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Microplastics contamination in Yellowfin tuna (*Thunnus albacares)* from the Indian Ocean

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Abstract: Yellowfin tuna (*Thunnus albacares*), a major export fin fish species in the Indian Ocean, is a vital indicator of ocean health due to its migratory behaviour and exposure to pollution. Detecting microplastics (MPs) in yellowfin tuna can aid in conserving marine ecosystems and safeguarding tuna-dependent communities. The study assessed the sources and concentrations of microplastics in Indian Ocean yellowfin tuna. Thirty-five randomly selected fish from commercial catches were examined. MPs in their gastrointestinal tracts (GITs) were extracted using a modified potassium hydroxide (KOH) digestion protocol. Visual identification under a microscope recorded the number, shape, size and colour of MPs in each sample. Fourier transform infrared (FTIR) spectroscopy was used to identify polymer types. The average weight of the fish was 36.87±8.20 kg, and the average fork length was 131.54±9.36 cm, indicating that they were mature. MPs Ingestion rate was 100% with the mean microplastic particles per individual was 2.77 ± 1.81 items/individual. Fibres constituted 91%, and fragments comprised 6% of the MPs, with Polyethylene (PE) being the predominant type at 56%, followed by Nylon at 25%. Particle size ranged from 0.054 mm to 1.494 mm. This study demonstrates significant MP contamination in the gastrointestinal tracts of yellowfin tuna, and highlights the need for further investigations using additional samples that account for seasonal and geographical variations in catches.

Keywords: Yellowfin tuna, Microplastics, Contamination, Gastrointestinal tracts, Indian Ocean

INTRODUCTION

The Indian Ocean Yellowfin tuna (*Thunnus albacares*) is an important export finfish species and a significant contributor to the export revenue of countries in the Indian Ocean region. The geographical location in the Indian Ocean contributes to its prominence in tuna fisheries. The countries in the region are actively engaged in both domestic consumption and international trade of tuna products; thus, the yellowfin tuna industry plays a significant role in domestic markets as well as in global exports (Gestsson et al., 2010).
The yellowfin tuna (*Thunnus albacares*) is a highly migratory species found in the Indian Ocean, exhibiting a wide distribution across tropical and subtropical waters and stands out as an economically and ecologically significant species. Yellowfin tuna are opportunistic predators, preying on a diverse array of fish, squid, and crustaceans (Kumar & Ghosh, 2020). In the Indian Ocean, yellowfin tuna often undertake extensive migrations between regions, either as trophic migrations for feeding or as genetic (reproductive) migrations.The Indian Ocean serves as both a critical foraging ground and a spawning area for yellowfin tuna. The rich biodiversity and productivity of the Indian Ocean provide abundant prey resources, influencing the feeding behaviour and growth of yellowfin tuna populations. , The Indian Ocean is particularly significant for Yellowfin tuna, serving both as a critical habitat and a major fishing ground for this species. Yellowfin tuna, being a large migratory fish, serves as a significant marker of ocean health due to its role as a top predator exposed to various anthropogenic influences across a broad geographical scale and from diverse sources.

Microplastics are plastic particles less than 5 millimeters in size that have become pervasive pollutants in marine environments. They originate from two primary sources: primary microplastics, which are intentionally manufactured at microscopic sizes for use in products like cosmetics and industrial abrasives, and secondary microplastics, which result from the degradation of larger plastic debris through environmental processes such as UV radiation and mechanical abrasion (Cole et al., 2011).

