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Research Article

A Preliminary Study on Microplastics Contamination in Wild Fishes Caught from Urbanised Sepanggar River of Kota Kinabalu, Sabah

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ABSTRACT

Urban areas with high population densities generate high levels of plastic waste from human activities, potentially raising microplastic levels in riverine systems. Microplastic pollution in rivers pose serious risks to fish through ingestion, toxicity, and bioaccumulation. Nevertheless, the paucity of previous studies on fish microplastic contamination in Sabah, Malaysia highlights knowledge gaps in this area. Thus, this study aimed to provide a preliminary assessment of microplastic contamination in fish from the urbanised Sepanggar River in Kota Kinabalu, Sabah. A total of 39 fish samples were caught from the river, dissected into muscles and internal organs, and digested with 10% potassium hydroxide (KOH). Microplastics were then extracted using the density separation method in 5M sodium chloride (NaCl) and counted by shape, colour, size, and polymer type. The present study demonstrated that microplastics were detected in 77% of fish caught from the Sepanggar River, with an average of 5.28 ± 6.51 items/fish. Small-sized (97%), fragment (54%) and black colour (40%) were the most prevalent characteristics of microplastics found in fish while rayon (23%) was the most prevalent polymer type. Microplastic abundance in internal organs (3.54 ± 3.63 items/fish) was significantly higher than that in muscles (1.74 ± 5.10 items/fish). The characteristics of ingested microplastics varied significantly by fish species, most likely due to the different feeding habits and diets. This study provides the first confirmation that fish in the Sepanggar River were contaminated by microplastics from adjacent domestic and industrial activities. Improved waste management is needed to monitor and reduce long-term microplastic pollution.

Keywords: Fish; internal organs; microplastics; muscles; Sabah; tidal rivers.

INTRODUCTION

Microplastic pollution in aquatic environments has become ubiquitous in rivers and oceans. Frias & Nash (2019) defined microplastics as insoluble plastic particles with regular or irregular shapes, ranging in size from 1 μm to 5 mm, and come in two forms: primary and secondary microplastics. Primary microplastics are originally manufactured as small particles, such as resin pellets and microbeads, while secondary microplastics are a result of fragmentation of larger plastic items (Idrus et al., 2022; Kwon et al., 2022). Microplastics have been extensively documented not only in river water and sediment (Ismanto et al., 2023; Karing et al., 2023) but also in various aquatic organisms, including fish (Lestari et al., 2023). Fish are ideal representatives for studying the impacts of microplastic pollution on the riverine ecosystem because fish are mobile and inhabit diverse habitats in flowing waters, which allows comprehensive coverage of the entire river area.

Microplastics in rivers are extensively sourced from fisheries (Choong et al., 2021), direct plastic littering and domestic waste disposal (Primus & Azman, 2022), textile washing (Chen et al., 2021) and wastewater leaching (Suardy et al., 2020). These sources would determine the sizes, types, shapes and colours of microplastics in the environment. Once in the environment, the biological, chemical, and physical degradation of microplastics causes surface embrittlement and changes in their colour, elasticity, and strength allowing them to break easily and disperse widely (Syakti et al., 2018; Hwi et al., 2020). Upon their entry, microplastics remain in the water column and are mistakenly ingested by fish because they resemble the fish's natural food sources, such as small zooplankton (Ory et al., 2017). Microplastics could also settle on the bottom sediment depending on their density and surface area, where highly dense fragments and pellets usually sink to the bottom sediment while lighter fibres and films float (Choong et al., 2021; Banik et al., 2024). Once settled on the bottom sediment, these microplastics can also be accidentally ingested by demersal fish while foraging or mistaking them for prey or plankton (Kibria, 2023).

Microplastics ingested by fish expose them to toxicity, tissue damage, and starvation due to digestive tract blockage (Bhuyan, 2022). Microplastics are capable of adsorbing surrounding chemical pollutants onto their surfaces posing toxicity to fish ingesting the contaminated microplastics (Laila et al., 2020). Bioaccumulation and biomagnification of microplastics occur from constant ingestion and microplastics can be transferred to a higher trophic level in the food chain (Yagi et al., 2022). Most studies on microplastic contamination in fish have focused on assessing the risk factors of microplastic ingestion, particularly in the gastrointestinal tract (GIT) and gills (Sarijan et al., 2019; Lim et al., 2023), rather than examining the entire fish, including its tissues. To better understand bioaccumulation in natural environments, studies should also focus on fish tissue, as examining microplastic presence in all parts of the fish offers a comprehensive view of contamination. Additionally, studying microplastics in fish tissue is crucial due to the potential for human consumption, as it raises concerns about food safety if microplastics reportedly accumulate in fish tissue (Daniel et al., 2020; Jitkaew et al., 2024).

The rapid pace of new development and infrastructural changes in Kota Kinabalu, Sabah, as the main city, has pressured expanding developments into the adjacent Sepanggar Town, leading to more mismanaged plastic waste (Dusim, 2021). Since rivers are easily accessible to locals, river resources such as fish are often utilised especially when fish is among a main source of protein for Sabah locals. Recognizing the potential impact on food security and human safety from microplastic contamination in fish (Bhuyan, 2022), it is important to address the rising issue of microplastics in river fish. However, the status of microplastic contamination in these fish remains unknown due to a lack of documentation and research. Hence, this research aims to close knowledge gaps regarding microplastic contamination of fish in the Sepanggar River, representing an urbanised river in Kota Kinabalu, Sabah. The objective of this study was to collect preliminary data on the occurrence, abundance and characteristics of microplastics in wild fish caught from the river. This baseline data is crucial to serve as an early warning on food safety and security for locals, and establish a foundation for future studies for the development of monitoring, mitigation, and action plans.

MATERIALS & METHOD

Study area

Sepanggar River is located in Sepanggar, a sub-district in the West Coast Division (Kota Kinabalu District) of Sabah, Malaysia adjacent to Sepanggar Bay Container Port, Universiti Malaysia Sabah (UMS), Universiti Teknologi MARA (UiTM) Sabah, Taman Indah Permai and Kampong Rampayan. The sub-district of Sepanggar covers an area of 317 km^2 with a total population density of 1061 per km^2 and annual rainfall of 3456.6 mm recorded in 2020 (Department of Statistics Malaysia, 2023). The expansion of adjacent Kota Kinabalu pressurised the urbanisation of Sepanggar through increased development. The selection of Sepanggar River was due to its proximity to UMS for sampling and analysis in the laboratory. Fish samples were collected on 11th May 2023 during high tide in the (1) downstream and (2) upstream of the river as shown in Fig. 1. Sampling details are summarised in Table 1.

