waste each year into the ocean. The world's 20 most polluting waterways, primarily in Asia, represent

Citation: Khan HMS, Setu S. Microplastic ingestion by fishes from Jamuna River, Bangladesh. Environ. Nat. Resour. J. 2022;20(2):157-167. (https://doi.org/10.32526/ennrj/20/202100164)

67% of overall pollution (Lebreton et al., 2017). Admittedly, rivers have gotten very little consideration concerning the issue of microplastic (MP) pollution (Costa and Barletta, 2015). Plastic particles less than 5 mm are commonly known as microplastics (Hartmann et al., 2019). In the early 1970s, microplastics were documented in seawater. (Guzzetti et al., 2018). Microplastics have been marked as deriving environmental pollutants that have also procured research concern at present. The micropollutants are present in both terrestrial and aquatic environments having deleterious effects on existing ecosystems (Karim et al., 2020).

The largest densities of microplastic debris have been reported from plankton (Yu et al., 2020), water bodies (Deng et al., 2020), and sediment (Castañeda et al., 2014). Predominantly found plastic particles within the aquatic environment are: fragments, fibers, and pellets (Veiga et al., 2016). Prior studies have used various methods to detach, identify, and validate plastic pollution in fish (Boerger et al., 2010; Vendel et al., 2017). For example, plastic objects were examined in the whole gastrointestinal tract (GIT) (Liboiron, 2019). Their origin classifies microplastics. Primary microplastics are cosmetic (i.e., shower gel, lipstick, and shaving cream), cleaning products, exfoliating scrubs, and medicines. Secondary microplastics result from micro-and macro debris fragmentation, subjected to mechanical forces, oxidation, and photochemical processes (Mathalon and Hill, 2014). Plastic enters an aquatic ecosystem by river drainage, storm water, and wastewater treatment plant (WWTP) discharges (Dris et al., 2015). A range of 19 to 447 particles/L of microplastics was found in the effluent of ten of Denmark's largest tertiary WWTPs and emitted up to 1 to 30 particles/L from three secondary WWTPs (Conley et al., 2019). The most polymer confronted; specifically, microplastics are polyethylene terephthalate (PET), polypropylene (PP), polyvinylchloride (PVC), polyethylene (PE), polystyrene (PS), and polytetrafluoroethylene (PTFE) (Rocha-Santos and Duarte, 2015; Xu et al., 2020).

A broad range of marine organism ingested microplastics have been reported in fishes (Bellas et al., 2016; Jovanović, 2017), turtles (Duncan et al., 2019), sea birds (Lavers et al., 2019), and mammals (Zantis et al., 2021). Obvious consequences of microplastic ingestion by aquatic organisms are blockage of GIT, growth retardation, reproduction failure, and alteration of feeding (Cole et al., 2015; Nelms et al., 2018; Sussarellu et al., 2016). In addition, contaminants accumulating on the surface of plastic materials may have detrimental health effects on fish (Critchell and Hoogenboom, 2018; Pannetier et al., 2020). Plastic has been shown to influence DNA damage, oxidative pressure, cirrhosis, embryo-toxicity, aberrant riposte, and lipid peroxidation (Brandts et al., 2018) in fishes. The prime goal of the following study was to identify the presence of MPs in the gastrointestinal tract (GIT) of freshwater fish. Particularly, the research objectives were to 1) assess the abundance, morphotype, and color of MPs in fish gut contents, 2) compare the MPs concentration among diverse species of fishes from different feeding habitats and tropic fractions, and 3) determine the association between MPs intake rate and fish length, body weight, and gut-weight. These findings provided the early sign of microplastic contamination of Jamuna River's fishes. The findings demonstrated that fishes of Jamuna River incorporate varying amounts of microplastics in the gastrointestinal tract.

2. METHODOLOGY

2.1 Study area

This study was carried out on Jamuna River, between 24°22'41.17"N, 89°47'49.08"E (S1; close to Bangabandhu Bridge, Tangail District) and 24°11' 42.17"N, 89°46'36.74"E (S2; near Chauhali Upazila, Sirajganj District) (Figure 1). A delta plain with tributaries of the Ganges (Padma), Brahmaputra (Jamuna), and Meghna Rivers occupying 79% of the nation. Jamuna-Brahmaputra Rivers are roughly victims of industrial (pulp, paper, textiles, fertilizers, and detergent) toxic discharges, lubricants, and heavy metals. Plastic particles scattered over the branches by stream gliding or weaving and tourist spots near Jamuna Bridge could be one of the basic explanations of plastic contamination in the normal natural way of life (Hossain et al., 2019; Uddin and Jeong, 2021).

2.2 Sample collection

In total, 45 individuals representing seven species with 20.74±8.65 cm average length were collected by 5 mm mesh nets during the time period of 20th April to 5th July 2019. During sampling, divergent feeding zones (demersal, benthopelagic, and pelagic) with feeding habits were considered (herbivore, carnivore, and omnivore) (Table 1). Sample collection also relied on the conventional fish consumption nature and accessibility of fishes for that certain fishing period. Therefore, resulting in different numbers of individuals for each species. Then, samples were put into an icebox to preserve and transport, and taken to the laboratory for storage in a refrigerator at -4°C for analysis (Peters and Bratton, 2016).

2.3 Sample preparation

In the laboratory, fish were allowed to thaw for about 30 minutes at room temperature before examining total length (TL) and body weight (W). Consequently, the GIT of each fish was dissected. After weighing, samples were transferred into individual clean beakers (Figure 2).

