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Widespread Microplastic Pollution in Commercial Fish from Visakhapatnam Harbour: Implications for Marine Ecosystems and Food Safety

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ABSTRACT:
Marine pollution, particular plastic-dominant waste, a mounting global crisis. India is among the leading contributors to global plastic pollution, with an estimated annual release of around 3.5 million tonnes of plastic waste into the environment. This study aimed to show the remnants of plastic dust in commercially valuable edible fish collected from Visakhapatnam Harbour. Samples were taken to analyse microplastic contamination on the surface of gills, digestive trac, and tissues, attributed to two species in the harbour. A total of 80% of microplastics were recorded during this study from the Visakhapatnam harbour pointing the chemical digestion and infiltration. Fibers were most dominant in all species followed by foam. Blue (35%), red (17%), and black (5%) plastics were the most prevalent colours. Average dimensions of the plastic debris range between 0.45mm in the Trichurus lepturus to 3.1mm in the Stelophorus commersonie. The major microplastic polymers identified using FTIR spectroscopy characterization include polyamide, PET, polyethylene, polyvinyl chloride, polystyrene, and polypropylene. Our findings demonstrate substantial microplastic contamination in fish and underscore the urgent need for further research on plastic pollution in coastal ecosystems.
KEYWORDS: *Stelophorus commersonie, Trichurus lepturus, FTIR spectroscopy, microplastics, marine pollution*

1. INTRODUCTION:

Microplastics — persistent, toxic, and pervasive contaminants — have emerged as a significant environmental hazard in marine ecosystems (Cole et al., 2011; Guo and Wang, 2019; Miller et al., 2020). Plastic debris consistently documented across the world's oceans (Barnes et al., 2009; Bergmann and Klages, 2012; Galgani et al., 1996, 2000; Ramirez-Llodra et al., 2011). Plastics constitute the dominant fraction of marine litter (Derraik, 2002; Moore, 2008), and particles smaller than 5 mm are collectively defined as microplastics (MP) (Arthur et al., 2009). Wide range of marine fauna — including amphibians, mammals etc — are known to have presence of both macro plastic dust and microplastics (Caron et al., 2018; Cartraud et al., 2019; Nelms et al., 2016), while invertebrate face a comparably increased risk (Walkinshaw et al., 2020). Microplastic intake may be direct or deliberately, when plastic dust visually resemble prey (Lusher et al., 2013), or incidentally during routine feeding (Rummel et al., 2016). MP can also found and through the consumption of contaminated prey (Batel et al., 2016; Nelms et al., 2018). Once ingested, microplastics pose a range of adverse health effects, partly due to the toxic additives they carry — including phthalates, bisphenol A (BPA), polybrominated diphenyl ethers (PBDE), and tetrabromobisphenol A (TBBPA) (Talsness et al., 2009; Barboza et al., 2018; Batel et al., 2016).
Microplastics leads to capturing contagious particles, including persistent organic pollutants (POPs), from seawater (Mato et al., 2001). Microplastics move up to through the food chain (Browne et al., 2007; Gassel et al., 2013), this wide spread leads to poor reproductivity and development of organisms (Hutchinson et al.; Murihead et al., 2006). The penetration of microplastics into ecosystem is deeper and leads to risks of accumulation in the marine life (Lusher, 2015). In the higher levels of food chain the accumulation shows sublethal effects (Akhter and Panhwar, 2022; Koelmans et al., 2015).
Bay areas accommodate wide species ranges fishes, these have high risk of taking up the harmful pollutants from marine water. (Browne et al., 2007; Gassel et al., 2013 & Sundblad et al., 2013). Particle feeder and substrate feeder both have a high risk of MPs accumulation by consuming the marine debrie with the presence of plastic particles (Lusher, 2015). Organic substances like Persistant Organic Pollutants (POPs) are absorbed by microplastics (Mato et al., 2001) which can easily trasfeered to fishes (Browne et al., 2007;

Gassel et al., 2013) impacting their growth, survival, and reproduction (Hutchinson et al., 1994; Murihead et al., 2006).