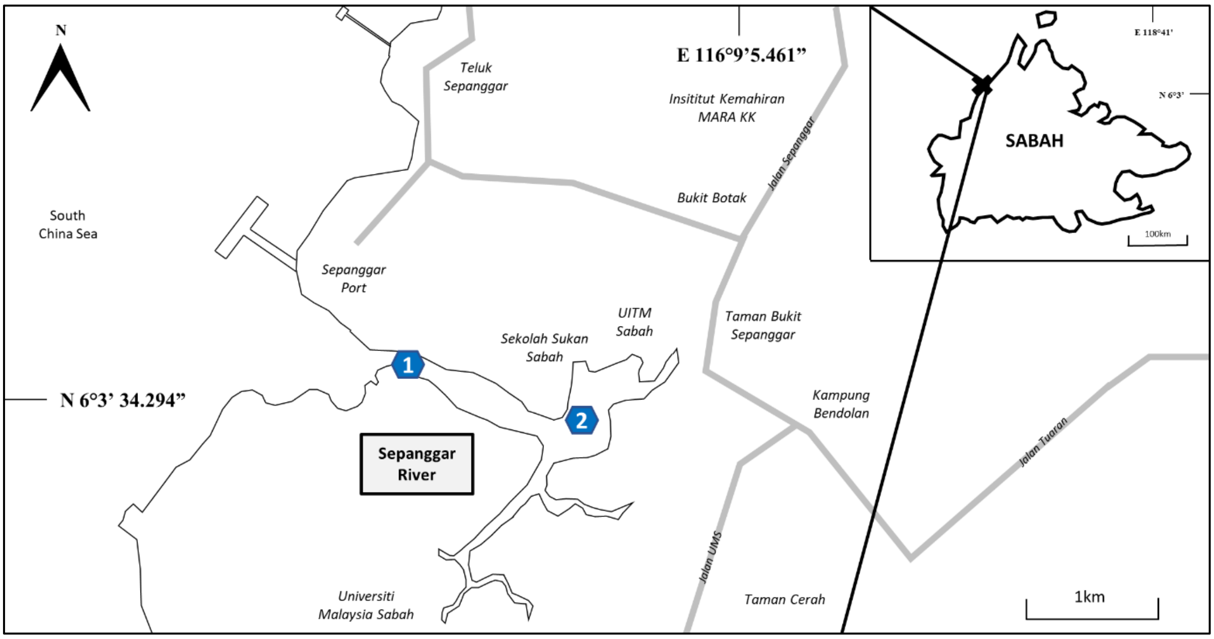

Figure 1: Study area map of Sepanggar River. Nets deployment in the river was indicated by a blue circle.

Table 1: Description of the sampling area, Sepanggar River.

Area	Depth (m)	Coordinates	Time	Observation
Location 1 - Downstream	4.0	06°03'39.9" N 116°07'46.5" E	8.45 am	Floating plastics, small wooden village houses along the river, boat jetties and hospital buildings nearby
Location 2- Upstream	1.1	06°03'29.9" N 116°08'24.8" E	9.55 am	

Fish collection

Fish collection and proper euthanasia were approved by the Animal Ethics Committee UMS [ref no: AEC0031/2022] prior to sampling. Sampling of fish was carried out using gill nets where three gill nets of 2 inches in mesh size were combined and deployed at (1) downstream and (2) upstream of the river. The nets were pulled up after two hours and all fish caught were collected and immersed in a stainless-steel pail with an overdose of NIKA Transmore solution, adhering to animal ethics guidelines on humane euthanasia with minimal suffering. The fish were placed in aluminium seal bags after confirmation of their death and transported to the Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah (UMS) laboratory in a cooler box for further analysis. All the collected fishes were cleaned with distilled water in the laboratory to remove impurities before taking morphometric measurements (standard length and total length to the nearest 0.1 cm and wet weight to the nearest 0.1 g) and photographs of individual fish species (Fig. 2). Fish were sorted, counted, and identified to species level where possible following available taxonomic identification books (Mansor et al., 1998; Annie & Albert, 2009; FAO, 2024; Froese & Pauly, 2024) before storing in a freezer at –20°C until further analysis. Information on habitat, feeding guilds, and food sources for each species were obtained from FAO (2024) and Froose & Pauly (2024). A total of 39 individual fishes accounting for eight species were caught from the Sepanggar River and used for microplastic extraction in this study (Table 2).

Sample analysis

Extraction of microplastics

Throughout the microplastic extraction and identification process, precautions were taken to reduce contamination of collected samples by airborne plastic particles, as proposed by Prata et al. (2019). All apparatus was made of glass or metal, and it was acid-washed when necessary and rinsed with distilled water. The surfaces of the bench and the working table were regularly cleaned by wiping these with 70% ethanol. Synthetic clothing was avoided during laboratory analysis, opting for cotton clothing. Distilled water was used as blanks and subjected to the same extraction and analysis processes as the samples for quality control purposes.

All fishes obtained were used for microplastic extraction. Each fish sample was dissected into (1) muscle consisting of fish skin and fillet, and (2) internal organs of heart, lungs, liver, stomach, intestines and gills and placed in two cleaned conical flasks (Fig. 3, Daniel et al., 2020). Internal organs and fish muscles were first digested with 10% potassium hydroxide (KOH) at the optimum temperature of 40°C for 72 hours and 60°C for 24 hours, respectively. The digested samples were then filtered into 100 ml glass beakers using a 10 mm stainless steel sieve. Microplastics were then extracted following density separation method where 5M of sodium chloride (NaCl) were poured into the beakers and left overnight for settling. The supernatant obtained the following day was vacuum filtered through a 1.2 µm pore size glass microfiber filter (Whatman GF/C) and placed into a clean petri dish with cover. This process was repeated thrice.

Table 2: Summary of fish species caught from Sepanggar River for microplastic extraction and associated morphometric measurements expressed in (mean and standard error), habitat, feeding habit, and diet source.

