

# Occurrence and characterization of microplastics in tilapia (*Oreochromis niloticus*) from Deduru Oya reservoir in Sri Lanka

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## Research Article

**Keywords:** Microplastic pollution, Freshwater fish, *Oreochromis niloticus* (Nile tilapia), Ingestion, FTIR spectroscopy, Polymer Hazard Index

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reservoir in Sri Lanka**

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## Occurrence and characterization of microplastics in tilapia (*Oreochromis niloticus*) from Deduru Oya reservoir in Sri Lanka

### Abstract

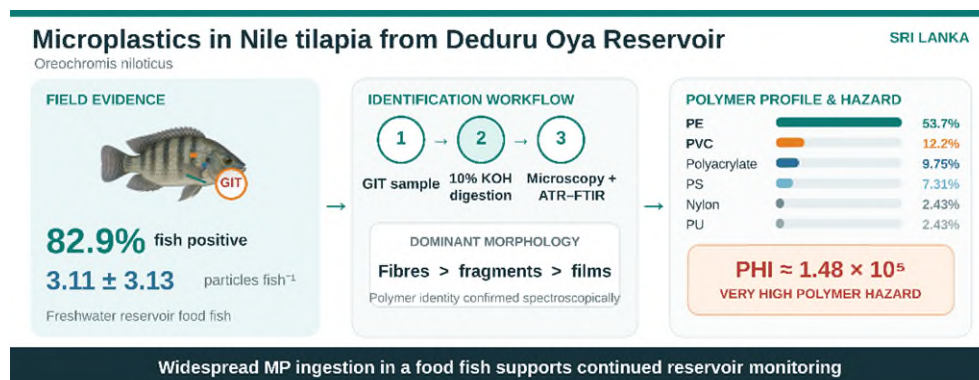
Microplastics (MPs) contamination in freshwater ecosystems has become a global environmental concern due to its widespread occurrence and potential impacts on aquatic organisms and food safety. However, information on MP ingestion by freshwater fish in Sri Lankan reservoirs remains limited. This study evaluated the characteristics, abundance, polymer composition, and potential biological implications of MPs in Nile tilapia (*Oreochromis niloticus*) collected from the Deduru Oya Reservoir, Sri Lanka. Gastrointestinal tract samples were digested using 10% KOH, and suspected MPs were identified by microscopic examination and polymer characterization using ATR-FTIR spectroscopy. MPs were detected in 82.9% of examined fish, with an average abundance of  $3.11 \pm 3.13$  particles per individual. Fibers were the dominant particle type, followed by fragments and films. Polyethylene (53.7%) was the most abundant polymer, followed by polyvinyl chloride (12.2%), polyacrylate (9.75%), polystyrene (7.31%), nylon (2.43%), and polyurethane (2.43%). The predominance of polyethylene suggests that buoyant polymers are more readily available for ingestion by tilapia within the reservoir ecosystem. The calculated Polymer Hazard Index (PHI) of approximately  $1.48 \times 10^5$  indicated a very high hazard level, suggesting that the identified MP polymers may pose substantial environmental and ecological risks. These findings provide important data on freshwater MP contamination in Sri Lanka and highlight the need for continued monitoring of MP pollution in reservoir fisheries used for human consumption and support future monitoring and management strategies.

**Keywords:** Microplastic pollution, Freshwater fish, *Oreochromis niloticus* (Nile tilapia), Ingestion, FTIR spectroscopy, Polymer Hazard Index

### Highlights

- Freshwater tilapia showed widespread ingestion of microplastics.
- Polyethylene dominated the identified microplastic polymer composition.
- Hazard assessment revealed a high polymer hazard index.
- Results highlight persistent plastic pollution in a tropical reservoir.
- Findings support improved freshwater plastic pollution management.

### Graphical abstract



## Introduction

Microplastics (MPs) are plastic particles measuring between 1  $\mu\text{m}$  and 5 mm. Due to their persistence and widespread distribution, they have become a significant environmental concern in freshwater, terrestrial, marine, and atmospheric systems (Aunurohim et al., 2024). Several studies have shown that plastic waste, including MPs, found in freshwater and marine environments primarily originates from terrestrial sources, highlighting the strong link between land and aquatic systems (Xu et al., 2018) (Parker et al., 2021) (Sefiloglu et al., 2026). MPs are composed of different polymer types produced through the polymerization of monomers (Ranjani et al., 2021). Most MPs identified in environmental samples originate from a limited group of widely used polymers, mainly polypropylene (PP), polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC) and polyethylene terephthalate (PET), which together account for nearly 90% of global plastic production (Andrady & Neal, 2009). In aquatic and coastal environments, MPs are exposed to sunlight, heat, and other environmental conditions that can accelerate their weathering and degradation, leading to the release of harmful chemical additives and associated contaminant (Schmidt et al., 2017). Hazard-ranking models based on the United Nations Globally Harmonized System (GHS) indicate that over half of plastic materials contain hazardous chemicals, emphasizing the potential ecological and biological risks of MP contamination (Lithner et al., 2011).

MPs have been widely detected in numerous fish species. In Thailand's Ubolratana Reservoir, MPs were detected in 96.4% of the examined fish, with an average of  $2.92 \pm 1.30$  particles per individual and significant variation among species (Kasamesiri, 2021). Another study investigating the translocation of MPs in Nile tilapia following dietary exposure to MPs (10–350  $\mu\text{m}$ ) for 7 days reported that MPs were detected in fewer than 50% of liver and gonad samples, while no MPs were identified in fillet tissue, suggesting limited translocation of MPs to edible muscle within the exposure period (Sefiloglu et al., 2026). In contrast, a high abundance of MPs was observed in fecal matter, indicating efficient excretion and minimal bioaccumulation in edible tissues. A study in Indonesia (Lake Ranu Grati) found MPs in Nile tilapia ( $n=25$ ) (*Oreochromis niloticus*), with 1116 particles in water, and 576 and 724 particles in flesh and GIT, respectively (Aunurohim et al., 2024). MPs were mainly fibres, with blue fibres in flesh and black fibers in GIT, while polyethylene (PE) dominated in water and polyamide (PA) in fish tissues.

Fish may ingest MPs by mistaking them for food, accidentally consuming them during feeding or water intake, or through trophic transfer within the food web (Sefiloglu et al., 2026) (Xu et al., 2018). Once ingested, MPs may cause physical and nutritional effects and can transport toxic chemicals and plastic additives, potentially impairing fish health, behaviour, habitat use, and migration (Chen et al., 2019). Exposure to MPs may also activate detoxification systems in fish due to the toxicity associated with the particles and their chemical additives. According to Mahdi et al (Banaee et al., 2025), Fish are commonly used to assess environmental pollution because they play important ecological roles and can accumulate contaminants. MP ingestion may cause intestinal blockage, reduce feeding activity, and expose fish to toxic plastic additives. In European seabass, plastic particles were reported in the gills (37%), liver (42%), muscle (45%) and gastrointestinal tract (50%) (Matias et al., 2023). Another study detected MPs in 42% of Nile tilapia fillet samples collected from a recirculating aquatic system (Sefiloglu et al., 2024). Further, previous study reported the presence of MPs in fillets of Mediterranean seafood species, including *Sardina pilchardus*, *Mullus surmuletus*, *Sparus aurata*, *Mytilus galloprovincialis* and *Solea solea*, (Ferrante et al., 2022).