Microplastics have become a widespread contaminant in the marine environment, posing significant threats to marine biodiversity and ecosystem health. These tiny plastic particles are found in seawater, sediments, and even deep-sea trenches, affecting a wide range of marine organisms. Filter-feeding species, such as mussels and plankton, inadvertently ingest microplastics, leading to bioaccumulation and potential transfer up the food chain (Lusher et al., 2017). Additionally, microplastics act as carriers for toxic pollutants, including persistent organic pollutants (POPs) and heavy metals, which can have long-term ecological and health consequences (Guzzetti et al., 2018). Marine ecosystems, including coral reefs, mangroves, and estuaries, are particularly vulnerable to microplastic pollution due to their role as biodiversity hotspots and nurseries for many marine species (Kershaw, 2015). The accumulation of microplastics in marine sediments further exacerbates environmental degradation by altering microbial communities and sediment composition (Browne et al., 2007). In particular, plastic waste and chemical contaminants pose a significant threat to the health and well-being of these pelagic fish. The rise of microplastic pollution poses a considerable danger to marine ecosystems, with fish in coastal environments being vulnerable to the ingestion of these microplastic particles. Previous studies have shown various negative impacts, including changes in growth rate, decreased feeding and weight, disruption of the endocrine system, organ transfer, inflammation, decline in reproductive capabilities, and liver toxicity and pathology (Browne et al., 2013; Naidoo & Glassom, 2019; Rochman et al., 2014). Also, MPs act as dual-nature vectors, capable of both sorption and desorption of organic and inorganic contaminants. The adsorbed contaminants pose a significant harmful impact on marine organisms when MPs are ingested across various trophic levels (Cho et al., 2019; Scopetani et al., 2018). Numerous studies worldwide have investigated the ingestion of MPs by economically and ecologically important marine species. Understanding the extent of microplastic pollution in these species is crucial for mitigating potential adverse effects on human health and ensuring the safety and sustainability of marine ecosystems.

This study aimed to evaluate the level of microplastics present in the GI tract of yellowfin tuna captured from the Indian Ocean. By identifying the sources and concentrations of microplastics in gastrointestinal tract of yellowfin tuna, evidence-based interventions can be facilitated through the management of the fisheries industry.

METHODOLOGY

Sampling

A total of 35 individual fish from the commercial catches were collected from Sri Lanka. The total weight and the fork length of each fish were measured. The Gastro-Intestinal Tract (GIT) was removed and rinsed with deionised water (18.2 MΩ cm^{-1}) to prevent contamination from outer walls. The wet weights (to the nearest 0.1 g) of the gut were recorded by using an analytical balance (Radwag AS R2 PLUS). The intestinal lengths were measured manually and recorded to the nearest 0.1 cm. Subsequently, the samples were transferred into glass containers.

Extraction and Identification of Microplastics

GIT samples were digested using the Potassium hydroxide (KOH) (analytical grade, Fisher Scientific, UK) digestion protocol with minor modifications to extract MPs. A 10% KOH solution was added for digestion, and 10% Tween-20 was used as a surfactant. The glass bottles were then covered with aluminium foil and placed in a laboratory oven at 60°C for 24 hours until a clear solution was formed. MPs in the digested solution were separated using the density separation method with NaCl (1.2 g/cm^3). After allowing the samples to cool at room temperature for 6 hours, the supernatant of the solution was filtered onto a Whatman glass fibre filter with a pore size of 1µm. The filter papers were then air-dried at room temperature. Once the sample is filtered, the filter paper is stored in a labelled petri dish until examination under a digital stereomicroscope and Fourier transform infrared (FTIR) spectroscopy. The filtered particles are first observed under the microscope at 40× magnification. The potential MPs are visually identified and characterised by their size, colour, and shape, and their polymer properties are confirmed based on transparency, brittleness, and softness.

The absorbance for each polymer was measured using a Perkin Elmer Spotlight 200i FT-IR Microscopy System (Perkin Elmer, USA) at 100 μm^{-1}, resolution with spectra collected over the wavenumber range of 4000-450 cm^{-1}. Fourier Transform Infrared (FT-IR) spectroscopy is an analytical technique used to identify chemical substances based on their molecular vibrations. When infrared (IR) radiation interacts with a sample, certain wavelengths are absorbed while others are transmitted, producing a characteristic absorption spectrum unique to each material. This spectrum serves as a molecular fingerprint, allowing for the identification of polymers by comparing their spectral patterns to reference databases.

However, challenges arose in identifying certain polymer types, particularly for smaller microplastic particles and thin fibres, due to weak or overlapping spectral signals. To improve identification, a selection of suspected MPs (ranging in size from 2500 to 100 µm) was carefully picked from each sample under a dissecting microscope. These particles were then analysed using Attenuated Total Reflectance (ATR) mode, where they were placed onto a diamond crystal. ATR-FTIR enhances the analysis of solid and small samples by allowing infrared light to penetrate only a few micrometers into the material, minimising sample preparation requirements while ensuring reliable spectral data for polymer identification (Kim et al., 2018).

