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Assessment of microplastic contamination in fish from the Sutlej River, India

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Abstract

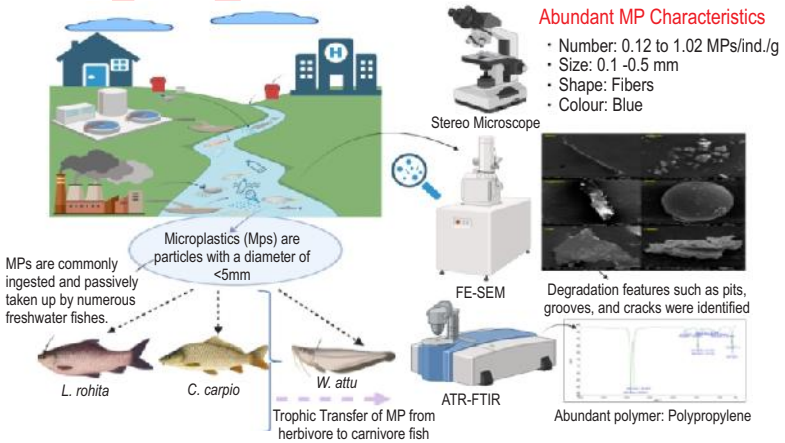
Aim: To evaluate the occurrence and distribution of microplastics (MPs) in non-edible tissues (gills and digestive tract) and edible tissue (muscle) of *Labeo rohita, Cyprinus carpio* and *Wallago attu*.

Methodology: Fish specimens were collected bimonthly from October 2024 to March 2025 from the Phillaur and Walipur Kalan stretches of Sutlej River. The collected samples were subsequently processed and analyzed by following the standardized protocol of National Oceanic and Atmospheric Administration (NOAA).

Results: Majority of MPs were detected in the intestine (48.0%) and gills (40.4%), whereas lower proportion was found in the muscle tissues (11.6%). The highest level of MP contamination was recorded in *W. attu* collected from Wallipur Kalan, followed by *L. rohita* and *C. carpio* which exhibited moderate levels of contamination. Among different MP shape, fibers were most abundant (58.36%), followed by films (24.21%) and fragments (13.2%). Regarding size distribution, 0.1-0.5 mm MPs were the most prevalent (30.87%), followed by 0.5-1 mm size category (25.18%). In terms of colour, blue MPs were the most abundant (35.48%), followed by transparent (26.33%) and red particles (15.01%). Surface morphological analysis of MPs using field emission scanning electron microscopy (FE-SEM) revealed characteristic weathering features including pits, grooves and cracks.

Interpretation: Present findings confirm that widespread occurrence of MPs in commercially important freshwater fish species from the Sutlej River, indicating contamination arising due to anthropogenic activities include direct discharge of plastic waste from industries and domestic source. This highlights the need for improved plastic waste management practices and reduced plastic utilization to mitigate MP pollution in fresh water ecosystems.

Key words: Bioaccumulation, Fresh water fishes, Microplastics, Non-edible tissues, River Sutlej



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Introduction

Since mid-twentieth century, the global population has increased by threefold. India's population is currently estimated at approximately 1.45 billion and is projected to reach 1.69 billion by 2054 (Nagendra *et al.*, 2026), resulting in substantial increase of municipal solid waste generation. Due to their superior functional properties and low production cost, plastics have become an essential component of contemporary life (Dou et al., 2023). However, their widespread use has led to environmental accumulation at the rate that far exceeds their natural degradation and capacity of conventional waste management systems (Dey *et al.*, 2024). In 2024, global plastic production reached approximate 430.9 million tonnes, which pose significant environmental challenge mainly in rapidly developing nations (Kaewprachu *et al.*, 2026). According to European Chemicals Agency, Microplastics (MPs) are defined as synthetic polymer particles measuring less than 5 mm in diameter (Vivekanand *et al.,* 2021). The formation of MPs occurs through complex degradation pathways, including UV radiation, mechanical abrasion, biological degradation processes and other weathering processes, which facilitates fragmentation of large plastic debris into smaller particles (Booth *et al.,* 2018).

Based on the origin, they can be classified into two categories: primary and secondary microplastics. Primary MPs are intentionally manufactured at microscopic size and enter the aquatic ecosystem through sources such as synthetic fibers, industrial raw polymer pellets and cosmetic formulations (Von Moos *et al.,* 2012). In contrast, Secondary MPs originate from environmental weathering, deterioration or photodegradation of large plastics within the ecosystem (Miri *et al.,* 2022). Microplastic are the microscopic and highly persistent particles that are readily ingested by wide range of aquatic organisms (Lusher *et al.,* 2020). Both marine and freshwater fish are particularly susceptible to the adverse effects of MPs, including reduced nutrition uptake, tissue damage and physiological stress resulting from the accumulation of these particles in different tissues (Cole *et al.,* 2016). Furthermore, fish constitute a major protein source for humans and higher trophic level organism, their contamination poses significant ecological and public health concerns. Thus, ingestion of MPs also facilitates bioaccumulation as well as biomagnification and their associated toxic contaminants through food web (Kutralam-Muniasamy *et al.,* 2020).

Consequently, predators-prey relationship plays a crucial role in the transfer of MPs across trophic level with the aquatic ecosystems (Wright and Kelly, 2017). Despite growing global concern regarding MP pollution, ecotoxicological studies conducted over past four years have been primarily focused on marine ecosystem and costal environments, but less significant knowledge gap concerning fresh water ecosystems, particularly in North India. Moreover, limited information is available on distribution and transfer of MPs in the freshwater food web. To address this research gap, present study aimed to assess microplastic contamination in commercially important fish species collected from critically polluted stretch of the Sutlej River in Punjab, India. Specifically, abundance and characteristics of Mps including their size, shape, colour and polymer composition in selected fish tissues.

Materials and Methods

Study area: Sutlej River is the easternmost and longest tributary of the Indus River, traversing Tibet, India and Pakistan. The river plays a vital role in hydroelectric power generation, water supply and agricultural irrigation in Punjab and adjacent regions. It also serves as spawning, breeding and nursery grounds for several freshwater species and provide livelihood to the local fishing communities. The present study was conducted along the Sutlej River stretch in Punjab, India, at two selected sites: Phillaur, near Ladowal Toll Plaza (NL 31°0'12" EL 75°47'14") and Walipur Kalan, where Buddha Nullah joins the River Sutlej (NL 30°59'52" EL 75°39'2") (Fig. 1).

Fish sample collection: During the study period from October 2024 to March 2025, a total of 30 fish specimens were collected from both sampling sites on bimonthly basis. Fifteen specimens were collected from each site, including common carp (*Cyprinus carpio*) (n=5), freshwater catfish (*Wallago attu*) (n=5) and rohu (*Labeo rohita*) (n=5), for the assessment of MP pollution. Fish species were identified using standard taxonomic keys described by Talwar and Jhingran (1991); Jayaram (1999). Immediately after the collection, samples were individually wrapped in aluminum foil, transported to laboratory under iced and stored at -18°C until further analysis.

Sample preparation: Prior to analysis, fish samples were thawed to room temperature and thoroughly rinsed with double-distilled water to remove sediments particles, blood and other adhering debris. Gill, intestine and muscle tissue were carefully dissected for MP analysis and transferred to 500 ml glass beakers covered with aluminum foil for the digestion.

Physio-chemical analyses: The standard protocol recommended by "National Oceanic and Atmospheric Administration (NOAA) was followed for the isolation of MPs (Masura *et al*., 2015). Each glass beaker containing tissue samples were treated with KOH, digested on a magnetic stirrer and sieved through 125 µm scientific sieve. The retained residue was collected in a clean beaker and subjected to WPO (Wet Peroxide Oxidation). Following samples were further treated with 20% H_2O_2 and 0.05 M Fe SO_4 and digested at 75°C under constant stirring (350 rpm) for 45 min. Subsequently, NaCl solution was added and manually stirred for 3 min, followed by the addition of $ZnCl_2$ solution. Finally, samples were covered with aluminum foil and left undisturbed for 22-24 hrs to facilitate density separation (Sheriff *et al.,* 2024). Thereafter, digested solution was passed thorough125 µm mesh and then collected in petri plates containing ultra-pure water. Finally, the digestive mixture was filtered through Whatman paper No. 42 filter paper using a vacuum filtration unit. After drying in a hot-air oven at 55°C, they were further evaluated under Leica stereo microscope (Model no: S 6D).