Nile tilapia, a member of the Cichlidae family originating from the Nile River basin in Africa, is now widely distributed worldwide and serves as an important food source due to its high nutritional value (La Rosa et al., 2025). Tilapia species have become important components of Sri Lanka's freshwater ecosystems, contributing substantially to inland fisheries and aquaculture production while also influencing the biodiversity of aquatic habitats (Athauda, 2010). Nile tilapia are benthopelagic fish that feed within the water column and near the bottom of freshwater habitats, and previous studies have reported that pelagic fish tend to ingest higher amounts of MPs compared to demersal species (Siddique et al., 2024). Analyzing the interaction between aquatic organisms and MP pollution, which has become a significant health and environmental concern, requires examining the gastrointestinal (GI) tract of fish.

The National Plastic Waste Inventory for Sri Lanka (2024) estimates that approximately 249,037 tonnes of plastic waste are produced annually, of which only 11% is recycled, while nearly 69% is inadequately managed (Lanka, 2024). Limited recycling and improper waste disposal may therefore contribute to the accumulation of plastic debris and MPs in Sri Lankan aquatic environments.

This research examined MPs in the gastrointestinal tracts of Nile tilapia, focusing on their abundance, morphology, colour, and polymer composition. The environmental risks posed by the identified polymers were assessed using the polymer hazard scores proposed by Lithner et al. and the Polymer Hazard Index (Lithner et al., 2011). Fish were carefully dissected, and their digestive tracts were analysed to detect and quantify MPs in accordance with relevant institutional ethical guidelines. To our knowledge, this is the first investigation of MP ingestion by tilapia from the Deduru Oya Reservoir.

## Material and Methods

### Study area and sampling

The Deduru Oya Reservoir is located within the Deduru oya River Basin, the fourth-largest river basin in Sri Lanka. Situated at 07°43'06"N, 80°16'28"E and approximately 68 m above sea level, the reservoir has a storage capacity of about 75 million m<sup>3</sup> and serves as the principal reservoir within the basin (Jayasiri et al., 2022). It supplies irrigation water to a command area of approximately 1.11 x 10<sup>4</sup> ha. More than 90% of the river basin lies within the Kurunegala District, which is home to around 7.5% of Sri Lanka's population. Agriculture is a major economic activity in the region, with approximately 18% of the population engaged in farming activities. Fish samples of Tilapia were collected from local fishermen around the Deduru oya Reservoir on the same day as capture. The GI tract samples of Tilapia were collected at the sampling location around the Deduru oya Reservoir and rinsed with deionized water to minimize external contamination. The GI tract samples were then transferred into clean glass containers for subsequent analysis. In addition, the body weight (g) and total length (cm) of each fish were measured using a measuring rule and a calibrated electronic scale ( $\pm 0.10$  cm and  $\pm 0.10$  g), respectively at the sampling site. A total of 35 tilapia (*Oreochromis niloticus*) specimens were collected from Deduru Oya Reservoir, Sri Lanka. The biometric parameters of each fish were recorded prior to MP analysis. All procedures involving fish followed the relevant institutional ethical guidelines. The condition factor (K) was calculated using Equation (1) to evaluate the overall health and physical condition of the fish.

$$K = (W/L^3) \times 100$$

Where  $W$  is the body mass in grams and  $L$  is the total measurement in centimeters (Nash et al., 2006).

## Sample preparation

### Determination of proximate composition

Tilapia fish samples were analyzed for ash, moisture, crude fiber, crude fat, and crude protein, content according to AOAC (2012) procedures (International, 2023).

### Evaluation of moisture content

Moisture content was measured using a moisture analyzer following AOAC 2000 method 934.0 (International, 2023). Cleaned and dried moisture dishes were weighed, and  $5.0 \pm 0.1$  g of sample was added equally to each dish. The samples were dried in an oven at  $105^\circ\text{C}$  for 8 h, cooled in a desiccator, and reweighed. Moisture content was calculated using the equation 02.

$$\text{Moisture Content} = \frac{(\text{Initial weight} - \text{Final weight}) \times 100}{\text{Initial weight}}$$

### Determination of crude protein content

Protein content was calculated using the Kjeldahl method according to AOAC 955.04 (International, 2023). Concentrated sulfuric acid and a catalyst tablet were used for digest the approximately  $0.50 \pm 0.01$  g of sample samples. After digestion, the sample was distilled, and the released ammonia was collected in boric acid solution containing a mixed indicator and titrated with 0.1 M HCl. A blank was prepared under the same conditions without the sample. Protein content was calculated using the following equation 03.

$$\text{Total N (g/100 g)} = \frac{[14.01 \text{ g mol}^{-1} \times (V1 - V2) \times M] \times 10^{-3} \times 100\%}{W}$$

Where,

$V1$  = volume (mL) of the standard acid used to titrate the sample digest

$V2$  = volume (mL) of the standard acid used to titrate the reagent blank

$M$  = Titrant molarity ( $\text{mol dm}^{-3}$ )

$W$  = weight (g) of the sample

Equation for protein percentage:

Crude protein % of tilapia fish = Total N  $\times$  5.8

### Determination of crude fat content

Crude fat content was determined according to AOAC 2000 method 963.15 using a Soxhlet extraction apparatus. Approximately 2.00 g of moisture-free sample was placed in a thimble and extracted with 98% ethanol for 6 h.

After extraction, the solvent evaporated, and the round-bottom flask was dried at 105 °C to constant weight. Crude fat content was calculated using the following equation 04.

$$\text{Crude Fat Content} = \frac{\text{Final weight of flask} - \text{Initial weight of the flask} \times 100}{\text{Final weight of the flask}}$$

#### **Evaluation of crude fibre content**

Total fiber content was determined according to AOAC 2000 procedures. Approximately 1 g of sample was sequentially digested with 1.25% sulfuric acid and sodium hydroxide solutions, followed by filtration and washing with hot water and 95% ethanol. The residue was dried at 105 °C, weighed, and then ashed in a muffle furnace at 525 °C. Fiber content was calculated based on the loss in weight after ashing.

#### **Determination of ash content**

Total ash content was determined according to specification 923.03 of AOAC 2000. The crucible was measured, and 5.00 g of sample was placed in it. The crucible was put in the muffle furnace and subjected to a temperature of 550°C for 24 hrs. The crucible was removed from the muffle furnace and transferred to a desiccator. The crucible's final weight was measured. The total ash content was calculated using the following equation 05.

$$\text{Total Ash Content} = \frac{\text{Weight of crucible with ash} - \text{Initial weight of crucible} \times 100}{\text{Initial weight of sample}}$$

#### **Analysis of microplastic**

##### **Sample preparation for microplastic analysis**

The GI tract samples were chemically digested using an alkaline digestion method based on previously reported MP extraction protocols (Dehaut et al., 2016). The GI tract was carefully dissected by making a midline incision along the ventral surface from the throat to the anus ((ISO), 2023). The internal organs were gently exposed, and the GI tract, including the stomach and intestine, was removed. To minimize external contamination, the excised GI tract was rinsed with deionized water. The samples were then transferred into clean glass containers for subsequent analysis. All fish handling and experimental procedures were performed in accordance with the applicable institutional ethical guidelines.

The excised GI tract samples were transferred into glass containers and digested using 10% KOH (analytical grade, Fisher Scientific, UK) solution at a volume three times that of the sample. Subsequently, 500 µL of 10% Tween-20 (polysorbate) was added as a surfactant (Clara et al., 2018). Each container was covered with aluminium foil and maintained at 60 °C for 24 h to digest the organic material (Bahri et al., 2020). After digestion, distilled water was added, and the samples were left undisturbed at room temperature for 6 h to allow density separation. The upper fraction containing buoyant particles was carefully removed with a pipette and vacuum-filtered through Whatman GF/C filter paper with a pore size of 1.2 µm. The filters were then placed in covered glass petri dishes and dried at room temperature before further analysis (Kasamesiri, 2021).