Fish Species	Total, n	TL (cm)	SL (cm)	Weight (g)	Habitat/ Environment	Feeding guilds	Diet sources
Glossogobius sp.	5	21.5 ± 1.3	17.5 ± 0.7	61.0 ± 5.9	Benthopelagic, amphidromous	Carnivorous	Mosquito larvae, earthworm, fish
Plotosus lineatus	5	20.3 ± 0.6	NA	49.6 ± 6.0	Demersal, amphidromous	Carnivorous	Fish, molluscs, crustaceans, worms
Pennahia sp.	2	15.0 ± 0.0	12.0 ± 0.1	35.7 ± 2.45	Benthopelagic, oceanodromous	Carnivorous	Invertebrates, small fishes
Diapterus auratus	1	9.2 ± 0.0	7.4 ± 0.0	10.9 ± 0.0	Demersal	Omnivorous	Plant, ostracods, copepods, nematodes, invertebrates,
Leiognathus equula	3	8.1 ± 1.0	6.6 ± 0.6	8.1 ± 2.6	Demersal, amphidromous	Omnivorous	Worms, crustaceans, polychaetes, fish
Karalla daura	2	7.1 ± 0.1	5.9 ± 0.1	5.4 ± 1.4	Demersal	Omnivorous	Sponges, crustaceans, bivalves, polychaetes,
Nemapteryx caelata	2	21.9 ± 1.1	17.7 ± 0.6	70.8 ± 1.8	Demersal, amphidromous	Carnivorous	Invertebrates, fishes
Arius venosus	19	17.2 ± 2.2	14.2 ± 2.0	40.3 ± 17.0	Demersal	Carnivorous	Invertebrates, fishes

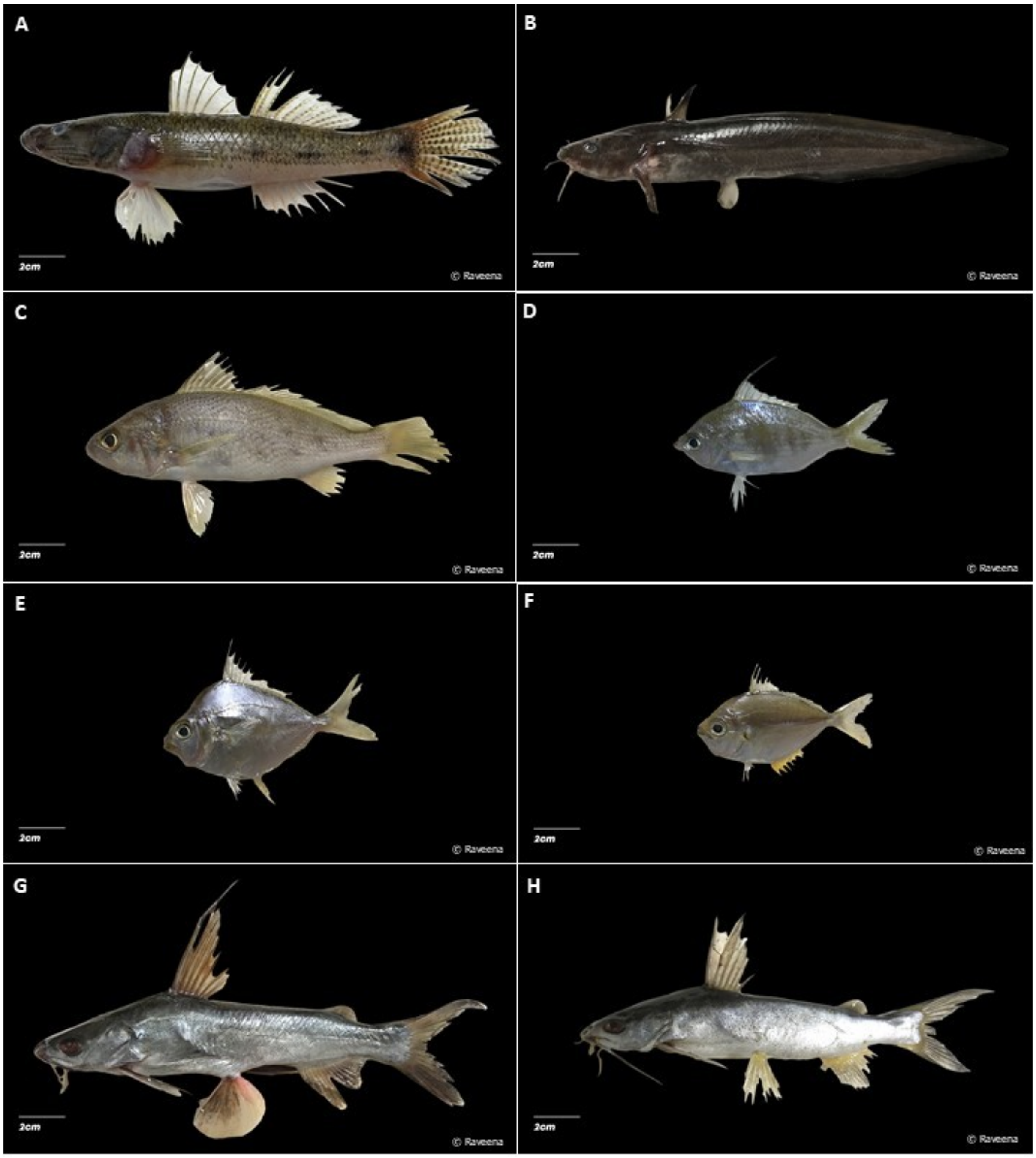

Figure 2: Fish species caught in Sepanggar River; **A.** *Glossogobius* sp., **B.** *Plotosus lineatus*, **C.** *Pennahia* sp., **D.** *Diapterus auratus*, **E.** *Leiognathus equula*, **F.** *Karalla daura*, **G.** *Nemapteryx caelata*, and **H.** *Arius venosus*.