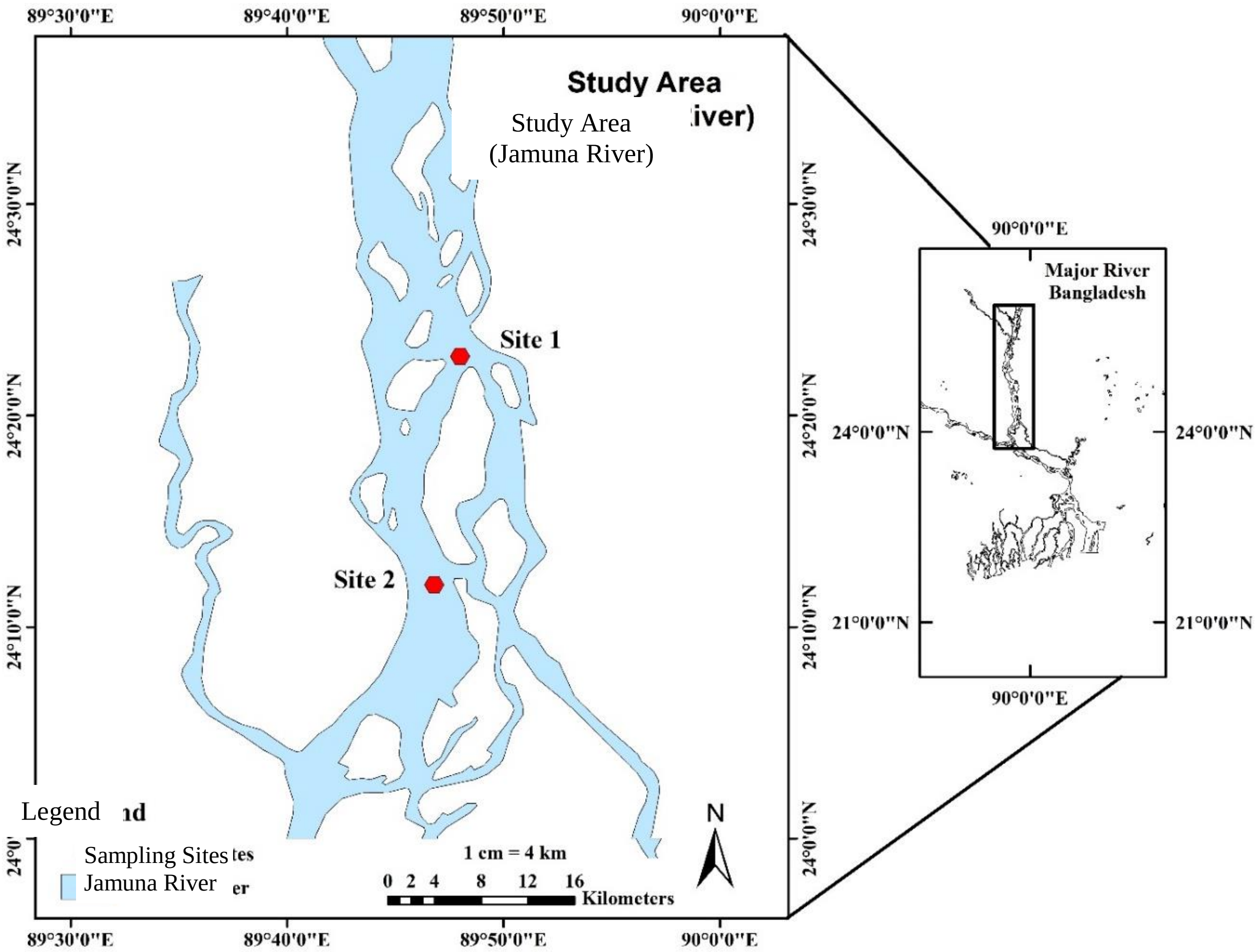

Figure 1. Map showing the study area (Jamuna River)

Table 1. Generic information about sample fishes, i.e., scientific name, local name, tropic fraction, feeding zone, and feeding group

Scientific name	Local name	Number (n)	Tropic fraction	Feeding zone	Feeding group	Total length (cm)	Total weight (g)	Gut weight (g)
Wallago attu	Boal	8	3.70±0.56	Demersal	Carnivore	31.46±3.73	142.50±50.90	3.62±0.70
Anguilla bengalensis	Biam	7	3.80±0.70	Benthopelagic	Omnivore	26.27±13.70	94.28±143.82	2.58±2.25
Labeo Calbasu	Karlbaous	8	2.00±0.00	Demersal	Omnivore	19.61±1.52	95.37±19.96	3.84±1.09
Ailia coila	Kajali	5	3.60±0.60	Pelagic	Carnivore	11.16±1.05	5.20±1.30	0.22±0.02
Cirrhinus reba	Tatkini	5	2.50±0.20	Benthopelagic	Herbivore	12.56±0.61	18.80±1.64	0.79±0.15
Ompok pabda	Pabda	7	3.80±0.60	Demersal	Carnivore	17.05±0.59	26.71±3.25	0.57±0.13
Clupisoma garua	Gaira	5	3.70±0.59	Demersal	Omnivore	20.52±1.77	50.40±12.62	2.80±1.17