## **Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) analysis**

MP particles were identified and characterised using microscopic examination followed by ATR-FTIR spectroscopy. After filtration, the filters were transferred to labelled glass petri dishes and stored until examination. Each filter was inspected under a digital stereomicroscope at 40× magnification, and suspected MPs were selected based on their size, morphology, colour, and physical appearance.

Polymer identification was carried out using a Perkin Elmer Spotlight 200i FT-IR microscopy system over the wavenumber range of 4000–450 cm<sup>-1</sup>. Selected particles (100–2500 µm) were further analysed using ATR-FTIR to improve identification accuracy, particularly for smaller fragments and fibres.

## **Polymer hazard index (PHI)**

The polymer hazard index (PHI) of MPs in samples was calculated to evaluate the potential risk associated with human consumption according to equation 06.

$$PHI = \sum (P_n \times S_n)$$

where  $P_n$  is the abundance (%) of polymer  $n$  relative to the total number of identified MPs, and  $S_n$  is the hazard score assigned to polymer  $n$ . The index was determined following the methodology described by Ranjani et al. (Ranjani et al., 2021) and Xu et al (Xu et al., 2018).

## **Statistical Analyses**

Statistical analysis was carried out using descriptive statistics to summarize the characteristics and abundance of MPs identified in the GI tracts of Tilapia. Data analysis and graphical presentations were performed using OriginPro software (Corporation, 2022).

## **Quality Control**

Fish were dissected, and the GI tracts were isolated at the reservoir using stainless steel trays. The extracted GI tracts were transferred to glass bottles and covered with aluminium foil for storage. Samples were transferred to the laboratory in an icebox. To minimize contamination, all equipment was thoroughly washed, oven-dried, and kept covered with aluminum foil prior to use, thereby reducing the risk of airborne MP contamination. To minimise contamination, non-plastic materials were used whenever possible, and all containers remained covered during sample handling. In addition, laboratory windows were kept closed, and the working area was cleaned before sample processing. After filtration, the filter papers were stored in covered glass petri dishes until analysis. To assess potential procedural contamination, three procedural blank per sampling site was prepared and processed under identical conditions.

## Results and Discussion

This study used 35 tilapia (*Oreochromis niloticus*) fish samples to analyze MP contamination. The descriptive analysis showed the morphological characteristics, the proximate analysis, and the MP contamination of tilapia (*Oreochromis niloticus*) collected from the Deduru Oya reservoir, Sri Lanka.

### Biometric characteristics of fish samples

The biometric characteristics of the sampled tilapia are summarized in table 1. The total body weight ranged from  $3.45 \times 10^2$  to  $1.83 \times 10^3$  g, with an average of  $8.82 \times 10^2 \pm 4.07 \times 10^2$  g, indicating considerable variation in fish size within the sampled population. Similarly, the GI tract weight varied between 23.1 and 108 g with a mean value of  $67.1 \pm 22.7$  g. The total length of the fish ranged from 25.0 to 46.5 cm, with an average length of  $35.2 \pm 5.83$  cm.

Table 1: Morphological characteristics of tilapia fish

|                    | Total weight (g)   | Total length (g) | Total GI Tract (cm) | Condition factor (K) |
|--------------------|--------------------|------------------|---------------------|----------------------|
| Minimum            | $3.45 \times 10^2$ | 23.1             | 25.0                | 1.14                 |
| Maximum            | $1.83 \times 10^3$ | 108              | 46.5                | 2.56                 |
| Average            | $8.82 \times 10^2$ | 67.1             | 35.2                | 1.91                 |
| Standard deviation | $4.07 \times 10^2$ | 22.7             | 5.83                | 0.24                 |

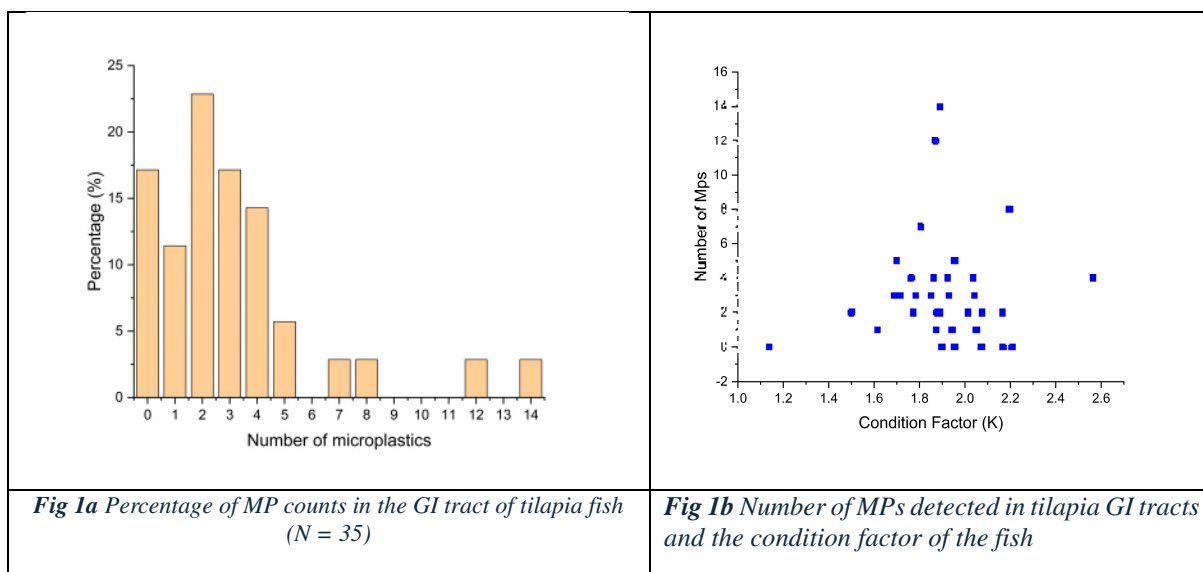
The condition factor (K) was calculated using the formula given in Eq. 01. The condition factor (K) showed values between 1.14 and 2.56, with a mean of  $1.91 \pm 0.24$ , suggesting that the majority of the fish were in good physiological condition (Ighwela & Ahmed, 2011). Overall, the observed variability in biometric parameters reflects differences in growth stages and individual conditions within the sampled tilapia population. The variation in total length can be attributed to the use of gillnets, as their mesh size selectively captures fish of different sizes. The fish samples analysed in this study were obtained from commercial catches and therefore are representative of fish commonly available for human consumption in the market.

### Proximate analysis of tilapia (*Oreochromis niloticus*)

The proximate composition of Nile tilapia samples was analysed. Moisture content was the predominant component, with a mean value of  $74.2 \pm 0.89\%$ , indicating the high-water content typical of fresh fish. Mean crude protein content was recorded at  $16.2 \pm 0.33\%$ , reflecting the nutritional significance of tilapia as a protein source. The mean crude fat content was relatively low ( $2.21 \pm 0.19\%$ ), suggesting that the samples can be classified as lean fish. Mean ash content, representing the total mineral fraction, was measured at  $1.24 \pm 0.16\%$ . Overall, the proximate composition of the tilapia samples was comparable to values previously reported for Nile tilapia and other freshwater fish species (Islam et al., 2021).

### Microplastics (MPs) analysis of tilapia fish

The analysis of MPs identified in the GI tract of tilapia fish, including their abundance, types, colours, and polymer composition.