Quality assurance and quality control

To minimise the risk of external contaminants affecting the samples, non-plastic materials were used whenever possible (Cole et al., 2011). Precautions included wearing polymer-free lab coats and gloves, and keeping samples and filters covered with glass throughout the experiment. Furthermore, all equipment was cleaned with deionised water before laboratory work. To confirm the removal of plastic particles, the NaCl and KOH solutions were dissolved in deionised water and filtered prior to the experiment. After filtration, the filters were kept in glass petri dishes until analysis. Furthermore, the same procedure was also applied to blank samples without a digestive tract to determine the potential for MP contamination in the experimental area.

RESULTS AND DISCUSSION

Studying the occurrence of microplastics is crucial for understanding their impact on aquatic ecosystems and assessing the potential risks to marine life and human health. Identifying the sources of microplastic pollution, such as industrial discharge, wastewater effluents, plastic waste degradation, and fishing activities, helps in developing effective mitigation strategies.

Sample Morphometrics

This study reports the presence of microplastic particles in the GI tract of Yellowfin tuna captured from the Indian Ocean. Table 1 shows the basic meristic parameters of the sampled fish. Accordingly, the average weight was 36.87±8.20 kg.

Table 1: Basic morphometric traits of the sampled Yellowfin tuna (n=35)

Parameter	Min	Max	Avg	SD
Total Weight (Kg)	25.00	55.00	36.87	8.20
Fork Length (cm)	116.84	151.13	131.54	9.36
GIT Weight (g)	42.54	102.62	78.87	16.70
GIT Length (cm)	38.10	81.28	59.51	9.96

The average length at maturity for yellowfin tuna (*Thunnus albacares*) has been documented in various studies, with some regional variations. For instance, a study conducted along the east coast of India reported that yellowfin tuna attains sexual maturity at a fork length of 87.5 cm, corresponding to an age of approximately 1.7 years. Additionally, FishBase (2023), a comprehensive fish database, reports the length at first maturity for yellowfin tuna as 103.3 cm, with a range of 78–158 cm Accordingly, the sampled fish were mature with an average fork length of 131.54±9.36 cm. The GIT weight ranged from 42.54 g to 102.62 g with an average of 78.87±16.70 g, while the GIT length ranged from 38.10 cm to 81.28 cm with an average of 59.51±9.96 cm (Table 01).

Abundance of Microplastics

The number of microplastic particles present in the GIT ranged from 1 to 8, with the corresponding percentages detailed in Figure 01. The abundance of MPs across the fish gut samples was observed to follow a distribution with varying frequencies of particle counts. The most common occurrence was of 2 particles, accounting for 37.1% of the total samples, followed by 1 particle at 22.9%. Fewer samples contained 3 particles (17.1%), with progressively lower frequencies for 4 particles (8.6%), 7 particles (5.7%), and 5 and 6 particles (2.9% each). Only 2.9% of samples contained 8 particles. This suggests that the majority of fish gut samples contained a relatively low number of MPs, with a notable decrease in the occurrence of higher particle counts, indicating that while MPs are prevalent in the gut samples, higher contamination levels are less common. The median number of MP particles found in the gastrointestinal tract (GIT) of the fish was 2, with 25% of the fish having at most 2 MPs and 75% having up to 3 MPs. This distribution also suggests that the majority of fish contained three or fewer MPs in their digestive systems. The relatively low median value, compared to the upper range, indicates that most fish had a limited MPs burden, though a few individuals ingested significantly higher amounts. Notably, microplastic ingestion was observed in 100% of the analysed fish samples, confirming that all individuals examined had ingested MPs to some extent. A study conducted in the Southwestern Tropical Atlantic found that 100% of analysed tuna specimens had ingested microplastics, with predominant polymer types including styrene-butadiene rubber (SBR), polyamide (PA), polyethylene terephthalate (PET), and polyethylene (PE), highlighting the widespread contamination of pelagic fish species (Justino, et al., 2023).