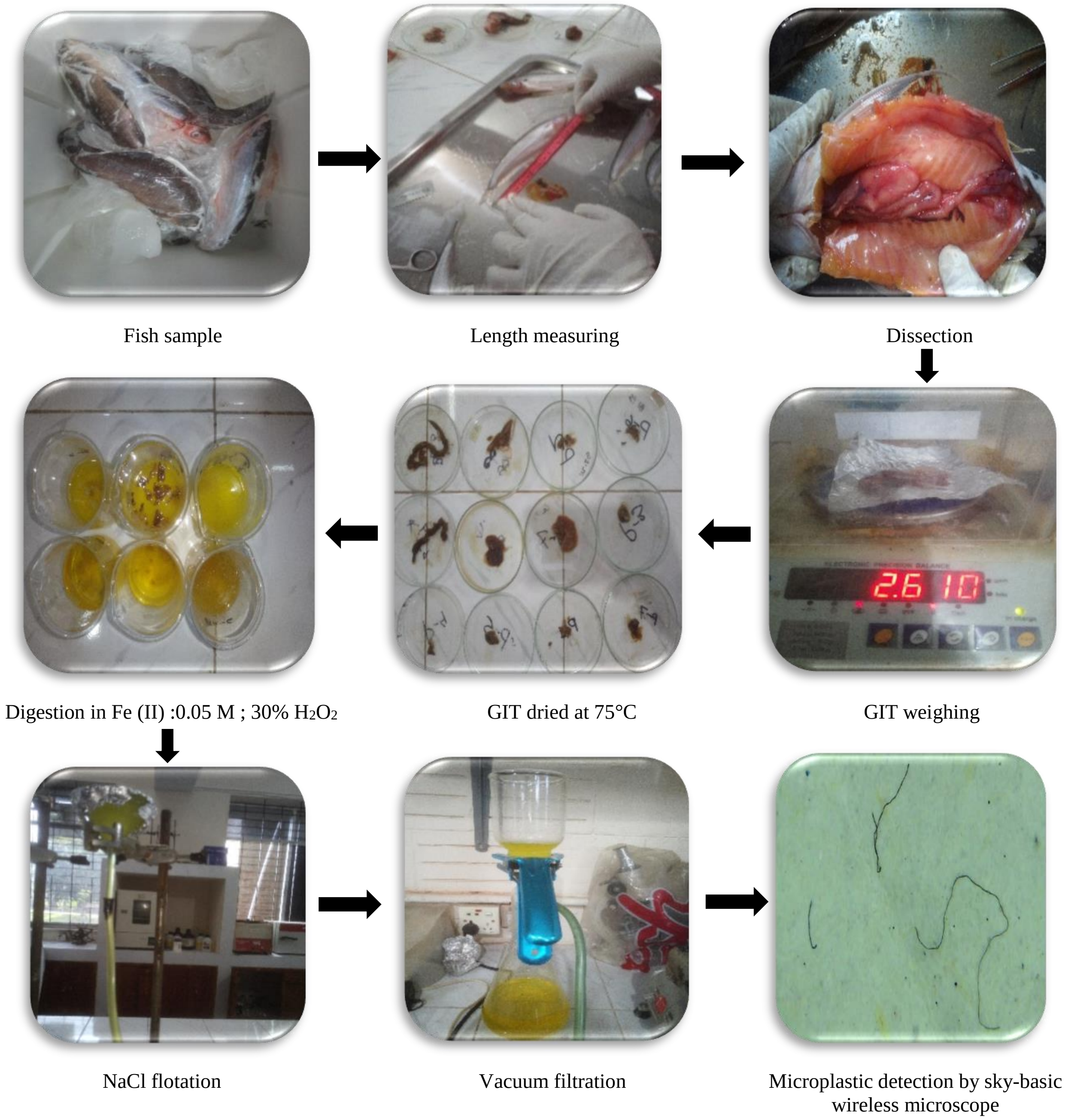

Figure 2. Preparation of samples, digestion, and analytical processes to identify microplastics in fish samples

2.4 Digestion and hydrogen peroxide (H_2O_2) treatment

The removed digestive tissue was dried a minimum of 24 h at 75°C in a hot air oven and added to 20 mL 0.05 M Fe(II) (7.5 g $FeSO_4.7H_2O$) (278.02 g/mole) in 500 mL water with 3 mL concentrated H_2SO_4) and 20 mL (H_2O_2 30%) at 75°C. The mixture was left to stand on a lab bench at room temperature for five minutes, then heated to 75°C on a hotplate. As gas bubbles affirmed, the beaker was removed from the hotplate and approximately 6 g of salt (NaCl) was added to increase the aqueous density. The mixture was heated to 75°C until the salt dissolved (McNeish et al., 2018). The developed analytical techniques have both advantages and disadvantages (Strungaru et al., 2019) for MPs detection in aquatic organisms. NaCl solution was used in this study because of its efficacy, low cost, and non-hazardous features. Instead of H_2O_2, HNO_3 (Chan et al., 2019), and NaOH (Yuan et al., 2019) was used to digest organic matter.

2.5 Density separation, floating, and vacuum filtration

The solution was transferred to the density separator (glass funnel fitted with a 50 mm segment of latex tube), putting a pinch clamp on top to control liquid flow. The beaker was rinsed with distilledwater and lined overnight by aluminum foiling to transfer all the remaining organs to the density separator. Visually inspected floating microplastics and remaining settled organs were vacuum filtered through 1.2 µm Whitman GF/Microfiber filter papers (Masura et al., 2015).

2.6 Detection of microplastics

Filters were observed under a sky-basic wireless digital microscope, and images of plastic items were taken by installing Max-See software in the android phone at 50X-100X magnifications at different resolutions (1,920×1,080, 1280×720, and 640×480). Then, visually assessed the plastic images and categorized them by color and shape (fiber, fragment, thread line, film, or foam) (Figure 3).

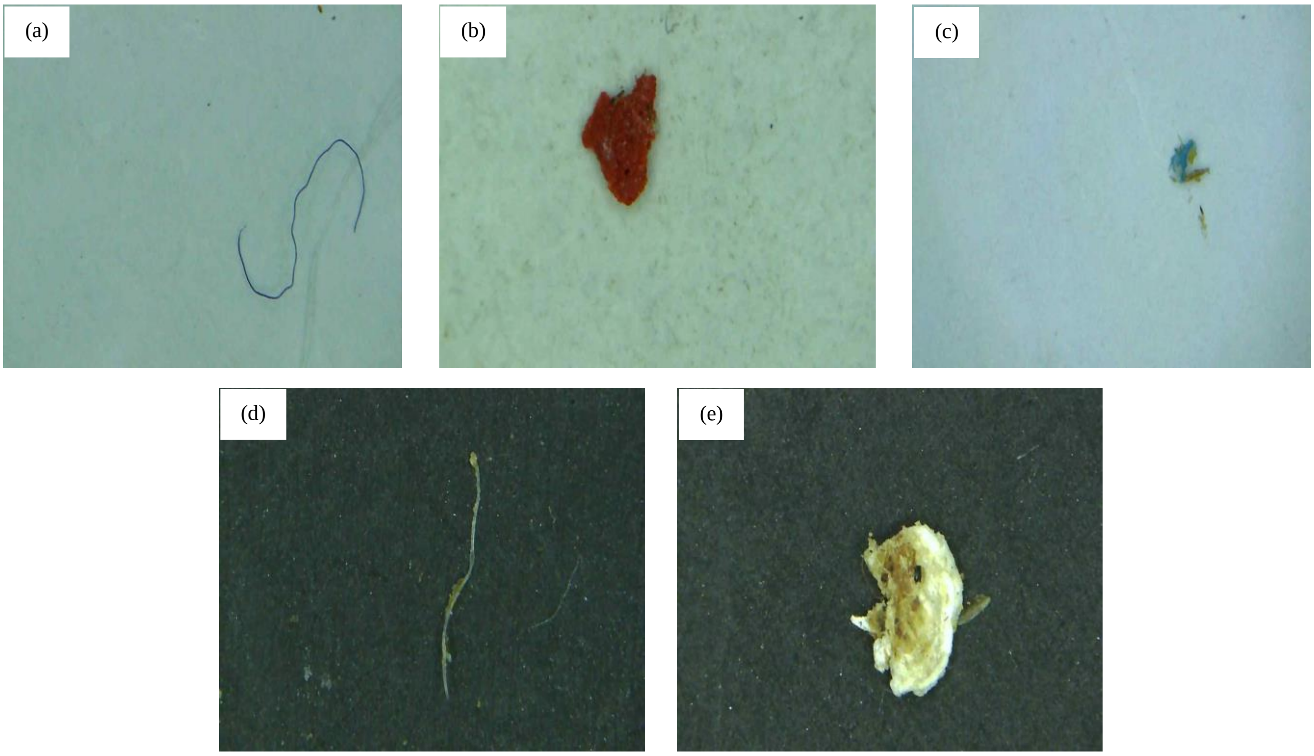

Figure 3. Example of microplastic found in fish from Jamuna River. The shapes included fiber (a), fragment (b), film (c), thread line (d), and foam (e).