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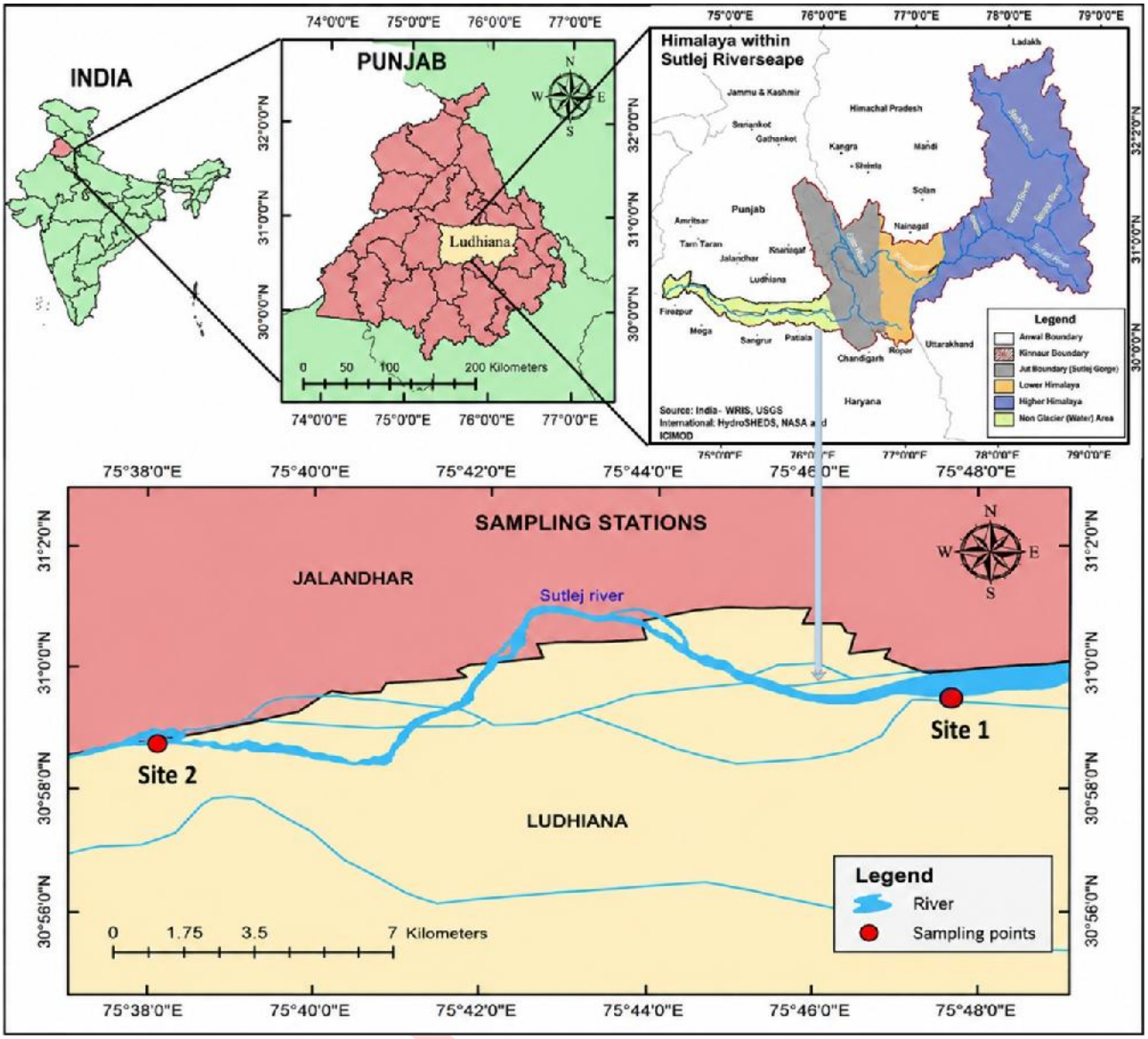


Fig.1: Sampling sites along with the sampling stations on Sutlej River.

Quality control: Strict quality control measures were adopted throughout the study period to minimize contamination. Immediately after collection, the fish samples were wrapped in aluminum foil and transferred in an ice box to laboratory. Head gear, nitrile gloves and suitable laboratory coat were worn throughout the experimental procedure. The working surface was covered with a clean aluminum foil sheet and all glasswares and samples were covered with aluminum foil to minimize airborne contamination. Procedural blanks were processed prior to sample processing to monitor background contamination and ensure the reliability of analytical results (ISO, 2023).

Quantitative and qualitative analyses: Quantitative analysis of MP was performed with Leica stereo zoom microscope (MODEL NO.- S 6D). Microplastics were classified according to shapes (fibers, film, fragments, flakes, beads, granules and foam) following Free (2014), while colour (violet, blue, pink, red, black, green and transparent) were classified into categories based on Young and Elliott (2016). IMAGE J software (version 2.0.0) was used to determine the size distribution of MP ranging from 5 mm. Field Emission Scanning Electron Microscopy (FE-SEM) was used to examine the surface morphological characteristics of recovered MPs and obtain high-resolution images. Polymer characterization was performed using attenuated total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR) (ISO, 2023). Individual MP particle was placed directly on the diamond crystal and 24 scans were recorded at a resolution of 4 cm^{-1} over wave number range of 400-4000 cm^{-1}. The obtained

spectrum peaks were compared with reference polymer spectra reported by Jung *et al.* (2018) and with Open Specy (online free software). Only particles exhibiting a spectral match of 70% or higher were considered (Browne *et al.* 2011; Cowger *et al.* 2021).

Statistical analyses: One-way ANOVA was performed to determine significant difference in MP concentrations among the samples, followed by Tukey's post-hoc test for multiple comparisons. Differences were considered statistically significant at p-values < 0.05. IBM-SPSS version 20.0 was used for statistical analyses of data and preparation and graphs.

Results and Discussion

Selected fish species collected from Phillaur and Wallipur Kalan exhibited significant variations in the number of MPs abundance. The highest level of MP concentration was recorded in *W. attu* (1.02 MPs ind^{-1} g^{-1}) collected from Wallipur Kalan, indicating comparatively higher level of MP pollution at this site of river. *L. rohita* and *C. carpio* had moderate concentration (0.43 and 0.39 MPs ind^{-1} g^{-1}) (Table 1). In contrast, *W. attu* from Phillaur showed moderate concentration (0.40 ind^{-1} g^{-1}), whereas *C. carpio* and *L. rohita* exhibited comparatively lower MP abundance (0.26 and 0.12 ind^{-1} g^{-1}), respectively. Variation in MP accumulation may be attributed to differences in fish size, metabolism, feeding behaviour, trophic position and environmental complexity. The mean ± SD values differed significantly between the species ($p < 0.05$). Similar findings have been reported by Garcia *et al.* (2021) and Piskuła *et al.* (2026), who observed greater microplastic accumulation in carnivorous fish than other species. Carnivorous fish accumulated higher MPs than omnivorous because of their higher trophic level in which trophic transfer and biomagnification were more likely to occur (Jamal *et al.*, 2024). However, Ismail *et al.* (2018) and Dib *et al.* (2026) reported higher MPs abundance in herbivorous fish than in carnivorous and omnivorous species, suggesting that feeding strategy alone does not always determine MP accumulation. These indicate that fish may accumulate MPs through both direct environmental exposure and indirect ingestion of contaminated prey (Hasegawa and Nakaoka, 2021; Prabhakar *et al.*, 2026). Furthermore, higher abundance observed in fish collected from Wallipur Kalan maybe associated with greater anthropogenic inputs, including untreated domestic discharge, agricultural run-off and industrial effluents.