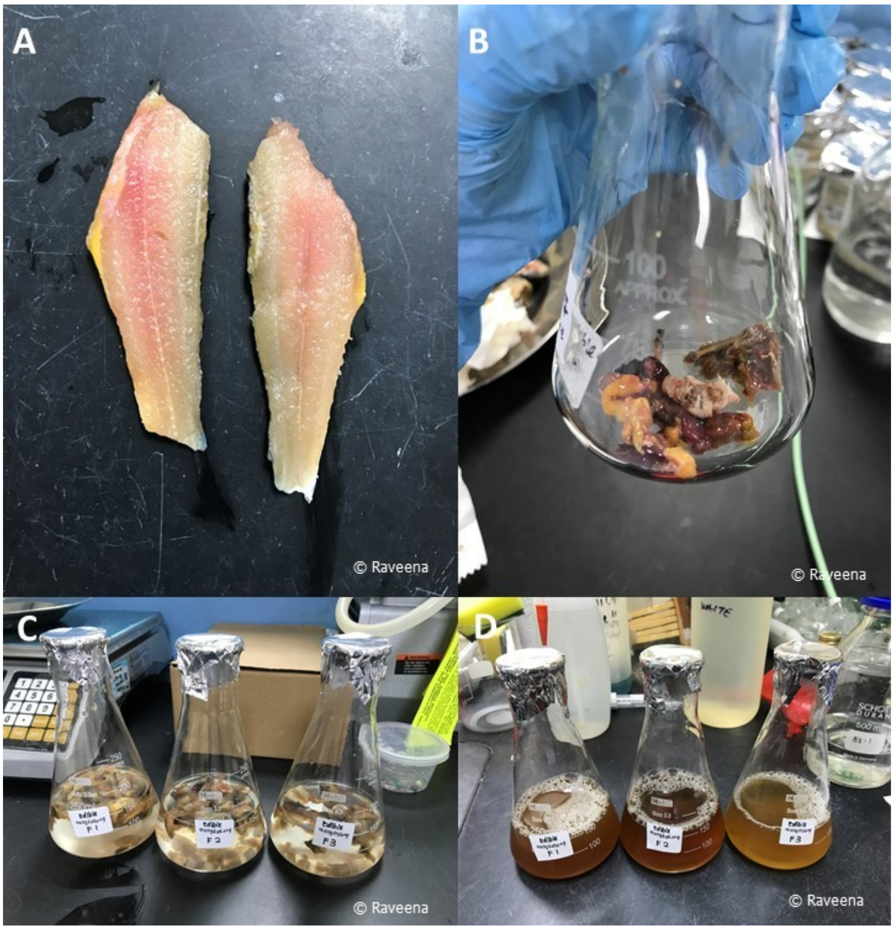

Figure 3: Microplastics extraction process; dissection of fish into **A.** Fish muscles and **B.** Internal organs, **C.** Pre-digestion, and **D.** Post-digestion of samples.

Identifications of MPs

Microplastics on filter paper were identified under a stereo microscope (Leica EZ24) according to shape, colour and size (Table 3). The heated needle test was used when the identification of microplastics was uncertain; if the object melted and curled when it came into touch with the heated needle, it was determined to be plastic. Microplastic concentration was expressed in unit of items/fish.

Table 3: Categories used in the description and identification of microplastic.

Characteristic	Categories	Description	References
Shape	Fibre	A very thin threadlike straight structure	Singh et al. (2022)
	Filament	A thicker and harder straight structure	
	Foam	A sponge-like lightweight structure,	
	Fragment	An irregular edge of hard structures	
	Pellet	A round spherical hard structure	
	Film	A thin layer plan of flimsy structure	
Colour	Black	Black, transparent black, grey and white-striped black	Peng et al. (2017)
	Blue	Deep blue, light blue, deep green, light green	
	Red	Red, purple, pink	
	White	Opaque white, silver	
	Yellow	Yellow, brown, orange	

	Transparent	Colourless
Size	SMP	< 1 mm
	LMP	1 – 5 mm

For polymer type identification, samples of four fish species of which three or more individuals were obtained were selected and only individuals with detectable microplastics in both internal organs and muscles were analysed, i.e., *Arius venosus* and *Glossogobius* sp. (5 individuals each), *Plotosus lineatus* (3 individuals), *Leiognathus equula* (2 individuals). Due to low microplastic count in fish, microplastics from the same fish species were pooled together to ensure a sufficient concentration for the subsequent polymer type analysis. Microplastics from the same fish species were pooled together through sonification with distilled water at 50 HZ for 10 minutes, followed by filtration into a new 1.2 μm pore size glass microfiber filter (Whatman GF/C). The filter papers were sent to ALS Technichem laboratory in Shah Alam, Malaysia for analysis using micro-FTIR (Nicolet iN10 MX). In the lab, microplastics on filter paper were sonicated with ultrapure water at 50HZ for 10 minutes, followed by organic matter digestion with Fenton reagent for 24 hours, and filtered on a 0.2 μm alumina oxide filter membrane. The filter membrane was then placed under the instrument to produce single spectra based on the functional groups of the particle. The spectrum obtained was compared with available libraries on established databases on polymer type with quality matching more than 80% with a size detection limit of 20 um for identification, counting and reporting.

Data analysis

All parameters studied were checked for outliers using boxplots, tested for normality using Shapiro-Wilk's test, and examined for equality of variances using Levene's test prior to statistical analysis. Non-parametric tests were used due to the violation of normality and equal variance of data. Kruskal Walis-H test was used to compare microplastic concentration and characteristics between fish species ($n \geq 3$) while the Mann-Whitney U-test was carried out to compare if there was any significant difference in microplastic concentration between internal organs and fish muscles at p value < 0.05.

RESULTS

Microplastic occurrence and abundance in river fishes

In this study, 77% of fish samples caught from the Sepanggar River, 30 out of a total of 39 fish samples were found to contain microplastics, with an average abundance of 5.28 ± 6.51 items per fish. *Leiognathus equula* (n = 3) had the highest average microplastic count at 12.67 ± 16.23 items per fish, followed by *Glossogobius* sp. (n = 5) each with 10.00 items per fish. *Arius venosus* (n = 19) exhibited the lowest microplastic count, with an average of 2.95 ± 2.50 items per fish. However, microplastic concentrations were not significantly different between the studied fish species ($n \geq 3$, $\chi^2(3)$, H = 6.628, $p = 0.009$) when tested with the Kruskal-Wallis H test (Table 4).

Table 4: Comparison of microplastic concentration and characteristics among fish species ($n \geq 3$) using the Kruskal-Walis H test.

Parameters	Test statistic, H	Asymptotic p value	Retain/Reject
Microplastic Concentration	6.628	0.09	Retain
Microplastic Type			
Fibre	**10.029**	**0.02**	**Reject**

Foam	0.684	0.88	Retain
Fragment	5.182	0.16	Retain
Film	7.764	0.05	Retain
Microplastic Colour			
Black	**9.301**	**0.01**	**Reject**
Blue	6.101	0.32	Retain
Red	**15.539**	**0.02**	**Reject**
Yellow	16.210	0.56	Retain
White	9.556	0.15	Retain
Transparent	27.316	0.68	Retain
Microplastic Size			
LMP	27.288	0.70	Retain
SMP	18.041	0.07	Retain

* The significant difference was indicated in bold, p value < 0.05.