3. RESULTS

3.1 Abundance of microplastic in fish

Out of seven species collected from Jamuna River, 34 of 45 individuals (76%) contained an average of 1.80±1.65 particles (SD) per total fish. Fish ranged in length from 54.3 to 10.2 cm and weight between 400 to 4 g. On average, the highest (3.50±1.93, 35%) microplastic particles per species are extracted from *Wallago attu* and the lowest MPs exhibited from *Ompok pabda* (1.00±0.58, 9%) followed by *Labeo calbasu* (2.12±1.55, 21%), *Anguilla bengalensis* (2.14±1.21, 18%), *Clupisoma garua* (1.00±1.12, 6%), *Cirrhinus reba* (1.00±1.41, 6%) and *Ailia coila* (0.80±1.30, 5%) (Figure 4(a) and 4(b)).

3.2 Morphotype and color distribution of microplastic

From the 81 particles, 57 were fiber (70%), 11 were film (14%), 8 line (10%), 3 fragment (4%), and 2 foam (2%) (Figure 4(c)). Color distribution of ingested microplastic was not homogenous. Five different colors of microplastic were found among the species. Black particles were most commonly found (27%), subsequently, white (26%), blue (24%), red (17%), and green (6%) (Figure 5(a)), which differs from Bessa et al. (2018) observed blue as most specific color (47%) led by transparent (30%) and black (11%). This study shows, the predominant fiber colors were black (39%) and blue (28%), followed by red (21%), green (9%), and white (3%) (Figure 5(b)).

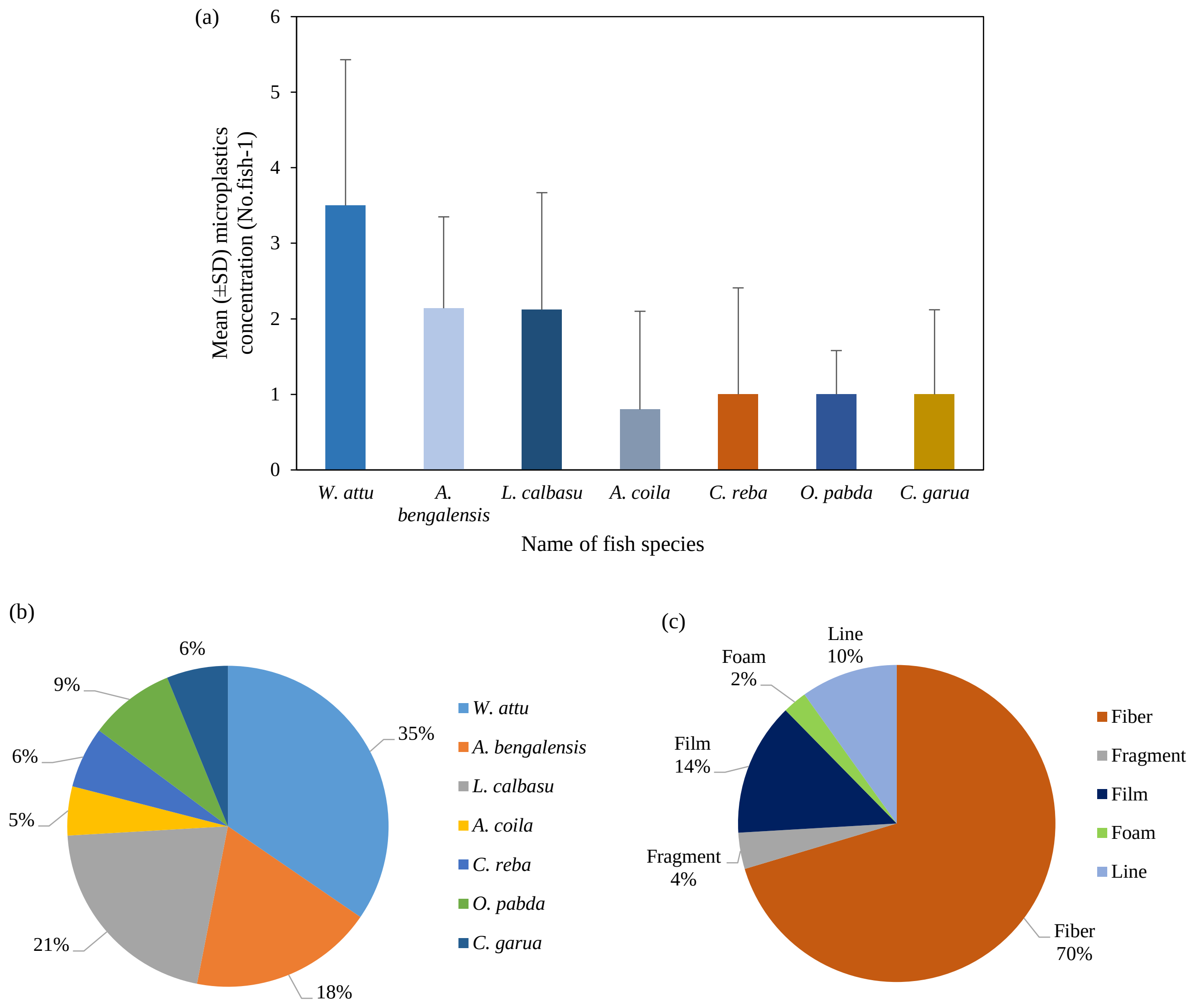

Figure 4. Average: (a) percentage (%), (b) morhotype, and (c) of microplastic in identified fishes