According to Fig. 1a, a total of 109 MP particles were detected in the GI tracts of 35 tilapia fish samples, indicating the notable presence of MPs in the studied fish population. Among the analysed samples, 29 fish contained detectable MPs, resulting in an ingestion rate of 82.9%. The abundance of MPs varied considerably among individuals, ranging from 0.00 to 22.9%. The highest number of MPs recovered from a single fish GI tract sample was 14 particles/individual, while 17.1% (6 out of 35) of the samples did not contain any detectable MPs, demonstrating variability in contamination levels among the sampled fish. The highest frequency of MPs occurrence was 2 particles per sample, which was observed in 8 samples (22.9%). In addition, 3 particles were detected in 6 samples (17.1%), 4 particles in 5 samples (14.3%), and 5 particles in 2 samples (5.71%) of the analyzed fish samples. The mean MPs abundance was  $3.11 \pm 3.13$  particles/individual, with a median value of 2 particles/individual, indicating a generally low level of contamination in most samples. However, several individuals contained comparatively higher numbers of MPs. This variation may be associated with differences in feeding intensity, environmental exposure conditions, and the heterogeneous distribution of MPs within the reservoir ecosystem. The Deduru Oya Reservoir receives inflow from several tributaries, including the Deduru Oya, Maguru Oya, Kibulwana Oya, and Hakwatuna Oya, which drain catchments comprising residential, agricultural, and commercial areas. These tributaries may transport a range of contaminants, including microplastics, into the reservoir (Krishly et al., 2020). It can be a reason for the relatively high MPs ingestion rate of tilapia fish collected from Deduru Oya reservoir.

A previous study was conducted in the Negombo Lagoon, Sri Lanka located approximately 20 km north of Colombo, which receives freshwater inflows (Athukorala et al., 2024). A total of 157 specimens belonging to 18 different fish species were collected and examined. MP particles were found in the GI tracts of 85 fish, corresponding to 54.1% of the specimens examined. The average MP burden was  $1.41 \pm 2.52$  particles per gram of wet tissue. Another study conducted in the Nile River reported a total of 211 MP particles in the GI tracts of 43 fish. (Khan et al., 2020). The mean abundance of this study was recorded as  $4.90 \pm 2.43$ . In Ubolratana reservoir, Thailand, 167 fish samples from 14 freshwater species were collected, and 488 MP particles were found in the GI tract of these fish samples (Kasamesiri, 2021). The mean abundance of MPs per fish sample from Ubolratana reservoir was recorded as  $2.92 \pm 1.30$  particle/individual. When considering the mean abundance of the above

three studies, the findings showed that the level of MP contamination of tilapia fish from the Deduru Oya reservoir is considerable.

Figure 1b illustrates the relationship between the number of MPs detected in the GI tracts of tilapia and the condition factor of the fish. The results showed no clear correlation between MP abundance and fish condition factors, body weight, or body length. Although a slight positive trend was observed, the low coefficient of determination ( $R^2 = 0.501$ ) indicates a weak relationship between these parameters. Similar observations have been reported by Pitt et al. (Pitt et al., 2024), who found moderate correlations between fish total length and MP abundance in both the GI tract ( $r = 0.51$ ,  $p = 0.03$ ) and muscle tissue ( $r = 0.48$ ,  $p = 0.04$ ) (Pitt et al., 2024). Fish with both low and high condition factors contained varying numbers of MPs, suggesting that MP ingestion was not strongly influenced by the physical condition or size of the fish. These findings suggest that MP exposure is more closely associated with environmental availability and feeding intensity than with individual growth characteristics. As omnivorous, bottom-feeding fish, tilapia can ingest MPs directly from contaminated sediments and suspended particles or indirectly through trophic transfer from prey organisms. Variability in MP abundance among individuals may reflect differences in age, feeding intensity, and the spatial distribution of MPs within the reservoir. The presence of MPs in tilapia confirms plastic contamination in the reservoir and highlights the potential for transfer through the aquatic food web (Triebkorn et al., 2019).

### Microplastic abundance and distribution pattern

Morphological analysis revealed that two types of MPs, namely fibres and fragments, were predominant in the GI tracts of the sampled fish.

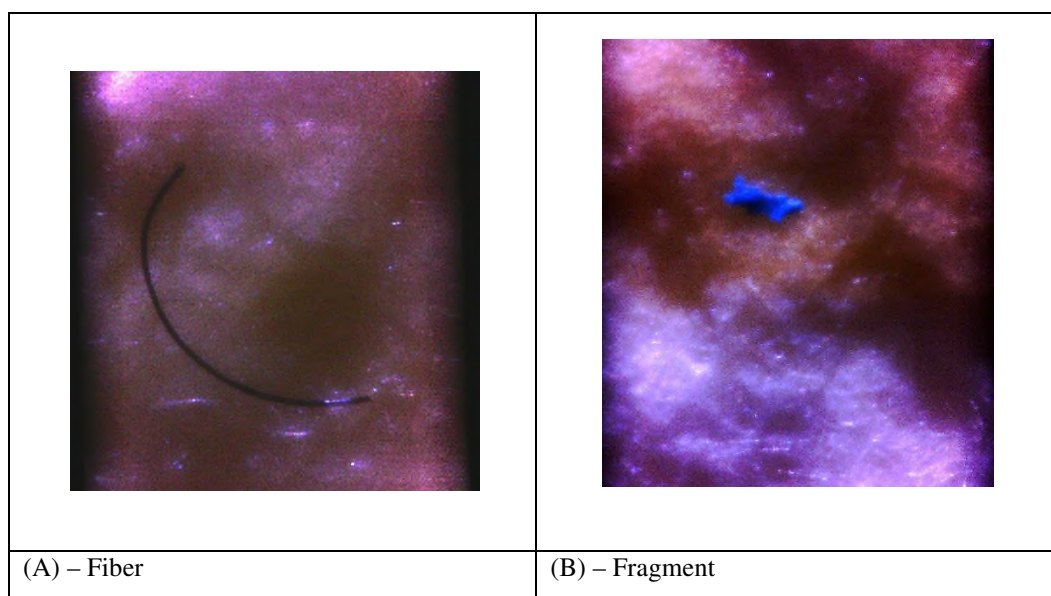


**Fig 2** Different MP types observed in the GI tract of tilapia fish by ATR–FTIR spectroscopy

As illustrated in figure 2, fibres (A) appeared as elongated, thread-like particles, whereas fragments (B) were irregular in shape and comparatively shorter. Among these, fibres were the most abundant MPs type, accounting for 90.8% of the total particles, while fragments constituted 9.21% (Figure 3a).