The analysis of gills, intestines, dorsal, ventral and caudal (tail) muscles of the fish revealed a total of 1652 MPs. Majority of the identified MPs were recovered from the intestine (48.0%) and gills (40.4%), whereas considerably lower proportions (11.6%) was detected in the muscle tissue, comprising dorsal (5.3%), ventral (4.1%) and caudal muscles (2.2%) (Fig. 2). At Phillaur, the maximum accumulation of MPs were found in the gills of *W. attu* (0.93 MPs g^{-1}), followed by *C. carpio* (0.59 MPs g^{-1}) and *L. rohita* (0.27 MPs g^{-1}). A similar pattern was observed in the intestine,

Table 1: Quantitative assessment of the microplastics among the selected fish species from selected sites of River Sutlej

Site	Fish species	Feeding habits	Total length (cm)	Total weight (kg)	No of individual	Average No. of MP per individual fish/g
	L. rohita	Herbivore	43.7±4.94	0.86±0.38	5	0.12^{c} ±0.07
Phillaur	*C. carpio*	Omnivore	43.6±5.13	1.62±0.52	5	0.26^{bc} ±0.08
	W. attu	Carnivore	57.8±2.59	1.16±0.16	5	0.40^{bc} ±0.04
	L. rohita	Herbivore	44.7±3.31	0.90±0.16	5	0.43^{b} ±0.07
Wallipur	*C. carpio*	Omnivore	46.6±1.14	1.84±0.39	5	0.39^{bc} ±0.01
kalan	*W. attu*	Carnivore	45.6±15.73	0.76±0.64	5	1.02^{a} ±0.31

Values (Mean ± S.D.) with different alphabetical superscripts (a, b, c...) differ significantly between various fish species (in a column) ($P < 0.05$)

Table 2: Assessment of microplastics accumulation in different targeted organs in selected fish species (Mps ind.$^{-1}$ g^{-1})

Site	Fish species	In Edible		Edible		
		Gill	Intestine	Dorsal muscle	Ventral muscle	Caudal muscle
	L. rohita	0.27 b,1 ±0.18	0.22a,12±0.23	0.02 d,2±0.03	0.004 a,2±0.009	NA*
Phillaur	*C. carpio*	0.59 b,1 ±0.21	0.56 cd,1 ±0.18	0.05 cd,2±0.01	0.04 a,2±0.03	$0.01^{bc,}$ 2±0.02
	W. attu	0.93 b,1 ±0.30	0.97 b,1 ±0.14	0. 07 bc,2±0.02	0. 02 a,2±0.02	$0.01^{bc,}$ 2±0.01
	L. rohita	0.96 b,1 ±0.21	1.12 b,1 ±0.21	0.04 cd,2±0.03	0.02 b,2±0.02	$0.004^{c,}$ 2±0.01
Wallipur	*C. carpio*	0.83 b,1 ±0.48	0.87 bc ±0.42	0.09 ab,2±0.04	0.10 b,2±0.03	$0.06^{a,}$ 2±0.05
kalan	*W. attu*	2.31 a,1±1.04	2.53 a,1±0.86	0.10 a,2±0.06	0.09 a,2±0.05	$0.06^{ab,}$ 2±0.04

Values (Mean ± S.D.) with different alphabetical superscripts (1, 2, 3...) differ significantly between various organs of a fish specimen (in a row) and with different numerical superscripts (a, b, c..) differ significantly between various fish species (in a column) ($P < 0.05$. NA* not available

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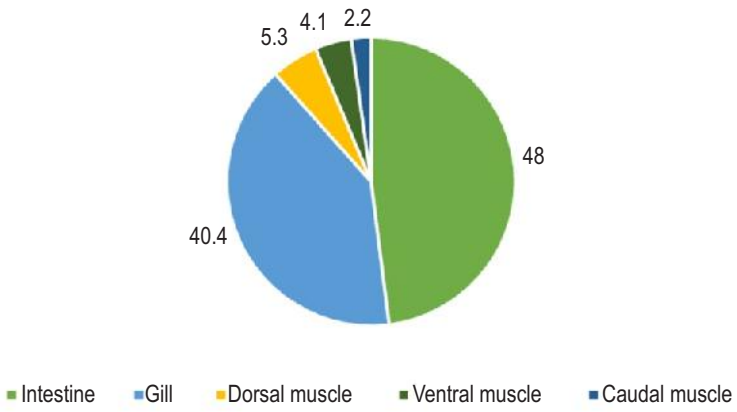


Fig. 2: Overall abundance of microplastics (%) in different targeted organs in all selected fish species.

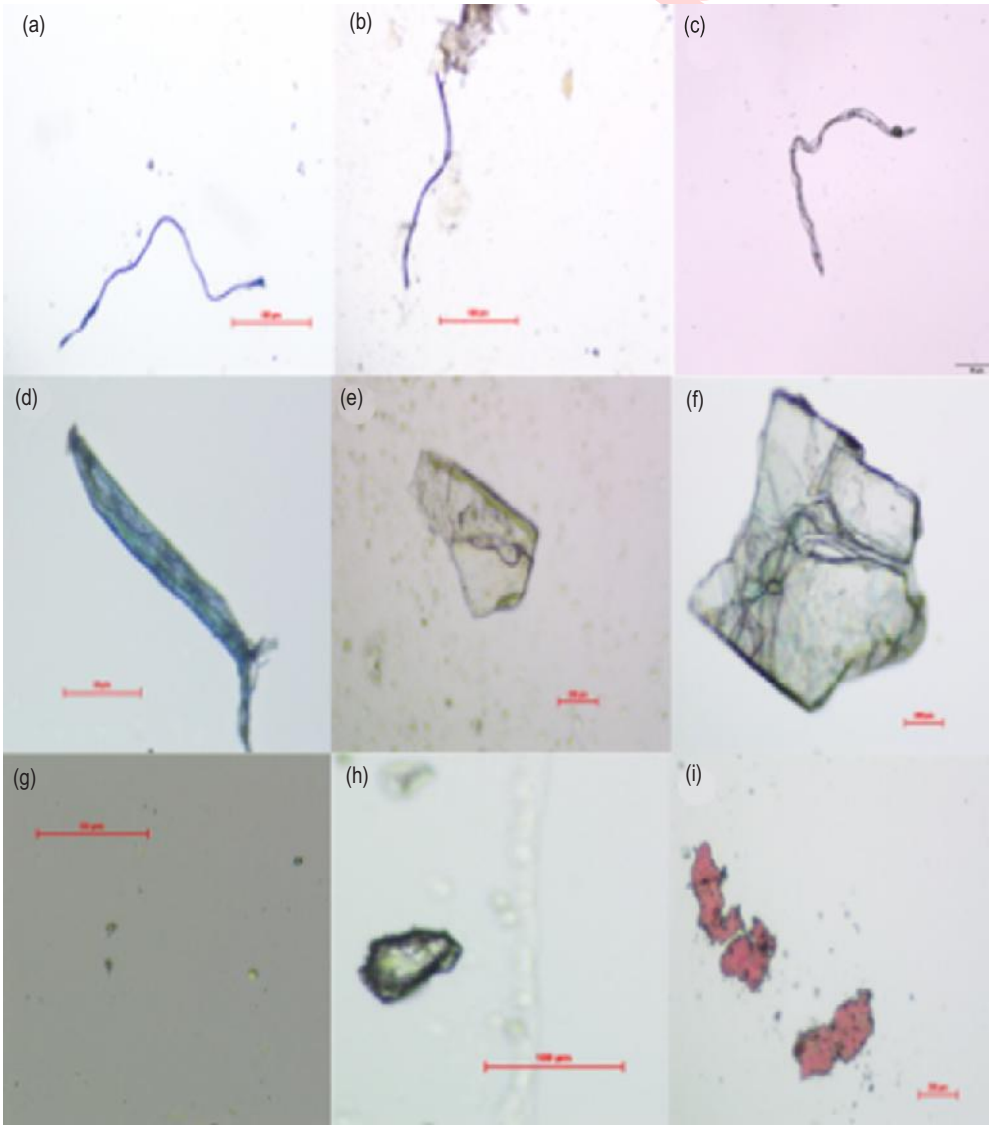


Fig. 3: Different shapes of microplastics available in fish species: (a-b) fibers;(c-d) Fragments; (e-f) Film; (g) Beads; (h) Granules and (i) Flakes.

where *W. attu* (0.97 MPs g^{-1}) and *C. carpio* (0.56 MPs g^{-1}) exhibited significant higher MP accumulation than *L. rohita* (0.22 MPs g^{-1}). MP abundance in the muscle tissues were significantly lower ($p < 0.05$), with higher concentration recorded in the dorsal muscle of *W. attu* (0.07 MPs g^{-1}), ventral muscle of *C. carpio* (0.04 MPs g^{-1}). In caudal muscle, MPs were not detectable in *L. rohita*; however, 0.01MPs g^{-1} was recorded in both *W. attu* and *C. carpio* (Table 2). In contrast, the fish collected from Wallipur Kalan exhibited significantly higher MP concentrations than those collected from Phillaur. MP accumulation in gills was highest in *W. attu* (2.31 MPs g^{-1}), followed by *L. rohita* (0.96 MPs g^{-1}) and *C. carpio* (0.83 MPs g^{-1}). A similar trend was observed in the intestine, where *W. attu* (2.53 MPs g^{-1}) and *L. rohita* (1.12 MPs g^{-1}) exhibited significantly higher MP accumulation than *C. carpio* (0.87 MPs g^{-1}). MP concentrations in the muscle tissues remained significantly lower ($p<0.05$). In dorsal muscle, the highest concentration was recorded in *W. attu* (0.10 Mps g^{-1}), whereas the lowest concentration was observed in *L. rohita* (0.04 MPs g^{-1}). In ventral and caudal muscles, the highest MP concentration was detected in *C. carpio* (0.10 and 0.06 MPs g^{-1}) whereas the lowest was found in *L. rohita* (0.02 and 0.004 MPs g^{-1}).