Comparing microplastic concentrations between internal organs and fish muscles, the internal organs of fish showed a higher count, with 3.54 ± 3.63 items per fish, compared to 1.74 ± 5.10 items per fish in the muscles. Statistically, a Mann-Whitney U test indicated significant difference in microplastic concentrations between these two parts. The mean rank for microplastic concentration in internal organs, 48.56 was significantly higher than the mean rank of 30.44 for fish muscles, U = 78, z = 3.671, p = 0.0002.

Variation of microplastic characteristics in river fishes

Microplastics extracted from fish samples caught from the Sepanggar River exhibited variations in shape, colour, size, and polymer type composition. Fig. 4 depicts the percentage composition of microplastic shapes, colours, sizes, and polymer types found in all fish samples caught from the Sepanggar River, while Fig. 5 illustrates the percentage composition of these microplastics for each fish species (n ≥ 3). Microplastics in those fishes were primarily small-sized (< 1mm), constituting 97% of the total microplastics (Fig. 4). The pattern of small microplastics dominating was similar across different fish species as well, with microplastic extracted from *P. lineatus* and *L. equula* accounting for 100% of small-sized microplastics. Among these, fragments were the most prevalent, making up 54% of the microplastics, followed by films at 36%. This dominance of fragment was also observed in most individual fish species, except for *L. equula*, where film was the highest at 76%. In terms of microplastic colours, the fishes exhibited the highest percentage of black microplastics, accounting for 40%, followed by blue (21%), red (19%), yellow (16%), transparent (3%), and white (1%). All fish samples caught from the Sepanggar River predominantly contained black microplastics, except for *A. venosus* which recorded the highest percentage of yellow microplastics (32%).

Polymer type analysis by micro-FTIR revealed that microplastics in this study consisted of nine different polymer types. Fig. 6 shows the spectra of polymer types identified from extracted microplastics from fish samples in this study. Rayon accounted for the highest polymer type (23%), followed by polyurethane (PU) at 20%, and both polyamides (PA) and polypropylene (PP) at 13% each. Similarly, microplastics in *Glossogobius* sp. (43%) and *P. lineatus* (22%) were also predominantly rayon. However, *L. equula* and *A. venosus* ingested the highest amounts of PA (24%) and PU (54%), respectively.

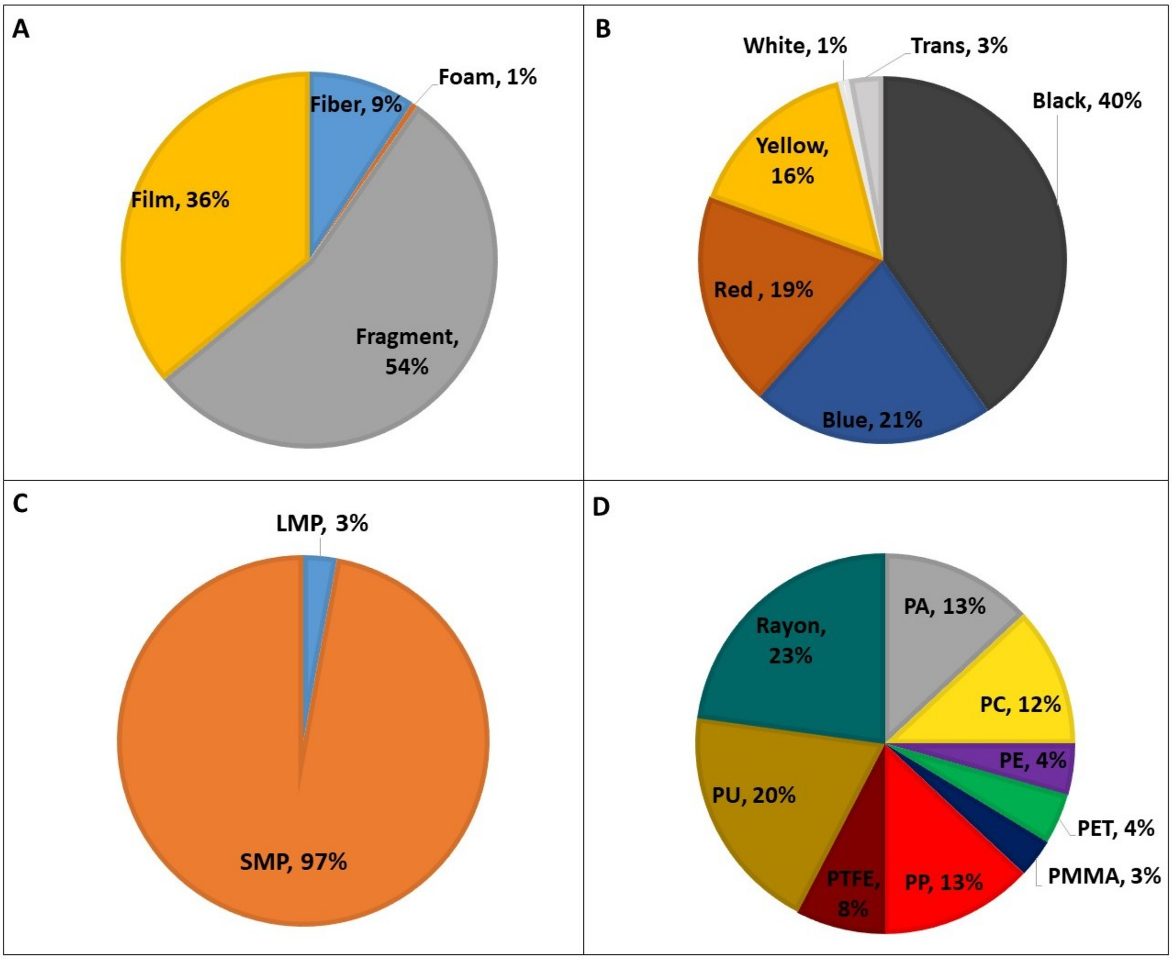

Figure 4: Composition of microplastic **A.** Shape, **B.** Colour, **C.** Size and **D.** Polymer type in fish samples caught from the Sepanggar River.