Plastic particles smaller than 5mm diameter are identifies as microplastics. European Marine Strategy Framework Directive (MSFD) posed variation relegations to prevent this concern. MPs enter the environment either by released directly into environment in small form because of personal care & cleaning products or released because of degradation of larger plastic particles. These are termed as primary and secondary microplastics respectively. Minute size and low density enable microplastics to be transported over long distances, causing to widespread distribution across the globe (Cozar et al., 2017; Barboza et al., 2019).

Traces of microplastics in the digestive tracts of economically valuable aquatic species leads a concern on the human welfare (Fossi et al. 2018). Aquatic organisms in water columns like filter feeders, suspension feeders and detritus feeders have evidence to consume plastic particles which results in the accumulation in gastrointestinal tract and finally reaches the human level (Lusher et al., 2015).

The South Asian subcontinent and nearby countries located along the Arabian Sea contribute significantly to the amount of discarded synthetic waste in the region, producing around 50,000 pieces on the coast. The ingestion of microplastics by marine fish has received much attention in India, with numerous amounts found in the range of 15 to 75 particles per individual of the *Carassius carassius* species (Vaid et al., 2021). The highest levels of microplastics along the southeastern coast of India were recorded in the coastal areas near the river mouths (Karthik et al., 2018; Robin et al., 2020). Small synthetic particles varying in coloration, shape, and material have been observed to accumulate in groups in nature (Li et al., 2021). These particles are likely scattered extensively throughout shoreline regions (Karthik et al., 2018; Robin et al., 2020). Microscopic surface dwellers to apex predators transport tiny plastic fragments. Crucially, such contaminants within seafood escalate public health risks via dietary intake (L.G.A. Barboza et al., 2018 and L.G.A. Barboza et al., 2020). Environmental pollutants, including synthetic textile fibers (Savoca et al., 2019), exhibit diverse physical traits that evolve over time (Andrady, 2017). These shifting flow shows how microplastics interact with chemicals (Hahladakis et al., 2018) and impact biological systems (Barboza et al., 2018a), especially as they degrade into hazardous nanoplastics (Rahman et al., 2021).

2. MATERIALS AND METHODS

2.1 Topography & Taxonomic Entities

Located in northeastern Andhra Pradesh along the Bay of Bengal, Visakhapatnam features a 130-km coastline that serves as a vital economic and ecological hub. The sea line is area for natural livelihood along with its commercial area. This leads to release of domestic sewages and industrial wastes into the sea (Satyanarayana et al. 1987, 1992; Pragnya et al. 2020). The influence of domestic, industrial, and urban sewage naturally enters the coastal waters. It may affect the physical and chemical characteristics of the coastal waters, and also increase the level of pollutants, mainly microplastics, in the coastal waters. The species *Stolephorus commersonnii* (Lacepede 1803) and *Trichurus lepturus (Linnaeus 1758)* are opted because of their geographic distribution and commercial exploitation. The local people of Visakhapatnam mostly consumed these fish.

2.2 Target Taxa

This research examined 130 specimens sourced directly from local fishers immediately following their harvest. Each individual was collected from a specific maritime zone delineated by the following coordinates: *Trichurus lepturus* is primarily found in the benthic zone, specifically in coastal and inner lagoon reefs. You'll typically find it in quiet, low-depth spots with sandy or muddy bottoms, frequently tucked away in underwater meadows or seaweed patches., at depths ranging from upto 200 meters. Anchovies primarily inhabit the epipelagic zone, also known as the sunlight zone, which extends from the ocean surface down to about 10 to 30 meters. They are typically found in coastal pelagic zones, often within 30 kilometres of the shore, and prefer areas with coastal upwelling. Anchovies were collected with Purse Seining, Trawl Nets, Lift Nets, Hook and Line (Sabiki Rig), and Beach Seining. Indian goat fish were collected with a Gill Net, Handlines, Hook-and-Line, Fishing Trawling, Seine Nets, Barrier Net Fishing.