These findings are consistent with the previous reports (Makhdoumi *et al*., 2021; Harikrishnan *et al*., 2023; Kumar and Ram, 2025 and Papini *et al*., 2026) who observed the highest abundance of MPs in inedible tissues following the order: intestine > gill > dorsal muscle > ventral muscle > caudal muscle. MP concentrations differed significantly ($p < 0.05$) among fish species, tissue and sampling locations. Fish collected from Wallipur Kalan consistently exhibited a greater MP, which indicate higher level of environmental contamination. The relative abundance of MP in different organs was evaluated based on their physiological functions and degree of exposure. Gills were the primary respiratory organs and remain continuously exposed to MPs suspended in the water column. Consequently, they are highly susceptible to the accumulation of suspended MP particles in gills and mucosal surface (Zink and Wood, 2024). Similarly, gastro-intestinal tract is renowned as primary route for MP uptake in fish, as it facilitates direct ingestion of suspended plastic matter from the aquatic environment as well as indirectly through contaminated prey (Bellasi *et al.,* 2020; Papini *et al.,* 2026). Furthermore, the presence of mucus and intestine villi increases the absorptive surface area and enhances particle entrapment, may facilitate retention of MPs within the gut epithelium. Due to trophic transfer, the MPs ingested by prey fish can bioaccumulate in predatory fish, resulting in higher MP loads in their gastro-intestinal tract (Li *et al.,* 2021; Nikhil *et al.,* 2026).

The size, shape and polymers type of MP may further influence their ability to translocate and accumulate in muscle tissues (Lee *et al.,* 2023; Sacco *et al.,* 2026; Arivukumar *et al.,* 2026). However, MPs are much less abundant in muscule tissues because they are not directly involved in filtration or injection process (Buwono *et al.,* 2021, Arivukumar *et al.,*, 2026). Relatively low concentration of MPs in muscle tissue, may also be attributed to biological barriers that limit translocation of larger microplastics from gastro-intestinal tract into the bloodstream, and subsequently into the muscle tissue (Hossain *et al.,* 2023; Su *et al.,* 2025). Microplastics isolated from the selected organs (gill, intestine, dorsal muscle, ventral muscle and caudal muscle) of test fish species were identified under stereo zoom microscope and categorized on the basis their size, shapes and colours following the classification of Harikrishnan *et al.* (2023) as shown in Fig. 3. MPs in the size range of 0.1-0.5 mm were the most abundant (30.87%), followed by 0.5-1 mm size (25.18%).

Particles ranging from 1 to 1.5 mm and 1.5 to 2 mm accounted for 17.37% and 10.29%, respectively. The smallest particle of <0.1 mm constituted 8.66%, while 2-5 mm size range was least abundant (7.63%) (Fig. 4). The present findings are consistent with Ghosh *et al.* (2021) and Motivarash *et al.* (2024) who reported that majority of MPs ranged between 0.05-0.1 mm in size, while Piskuła and Astel (2023) interpreted that abundant MPs were in the range of 0.1 - 0.5 mm. The predominance of smaller MPs suggest progressive fragmentation of large plastic debris into finer particles through environmental weathering. These smaller particles are more readily injected by the aquatic organisms and tend to persist within the aquatic ecosystem, thereby increasing their ecological availability (Sutkar *et al.,* 2023; Sacco *et al.,* 2026).

Among different MP shapes, the fibers were most abundant (58.36%), followed by films (24.21%) and fragments (13.2%). Granules (2.72%) and beads (1.09%) occurred less frequently, whereas flakes were rarely observed (0.42%) (Fig. 5). The results of the present study corroborate with Khan and Setu (2022), who reported fibers (70%) as the dominant MP type. Similarly, Sultana *et al.,* (2023) found that fibre (50%) where the predominant MP type in both wild and found freshwater fish species from Bangladesh. The predominant of secondary MPs particularly fibers and films, indicates environmental degradation of large plastic debris (Arivukumar *et al.,* 2026). The high abundance of fibers may be attributed to domestic waste water discharge containing synthetic textile fibers, together with inputs from fishing and aquaculture activities (Chan *et al.,* 2023). Film particles were generally derived from plastic packaging materials following prolonged exposure to sunlight and environmental weathering (Chan *et al.,* 2023; Nikhil *et al.,* 2026). Likewise, the fragmented MPs originate form degraded of macro-plastics and meso-plastics through environmental process such as biofouling, UV radiation and physical abrasion (Andrady, 2022; Sacco *et al.,* 2026). Granules and microbeads were commonly associated with industrial raw materials and personal care products (Sutkar *et al.,* 2023) whereas flakes are generated through exfoliation of multilayer plastic surfaces (Kye *et al.,* 2023; Collins and Norton, 2025). Among the observed MPs, blue-coloured particles were predominated (35.48%), followed by transparent (26.33%) and red particles (15.01%). Other colours identified included violet (8.23%), yellow (6.17%), black (3.63%), green (2.24%), orange (1.76%) and brown (1.15%) (Fig. 6). Predominance of blue-coloured MPs in aquatic organisms may be attributed to their accidental ingestion during feeding, which is in line with the of

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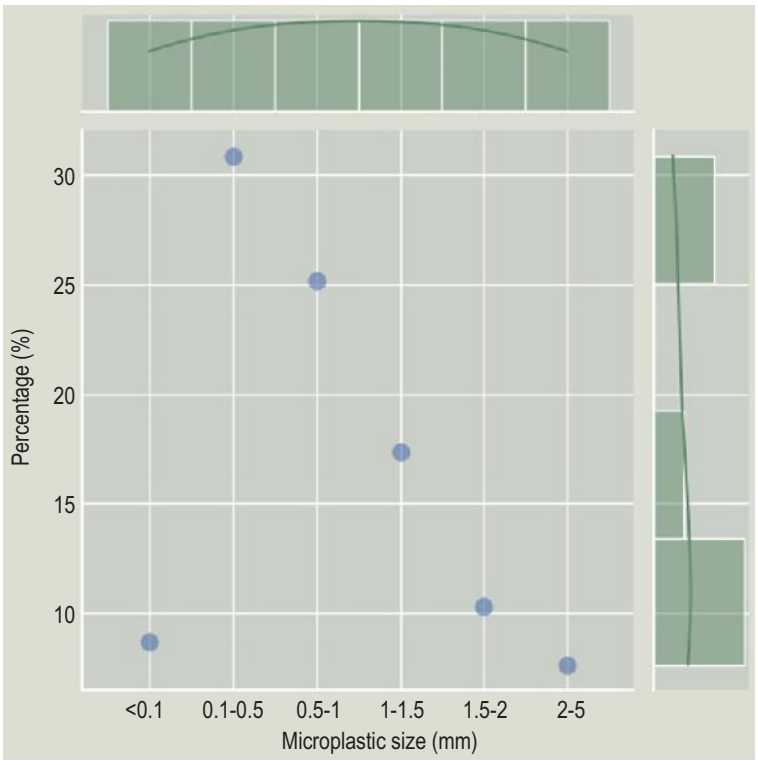


Fig. 4: Overall assessment of microplastics based on size (%) in the fish samples collected from selected sampling sites of River Sutlej.