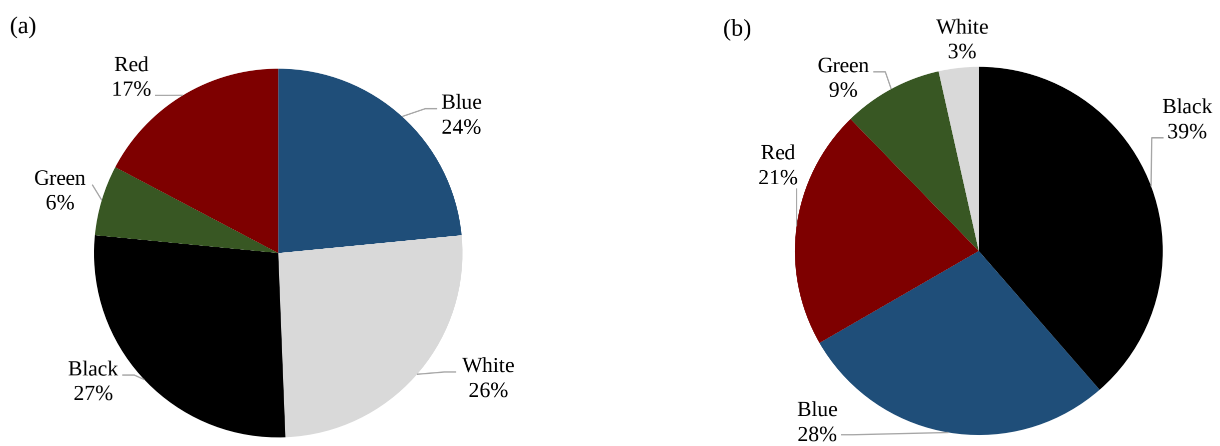

Figure 5. Percentage of MPs by color (a), frequency of fibers color (b), average of microplastic in different fish feeding zone of seven fish species (c)

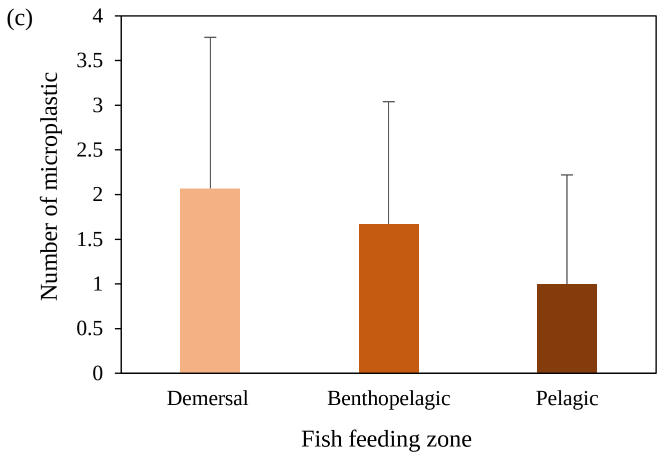

Figure 5. Percentage of MPs by color (a), frequency of fibers color (b), average of microplastic in different fish feeding zone of seven fish species (c) (cont.)

3.3 MPs abundance with fishing habitat and tropic level

A one-way ANOVA indicated that the mean microplastic particles were significantly different among the seven taxa (F=3.062, df=6, and P=0.015), but an insignificant effect of fish FFG on microplastic concentration was found (F=0.736, df=2, and P=0.485) (Table 2).

3.4 Influence of MPs absorption among fish body length, body weight, and gut weight

Fish body size (R^2=0.436, P<0.05), body weight (R^2=0.459, P<0.05) were positively correlated with the microplastic abundance in fish specimens. The relationship between the rate of microplastic intake and gut-weight was statistically significant (R^2=0.439, P<0.05) (Figure 6(a), 6(b), and 6(c)). Whereas, number of microplastics and tropic fraction showed an indistinct correlation. (Spearman's correlation, rho=0.119, P>0.05).

Table 2. Comparison of mean microplastic concentration among taxa and fishing groups, using one-way ANOVA and Kruskal-Wallis statistical analyses

Sample type	df	ANOVA		Kruskal-Wallis		
		F Value	P Value	H	X^2	P Value
Fish Taxa	6	3.062	0.015	13.331	12.591	0.038
Fish FFG	2	0.736	0.485	1.896	5.991	0.395

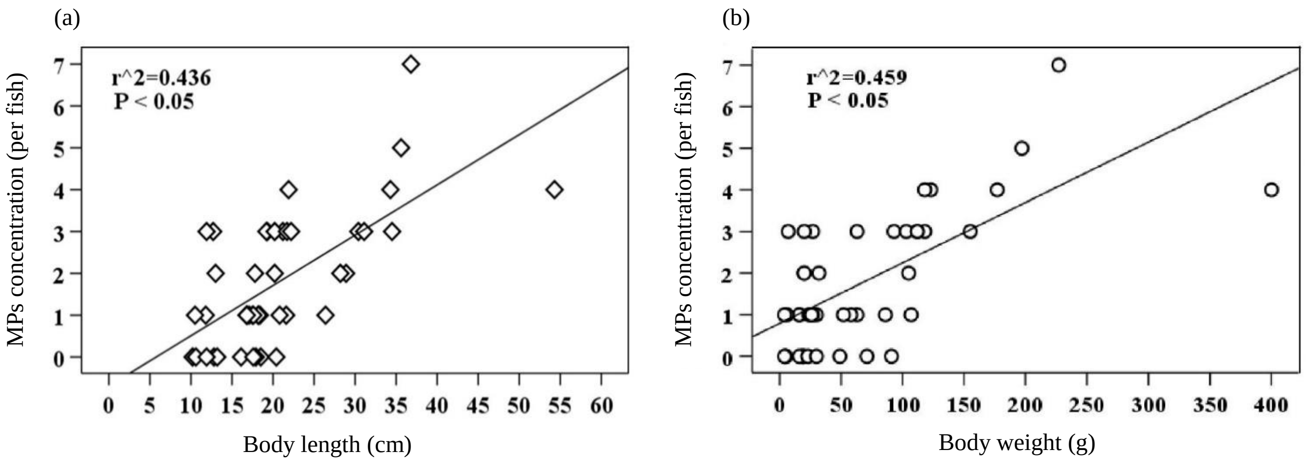

Figure 6. Linear regression analysis for number of microplastic with fish size (a), body weight (b), and gut weight (c)