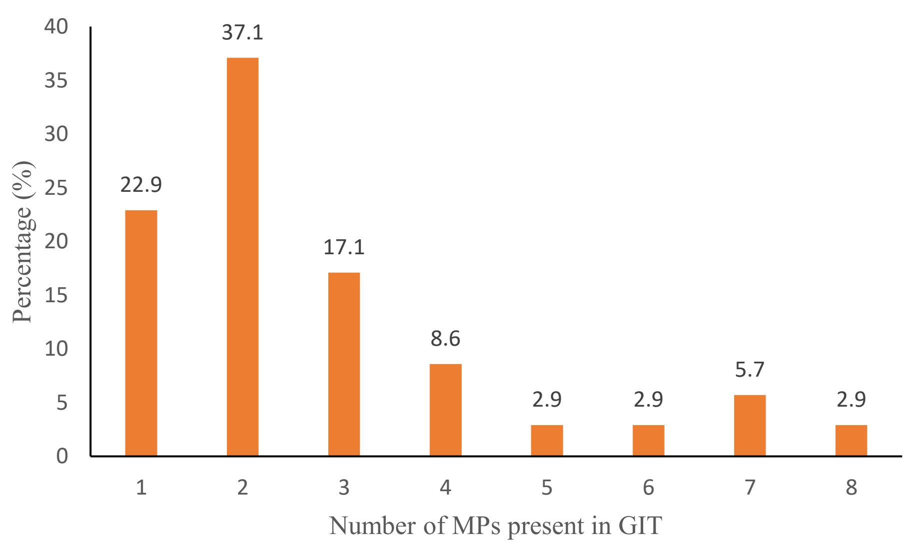


Fig 1. Percentage of microplastic particles present in the studied Yellowfin tuna.

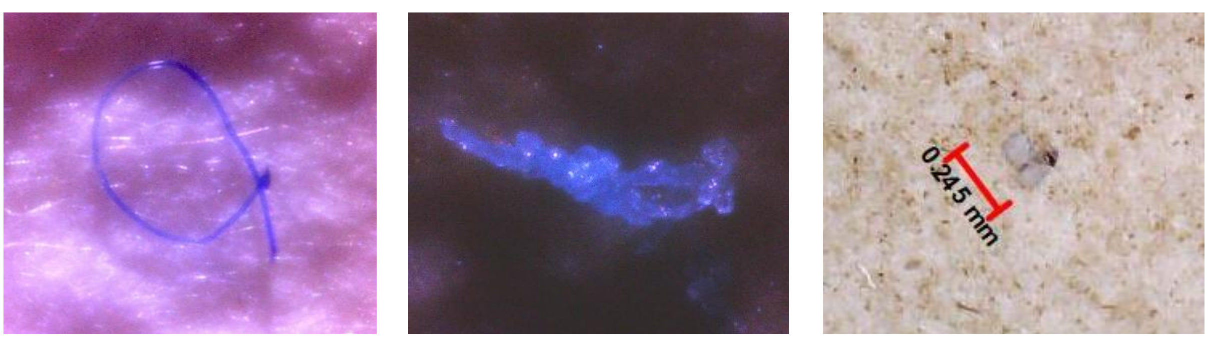
The mean Microplastic particals per individual was 2.77 ± 1.81 items per individual. The number of microplastic particles present in the GIT ranged from 1 to 8. The most frequently observed occurrence was two microplastic particles per fish, comprising 37.1% of the total samples. The average number of microplastic particles per gram of gastrointestinal tissue was 0.02±0.01 MPs/g, while the average number of microplastics per gram of whole fish body weight was 0.07±0.04 MPs/g. A study conducted in 2020 by Narmatha Sathish et al. reported that the number of microplastic particles in epipelagic and mesopelagic fishes from Tuticorin, on the southeast coast of India, ranged from 0.11 ± 0.06 to 3.64 ± 1.7 items per individual (Sathish et al., 2020). Our results also confirm these values, showing a similar range of microplastic contamination in the fish samples analysed. A study conducted in the English Channel reported an average of 1.90 ± 0.10 microplastic particles per animal (Lusher et al., 2013). Similarly, research on bogue (*Boops boops*) from the Balearic Islands reported an average of 3.75 microplastic items per fish (Nadal et al., 2016), while a study on flathead grey mullet (*Mugil cephalus*) from Durban Harbour, South Africa, found an average of 3.8 particles per individual (Naidoo et al., 2016). These findings highlight the widespread occurrence of microplastic ingestion in fish across diverse marine environments.

Characteristics of Microplastics in Yellowfin Tuna

In the study, microplastics were identified in various shapes, sizes, colours and types. The shapes of MPs in GIT samples were categorised as fibres, fragments, and films (Figure 02). Among these, fibres dominated (91%), followed by fragments (6%) and films (3%) (Figure 3B). Microplastic particles were detected, with sizes ranging from 0.054 mm to 1.494 mm. Previous studies conducted in China have found that fibre (90.74%) were the common shape among microplastics ingested by fish (Wu et al., 2020).