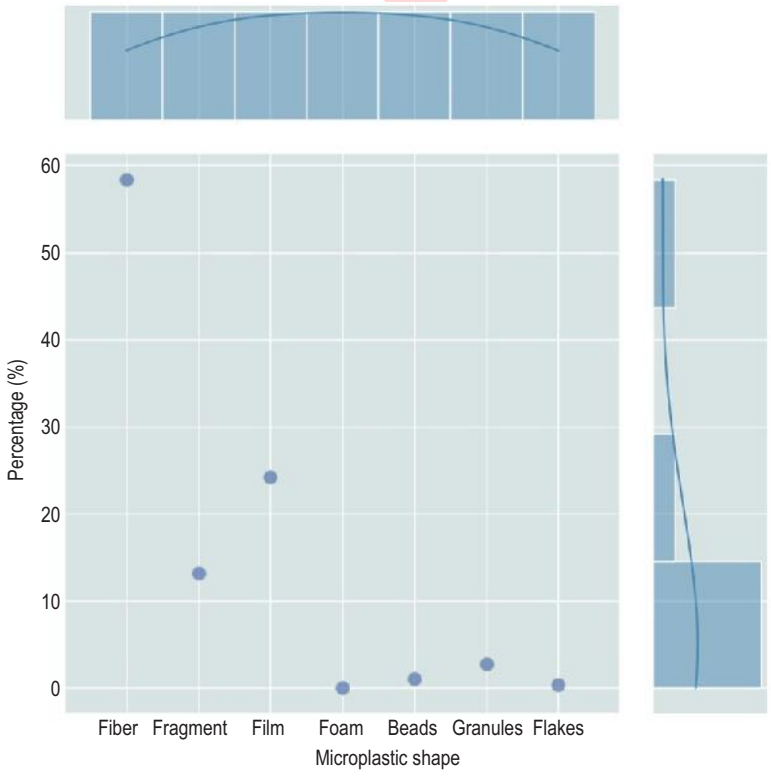


Fig. 5: Overall assessment of microplastics based on shape (%) in the fish samples collected from selected sampling sites of River Sutlej.

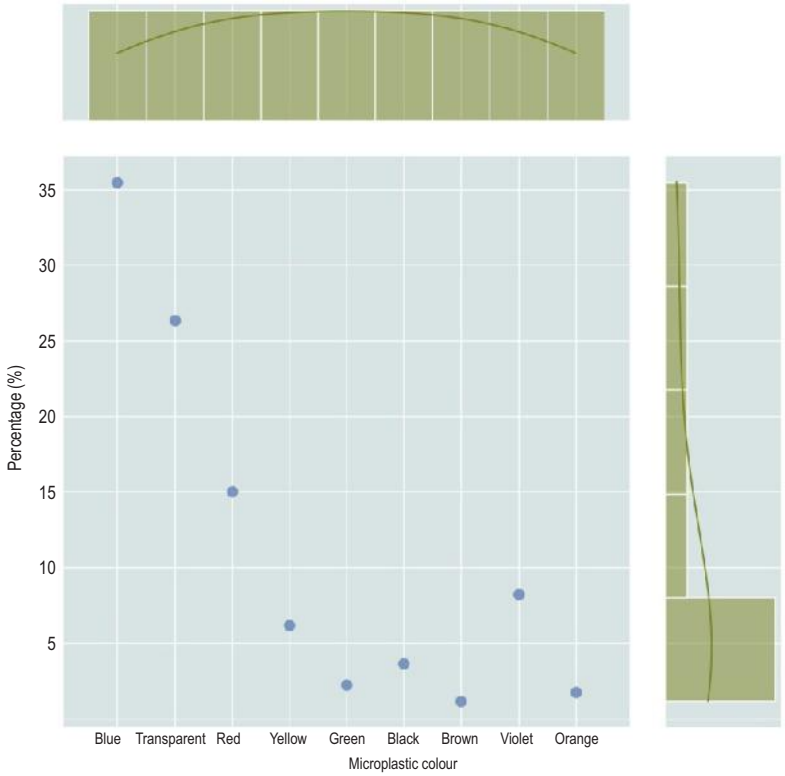


Fig. 6: Overall assessment of microplastics based on colour (%) in water samples from the selected collected sites of River Sutlej.

reports Barboza *et al.* (2020). In contrast, Khan and Setu (2022) reported black-coloured (27%) as dominant and Sultana *et al.* (2023) reported transparent (47.06%) as the most dominant.

The visibility of bright coloured MPs (blue, red and yellow) may be likely to be consumed unintentionally due to resemblance with their food. The occurrence of different colours may also be associated with the selective feeding behaviour of aquatic animals (Cverenkárová *et al.,* 2021). In the present study, predominance of blue coloured particles may be associated with the degradation of synthetic textiles, fishing nets and ropes that are commonly pigmented blue (Paul *et al.,* 2024; Arivukumar *et al.,* 2026; Nikhil *et al.,* 2026). Transparent MPs are generally derived from the degradation of packaging materials including LDPE, PP and PET (Sabatino *et al.,* 2024). In contrast, red MPs were likely to originate from coloured consumer products, synthetic garment fibres and coloured plastic material. Microplastics including fibers, fragments, films, granules, beads and flakes, which were isolated from the gills, intestines and muscle tissues of fish were analysed with FE-SEM, (Fig. 7). Among these fibers, the most abundant were typically long, thin and thread-like resemblance (Militký *et al.,* 2024). These fibers were primarily generated from synthetic textiles and industrial fabrics through mechanical abrasion and fiber breakage.

Mechanical fragmentation of larger plastic debris produces irregularly shaped particles with rough surfaces, sharp edges and fractured structures (Cverenkárová *et al.,* 2021). Similarly, weathering and degradation of plastic wrappers, packaging material and plastic bags result in the formation of film type (Menger *et al.,* 2024). Flakes were irregular, flat particles that often consist of multiple layers. Microbeads, classified as primary MPS are widely used in personal care products, such as facial cleaners and exfoliating scrubs (Andrady, 2011; Thomas *et al.,* 2025). Surface weathering features observed in the recovered MPs included pits, grooves, cracks, sharp edges and fractured surfaces, which indicate physical degradation and prolonged environmental exposure (Nagendra *et al.*, 2025).

The chemical composition of recovered MPs was characterised using ATR-FTIR. Polymer identification was performed with MP isolated from different fish tissues (gill, intestine, dorsal, caudal, ventral muscle). FTIR spectrum of polyethylene revealed absorption bands at 2914.13 cm^{-1} and 2847.85 cm^{-1}, corresponding to symmetric and asymmetric stretching vibrations of C-H bonds in methylene (-CH_2-) groups (Fig. 8). CH_2 bending (scissoring) vibrations were responsible for the absorption at 1462.83 cm^{-1}, which suggests existence of repeated -CH_2- sequences. FTIR spectrum of polypropylene revealed C-H stretching vibrations in the methylene (-CH_2-) and methyl (-CH_3) groups responsible for prominent peaks at 2918.46 cm^{-1} and 2867.76 cm^{-1} (Fig. 8). A hallmark of isotactic structure of polypropylene was presence of alternating methylene and methyl groups, as shown by CH_2 bending vibrations measured at