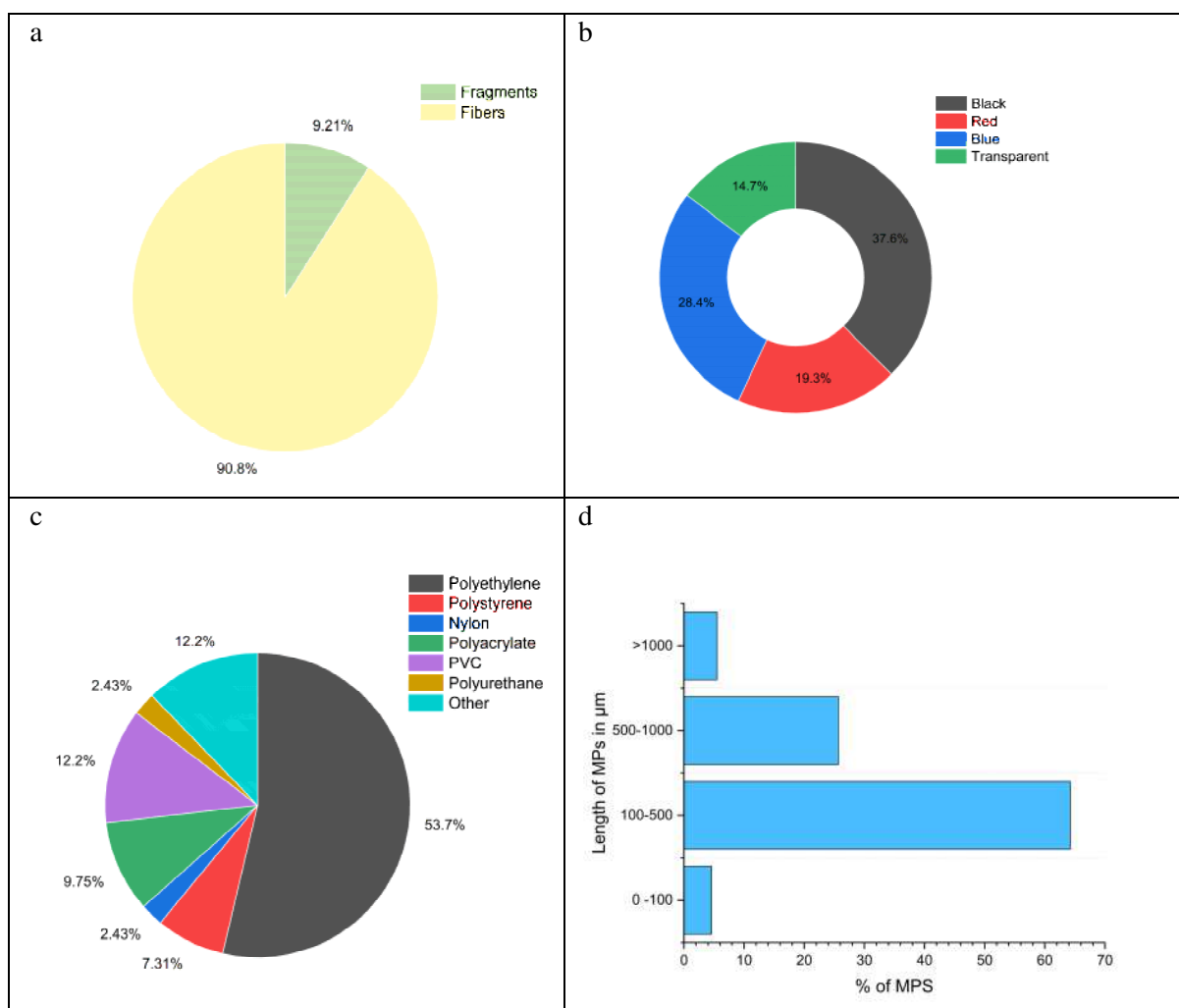


**Fig 3** Percentage of MP types of variation (a), colour variation (b), Polymer types (c) and length variation (d) of MPs observed in the GI tract of tilapia fish

Several studies have reported fibres as the dominant type of MPs in the GI tracts of fish. For instance, Kasamesiri et al. (2020) observed that fibres constituted 98.2% of MPs in fish collected from the Ubolratana Reservoir in Thailand (Kasamesiri, 2021). Similar results were observed in Bangladesh, where fibres were identified as the dominant shape of MPs, accounting for 90.95% of the total particles extracted from fish (Siddique et al., 2024). However, some variation has been reported depending on tissue type; for example, Amol Shivaji Mali et al. (Mali et al., 2025) found that fragments were predominant in the GI tract (49–68% across sites), whereas fibres were more prevalent in gills and muscle tissues (53–82%). In addition, a study by Khalida Jabeen et al. in China reported that fibres accounted for 100% of MPs in *Cyprinus carpio* and *Hemiculter bleekeri*, and 90.3% in *Muraenesox cinereus* (Jabeen et al., 2017). There are several reasons why fiber was the most abundant MP type. Fibers are smaller and elongated shaped compared to other MP types. Because of that, fibers are easily ingested by freshwater fish such as tilapia. MP fibers were commonly found in different sources, such as synthetic textiles and household items, while nylon fibers are widely used in the fishing industry (Wang et al., 2019). The high abundance of fibres suggests that fishing activities, particularly the degradation of fishing nets and ropes, may represent an important source of microplastics in the reservoir. Moreover, fiber's thin and lightweight structure allows them to remain suspended in the water column for longer periods, increasing the likelihood of ingestion by Tilapia during feeding. In addition, fibres can easily become entangled with organic matter and food particles, making them more

accessible to fish in freshwater ecosystems. Furthermore, fibres may pose greater risks compared to other MP types due to their shape and persistence. The high proportion of small particles ( $<100\text{ }\mu\text{m}$ ) is of particular concern, as such particles have the potential to cross intestinal barriers and translocate to internal organs (Lu et al., 2018). In addition, tissue-specific distribution patterns reported in the literature, with higher MP loads in the GI tract followed by gills and muscle, suggest that ingestion is the primary pathway of exposure, with possible secondary uptake occurring via respiration (Mali et al., 2025).

### **Color variation of MPs presents in GI tracts of tilapia fish**

Figure 3b illustrates the distribution of MPs colours identified in this study. Black was the dominant colour, accounting for 37.6% of the total MPs, followed by blue (28.4%) and red (19.3%), while transparent particles were the least abundant (14.7%). These findings are comparable with previous studies, although some variations in colour distribution have been reported. Nawarathna *et al.* reported that approximately half of the MPs were black and white, comprising the smallest proportion at only 1.00% in the *Thunnus albacares* (Yellowfin Tuna) commercial catch in Sri Lanka (Nawarathna et al., 2026). For instance, Jabeen et al. reported that transparent MPs were the dominant type, followed by black and blue particles ( $p < 0.01$ ) (Jabeen et al., 2017). Such differences in colour composition may be attributed to variations in local pollution sources, environmental conditions, and hydrodynamic factors influencing the distribution and availability of MPs in aquatic systems.

Black and blue MPs are frequently reported in freshwater systems and are often linked to urban runoff, tyre wear, industrial materials, synthetic textiles, and consumer products. In addition, Black particles are also commonly produced through weathering and ageing processes, where prolonged exposure to sunlight and environmental conditions causes colour fading and darkening of plastics (Martinez-Tavera et al., 2021). The higher abundance of black particles in the GI tracts of Tilapia could also be related to their resemblance to natural food items or organic debris, increasing the chance of accidental ingestion. In contrast, blue and red MPs may originate from coloured fishing nets, ropes, textiles, and consumer products (Siddique et al., 2024).

### **Size variation of MPs presents in GI tracts of tilapia fish**

MPs particle sizes ranged from  $6.70 \times 10^1\text{ }\mu\text{m}$  to  $2.04 \times 10^3\text{ }\mu\text{m}$ . Representative MPs with varying lengths are illustrated in Figure 3d, where the smallest particles were  $< 100\text{ }\mu\text{m}$  and the largest exceeded  $1000\text{ }\mu\text{m}$ . Based on size distribution (Figure 4), MPs were categorised into four classes:  $< 100\text{ }\mu\text{m}$ ,  $100 - 500\text{ }\mu\text{m}$ ,  $500 - 1000\text{ }\mu\text{m}$ , and  $>1000\text{ }\mu\text{m}$ . The  $100 - 500\text{ }\mu\text{m}$  size fraction was the most abundant, accounting for 64.2 % of the total MPs, followed by the  $500 - 1000\text{ }\mu\text{m}$  fraction at 25.7 %. Particles larger than  $1000\text{ }\mu\text{m}$  and smaller than  $100\text{ }\mu\text{m}$  represented 5.50 % and 4.50 % of the total MPs, respectively.