A study conducted on shrimps from the Negombo Lagoon, Sri Lanka, also reported that fibers were the most dominantly detected microplastics, accounting for 93%, while the remaining microplastics were identified as fragments (Lawan et al., 2024). This finding highlights the predominance of fibre contamination in aquatic organisms from Sri Lanka.

A recent study conducted on the sandy beaches of Gujarat State, India, confirmed that fibres were the most abundant type of microplastics (89.98%), followed by films (4.75%), fragments (3.36%), and foam (1.89%) (Rabari et al., 2022). The entanglement and aggregation of small MPs, particularly fibres, may hinder or prevent food ingestion by creating agglomerates or blocking organs (Ziajahromi et al., 2017). The study conducted by Kibria et al. (2022) provided a comprehensive review of the impacts of microplastic pollution on various seafood organisms and other marine biota, including oysters, mussels, fish, lobsters, sharks, and seaweeds, across 36 locations worldwide. The findings indicated that fibres were the most frequently ingested microplastic shape, with ingestion rates ranging between 33% and 99% among different seafood species. Furthermore, Sathish et al. (2020) reported that fibres accounted for 46% of the microplastics in water samples from Tuticorin, on the Southeast Coast of India, followed by fragments (25%), films (15%), and foam (14%). These findings indicate that fibre-based microplastics, likely originating from textiles, fishing gear, and other synthetic materials, dominate coastal microplastic pollution in this region. Marine organisms can be exposed to microplastic debris through various pathways, due to the widespread distribution of these particles in the seawater column (Desforges et al., 2014; Hildebrandt et al., 2022).



(a) (b) (c)

Fig 2. MPs shapes (a); Fibre; (b) Fragments, and (c) Thin film

Colour composition of Microplastics

Based on this study, six different colours of MPs were identified: black, red, blue, transparent, green, and white. Among these, black was the most dominant (59%), followed by transparent (28%), while white was the least prevalent, accounting for only 1% (Figure 3A).

According to previous studies, orange, blue, white, black, red, purple and green were the coloured polymers ingested by various seafood organisms (Kibria et al., 2022). When reviewing the colours of MPs, different studies have reported varying percentages. In the South Pacific Subtropical Gyre, black (22%), blue (18%), white (17%) and transparent (12%) were found to be the dominant colours of ingested MPs by commercial marine fish (Markic et al., 2018). In a study on small pelagic fish species such as pilchard (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*) from the Spanish Mediterranean coast, the dominant colours of ingested MPs were blue (45.8%) and transparent (20.8%) (Compa et al., 2018).

The GIT of a similar species, Skipjack Tuna, was also found to contain fibres (75%) as the predominant shape and black (76%) as the predominant colour, as reported by Lessy & Sabar (2021). These findings are consistent with the higher proportions of fibres and black microplastics observed in this study.

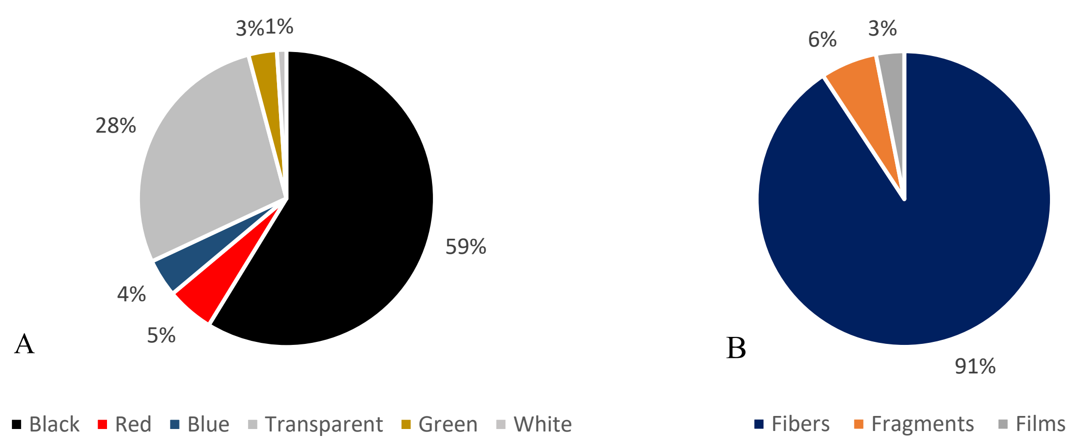


Fig 3. The proportion of MPs in fish sample based on colours (A) and types (B)

Among the 52 identified particles, Polyethylene (PE) (56%) was the predominant type, followed by Nylon (25%), Polyolefins (7%), Polycarbonate (6%), Polystyrene (4%) and Ethylene Tetrafluoroethylene (ETFE) (2%) (Figure 04).