Although the characteristics of microplastic composition varied between fish species, only fibre as well as black and red colour microplastics were statistically significant ($p < 0.05$) among the fish species as presented in Table 4. Table 5 summarizes the significant pairwise comparisons of fish species for multiple comparisons for microplastic characteristics. *Plotosus lineatus* ingested significantly ($p < 0.05$) more fibres than *A. venosus*. Microplastics in *Glossogobius* sp. on the other hand were of higher black ($p = 0.046$) and red colour ($p = 0.049$) compared to *A. venosus*. Red colour microplastics in *Glossogobius* sp. were also significantly higher than *P. lineatus* at $p = 0.037$.

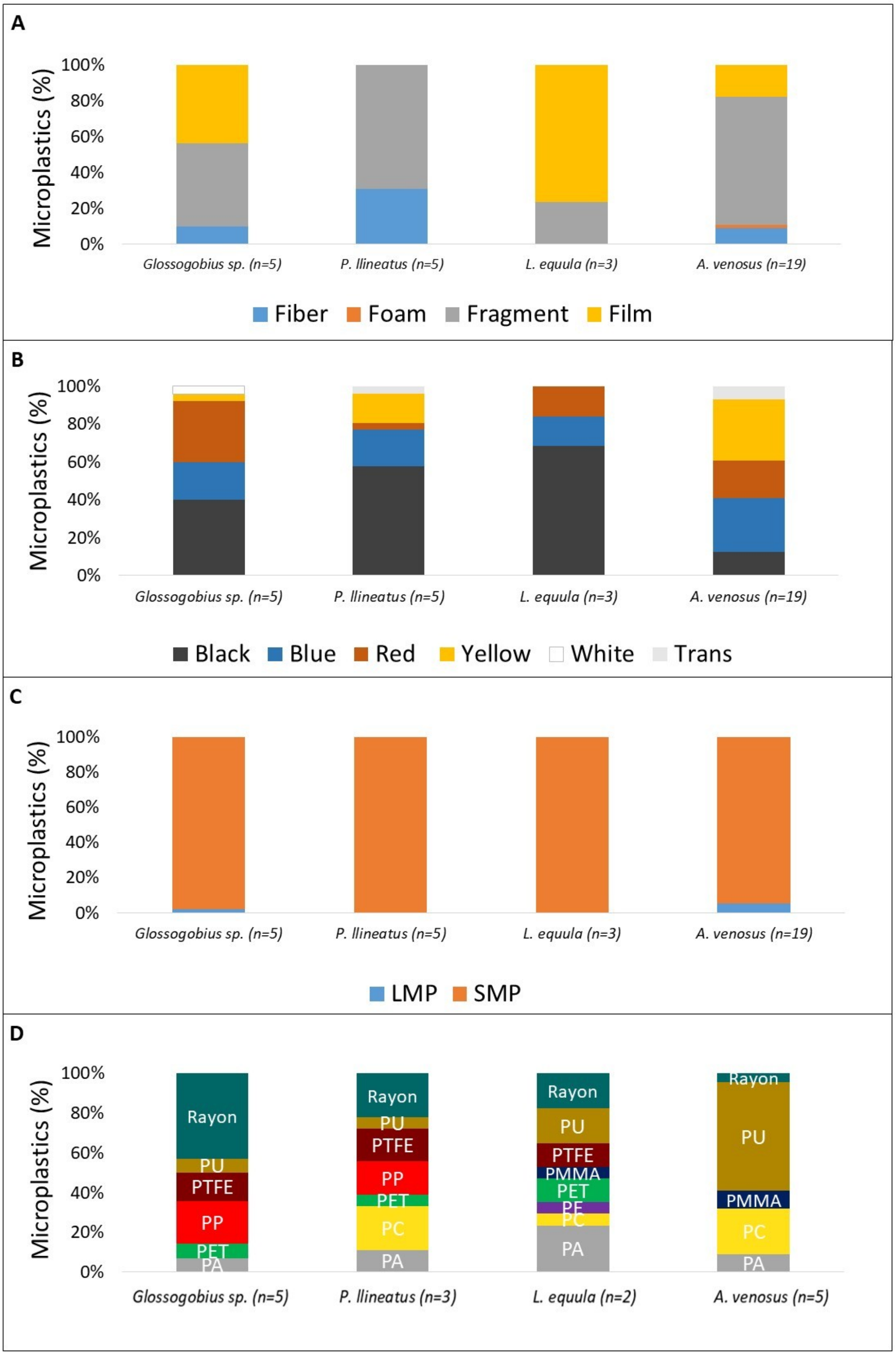

Figure 5: Composition of microplastic **A.** Shape, **B.** Colour, **C.** Size and **D.** Polymer type in selected fish species caught from the Sepanggar River.