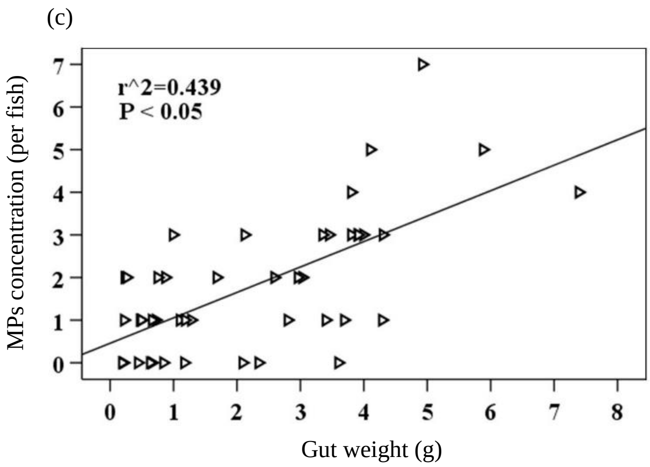

Figure 6. Linear Regression analysis for number of microplastic with fish size (a), body weight (b), and gut weight (c) (cont.)

4. DISCUSSION

In spite of the nutrient value of fish and its crucial role in the aquatic ecosystem, few studies particularly look at plastic burden in freshwater species. Our study is reputedly the first to portray ingestion of plastic by Jamuna River fishes. Bangladesh produced approximately 400 to 4,500 tons of solid debris daily which usually carries mismanaged plastic, more than half of this waste is disposed of in low-lying soil or freshwater (Arefin and Mallik, 2017). Thus, Bangladesh placed 10th over 20 improperly managed plastic generator countries around the globe. ESDO (2016) asserted Bangladesh has 7,928 billion microbeads entering its rivers, canals, and alternative water resources.

More than 250 particles were sorted from the gut contents and examined under a microscope. By characterizing the morphotype, we determined 81 particles as plastic those found in several studies (e.g., Vendel et al., 2017; Herrera et al., 2019; Arias et al., 2019). Almost all synthetic fibers are released from textile and domestic washing (Cesa et al., 2017). The line probably derives from fishing gear, nets, and sewing thread. Even so, the fragments and films come from an array of indefinite sources, from land and aquatic features. In this research, the size and nature of plastic could not be confirmed by applying FTIR spectroscopy due to the small width of plastic.

In the current study, 78% of sample fish contained microplastic with fiber (70%) most dominated. This result can be closely analogous to the findings of other research conducted in various regions. The ingestion of MPs reported in 68% in *Boops boops* from Balearic Island (Nadal et al., 2016), 95.7% in freshwater fishes from china (Jabeen et al., 2017), 85% in lake Michigan (USA) where 97-100% of all particles were fiber (McNeish et al., 2018), 8% in fishes from Mexican Gulf (Phillips and Bonner, 2015).

Sanchez et al. (2014) exposed the first proof on MPs ingestion by freshwater fish in wild gudgeons (*Gobio gobio*), about 12%. In particular, MPs were retrieved from *Wallago attu* (35% and *Labeo calbasu* (21%) in the present study. *Lepomis macrochirus* and *L. megalotis* had 45% particles that were collected from the Central River Basin of Brazos, Texas (Peters and Bratton, 2016) and ESDO (2016) found 35% microplastic in rui (*Labeo rohita*) and 2.2% in sharputi (*Puntius sarana*). MPs reported about 33%, 49%, and 18% in *H. translucens*, *H. nehereus*, and *S. gibbosa* fishes, respectively, from the coastline of northern Bay of Bengal, carried fiber mostly ascendant, while MPs differed significantly among fish species and relevant with body and GIT weight (Hossain et al., 2019). Pazos et al. (2017) reported 96% of the fiber in fish from Río de la Plata estuary, merging no correlation between MPs quantity and fish length, weight, and feeding habit. In constant, particles constituted fragments at 54% in South-western Germany (Roch et al., 2019). Pegado et al. (2018) showed the number of MPs was not correlated with weight and tropic level.

Based on feeding habits, Carnivore and omnivore guild contained 20 fishes, and the Herbivore guild had five fish. (Table 1). As a result, determining which feeding habit incorporates more MPs ingestion was difficult. According to Ismail et al. (2018), microplastic density in omnivore and carnivore fishes was lower comparing herbivore fishes from Biawak Island. Nevertheless, Garnier et al. (2019) reported herbivore fish *Siganus* spp. had the lowest MPs (0.15±0.10) and carnivore fish *Epinephelus merra* contained the highest number of MPs (0.39±0.14) per fish. Andrade et al. (2019) depicted herbivores had observed lowest percentage of plastics (13.3% for *Myloplus rubripinnis* and rose to 27.3% for *Metynnis guaporensis*). Omnivores had the greatest degree of frequency, with *Acnodon normani* accounted for 25.0% and *Myloplus rhom boidalis* making up 100%. In Carnivore stomachs, microplastic was found at a sufficient amount ranging from 14.3% in *Semasalmus manueli* to 75.0% in *Pygocentrus nattereri*. The current study found that the feeding zones have an influence on MPs assimilation by fish. The presence of MPs in demersal (2.07±1.69) fishes were higher than benthopelagic (1.67±1.37) and pelagic (1.00 ±1.22) fishes (Figure 5(c)) as demersal species are both carnivorous and omnivorous, eating a wide range of plant and animal-based foods (e.g., larvae, insects, crustaceans, mollusks, and algae).

5. CONCLUSION

Based on the study, it can be concluded that fishes from the Jamuna River are at risk of being contaminated with microplastics. Approximately 76% of processed microplastics 70% were fibers and 14% were films. We observed a significant difference in the frequency of microplastic occurrence between the different fish species. Microplastics were most abundant in carnivore species, *Wallago attu* and the lowest recorded in herbivore: *Ailia coila*. This study also showed that the number of the microplastics ingested are independent of the feeding habits but had reliant on feeding zone. Our findings include a benchmark estimate that should be considered not just in future studies aimed at describing the possible effects of microplastic in fish assemblages and potential ecological threats, as well as in studies aimed at assessing the impacts of microplastic contamination on native communities that rely on fish as food supply. Furthermore, research should be carried out within a wide variety of fish and organisms to understand the dormant effects and to clarify the MPs movement across the terrestrial-aquatic boundary on the freshwater ecosystem in Bangladesh.