The ethical guidelines and rules for Safeguard of Specimens in for scientific research in Portugal & Europe were followed when handling live fish, with the exception of chemical anaesthetics, which were not employed. Following capture, fish were quickly cooled under cold-induced anaesthesia to minimize Adverse effects during transportation and Shielding specimens from environmental plastic infiltration. speedy cooling has been used to sacrifice fish as a human tradition since it causes speedy death with less stress than some chemical-based methods (Wilson et al., 2009).

2.3 Sample preparation:

The sample preparation workflow included recovering particles from biological specimens, characterizing and identifying particle types, weighing the samples, and collecting and dissecting biological material.
For each fish, the total length (hereafter referred to as length) and total body mass (wet weight) were measured and documented. The gastrointestinal tract (GT), gills, and muscle tissues were then carefully separated from each specimen on to the ice. Subsequently, each tissue type was weighed separately and stored at −20 °C for further analysis of plastic particles. The number of samples analysed from gills, muscle, and gastrointestinal tract is irrespective of the total fish examined, which totals overall 130 samples (110 anchovies and 20 Indian ribbon fish). Samples with no plastic particles were considered as plastic free with reference to Barboza et al..

2.4 Extraction, separation, and characterization of plastic particles

The protocol for plastic recovery was based on the procedures outlined by the National Oceanic and Atmospheric Administration, with minor modifications. In brief, a 4 M KOH solution was prepared using distilled water, and an amount proportional to 5 g of biological tissue was added to each sample to facilitate the digestion of organic matter. The mixture was stirred for 1 hour at 350 rotations per minute (RPM) with a magnetic stirrer. After 1 hour, add 30% H_2O_2 to each sample, spin it again for 30 minutes. Keep all the samples at room temperature for 2 hours. All samples were examined under a stereomicroscope, and images were captured for each detected particle. Transfer the samples into the mesh, i.e., 45µ sieve, using the squirt bottle, and ensure that the particles are from the sieves. For the process of wet peroxide oxidation, add 0.05M $FeSO_4$ solution and 30% of H_2O_2. After that, samples are transmitted for the process of sieving to collect the microplastic particles at the edge of the sieve using a squirt bottle. Place the samples in a desiccator for 1 day to remove the moisture content.
Each filtered sample was transferred into a covered glass Petri dish and dried on a hot plate at 75 °C for approximately 1–2 hours. To investigate the type of polymer, we used FTIR spectroscopy. FTIR spectra record the microplastic particles. Analysis was conducted using a Bruker HYPERION 3000 FTIR microscope coupled to a Bruker TENSOR 27 spectrometer. Spectra were acquired in transmission mode as the average of 15 scans over 3850–900 cm^{-1}, with a resolution of 4 cm^{-1} and a 6 mm aperture. The polymer composition of particles was determined by matching spectra with a custom-built library in OPUS 7.0. Approximately 70% of the recovered particles were further analysed using FT-IR to confirm their plastic nature and identify polymer types. Particles were categorized by morphology into fibres (elongated), fragments (irregular), and pellets (spherical or ovoid), following Barboza et al.. They were also classified based on colour (e.g., white, transparent, blue, black, red, green, among others) and size as microplastics (100–4999 µm), mesoplastics (5000–9999 µm), or macroplastics (≥10,000 µm).