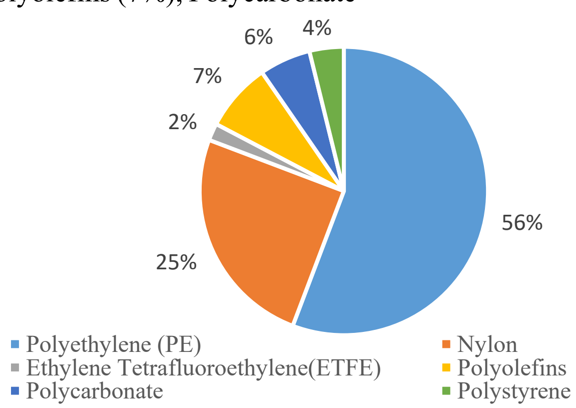


Fig 4. The Proportion of MPs in fish sample based on the identified polymer type

Polyethylene is widely used in everyday products such as plastic bags, packaging materials, and bottles, making it one of the most common plastics found in the environment. Its durability and resistance to degradation contribute to its persistence in ecosystems, where it eventually fragments into microplastics. Nylon, in contrast, is widely used in textiles, fishing nets, and ropes, which are frequently discarded or lost into marine environments. The high prevalence of these materials indicates that their widespread use and disposal contribute significantly to microplastic pollution. The large proportions of PE and Nylon in the study may reflect their extensive use in both industrial and consumer products, highlighting the need for targeted policies aimed at reducing the release of these materials into the environment.

The presence of MPs in varying sizes suggests multiple ingestion pathways, including direct consumption from seawater and trophic transfer through prey species. The tuna fish may ingest microplastics either through direct consumption by filtering seawater or indirectly by consuming prey that has already ingested plastic through trophic transfer. The entanglement and aggregation of small microplastics, particularly fibres, may hinder or prevent food ingestion by creating agglomerates or blocking organs (Ziajahromi et al., 2017).

The main source of MPs in the coastal environment is terrestrial activities, with microplastics primarily transported to the ocean via rivers and runoff passing through the country (HS et al., 2017). As ocean-based activities, offshore fishing and aquaculture operations have been identified as major sources of plastic pollution, releasing plastic into ocean basins and coastal ecosystems (Lavender & Thompson, 2014). In a previous study, the predominant polymer type identified in fish biota was polyethylene (PE), accounting for 55 % of the total microplastics detected. (Ghosh et al., 2021). This study revealed a predominance of similar types of microplastics in Yellowfin tuna species, as indicated by the proportional distribution of the identified particles. Polyethylene fibres predominantly originate from domestic laundry discharges via wastewater treatment plant effluents and from the fragmentation of fishing and recreational sailing equipment (Browne et al., 2011).

CONCLUSIONS

Fish is a vital protein source for the Sri Lankan population, making the presence of MPs in fish a significant concern. This study found MPs in all examined, fish resulting in a 100% ingestion rate, which exceeds the global average. The predominant type of MPs ingested consisted mainly of black-coloured fibres, with polyethylene and nylon being the most common polymer types.

These findings raise concerns about the potential impacts on marine biota and human health due to the consumption of contaminated seafood. As a preliminary study, this research highlights the urgent need for improved waste management strategies to mitigate microplastic pollution. Future studies should aim to identify major sources of MPs in local water bodies, assess microplastic contamination across different fish species, and determine whether MPs accumulate in specific tissues of commonly consumed fish. Additionally, research on microplastic levels in local water and sediments, along with public awareness of MPs in seafood consumption, can provide valuable insights. Investigating the role of improper plastic waste disposal in microplastic pollution will also help develop practical and effective waste management solutions. Implementing these studies will enhance understanding of microplastic pollution in Sri Lanka and support efforts to mitigate its impact on both the environment and human health.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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