ACKNOWLEDGEMENTS

For the entire study, the authors covered all expenditures on their own. The authors thank the personnel of the research lab of the ESRM Department, MBSTU for assuring all of the required equipment and nonchalant laboratory conditions for this work. We would thankfully acknowledge the editor and anonymous reviewers for their constructive feedback that improved greatly the manuscript.

REFERENCES

Andrade MC, Winemiller KO, Barbosa PS, Fortunati A, Chelazzi D, Cincinelli A, et al. First account of plastic pollution impacting freshwater fishes in the Amazon: Ingestion of plastic debris by piranhas and other serrasalmids with diverse feeding habits. Environmental Pollution 2019;244:766-73.

Arefin MA, Mallik A. Sources and causes of water pollution in Bangladesh: A technical overview. Bibechana 2017;15: 97-112.

Arias AH, Ronda AC, Oliva AL, Marcovecchio JE. Evidence of microplastic ingestion by fish from the Bahía Blanca Estuary in Argentina, South America. Bulletin of Environmental Contamination and Toxicology 2019;102:750-6.

Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, et al. Plastic pollution: A focus on freshwater biodiversity. Ambio 2021;50:1313-24.

Bellas J, Martínez-Armental J, Martínez-Cámara A, Besada V, Martínez-Gómez C. Ingestion of microplastics by demersal fish from the Spanish Atlantic and Mediterranean coasts. Marine Pollution Bulletin 2016;109:55-60.

Bessa F, Barría P, Neto JM, Frias JPGL, Otero V, Sobral P, et al. Occurrence of microplastics in commercial fish from a natural estuarine environment. Marine Pollution Bulletin 2018;128: 575-84.

Boerger CM, Lattin GL, Moore SL, Moore CJ. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin 2010;60:2275-8.

Boucher J, Friot D. Primary Microplastics in the Oceans: A Global Evaluation of Sources. Gland, Switzerland: IUCN; 2017.

Brandts I, Teles M, Tvarijonaviciute A, Pereira ML, Martins MA, Tort L, et al. Effects of polymethylmethacrylate nanoplastics on Dicentrarchus labrax. Genomics 2018;110:435-41.

Castañeda RA, Avlijas S, Simard MA, Ricciardi A. Microplastic pollution in St. Lawrence River sediments. Canadian Journal of Fisheries and Aquatic Sciences 2014;71:1767-71.

Chan HS, Dingle C, Not C. Evidence for non-selective ingestion of microplastic in demersal fish. Marine Pollution Bulletin 2019;149:Article No. 110523.

Cole M, Lindeque P, Fileman E, Halsband C, Galloway TS. The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod *Calanus helgolandicus*. Environmental Science and Technology 2015;49:1130-7.

Conley K, Clum A, Deepe J, Lane H, Beckingham B. Wastewater treatment plants as a source of microplastics to an urban estuary: Removal efficiencies and loading per capita over one year. Water Research X 2019;3:Article No. 100030.

Costa MF, Barletta M. Microplastics in coastal and marine environments of the western tropical and sub-tropical Atlantic Ocean. Environmental Sciences: Processes and Impacts 2015;17:1868-79.

Critchell K, Hoogenboom MO. Effects of microplastic exposure on the body condition and behaviour of planktivorous reef fish (*Acanthochromis polyacanthus*). PloS One 2018;13:1-19.

Deng H, Wei R, Luo W, Hu L, Li B, Di Y, et al. Microplastic pollution in water and sediment in a textile industrial area. Environmental Pollution 2020;258:Article No. 113658.

Dris R, Imhof H, Sanchez W, Gasperi CJ. Beyond the ocean: Contamination of freshwater ecosystems with (micro-) plastic particles. Environmental chemistry 2015;12:539-50.

Duncan EM, Broderick AC, Fuller WJ, Galloway TS, Godfrey MH, Hamann M, et al. Microplastic ingestion ubiquitous in marine turtles. Global Change Biology 2019;25:744-52.

Denuncio P, Bastida R, Dassis M, Giardino G, Gerpe M, Rodríguez D. Plastic ingestion in Franciscana dolphins, *Pontoporia blainvillei* (Gervais and d'Orbigny, 1844), from Argentina. Marine Pollution Bulletin 2011;62:1836-41.

Environment and Social Development Association (ESDO). Study Report Microbeads! Unfold Health Risk and Environmental Pollutant. Environment and Social Development Association; 2016.

Faure F, Demars C, Wieser O, Kunz M, De Alencastro LF. Plastic pollution in Swiss surface waters: Nature and concentrations, interaction with pollutants. Environmental Chemistry 2015; 18;12:582-91.

Garnier Y, Jacob H, Guerra AS, Bertucci F, Lecchini D. Evaluation of microplastic ingestion by tropical fish from Moorea Island, French Polynesia. Marine Pollution Bulletin 2019;140:165-70.

Giarrizzo T, Andrade MC, Schmid K, Winemiller KO, Ferreira M, Pegado T, et al. Amazonia: The new frontier for plastic pollution. Frontiers in Ecology and the Environment 2019;17:309-10.

Guzzetti E, Sureda A, Tejada S, Faggio C. Microplastic in marine organism: Environmental and toxicological effects. Environmental Toxicology and Pharmacology 2018;64:164-71.

Hartmann NB, Hüffer T, Thompson RC, Hassellöv M, Verschoor A, Daugaard AE, et al. Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. Environmental Science and Technology 2019;53:1039-47.

Herrera A, Ŝtindlová A, Martínez I, Rapp J, Romero-Kutzner V, Samper MD, et al. Microplastic ingestion by Atlantic chub mackerel (*Scomber colias*) in the Canary Islands coast. Marine Pollution Bulletin 2019;139:127-35.

Hossain MS, Sobhan F, Uddin MN, Sharifuzzaman SM, Chowdhury SR, Sarker S, et al. Microplastics in fishes from the Northern Bay of Bengal. Science of the Total Environment 2019;690:821-30.

Ismail MR, Lewaru MW, Prihadi DJ. Microplastics Ingestion by fish in the Biawak Island. World Scientific News 2018;106: 230-7.