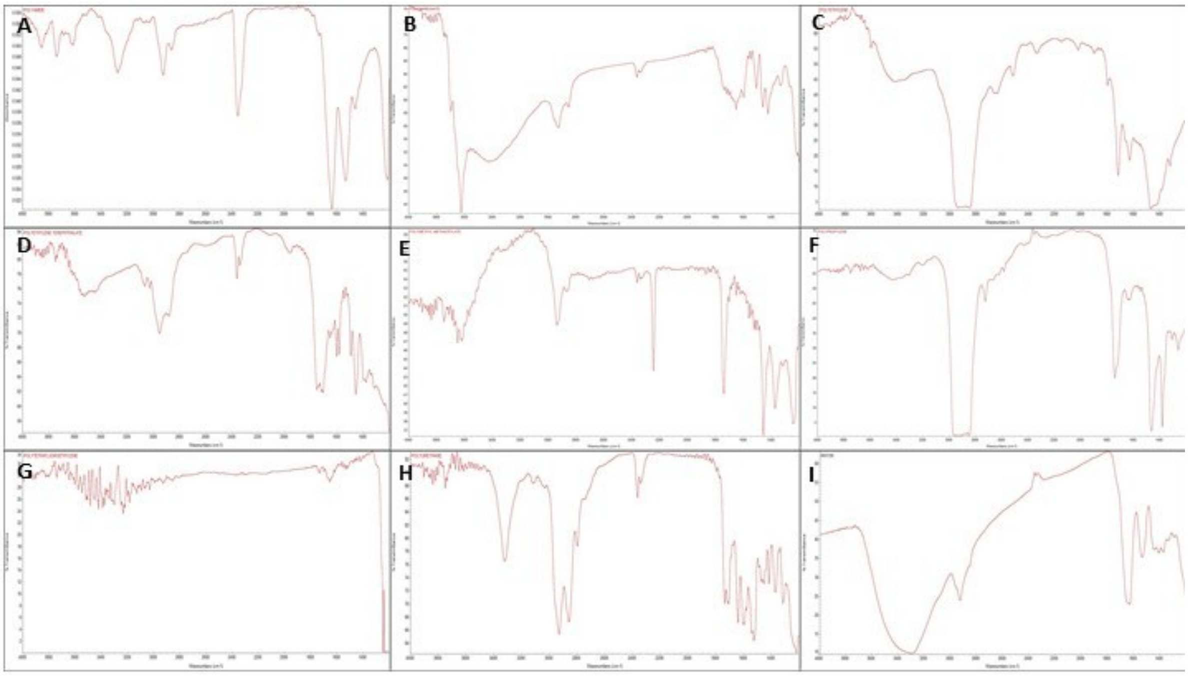

Figure 6: Micro-FTIR spectrum of polymer type **A.** Polyamides (PA), **B.** Polycarbonate (PC), **C.** Polyethylene (PE), **D.** Polyethylene Terephthalate (PET), **E.** Poly Methyl Methacrylate (PMMA), **F.** Polypropylene (PP), **G.** Polytetrafluoroethylene (PTFE), **H.** Polyurethane (PU) and **I.** Rayon.

Table 5: Pairwise comparisons using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons for significant parameters.

Parameter	Fish species	Test Statistics	Adjusted p value
Fibre	*Plotosus lineatus* > *Arius venosus*	10.521	0.049
Black	*Glossogobius* sp. > *Arius venosus*	11.563	0.046
Red	*Glossogobius* sp. > *Plotosus lineatus*	15.000	0.037
	Glossogobius sp. > *Arius venosus*	11.500	0.049

*Higher mean rank is indicated by the symbol (>)

DISCUSSION

Microplastic ingestion by fish in the Sepanggar River

Based on a single sampling event, 77% of fish collected from Sepanggar River (n = 39) contained microplastics. This study provides the first confirmation that fish in the Sepanggar River were contaminated with microplastics, highlighting the global challenge of escalating microplastic contamination in aquatic organisms, including fish. With no national or standardised regulations addressing microplastic contamination in river fish, the concentrations were compared with other studies to gauge the overall microplastic contamination status in river fish. Previous research has predominantly focused on microplastic ingestion in separate parts of the fish, i.e., the gastrointestinal track and gills, with only a few that analysed fish tissue (Table 6), instead of the whole fish. In comparison to previous studies, this study analysed microplastics in internal organs separately from the fish tissue (muscles). Similarly, various available literature also shows ranges of percentages of microplastics in their studied river fishes. Overall, fish samples caught from the Sepanggar River were moderately polluted compared to fish in other studies. This study detected microplastics in both fish muscles and internal organs of the fish; however, the concentrations of microplastics in fish muscles were significantly lower than those in their internal organs such as gills, stomach, and intestines ($p < 0.05$). Likewise, fish in Songkhla River in Thailand also demonstrated a lower abundance of microplastics in the fish muscles compared to their internal organs (Pradit et al., 2023; Jitkaew et al., 2024).

All fish species that were caught from Sepanggar River in this study are demersal fish that feed on invertebrates such as small crustaceans, molluscs, worms, and tiny fish from demersal habitat except for *Pennahia* sp. and *Glossogobius* sp. which are benthopelagic habitat fish species (Table 2). Sarijan et al. (2019) and Sultan et al. (2023) reported that bottom-feeding species inhabiting benthic-pelagic and demersal habitats exhibited the highest microplastic ingestion rate. It is postulated that the bottom sediment contains higher microplastic abundance compared to the water column (Ismanto et al., 2023; Karing et al., 2023). Therefore, these bottom-feeding fishes may mistakenly ingest microplastics directly from sediment when scavenging or feed on benthic organisms inhabiting in the benthic realm that were contaminated with microplastics (James et al., 2021).

Although not statistically significant, the highest microplastic ingestion by *L. equula* (12.77 ± 16.26 items/fish) corresponds to it being an omnivorous fish as omnivorous fish have a greater likelihood and higher risks of ingesting microplastics compared to herbivorous and carnivorous fish due to their diverse habitat interaction (James et al., 2021; Yasaka et al., 2022; Sutan et al., 2023). Similarly, *Diapterus auratus* is also an omnivorous fish that had high microplastic count (9.20 ± 0.00 items/fish) likely due to microplastics resembling items in its diet, which includes organisms such as ostracods, copepods, and nematodes. *Glossogobius* sp. were among the second highest most ingested microplastic fish as they inhabit and feed in both benthic and midwater zones, making them susceptible to microplastic contamination from the water column as well as settled microplastics in bottom mud sediments (Kibria, 2023).

The potential sources of microplastic ingested by fish

Microplastics extracted from fish samples caught from the Sepanggar River exhibited a diverse range of characteristics, including variations in shape, colour, size and polymer type. All microplastics ingested by these fish were secondary microplastics originating from the fragmentation of larger plastics, as evidenced by the absence of pellets in their internal organs or muscles. The diverse array of microplastic characteristics extracted from these fish offers insight into their origins. The presence of secondary microplastics in the river fish suggests that they originate from various activities along the Sepanggar River, contributing to variations in their ingested compositions of microplastic characteristics. The major sources of microplastics identified in this study were materials released from domestic waste discharge and industrial activities along the upstream.

Sepanggar River is situated within an urbanised area characterised by dense residential zones and is influenced by upstream rivers passing through active industrial areas, automotive workshops, tyre shops, furniture shops, and densely populated residential neighbourhoods. Additionally, plastic waste such as wrappers, bags, and sachets were seen floating on the surface waters during field sampling, likely discarded from the adjacent residential areas. The highest percentages of fragments (54%) in fish were therefore possibly released from the fragmentations of hard plastic such as plastic bottles, drums, containers, and other materials derived from those residential and industrial activities (Singh et al., 2022; Sultan et al., 2023). Previous studies also reported fragments as highly ingested microplastics in river fishes sourced from residential activities (Karbalaei et al., 2019; Yasaka et al., 2022).

Table 6: Summary of the microplastics concentration (Items/fish) in different parts of tidal river fishes in Southeast Asia.