2.5 Quality control:

Stringent measures were implemented throughout the procedure to minimize external and cross-contamination, following Barboza et al.. All steps were performed in controlled, pre-cleaned environments with restricted access, and all equipment was thoroughly rinsed three times with distilled water and dried prior to use. Researchers wore 100% cotton lab coats and nitrile gloves, and all materials were either sterile or thoroughly pre-cleaned. Distilled water was used at every stage, including for rinsing equipment and dissection tools. Because of the inert nature glass and stainless steel (SS) instruments are used all the procedures. The samples were protected by covering whenever not being used, procedural blanks were incorporated into the process, and airborne contaminants were determined via filter exposure studies, adhering to standard procedures (e.g., Bessa et al.; Barboza et al.; Capillo et al.).

2.6 Data analysis:

Statistical analyses were conducted using IBM SPSS Statistical database for Windows. In each species microplastic occurrence was expressed as the percentage of affected individuals. A one-way ANOVA was applied to assess the relationship between fish weight and microplastic abundance. The Kruskal–Walli's test was used to evaluate differences in microplastic abundance among gastrointestinal tract, gill, and tissue samples, as well as across habitat types. Statistical significance was set at $p < 0.05$. Additionally, Spearman's rank correlation coefficient was used to examine the association between microplastic abundance and habitat type.

3. RESULTS

3.1 The abundance of microplastics in fish samples:

Despite the GIT always having the greatest plastic burden, the existence of microplastics in the muscles of fish indicated that the problem cannot be ignored. Overall, when both the GIT and fish muscle samples were taken into account, a highly negative correlation coefficient ($R^2 = 0.99$, $n = 24$, $p < 0.001$) existed between the average weight of the fish and the average number of microplastics per individual. The inverse correlation ($R^2 = 0.44$, $n = 24$, $p < 0.001$) between microplastic concentration and maximum depth at which the species lives was also evident. Based on habitat, the analysed fish were categorized into pelagic-neritic and demersal groups. No statistically significant difference in the mean number of microplastics per individual was found between these habitat types (Mann–Whitney test, $n = 22$, $p = 0.083$).

Figure 1-Collected fish samples from the study site: Representative individuals of *Trichiurus lepturus* and *Stolephorus commersonii* collected from Visakhapatnam Harbour prior to laboratory processing.

3.2 Size of microplastics:

From a total of 0.5 mm to >1 mm sized plastics 85% are microplastics from the samples. Size distribution varied with different tissues, where 1–2.5 mm in gills, 1.5–2 mm in gastrointestinal tract, and 3–4.5 mm in muscle tissue. The recovered particles on the basis of morphology can be categorized into fibres, fragments, foams, and beads. Fibres are dominantly identified in all samples. Fibres present for 79.8%, then followed by fragments (11.4%) and foams (8.8%), while beads are under particles of small proportion.

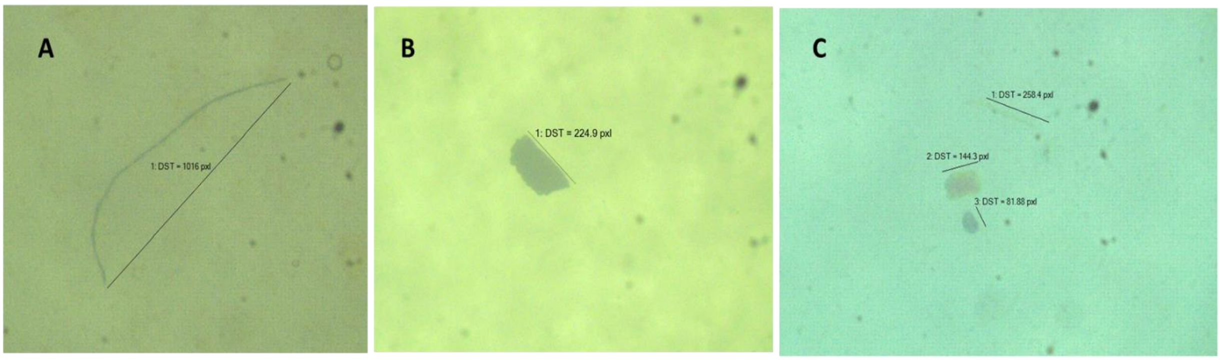
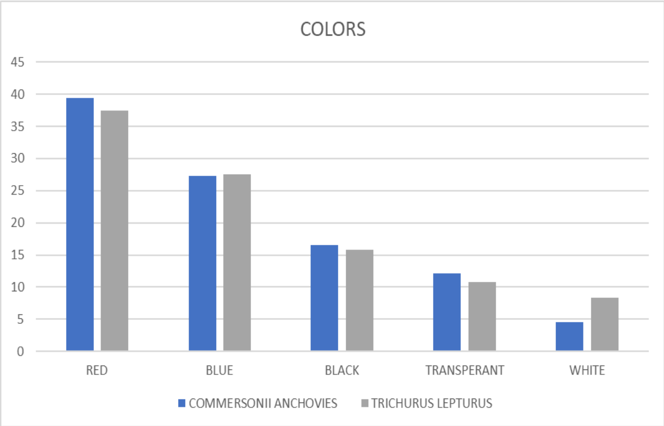