**Fig 4** MPs images taken from digital microscope (A - length less than 100  $\mu\text{m}$ , B - length between (100  $\mu\text{m}$  - 500  $\mu\text{m}$ ), C - length between (500  $\mu\text{m}$  – 1000  $\mu\text{m}$ ), D - length higher than 1000  $\mu\text{m}$ )

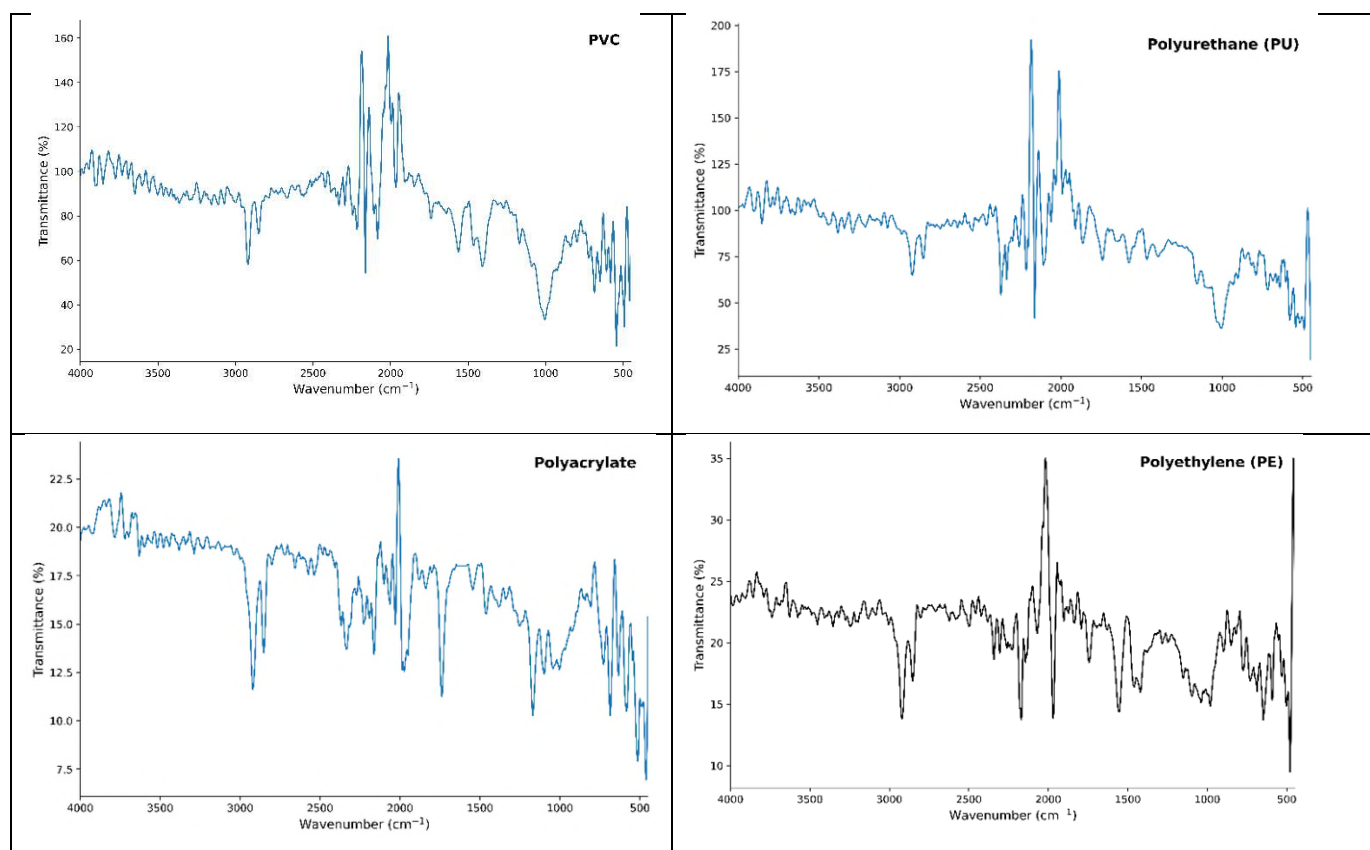
Nawarathna *et al.* observed the length of MPs ranged from  $5.0 \times 10^1 \mu\text{m}$  to  $4.2 \times 10^3 \mu\text{m}$  in *Thunnus albacares* (yellowfin tuna) from the commercial catch in Sri Lanka (Nawarathna *et al.*, 2026). Previous studies on tilapia in Bangladesh reported that MPs sized 45–1000  $\mu\text{m}$  accounted for 81% of the total particles (Siddique *et al.*, 2024), while a study from the Tallo River, Indonesia, found that 76% of MPs were smaller than 1 mm (Bahri *et al.*, 2020). A surface water studies from the Changjiang Estuary, China, reported that MPs sized 700–1000  $\mu\text{m}$  and 1–5 mm accounted for 68.4% and 26.2% of the total particles, respectively (Xu *et al.*, 2018).

In Sri Lanka's Western Province, MPs < 1000  $\mu\text{m}$  predominated in water and sediment samples from 15 sites in the Weras Ganga–Bolgoda North Lake system, while particles > 3000  $\mu\text{m}$  were virtually absent (Jayaweera *et al.*, 2025). Smaller MPs (<1000  $\mu\text{m}$ ) are commonly reported because larger plastic debris gradually fragments into smaller particles through sunlight exposure, physical abrasion, and biological activities in aquatic environments (Jayaweera *et al.*, 2025). In addition, small MPs are more easily suspended in water and are more readily ingested by fish during feeding. Their higher abundance may also be associated with analytical methods, as microscopic and spectroscopic instruments can more effectively detect and identify smaller particles during MP analysis (Xu *et al.*, 2018).

### **Polymer type variation of MPs presents in GI tracts of tilapia fish**

The composition of a MP sample was identified without any damage using the non-invasive technique of ATR-FTIR spectroscopy. This method has been widely accepted as the standard method for determining the chemical composition of different samples (Mali *et al.*, 2025), (Campanale *et al.*, 2023), (Chen *et al.*, 2019), (Xu *et al.*, 2018).

The spectra showed prominent absorption bands in the range of 2800–3000  $\text{cm}^{-1}$  and 1300–1470  $\text{cm}^{-1}$ , corresponding to C–H stretching and bending vibrations, respectively, which are characteristic of polyethylene (PE). In addition, absorption bands observed at 2800–3000  $\text{cm}^{-1}$ , 1425–1435  $\text{cm}^{-1}$ , and 600–800  $\text{cm}^{-1}$  were attributed to C–H stretching, C–H bending, and C–Cl stretching vibrations, respectively, indicating the presence of polyvinyl chloride. Furthermore, peaks identified at 2800–3000  $\text{cm}^{-1}$ , 1600–1620  $\text{cm}^{-1}$ , and 690–900  $\text{cm}^{-1}$  correspond to C–H stretching, C=C stretching, and aromatic ring vibrations, respectively, which are characteristic of polystyrene (PS). Additional absorption bands at 1630–1650  $\text{cm}^{-1}$  and 1530–1550  $\text{cm}^{-1}$  were assigned to amide I (predominantly C=O stretching) and amide II (N–H bending coupled with C–N stretching) vibrations, respectively, confirming the presence of nylon. Moreover, the occurrence of absorption bands at 2800–3000  $\text{cm}^{-1}$ , 1700–1750  $\text{cm}^{-1}$ , and 3100–3500  $\text{cm}^{-1}$ , corresponding to C–H stretching, C=O stretching, and N–H stretching vibrations, respectively, indicates the presence of polyurethane (PU). Polyacrylate was identified by characteristic absorption bands corresponding to ester carbonyl (C=O) stretching ( $\sim 1730 \text{ cm}^{-1}$ ), ester C–O–C stretching (1270–1240  $\text{cm}^{-1}$ ), C–O stretching (1190–1140  $\text{cm}^{-1}$ ), and aliphatic C–H stretching (2920–2850  $\text{cm}^{-1}$ ). The strong agreement between the sample spectra and reference polymer spectra confirms that the MPs present in the analysed tilapia samples consisted mainly of PE, PVC, polystyrene, nylon, and PU. Figure 5 shows the FTIR spectra of the particles isolated from the samples.