Jabeen K, Su L, Li J, Yang D, Tong C, Mu J, et al. Microplastics and mesoplastics in fish from coastal and fresh waters of China. Environmental Pollution 2017;221:141-9.

Jovanović, B. Ingestion of microplastics by fish and its potential consequences from a physical perspective. Integrated Environmental Assessment and Management 2017;13:510-5.

Karim ME, Sanjee SA, Mahmud S, Shaha M, Moniruzzaman M, Das KC. Microplastics pollution in Bangladesh: Current scenario and future research perspective. Chemistry and Ecology 2020;36:83-99.

Lahens L, Strady E, Kieu-le T, Dris R, Boukerma K, Rinnert E, et al. Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. Environmental Pollution 2018;236: 661-71.

Lavers JL, Stivaktakis G, Hutton I, Bond AL. Detection of ultrafine plastics ingested by seabirds using tissue digestion. Marine Pollution Bulletin 2019;142:470-4.

Lebreton LC, Van Der Zwet J, Damsteeg JW, Slat B, Andrady A, Reisser J, et al. River plastic emissions to the world's oceans. Nature Communications 2017;8:1-10.

Liboiron M. How to Investigate Fish Guts for Marine Microplastics. Civic Laboratory for Environmental Action Research; 2019.

Lusher AL, Welden NA, Sobral P, Cole M. Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Analytical Methods 2017;9:1346-60.

Masura J, Baker J, Foster G, Arthur C. Laboratory Methods for the Analysis of Microplastics in the Marine Environment: Recommendations for Quantifying Synthetic Particles in Waters and Sediments. NOAA Technical Memorandum; 2015.

Mathalon A, Hill P. Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Marine Pollution Bulletin 2014;81:69-79.

McNeish RE, Kim LH, Barrett HA, Mason SA, Kelly JJ, Hoellein TJ. Microplastic in riverine fish is connected to species traits. Scientific Reports 2018;8:1-12.

Nadal MA, Alomar C, Deudero S. High levels of microplastic ingestion by the semipelagic fish bogue *Boops boops* (L.) around the Balearic Islands. Environmental Pollution 2016; 214:517-23.

Nelms SE, Galloway TS, Godley BJ, Jarvis DS, Lindeque PK. Investigating microplastic trophic transfer in marine top predators. Environmental Pollution 2018;238:999-1007.

Pannetier P, Morin B, Le Bihanic F, Dubreil L, Clérandeau C, Chouvellon F, et al. Environmental samples of microplastics induce significant toxic effects in fish larvae. Environment International 2020;134: Article No. 105047.

Pazos RS, Maiztegui T, Colautti DC, Paracampo AH, Gómez N. Microplastics in gut contents of coastal freshwater fish from Río de la Plata estuary. Marine Pollution Bulletin 2017; 122:85-90.

Pegado T, Schmid K, Winemiller KO, Chelazzi D, Cincinelli A, Dei L, et al. First evidence of microplastic ingestion by fishes from the Amazon River estuary. Marine Pollution Bulletin 2018;133:814-21.

Peters CA, Bratton SP. Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos River Basin, Central Texas, USA. Environmental Pollution 2016;210: 380-7.

Phillips MB, Bonner TH. Occurrence and amount of microplastic ingested by fishes in watersheds of the Gulf of Mexico. Marine Pollution Bulletin 2015;100:264-9.

Plastics Europe, European association of plastic recycling and recovery organizations (EPRO). Plastics-the Facts 2016. An Analysis of European Plastics Production, Demand and Waste Data. Plastics Europe; 2016.

Roch S, Walter T, Ittner LD, Friedrich C, Brinker A. A systematic study of the microplastic burden in freshwater fishes of South-western Germany-Are we searching at the right scale? Science of the Total Environment 2019;689:1001-11.

Rocha-Santos T, Duarte AC. A critical overview of the analytical approaches to the occurrence, the fate and the behavior of microplastics in the environment. TrAC-Trends in Analytical Chemistry 2015;65:47-53.

Cesa FS, Turra A, Baruque-Ramos J. Synthetic fibers as microplastics in the marine environment: A review from textile perspective with a focus on domestic washings. Science of the Total Environment 2017;598:1116-29.

Sanchez W, Bender C, Porcher JM. Wild gudgeons (*Gobio gobio*) from French Rivers are contaminated by microplastics: Preliminary study and first evidence. Environmental Research 2014;128:98-100.

Strungaru SA, Jijie R, Nicoara M, Plavan G, Faggio C. Micro-(nano) plastics in freshwater ecosystems: Abundance, toxicological impact and quantification methodology. TrAC Trends in Analytical Chemistry 2019;110:116-28.

Sussarellu R, Suquet M, Thomas Y, Lambert C, Fabioux C, Pernet MEJ, et al. Oyster reproduction is affected by exposure to polystyrene microplastics. Proceedings of the National Academy of Sciences of the United States of America 2016;113:2430-5.

Uddin MJ, Jeong YK. Urban river pollution in Bangladesh during last 40 years: Potential public health and ecological risk, present policy, and future prospects toward smart water management. Heliyon 2021;7:e06107.

Veiga JM, Fleet D, Kinsey S, Nilsson P, Vlachogianni T, Werner S, et al. Identifying Sources of Marine Litter. JRC Technical Report; 2016.

Vendel AL, Bessa F, Alves VE, Amorim AL, Patrício J, Palma AR. Widespread microplastic ingestion by fish assemblages in tropical estuaries subjected to anthropogenic pressures. Marine Pollution Bulletin 2017;117:448-55.

Xu S, Ma J, Ji R, Pan K, Miao AJ. Microplastics in aquatic environments: Occurrence, accumulation, and biological effects. Science of the Total Environment 2020;703:Article No. 134699.

Yu H, Zhang X, Hu J, Peng J, Qu J. Ecotoxicity of polystyrene microplastics to submerged carnivorous *Utricularia vulgaris* plants in freshwater ecosystems. Environmental Pollution 2020;265:Article No. 114830.

Yuan W, Liu X, Wang W, Di M, Wang J. Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. Ecotoxicology and Environmental Safety 2019;170:180-7.

Zantis L, Carroll EL, Nelms SE, Bosker T. Marine mammals and microplastics: A systematic review and call for standardization. Environmental Pollution 2021;269:Article No. 116142.