Figure 2. Morphological characterization of microplastics under microscope: (A) Stelophorus commersonie, gut samplemicroplastics showing irregular morphologywith measuredsize of ~1016 px.(B) Stelophorus commersonie tissue sample-Fibre-type microplastic exhibiting elongatedmorphology with a measured lengths of ~224.9px.(C) Trichurus lepturus, gill sample-Irregularfragment particle with a measured sizes of~258.4 px, 144.3 px, and 81.88 px.

3.3 Colour and shape of microplastics in fish:

Identified seven colours of microplastics are - red, transparent, black, blue, green, yellow, and white. Red (57%) and Blue (35%) are prevalently found while other contribute as follow - black (25%), transparent (17%), white (10%), green (7%), and yellow (5%). As mentioned above MP's were categorized into fibres, fragments, and foams based on their morphology and the classification was based on morphology of the particle isolated.



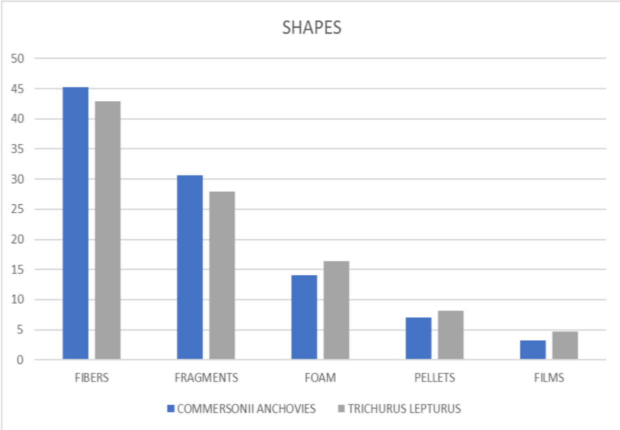


Fig. 3: Microplastic distribution inrelation to color and morphology: Red is the dominant among the both species *Stolephorus commersonii* and *Trichiurus lepturus*, blue, black, clear, and white are next to it. The predominant type based on morphology was fibres followed by fragments, foam, pellets, and films.

3.4 Identification of microplastics using μ-FTIR:

With μ-FTIR a total of 30 isolated particles were confirmed as microplastics, providing the basis for the identification of polymer composition. Among the most common polymers polyamide, PET, polyester, polyethylene, polyacrylate, and polypropylene falls in place. With 64.21% polyamide and polyethylene terephthalate (PET) stand out as dominant ones, together comprising of the identified microplastics. Polyester (24%), polyethylene (15%), polyacrylate (10%), and polypropylene (7%) were other polymers detected.