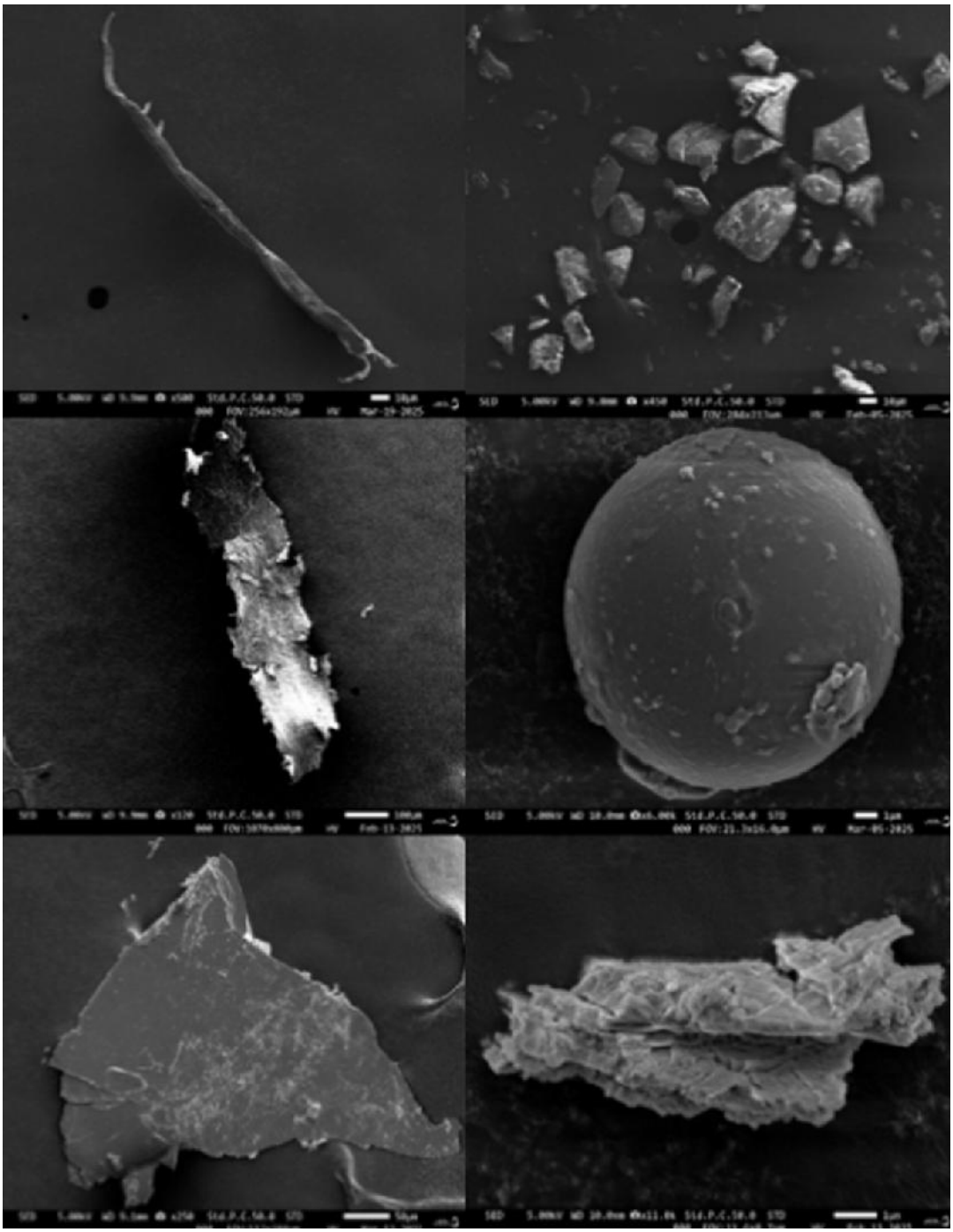


Fig. 7: FE-SEM analysis of MP segregated from the fish samples of Sutlej River.

1456.20 cm^{-1} and 1376.20 cm^{-1}. FTIR spectrum of polyethylene terephthalate revealed the prominent peak at 1710.33 cm^{-1} associated with the C=O stretching vibration of ester functional groups (Fig. 8). This confirms the existence of -COO- group in polymer backbone. Absorptions at 1244.40 cm^{-1} and 1100.41 cm^{-1} were linked to C-O stretching vibrations in ester bonds.

Similarly, Makhdoumi *et al.* (2021) identified polyethelene, polypropylene, polystyrene and polyamide as the most abundant polymers in the gut and muscle tissues of riverine fish from Iran. Garcia *et al.* (2021) also reported that polyethylene terephthalate, polyesters and polythene detected in the freshwater fish collector from Betania Dam, Colombia. Likewise

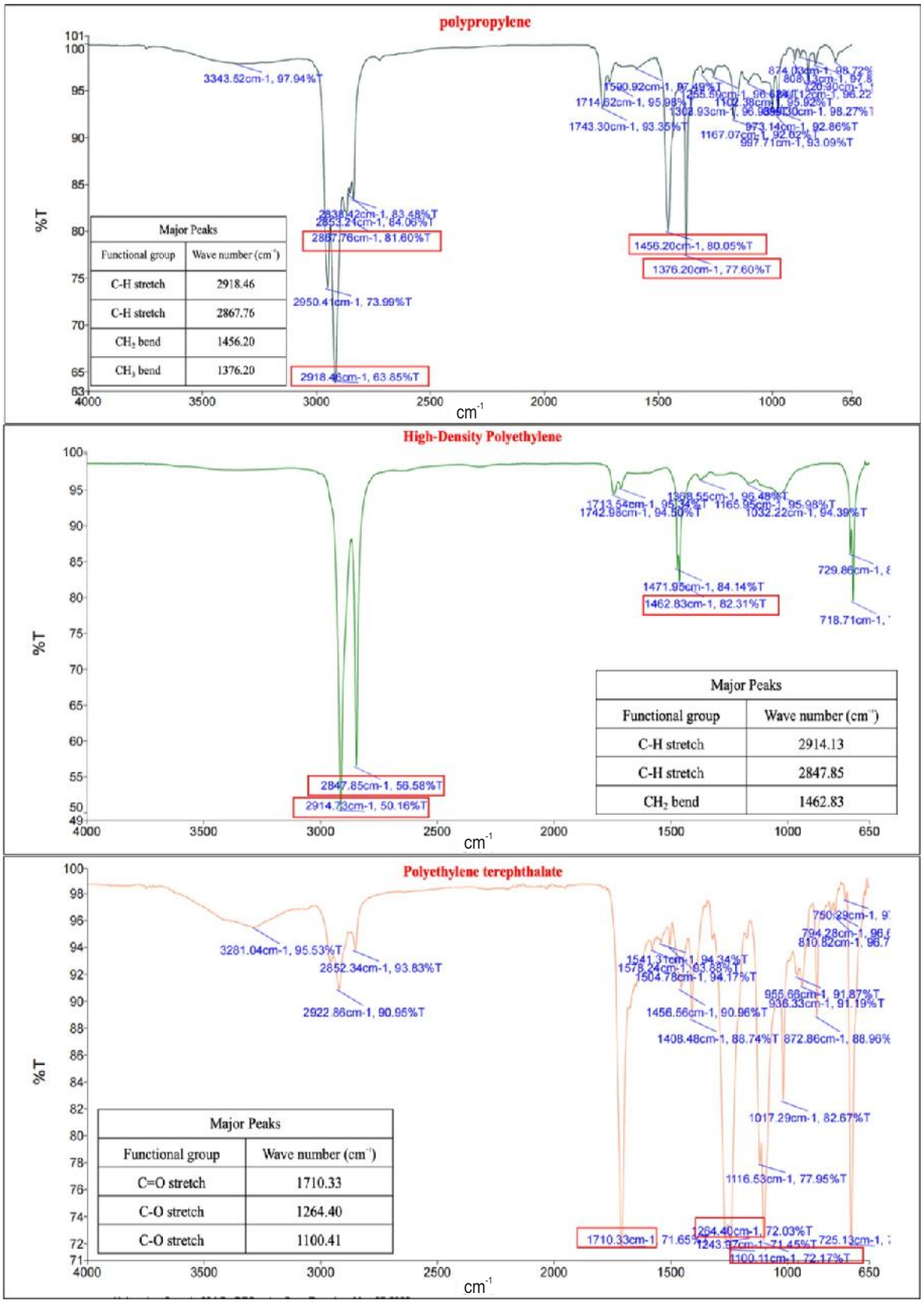


Fig. 8: FTIR spectrum of MP samples segregated from fish samples.

polythene, polypropylene and Polystyrene have been consistently reported as dominant polymer types in freshwater ecosystems worldwide (Bordós *et al.,* 2019). Polyethylene is one of the most widely used synthetic polymers in the manufacture of plastic products, accounting for nearly 64 % of global plastic production (Liu *et al.,* 2024). In addition polyethylene is frequently used in personal care products, including facial scrubs and face wash in the form of microbeads. The minute size of polyethylene based microbeads enable them to pass through conventional sewage treatment systems and enter the aquatic ecosystems (Browne *et al.,* 2011). Recently, Giacinto *et al.* (2023), reported polypropylene was the predominant polymer in the edible muscles of swordfish and bluefin tuna.

Low-density polymers, including LDPE, polystyrene and acrylic exhibit a greater tendency to remain suspended in the water column, therefore more likely to be ingested by pelagic fish species, particularly planktivorous and filter-feeding fishes (Zeytin *et al.,* 2025). Furthermore, Arivukumar *et al.* (2026) reported that blue-coloured Polyethylene, Polypropylene and Polyamide were frequently released into the aquatic environment from fishing equipment and other fishing gear. Phillips and Bonner (2015) and Sacco *et al.* (2026) reported that polystyrene exposure can cause respiratory issues and cell mutation in fish. Similarly, exposure to micro-and nano-plastics have been associated with necrosis, inflammatory infiltration, lipid accumulation and inflammation in zebrafish have been associated with necrosis, infiltration, lipid accumulation and inflammation (Lu *et al.,* 2016). Although fish are generally eviscerated before consumption, thereby reducing direct human exposure to microplastic present in the digestive tract, but associated toxic continent may still bioaccumulate and bio magnify through food chain, which processes an indirect risk to human health (Zeytin *et al.,* 2025).

The present findings demonstrated the widespread occurrence of various microplastics in all examined fish samples, indicating substantial environmental contamination within the study area. The widespread occurrence of microplastics in commercial important freshwater fish highlights their potential for bioaccumulation and biomagnification through aquatic food webs, thereby posing potential ecological risks and indirect health concern for the higher trophic-level organisms, including humans.

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References

Andrady, A.L.: Microplastics in the marine environment. *Mar. Pollu. Bull.,* **62**, 1596-1605 (2011).

Andrady, A.L.: Weathering and fragmentation of plastic debris in the ocean environment. *Mar. Pollu. Bull.,* **180**, 113761 (2022).