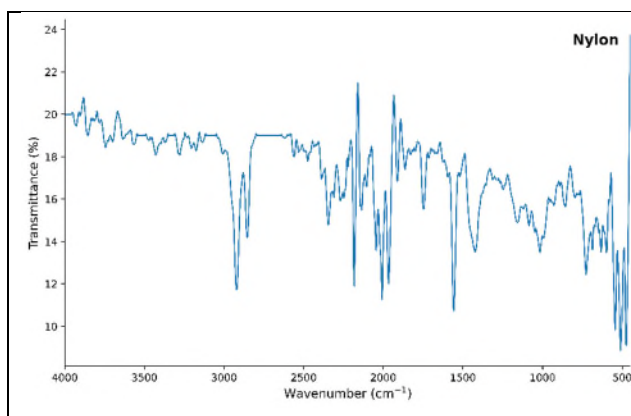


**Fig 5** FTIR spectra of the particles isolated in the samples

Based on Figure 3c, a range of polymer types was identified in the GI tracts of tilapia, indicating diverse sources of MP contamination in the study area. The dominant polymer was PE, accounting for 53.7% of the total identified MPs. The predominance of PE in the GI tracts of Tilapia may be related to its relatively low density (0.91–0.96 g/cm<sup>3</sup>) (Xu et al., 2018), which allows PE particles to remain suspended or float in the water column, making them more available for ingestion by fish. Other polymers detected included PVC (12.2%), polyacrylate (9.75%), PS (7.31%), nylon (2.43%), and PU (2.43%). In contrast, higher-density polymers such as PVC (~1.41 g/cm<sup>3</sup>), polyacrylate, PS (~1.05 g/cm<sup>3</sup>), nylon, and PU are generally more likely to settle into sediments. Tilapia are omnivorous, opportunistic feeders that may ingest microplastics from the water column, sediment-associated food, or prey organisms. Due to this, the occurrence of these polymers suggests that sediment disturbance, water movement, biofouling, and the feeding behavior of tilapia may contribute to the ingestion of both floating and sinking MPs. PE in common consumer products such as plastic bags, packaging materials, and containers, which are easily introduced into freshwater systems through improper waste disposal. Furthermore, the detection of polymers such as PVC, polyacrylate, and PS highlights the heterogeneous nature of plastic pollution in this reservoir.

A study conducted along the southern coast of Sri Lanka reported that PP and PE films, together with monofilament lines, were the dominant types of MPs identified (Bimali Koongolla et al., 2018). Another study from seafood markets across Sri Lanka found that acrylic resin (35%) and PE (24%) were the major polymer types detected in fresh fish samples (Wootton et al., 2025). Similarly, Nawarathna et al. reported PE (56%) and nylon (25%) as the predominant polymers in *Thunnus albacares* (yellowfin tuna) obtained from commercial catches in Sri Lanka (Nawarathna, 2024). Another study conducted in Bangladesh on the GI tract of tilapia reported that PE was the dominant polymer type (46.15%), followed by PVC (30.77%), PP(14.79%), and polyethylene terephthalate (PET) (8.28%) (Siddique et al., 2024). A study in the Changjiang Estuary reported that PE, PP, and PVC accounted for 82.4%, 9.10%, and 6.50% of the MPs identified in surface water samples, respectively (Xu et al., 2018). Overall, these findings indicate that different types of MPs are widely present in aquatic environments and fish species.

### **Risk assessment of polymers**

The Polymer Hazard Index (PHI) is used to assess the potential environmental risk associated with identified MP polymers based on their chemical hazard scores. The PHI was calculated using polymer hazard scores reported by Lithner et al. (Lithner et al., 2011; Xu et al., 2018) based on the chemical toxicity and environmental hazard potential of different plastic polymers (equation 06).

Table 2: Summary of hazard classifications and scores for detected MP polymers

| Polymer | Relative abundance (P <sub>n</sub> ) | Hazard Score (S <sub>n</sub> ) | Polymer Hazard Index (PHI) | Hazard Category       | Risk Category |
|---------|--------------------------------------|--------------------------------|----------------------------|-----------------------|---------------|
| PE      | 53.7                                 | 11                             | 5.91 x 10 <sup>2</sup>     | High hazard           | III           |
| PS      | 7.31                                 | 30                             | 2.19 x 10 <sup>2</sup>     | High hazard           | III           |
| Nylon   | 2.43                                 | 50                             | 1.22 x 10 <sup>2</sup>     | High hazard           | III           |
| PVC     | 12.2                                 | 10551                          | 1.29 x 10 <sup>5</sup>     | Extremely high hazard | V             |
| PU      | 2.43                                 | 7384                           | 1.79 x 10 <sup>4</sup>     | Extremely high hazard | V             |

No Hazard Score (S<sub>n</sub>) was available for polyacrylate in the hazard ranking proposed by Lithner et al., therefore, it was excluded from the PHI calculation. The PHI values were classified into different hazard levels, where values < 10 indicate low hazard, 10–100 indicate moderate hazard, 100–1000 indicate high hazard, 1000–10,000 indicate very high hazard, and values >10,000 represent extremely high hazard levels. Table 2 summaries the hazard classifications and corresponding hazard scores of the microplastic polymers detected in the analyses fish samples.

$$PHI = \sum(P_n \times S_n)$$

$$PHI \approx 1.48 \times 10^5$$

The calculated PHI value of approximately 1.48 x 10<sup>5</sup> indicates an extremely high hazard level, suggesting that the identified MP polymers may pose significant potential environmental and ecological risks. PVC accounted for 12.2 % of the identified MPs and contributed substantially to the PHI because of its high polymer hazard score. Environmental degradation of PVC may release residual vinyl chloride monomers, plasticizers, and other additives, while its surface can adsorb persistent organic pollutants, potentially increasing toxicity to aquatic organisms (Lithner et al., 2011; Xu et al., 2018). Therefore, even at moderate abundance, PVC can disproportionately increase polymer-related ecological risk. The relatively high occurrence of PVC may be associated with agricultural pipes, domestic waste disposal, fishing-related materials, and construction activities surrounding the reservoir.

### Occurrence of microplastics in fish from Sri Lanka

The summarized literature data indicate that MP contamination has been widely reported in fish species from different aquatic environments in Sri Lanka, including marine, lagoon, wetland, and freshwater ecosystems (table 3). Most studies reported the presence of MPs in both GI tracts and gills, confirming that fish are continuously exposed to MP pollution through feeding activities and water filtration processes.