Location	**Method**	**Fish part**	**Number of species, (n= ind.)**	**MP occurrence (%)**	**Concentration (Items/fish)**	**Reference**
Barangay Britania, Philippines	Fishers	GIT	5(n=180)	12	4.00 ± 2.00	Gomez et al. (2020)
Lubuk Yu River, Pahang	Fish net	GIT	8(n=32)	33-50	NA.	Harith et al. (2021)
Melayu River, Johor	Captured wild	GIT	3(n=14)	NA.	4.50 ± 4.50	Primus & Azman (2022)
Nam Pong River, Thailand	Trawling/Netting	GIT	NA.	38	7.60 ± 17.70	Yasaka et al. (2022)
Kuala Selangor	Fishers	GIT	1(n=12)	NA.	1.75 ± 1.92	Lim et al. (2023)
Kuantan, Pahang	Fishers	GIT	1(n=32)	NA.	2.34 ± 1.98	Lim et al. (2023)
Mukah, Sarawak	Fishers	GIT	1(n=5)	NA.	4.00 ± 0.63	Lim et al. (2023)
Sungai Besar, Selangor	Fishers	GIT	1(n=13)	NA.	2.62 ± 0.61	Lim et al. (2023)
Songkhla, Thailand	Fishers	Gills, stomach	1(n=40)	81	2.60 ± 0.28	Pradit et al. (2023)
Songkhla Lagoon, Thailand	Fishers	Gills, stomach	1(n=35)	100	3.06 ± 0.42	Jitkaew et al. (2024)
Nam Pong River, Thailand	Trawling/ Netting	Tissue	NA.	0	0.00 ± 0.00	Yasaka et al. (2022)
Songkhla, Thailand	Fishers	Tissue	1(n=40)	81	1.55 ± 0.19	Pradit et al. (2023)
Songkhla Lagoon, Thailand	Fishers	Tissue	1(n=35)	100	1.97 ± 0.19	Jitkaew et al. (2024)
Sepanggar River	3-layer net	Gills, organs	8(n=39)	74	3.54 ± 3.63	Present study
Sepanggar River	3-layer net	Tissue	8(n=39)	44	1.74 ± 5.10	Present study

The film, which is the second-highest microplastics (36%) ingested by fish samples in this study, likely originated from food packaging and plastic bag manufacturing released from the above activities (Sang et al., 2021). The small proportions of fibres ingested by fish samples may derive from synthetic fibres potentially released into watercourses through domestic wastewater discharge, from wear and tear during clothes washing or fibre materials from residential areas (Anuar et al., 2023).

The sources of microplastics that are ingested by fish samples in the Sepanggar River are supported by the polymer type analysis. The highest polymer type obtained; rayon (23%) in the present study suggested that these semi-synthetic cellulose-based polymer fibres could be released from washing activities while the second highest polyurethane (PU) polymer type (20%) suggested that these materials potentially stem from manufacturing factories, such as those used in shoe soles, car seats, furniture, and mattresses. The polyethylene (PE), polypropylene (PP), and polytetrafluoroethylene (PTFE) polymer types collectively accounted for 25% of the analysed polymer types from the extracted microplastics in fish are commonly found in household items. For example, PE is extensively used in the manufacturing of various items such as plastic bags and films, releasing film-shape microplastics, while PP materials used as containers for plastic bottles, pipes, plumbing components, as well as toys and household goods, release fragment-shape microplastics (He et al., 2020). Conversely, PTFE is a microplastic polymer commonly found in non-stick coatings for both cookware and labware, while PP is frequently utilised in the production of plastic materials for packaging and fishing gear (Hwi et al., 2020).

Study limitations and future directions

The present study serves as an initial effort to delve into microplastic contamination in wild fish caught from the Sepanggar River in the Sabah region. Although the results offer solid evidence of fish contamination by microplastic in Sabah and insightful information on possible food safety for the local population, it is important to acknowledge a number of limitations that could affect how the findings are interpreted. The primary drawback of the present study is its one-time sampling strategy, which might not adequately represent the dynamic fluctuations of microplastic contamination in fish throughout the year. Microplastic levels in aquatic environments can fluctuate due to seasonal changes, weather events, and human activities (Nithin et al., 2022; Johnson et al., 2020). Additionally, the small sample size of 39 fish may not fully represent the microplastic contamination levels present in the Sepanggar River, potentially skewing the findings. Unequal sample sizes between species also make it difficult to conclude microplastic ingestion across different fish species. Certain species may have been under-represented, and the variability in feeding habits may not have been adequately reflected. This singular snapshot may not represent the broader patterns of contamination, limiting our ability to generalise the results to the entire fish population in the Sepanggar River.

Future research should aim to address these limitations by conducting multiple samplings across different seasons and tidal conditions to capture temporal variations in microplastic concentrations. Increasing the sample size will enhance the robustness of the findings and allow for more comprehensive comparisons of microplastic ingestion among various fish species inhabiting the Sepanggar River. Such data will also allow for more meaningful comparisons of microplastic concentrations among different feeding guilds. Furthermore, research may look into the relationship between microplastic contamination and environmental factors, such as water quality and sediment composition, which may influence microplastic levels and their accumulation in fish tissues. Integrating findings across water, sediment, and fish will provide a more holistic understanding of the dynamics of microplastics in riverine systems (Sayed et al., 2021; Blankson et al., 2022).

CONCLUSION

This study marked the first investigation into the microplastic contamination in fish from the Sepanggar River, an urbanised river in Kota Kinabalu, Sabah. The findings of this study demonstrated that fish from the Sepanggar River were contaminated with microplastics, with significantly higher microplastics found in internal organs than those in muscle. Microplastics ingested by the fish samples were all small-sized secondary microplastics consisting primarily of fragments, film, fibres and foam shape potentially sourced from residential waste disposal and industries activities nearby the river. Therefore, proper waste management for domestic household discharge and industrial activities is recommended to reduce the microplastic contamination risk on Sepanggar River fish in the long run.

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DECLARATIONS

Research permits. This study was conducted with the approval of the Sabah Biodiversity Council [Access License Ref. - JKM/MBS.1000-2/2 JLD.16 (53–55)].
Ethical approval/statement. This study was conducted with the approval from Animal Ethics Committee UMS (Ref no: AEC0031/2022).
Generative AI use. We declare that generative AI was not used in this study nor in the writing of this article.

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