Arivukumar, E., R. Shalini, U. Arisekar, B. Sivaraman, K. Iswarya and D. Manimekalai: Microplastic contamination in thirty commercially important fish species: Distribution, polymer composition, pollution indices and human health risks. *Mar. Pollu. Bull.,* **226**, 119360 (2026).

Barboza, L.G.A., C. Lopes, P. Oliveira, F. Bessa, V. Otero, B. Henriques and L. Guilhermino: Microplastics in wild fish from North-east Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *Sci. Total Environ.,* **717**, 134625 (2020).

Bellasi, A., G. Binda, A. Pozzi, S. Galafassi, P. Volta and R. Bettinetti: Microplastic contamination in freshwater environments: A review, focusing on interactions with sediments and benthic organisms. *Environments,* **7**, 30 (2020).

Booth, A.M., S. Kubowicz, C. Beegle-Krause, J. Skancke, T. Nordam, E. Landsem and S. Jahren: Microplastic in global and Norwegian marine environments: Distributions, degradation mechanisms and transport. Report No. M-918, Norwegian Environment Agency, Norway (2018).

Bordós, G., B. Urbányi, A. Micsinai, B. Kriszt, Z. Palotai, I. Szabó and S. Szoboszlay: Identification of microplastics in fish ponds and natural freshwater environments of the Carpathian basin, Europe. *Chemosphere,* **216**, 110-116 (2019).

Browne, M.A., P. Crump, S.J. Niven, E. Teuten, A. Tonkin, T. Galloway and R. Thompson: Accumulation of microplastic on shorelines worldwide: Sources and sinks. *Environ. Sci. Technol.,* **45**, 9175-9179 (2011).

Buwono, N.R., Y. Risjani and A. Soegianto: Contamination of microplastics in Brantas River, East Java, Indonesia and its distribution in gills and digestive tracts of fish *Gambusia affinis*. *Emerg. Contamin.,* **7**, 172-178 (2021).

Chan, C.K.M., J.K.H. Fang, B. Fei and C.W. Kan: Microfibres release from textile industry wastewater effluents are underestimated: Mitigation actions that need to be prioritised. *Fibers,* **11**, 105 (2023).

Collins, S.F. and A. Norton: The plastic size spectra: Assessing the size

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structure of plastic particles across the land–water ecotone. *Environ. Pollu.,* **374**, 126263 (2025).

Cowger, W., Z. Steinmetz, A. Gray, K. Munno, J. Lynch, H. Hapich, S. Primpke, H.D. Frond, C. Rochman, O. Herodotou: Microplastic spectral classification needs an open source community: open specy to the rescue!. *Analy. Chem.,* **93**, 7543-7548 (2021).

Cox, K.D., G.A. Covernton, H.L. Davies, J.F. Dower, F. Juanes and S.E. Dudas: Human consumption of microplastics. *Environ. Sci. Technol.,* **53**, 7068-7074 (2019).

Cverenkárová, K., M. Valachovičová, T. Mackuľak, L. Žemlička and L. Bírošová: Microplastics in the food chain. *Life,* **11**, 1349 (2021).

Dey, S., G.T.N. Veerendra, P.A. Babu, A.P. Manoj and K.J.B.M. Nagarjuna: Degradation of plastics waste and its effects on biological ecosystems: A scientific analysis and comprehensive review. *Biomed. Mater. Devic.*, **2**, 70-112 (2024).

Di Giacinto, F., L. Di Renzo, G. Mascilongo, V. Notarstefano, G. Gioacchini, E. Giorgini and M. Berti: Detection of microplastics, polymers and additives in edible muscle of swordfish (*Xiphias gladius*) and bluefin tuna (*Thunnus thynnus*) caught in the Mediterranean Sea. *J. Sea Res.,* **192**, 102359 (2023).

Dib, S., A. Mohamed, F.A. Al-Khayat, S. Veerasingam, V.M. Aboobacker, J.A. Al-Khayat and P. Vethamony: Distinguishing microplastics from microplastic-like particles in the marine fish from Qatar. *Sci. Rep.*, **16**, 5981 (2026).

Dou, C., H. Choudhary, Z. Wang, N.R. Baral, M. Mohan, R.A. Aguilar and N. Sun: A hybrid chemical-biological approach can upcycle mixed plastic waste with reduced cost and carbon footprint. *One Earth*, **6**, 1576-1590 (2023).

European Chemicals Agency: Restricting the use of intentionally added microplastic particles to consumer or professional use products of any kind. ECHA European Commission, pp. 2-7 (2020).

Free, C.M., O.P. Jensen, S.A. Mason, M. Eriksen, N.J. Williamson and B. Boldgiv: High-levels of microplastic pollution in a large, remote, mountain lake. *Mar. Pollu. Bull.,* **85**, 156-163 (2014).

Garcia, A.G., D.C. Suárez, J. Li and J.M. Rotchell: A comparison of microplastic contamination in freshwater fish from natural and farmed sources. *Environ. Sci. Pollu. Res.,* **28**, 14488-14497 (2021).

Ghosh, G.C., S.M. Akter, R.M. Islam, A. Habib, T.K. Chakraborty, S. Zaman and M.A. Wahid: Microplastics contamination in commercial marine fish from the Bay of Bengal. *Reg. Stud. Mar. Sci.*, **44**, 101728 (2021).

Harikrishnan, T., M. Janardhanam, P. Sivakumar, R. Sivakumar, K. Rajamanickam, T. Raman and G. Singaram: Microplastic contamination in commercial fish species in southern coastal region of India. *Chemosphere,* **313**, 137486 (2023).

Hasegawa, T. and M. Nakaoka: Trophic transfer of microplastics from mysids to fish greatly exceeds direct ingestion from the water column. *Environ. Pollu.,* **273**, 116468 (2021).

Hossain, M.B., F.H. Pingki, M.A.S. Azad, A.A.U. Nur, P. Banik, B.A. Paray and J. Yu: Microplastics in different tissues of a commonly consumed fish, Scomberomorus guttatus, from a large subtropical estuary: Accumulation, characterization and contamination assessment. *Biology,* **12**, 1422 (2023).

Ismail, M.R., M.W. Lewaru and D.J. Prihadi: Microplastics ingestion by fish in the Biawak Island. *World Scientific News,* **106**, 230-237 (2018).

ISO: Principles for the analysis of microplastics present in the environment. ISO 24187:2023, 1st Edn., International Organization for Standardization, Geneva, Switzerland, 21 pages (2023).

Jamal, N.T., M.R.U. Islam, S. Sultana, P. Banik, A.A.U. Nur, M.F. Albeshr and M.B. Hossain: Microplastic contamination in some popular seafood fish species from the northern Bay of Bengal and possible consumer risk assessment. *Food Control,* **171**, 111114 (2025).

Jayaram, K.C.: The Freshwater Fishes of the Indian Region. Narendra Publishing House, Delhi, India, 551 pages (1999).

Jung, M.R., F.D. Horgen, S.V. Orski, V. Rodriguez, K.L. Beers, G.H. Balazs and J.M. Lynch: Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms. *Mar. Pollu. Bull.,* **127**, 704-716 (2018).

Kaewprachu P., W. Klunklin, C. Jaisan, S. Rawdkuen, P. Sangsawad, W. Tongdeesoontorn, P. Kingwascharapong and S. Kraithong: Comparative study of cellulose nanocrystals from young and mature coconut husks as reinforcement agents in sustainable gelatin-based films. *Polymers.*, **18**, 708 (2026).

Khan, H.S. and S. Setu: Microplastic ingestion by fishes from Jamuna River, Bangladesh. *Environ. Nat. Resour. J.,* **20**, 157-167 (2022).

Kumar, A. and K. Ram: Microplastics in commercial fishes in the River Ganga and their human health risk assessment. *ACS ES&T Water,* **5**, 6268-6277 (2025).

Kutralam-Muniasamy, G., F. Pérez-Guevara, I. Elizalde-Martínez and V.C. Shruti: An overview of recent advances in micro/nano beads and microfibers research: Critical assessment and promoting the less known. *Sci. Total Environ.,* **740**, 139991 (2020).

Kye, H., J. Kim, S. Ju, J. Lee, C. Lim and Y. Yoon: Microplastics in water systems: A review of their impacts on the environment and their potential hazards. *Heliyon,* **9**, e14359 (2023).

Lee, Y., J. Cho, J. Sohn and C. Kim: Health effects of microplastic exposures: Current issues and perspectives in South Korea. *Yonsei Medi. J.,* **64**, 301-307 (2023).