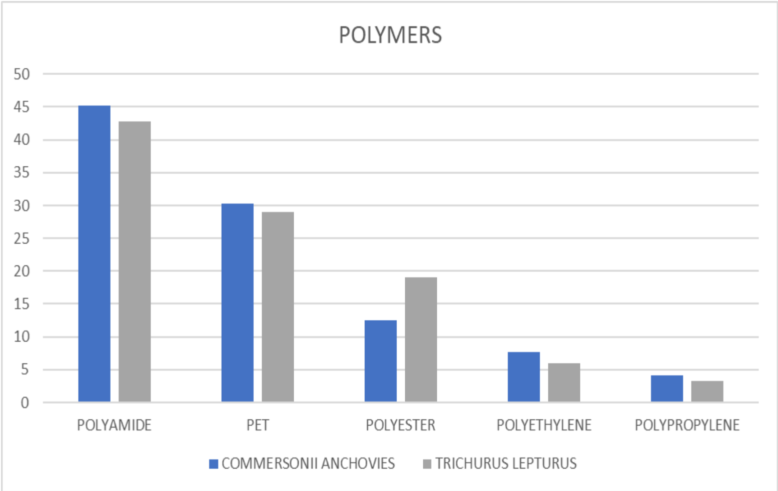


Figure 4: Composition of polymers in microplastics.

Polyamide and PET were major polymers detected in *Stolephorus commersonii* and *Trichiurus lepturus*, with polyester, polyethylene, and polypropylene following. Similar polymer compositions among species suggest that the same sources contributed to the formation of microplastics, including synthetic materials from fishing operations.

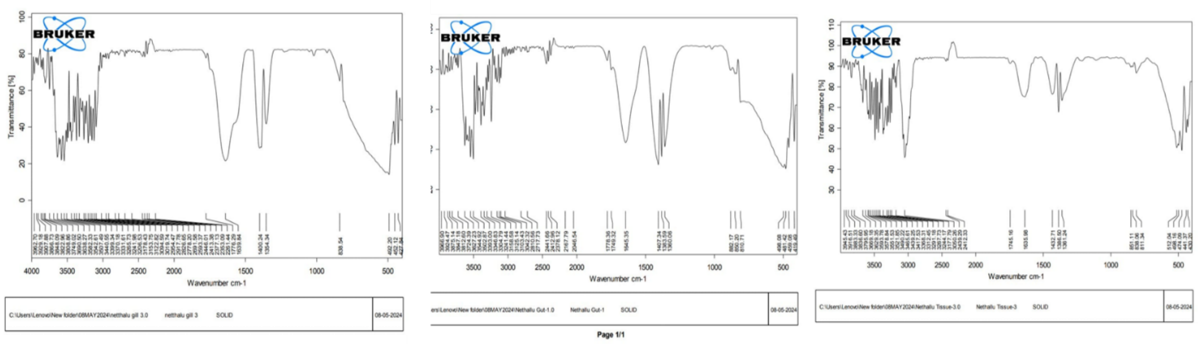


Figure 5. FTIR spectra of representative microplastic particles: FTIR spectra obtained from microplastics isolated from gill, gastrointestinal tract, and tissue samples show characteristic absorption peaks in regions corresponding to functional groups such as C=O (~1700 cm⁻¹), C–H (~2800–3000 cm⁻¹), and C–O (~1000–1300 cm⁻¹). These spectral features confirm the presence of synthetic polymeric materials, consistent with polymers such as polyamide, PET, and polyethylene.

Species	Tissue	Key Peaks (cm⁻¹)	Functional Groups	Identified Polymer (Likely)
Anchovy	Gill	~1700, ~2900, ~1200	C=O, C–H, C–O	PET / Polyester
Anchovy	GIT	~1650, ~3300, ~1540	N–H, amide	Polyamide (Nylon)
Anchovy	Tissue	~2915, ~2845	C–H stretch	Polyethylene (PE)
Ribbonfish	Gill	~1777, ~1410, ~1335	Ester, C–H	PET / Polyester
Ribbonfish	GIT	~1631, ~1406	Amide / C–H	Polyamide / PP (needs confirmation)
Ribbonfish	Tissue	~1717, ~1407, ~1335	Ester groups	PET / Polyester