Table 3: Summary of published studies on MP contamination in fish species from different aquatic environments in Sri Lanka

| Location | Species / Study | Reported MPs | Reference |
|----------|-----------------|--------------|-----------|
|----------|-----------------|--------------|-----------|

|                                                                 |                                                                                |                                                                                                                                                                              |                           |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| Commercial fish species in a natural Negombo lagoon environment | GI tracts and gills of 157 commercially important fish representing 18 species | 54.1% fish contaminated; average is $1.41 \pm 2.52$ items/g w.w. tissues                                                                                                     | (Athukorala et al., 2024) |
| Bellanwila-Attidiya Wetland, Sri Lanka.                         | GI tract and gills of common food fish                                         | 93.5 % of fish contaminated and the average abundance of MPs in the GI tract and gill, was $11.0 \pm 2.0$ items/individual and $2.0 \pm 1.0$ items/individual, respectively. | (Weerasuriya, 2023)       |
| Negombo fish market                                             | Common wild-caught seafood varieties                                           | 92% of finfish samples and 88% of shellfish samples exhibited MP contamination.                                                                                              | (Kandeyaya et al., 2023)  |
| Major fish markets associated with fishing ports in Sri Lanka   | GI tract of fresh and dried pelagic fish                                       | 82.3% had MPs and average $3.64 \pm 0.26$ particles/individual                                                                                                               | (Wootton et al., 2025)    |
| Udawalawe Reservoir, Walawe River Basin, Sri Lanka              | Gills and GI tracts of five species                                            | Gills and GI tracts containing $2.67 \pm 1.43$ particles/individual and $2.56 \pm 1.18$ particles/individual                                                                 | (Lahiru, 2025)            |
| Freshwater tilapia from Deduru oya reservoir, Sri Lanka         | GI tracts of tilapia                                                           | $3.11 \pm 3.13$ particles/fish                                                                                                                                               | This study                |

The reported abundance of MPs varied considerably among studies, which may be associated with differences in sampling locations, environmental conditions, fish species, feeding behaviour, analytical methods, and contamination levels of the studied ecosystems. In many studies, GI tracts contained higher MP abundance compared to gills, suggesting that ingestion is a major pathway of MP uptake in fish.

The available studies are mainly focused on coastal and lagoon environments, while information related to freshwater edible fish species from inland reservoirs remains limited. Therefore, the present study contributes important information on MP contamination in freshwater tilapia from Sri Lanka. The increasing occurrence of MPs reported across different aquatic environments highlights the growing concern regarding plastic pollution and its potential ecological and food safety implications.

### Microplastic accumulation in fish and food safety concerns

Several studies have been conducted to evaluate the relationship between MP ingestion and contamination in edible fish tissues. These findings indicate the widespread presence of MPs in edible fish species, raising potential food safety and human health concerns. Pitt et al. (2024) investigated killifish (*Fundulus heteroclitus*) collected from two sampling locations and used a Random Forest model to predict MPs in muscle tissues based on fish

length, sex, and GI tract plastic content (Pitt et al., 2024). In sampling location 1, the median concentration of MPS in the GI tract was 83 particles/g w.w., while muscle tissue contained a median concentration of 11 particles/g w.w. In sampling location 2, both GI tract and muscle samples showed median concentrations of 0 particles/g w.w., although the GI tract exhibited a 2.6-fold greater range compared to muscle tissue. McIlwraith et al. (2021) examined MPs in the GI tract, fillet, and liver tissues of seven species of sportfish from Lake Simcoe, Ontario, Canada (McIlwraith et al., 2021). The study reported a positive correlation between GI tract MPs and combined fillet and liver MP abundance across all species ( $R_{s(66)} = 0.29$ ,  $p = 0.015$ ). However, the observed relationship was relatively weak, suggesting that short-term concentrations of MPs in the GI tract may not directly reflect the level of MPs accumulation in fish tissues. Another study conducted on Nile tilapia (*Oreochromis niloticus*) from Lake Ranu Grati, Pasuruan, East Java, Indonesia, detected 576 MP particles in flesh tissues and 724 particles in GI tract samples from 25 fish. The study reported no significant difference in MP abundance between flesh and GI tract samples ( $p > 0.05$ ), suggesting that GI microplastic levels may not directly reflect contamination in edible tissues. In consistent findings regarding particle translocation have raised uncertainty about the ability of MPs to accumulate in other tissues (Triebkorn et al., 2019). This suggests that a high number of MPs in the fish gut does not necessarily indicate contamination of edible muscle parts, even in food fish such as tilapia. Father, Sefiloglu et al. reported that the low accumulation of MPs in liver and gonad tissues, together with the absence of MPs in fillet samples, suggested limited translocation and bioaccumulation of particles within the tested size range of 10–350  $\mu\text{m}$  (Sefiloglu et al., 2026).

The accumulation of MPs in fish may interfere with the digestive system by obstructing the GI tract, altering digestion, and reducing nutrient absorption efficiency (Banaee et al., 2025). Moreover, MPs in the digestive system might provide a misleading feeling of fullness and reduce appetite for feed among fish (Bahri et al., 2020). Furthermore, MPs may act as carriers for chemical contaminants, increasing their migration and potentially exposing fish to harmful organic and inorganic compounds (Triebkorn et al., 2019). Although the currently available findings are somewhat positive from a human food safety perspective, the increasing occurrence of MPs in fish GI tracts remains an alarming environmental concern and highlights the importance of reducing MP pollution in aquatic ecosystems. However, there is still limited understanding regarding the extent and mechanisms involved in the transport of small particles within the body.

## Conclusion

In conclusion, MP contamination was widely detected in tilapia collected from Deduru Oya Reservoir, with an ingestion rate of 82.9%, indicating that most fish had ingested MPs. The mean abundance of MPs was  $3.11 \pm 3.13$  particles per individual, while the highest number detected in a single GI tract sample was 14 particles. The predominance of the 100–500  $\mu\text{m}$  size fraction suggests that smaller MP particles are more readily available for ingestion by fish. PE represented more than half (53.7%) of the identified MPs, whereas PVC (12.2%), polyacrylate (9.75%), PS (7.31%), nylon (2.43%), and polyurethane (2.43%) occurred at lower frequencies, indicating that polymer density may influence the distribution and ingestion of MPs in the reservoir. Although some fish samples did not contain MPs, the overall results confirm the presence of considerable MP contamination in the reservoir ecosystem. Furthermore, the very high Polymer Hazard Index value ( $\sim 1.48 \times 10^5$ ) indicates that the detected polymer types may pose significant environmental and ecological risks due to their hazardous

chemical characteristics. The diversity of polymer types identified in this study indicates that tilapia in the Deduru Oya reservoir is exposed to multiple sources of plastic pollution, raising concerns about ecological impacts and potential risks to human consumers. This study provides important information on MP contamination in freshwater fish from Sri Lanka, where available data remain limited. These findings highlight the need for proper plastic waste management and continuous monitoring of freshwater ecosystems to reduce potential impacts on aquatic organisms and food safety.

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### *Statements and Declarations*

*All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.*

### *Competing Interests*

*The authors declare that they have no known financial or non-financial competing interests that could have influenced the work reported in this paper.*

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### *Author contributions*

**R.M.N.P. Rathnayake:** Supervision, Conceptualization, Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Dulanjalee Madhusa Rajapaksha:** Conceptualization, Writing – original draft, Writing – review & editing, , Methodology, Investigation, Funding acquisition, Formal analysis, Validation. **Muditha Lakshan Jayasundara:** Methodology, Writing – original thesis, Visualization, Validation, Data curation, Formal analysis. **Thiwanka Lakmali Weerakkody:** Writing – review & editing, Methodology, Project administration, Resources. **M. Senevirathne:** Conceptualization, Supervision, Writing – review & editing, Investigation.

### *Data Availability*

*The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.*

### *Ethics Approval*

The fish specimens were obtained from local fishers after being harvested for human consumption and were not collected or euthanised specifically for this study. The specimens were carefully dissected, and their gastrointestinal tracts were analysed for microplastic detection and quantification in accordance with relevant institutional guidelines. Therefore, formal animal ethics approval was not required.

#### **Declaration of generative AI and AI-assisted technologies in the manuscript preparation process**

During the preparation of this work, the authors used openAI and Grammarly to improve language and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and took(s) full responsibility for the content of the published article.

#### **Consent to Participate**

Not applicable.

#### **Consent for Publication**

Not applicable.

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