Li, B., W. Liang, Q.X. Liu, S. Fu, C. Ma, Q. Chen and H. Shi: Fish ingest microplastics unintentionally. *Environ. Sci. Technol.,* **55**, 10471-10479 (2021).

Liu, X., Z. Wang, C. Wang, B. Wang, H. Cao, J. Shan and X. Zhang: Mercury distribution, exposure and risk in Poyang Lake and vicinity, China. *Environ. Pollu.,* **344**, 123409 (2024).

Lu, Y., Y. Zhang, Y. Deng, W. Jiang, Y. Zhao, J. Geng and H. Ren: Uptake and accumulation of polystyrene microplastics in zebrafish (*Danio rerio*) and toxic effects in liver. *Environ. Sci. Technol.,* **50**, 4054-4060 (2016).

Lusher, A.Á., N.A. Welden, P. Sobral and M. Cole: Sampling, isolating and identifying microplastics ingested by fish and invertebrates. In: Analysis of Nanoplastics and Microplastics in Food. CRC Press, pp. 119-148 (2020).

Makhdoumi, P., H. Hossini, Z. Nazmara, K. Mansouri and M. Pirsaheb: Occurrence and exposure analysis of microplastic in the gut and muscle tissue of riverine fish in Kermanshah province of Iran. *Mar. Pollu. Bull.,* **173**, 112915 (2021).

Menger, F., M. Römerscheid, S. Lips, O. Klein, D. Nabi, J. Gandrass and L. Hildebrandt: Screening the release of chemicals and microplastic particles from diverse plastic consumer products into water under accelerated UV weathering conditions. *J. Hazar. Mater.,* **477**, 135256 (2024).

Militký, J., J. Novotná, J. Wiener, D. Křemenáková and M. Venkataraman: Microplastics and fibrous fragments generated during the production and maintenance of textiles. *Fibers,* **12**, 51 (2024).

Miri, S., R. Saini, S.M. Davoodi, R. Pulicharla, S.K. Brar and S. Magdouli: Biodegradation of microplastics: Better late than never. *Chemosphere,* **286**, 131670 (2022).

Motivarash, Y., A. Bhatt and H. Kardani: Microplastic occurrence in pelagic and demersal fishes of Gujarat, North-west coast of India. *Environ. Sci. Pollu. Res.,* **31**, 17239-17255 (2024).

Nagendra, P.S., S.N. Datta and G. Tewari: Ecological risk and trophic transfer of microplastics in freshwater fish from the Sutlej River stretch in Punjab, India. *Environ. Monit. Assess.*, **198**, 930 (2026).

Nagendra, P.S., S.N. Datta, D. Pathak, G. Tewari, K. Gupta and G.D. Leishangthem: Assessment of microplastic contamination and

ecological risk in the middle stretch of the Sutlej River, Punjab, India. *Asian J. Environ. Ecol.,* **24**, 33-51 (2025).
Nikhil, V.G., C. Abisha, R. Raghavan, A.A. Ph and G.K. Varghese: Bioaccumulation and trophic transfer of microplastics in oceanic food webs. *Mar. Pollu. Bull.,* **224**, 119113 (2026).
Masura, J., J. Baker, G. Foster and C. Arthur: Laboratory methods for the analysis of microplastics in the marine environment: Recommendations for quantifying synthetic particles in waters and sediments (Ed.: C. Herring). NOAA Technical Memorandum NOS-OR&R-48, pp. 1-39 (2015).
Papini, G., C. Boglione and A. Rakaj: Microplastics interception from riverine ecosystems and translocation to fish internal organs. *Sci. Rep.,* **16**, 10824 (2026).
Paul, S., S. Nath, S. Bhattacharjee and S. Mukherjee: Unveiling the effects of microplastics pollution on marine fauna. *Blue Biotechnol.,* **1**, 6 (2024).
Phillips, M.B. and T.H. Bonner: Occurrence and amount of microplastic ingested by fishes in watersheds of the Gulf of Mexico. *Mari. Pollu. Bull.,* **100**, 264-269 (2015).
Piskuła, P. and A. Astel: Comparative study on microplastic abundance in fish organs from marine and freshwater ecosystems of the southern Baltic Sea region: Influence of habitat zone and feeding preferences. *Mar. Pollu. Bull.,* **223**, 118959 (2026)
Piskuła, P. and A.M. Astel: Microplastics in commercial fishes and by-catch from selected FAO major fishing areas of the Southern Baltic Sea. *Animals,* **13**, 458 (2023).
Prabhakar, S., Z.J. Aguiar, G. Chakraborty and R. Premanath: Investigating microplastics and their trophic transfer in seafood: A study from Mangalore. *Int. J. Environ. Res.,* **20**, 116 (2026).
Sabatino, R., R. Zullo, A. Di Cesare, R. Piscia, S. Musazzi, G. Corno and S. Galafassi: Traditional and biodegradable plastics host distinct and potentially more hazardous microbes when compared to both natural materials and planktonic community. *J. Hazar. Mater.,* **475**, 134719 (2024).
Sacco, V.A., A. Selinger, E.S. Lemunie, G.T. Adami, F. Teixeira-de-Mello, N.C. de Castilhos Ghisi and R.L. Delariva: Beyond concentration: Particle traits shape the toxicity of microplastics in fish – A global meta-analysis. *Environ. Res*., **301**, 124478 (2026).
Sheriff, I., N.A. Awang, H.B. Halim, O.S. Ikechukwu and A.F. Jusoh: Extraction and analytical methods of microplastics in wastewater treatment plants: Isolation patterns, quantification and size characterization techniques. *Desalin. Water Treat.,* **318**, 100399 (2024).
Su, M., D. Gu, L. Liang, Z. Zhou, C. Zhu, J. Qi, P. Wu, T. Xu and Z. Jiang: Size-dependent and tissue-specific accumulation of polystyrene microplastics and nanoplastics in zebrafish. *Aquat. Toxicol*., **291**, 107678 (2026).
Sultana, N., R.R. Tista, M.S. Islam, M. Begum, S. Islam and M.N. Naser: Microplastics in freshwater wild and farmed fish species of Bangladesh. *Environ. Sci. Pollu. Res.,* **30**, 72009-72025 (2023).
Sutkar, P.R., R.D. Gadewar and V.P. Dhulap: Recent trends in degradation of microplastics in the environment: A state-of-the-art review. *J. Hazar. Materi. Advan.,* **11**, 100343 (2023).
Talwar, P.K. and A.G. Jhingran: Inland Fishes of India and Adjacent Countries. CRC Press, New Delhi, India, **Vol. 2**., pp. 543-1158 (1991).
Thomas, N.M., S. Shetye, A. Patil, K.S. Kulal, R. Patil and S.U. Kamath: Microplastics in cosmetics and their impact on human health. *Discov. Appl. Sci.*, **8**, 172 (2025).
Vivekanand, A.C., S. Mohapatra and V.K. Tyagi: Microplastics in aquatic environment: Challenges and perspectives. *Chemosphere,* **282**, 131151 (2021).
Von Moos, N., P. Burkhardt-Holm and A. Köhler: Uptake and effects of microplastics on cells and tissue of the blue mussel *Mytilus edulis* L. after an experimental exposure. *Environ. Sci. Technol.,* **46**, 11327-11335 (2012).
Wang, F., H. Wu, W. Wu, L. Wang, J. Liu, L. An and Q. Xu: Microplastic characteristics in organisms of different trophic levels from Liaohe Estuary, China. *Sci. Total Environ.,* **789**, 148027 (2021).
Wang, T., X. Zou, B. Li, Y. Yao, Z. Zang, Y. Li and W. Wang: Preliminary study of the source apportionment and diversity of microplastics: Taking floating microplastics in the South China Sea as an example. *Environ. Pollut.,* **245**, 965-974 (2019).
Young, A.M. and J.A. Elliott: Characterization of microplastic and mesoplastic debris in sediments from Kamilo Beach and Kahuku Beach, Hawai'i. *Mar. Pollu. Bull.,* **113**, 477-482 (2016).
Zeytin, S., A. Klinke, G. Wagner, G. Gerdts and M.J. Slater: Variation of ingested microplastic size and quantity in different tissues of juvenile European seabass (*Dicentrarchus labrax*). *Mar. Environ. Res.,* **213**, 107699 (2025).
Zink, L. and C.M. Wood: The effects of microplastics on ionoregulatory processes in the gills of freshwater fish and invertebrates: A prospective review. *Compar. Biochem. Physiol. Part A: Mole. Integr. Physiol.,* **295**, 111669 (2024).

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