Table 1. FTIR-based identification of microplastics from fish samples (Source: Authors)

DISCUSSION

Fish collected from Visakhapatnam Harbour contained a wide variety of plastic particles, including five polymer types, five colour groups, and six size classes. Even with this diversity, microplastics were by far the most common, accounting for 97% of all particles correlating with Barboza et al. 2020, while fibres alone represented 84% of the total population. Most particles measured between 0.5 and 4.5 mm, which is similar to ranges reported from other marine regions such as the English Channel and the North and Baltic Seas. Fibres made mainly of polyamide, polyethylene, and PET were dominant, with red, blue, and black particles appearing most frequently, indicating widespread plastic contamination in the marine environment. To reduce the effect of differences in fish size and feeding behaviour, plastic abundance was normalised to sample weight before comparisons were made. Previous studies examining the relationship between fish length and microplastic load have shown mixed results, with some reporting positive, negative, or no correlations at all. Such variation may arise from differences in habitat, feeding patterns, environmental contamination levels, life stage, and even the methods used for analysis. Reports by Barboza et al. (2020) and Su et al. (2019) present study recorded a very high prevalence of microplastics (94%) with an average of 8 ± 7 particles per fish, suggesting considerable contamination in the harbour ecosystem and significant exposure of commercially important species such as Indian goatfish and anchovies. Filter feeding behaviour in Anchovies is reported by Ribeiro et al. (2020) and Tanaka et al.

(2006). Likely sources include sewage discharge, urban runoff, industrial waste, fishing-related activities, tourism, river inflow, and agricultural runoff.
Karami et al. (2017) and Akhbarizadeh et al. (2018) discussed the translocation of microplastics into different tissues. Among all tissues examined, the gastrointestinal tract showed the highest accumulation of plastic particles. Ribbonfish and anchovies in particular contained a greater variety of colours and particle sizes within the gut, indicating exposure through both direct ingestion from surrounding waters and indirect uptake through prey organisms. Feeding strategy also appears to influence accumulation. Anchovies, being planktivorous filter feeders with specialised gill rakers, are more likely to encounter suspended microplastics because these particles are similar in size to their natural prey such as copepods. This increases the possibility of trophic transfer through the food chain. Plastics were also detected in the gills, where fibres were more abundant than fragments and particle sizes were generally smaller compared to those in the gut. Their retention in gill tissues suggests continuous exposure during respiration and may lead to tissue damage, reduced respiratory efficiency, and higher susceptibility to infections. In addition, the detection of microplastics in muscle tissue confirms that some particles are capable of moving beyond the digestive tract and gills into internal tissues. Fibres were again dominant, possibly because of their greater environmental abundance and easier uptake. Although smaller particles are known to move more easily across biological barriers, larger particles may also enter tissues through lesions after prolonged exposure. The occurrence of microplastics in edible muscle tissue raises concerns regarding seafood safety and possible human exposure through consumption of contaminated fish as discussed by Desforges et al., 2015; Talley et al., 2020.

CONCLUSION

This study provides novel insight into the occurrence, distribution, and characteristics of microplastics (MPs) in commercially important fish from Visakhapatnam Harbour. MPs were detected across all examined tissues, with the gastrointestinal tract showing the highest accumulation, followed by gills and muscle. Fibres were the predominant form, mainly within the 0.5–4.5 mm size range, and key polymers included polyamide, polyethylene terephthalate (PET), and polyethylene, indicating largely synthetic and fishing-related sources. Variations in microplastics abundance among species and tissues suggest the influence of feeding behaviour and habitat, with evidence of both direct ingestion and trophic transfer. The presence of MPs in edible tissues highlights potential human exposure through seafood and confirms their integration into marine food webs. These findings emphasize the need for taking care and proper disposal of plastic wastes and treatment.

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