

Occurrence and Characterisation of Microplastics in Fish Tissues and Water from Yusuf Bage River, Unguwar Rimi, Kaduna State, Nigeria

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ABSTRACT

Microplastic pollution in freshwater systems is a growing environmental concern with potential implications for aquatic organisms and human consumers through the food chain. This study assessed the occurrence and characteristics of microplastics (MPs) in fish tissues and water samples collected from Yusuf Bage River, near Unguwar Rimi, Kaduna State, Nigeria. A total of 18 fish specimens (n = 6 per species) comprising African catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*) and silver moony (*Monodactylus sebae*), together with six water samples, were collected in May 2025. Fish tissues (flesh, gills and intestine) and water samples were subjected to potassium hydroxide (KOH) digestion, density separation, stereomicroscopic enumeration, Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy and Scanning Electron Microscopy (SEM). FTIR spectra indicated dominant polyethylene (PE) signatures (CH_2 rocking at $720\text{--}730\text{ cm}^{-1}$), with contributions from polyethylene terephthalate (PET) and polypropylene (PP), confirmed by library match quality factors ≥ 0.75 . SEM revealed irregular fragments, fibres and sheet-like particles with sharp edges and weathering features. Microplastics were present in all tissues and water, with mean abundances ranging from 2.3 ± 0.8 to 8.7 ± 2.1 particles/g wet weight in fish tissues and 45.3 ± 12.6 particles/L in water. Higher abundances were observed in gills ($5.8\text{--}8.7$ particles/g) and intestine ($4.2\text{--}7.1$ particles/g) compared with flesh ($2.3\text{--}3.8$ particles/g). Findings document measurable microplastic contamination in this urban-influenced river and provide a baseline for future monitoring and management.

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INTRODUCTION

Microplastics are synthetic polymer particles less than 5 mm in size that have become ubiquitous environmental contaminants in aquatic ecosystems worldwide (Thompson et al., 2004). They originate from primary sources (for example, microbeads in personal care products) and secondary fragmentation of larger plastic debris due to weathering, ultraviolet radiation and mechanical abrasion (Andrady, 2011). Once in the environment, microplastics may be ingested by aquatic organisms, with potential physical effects such as blockage or tissue abrasion, and may act as vectors for adsorbed pollutants (Rochman et al., 2013; Wright et al., 2013).

In Africa, and particularly in Nigeria, rapid urbanisation, population growth and inadequate waste-management infrastructure have intensified plastic pollution in rivers and lakes (Akindele et al., 2019; Adewuyi, 2024). Nigerian rivers serve multiple purposes, including drinking-water supply, irrigation and fisheries, making them critical for food security and public health. Studies in southern Nigeria, such as those on the Osun River, have reported high microplastic concentrations in river water and biota (Akindele et al., 2020; Olarinmoye et al., 2020; Ndibe et al., 2023). However, data from northern Nigeria, including Kaduna State, remain scarce despite similar anthropogenic pressures.

Yusuf Bage River in Kaduna State is a key freshwater resource supporting local communities and fisheries. This study provides a baseline assessment of microplastic occurrence in fish tissues (flesh, gills and intestine) and water

from this river. The aim of the study was to quantify microplastic abundances in selected fish tissues and river water, identify the principal polymer types using ATR-FTIR spectroscopy, characterise particle morphology using SEM, and provide a preliminary estimate of human exposure through fish consumption based on measured particle abundances in edible tissue.

MATERIALS AND METHODS

Study Area

Yusuf Bage River is located in Unguwar Rimi, Kaduna State, Nigeria (approximately $10^{\circ}31'N$, $7^{\circ}26'E$). The river flows through a densely populated urban area with limited waste-management infrastructure and receives inputs from domestic sewage, agricultural runoff and informal solid-waste disposal. The river supports local fisheries and is used as a source of water for domestic and agricultural purposes.

Sample Collection

Three commercially important fish species—African catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*) and silver moony (*Monodactylus sebae*)—and water samples were collected from Yusuf Bage River in May 2025. Sampling points were selected to reflect observed anthropogenic inputs (Ogbomida & Emeribe, 2013). Six individuals of each species (total n = 18) were obtained from local fishermen using gill nets and hand nets. Fish were transported on ice to the laboratory. Each fish was measured (total length, wet weight) and dissected under clean

laboratory conditions to obtain samples of flesh (edible muscle), gills and the entire gastrointestinal tract (intestine). Tissue samples were rinsed with filtered ultrapure water, weighed and stored at 4 °C until digestion.

Six surface-water samples (1 L each) were collected in pre-cleaned glass bottles from the same locations, transported under cool conditions and processed within 48 h. Field blanks (filtered ultrapure water exposed during sampling) were included to monitor external contamination.

Microplastic Extraction

Fish tissues were digested using 10 % (w/v) potassium hydroxide (KOH) solution at 60 °C for 24–48 h (or until tissues were fully digested), following protocols validated for lipid-rich fish tissues (Foekema et al., 2013; Dawson et al., 2020). After digestion, the solutions were subjected to density separation with a saturated sodium chloride solution (density $\approx 1.2 \text{ g cm}^{-3}$) followed, where necessary, by a second density separation using zinc chloride solution (density 1.5 g cm^{-3}) to recover denser polymers. Supernatants were vacuum-filtered through glass-fibre filters (pore size $0.7 \text{ }\mu\text{m}$ or $1.2 \text{ }\mu\text{m}$). Filters were dried at 40–60 °C in covered glass dishes prior to microscopic examination.

Water samples (1 L) were filtered directly or after minimal pre-treatment through the same filter type. All glassware was rinsed three times with filtered ultrapure water before use. Laboratory procedural blanks (KOH solution without tissue, processed identically) and recovery tests (spiked clean tissue with known polymer particles) were performed with every batch.

Stereomicroscopic Enumeration and Size Classification

Filters were examined under a stereomicroscope. Particles suspected to be microplastics (synthetic appearance, no cellular structure) were counted, measured and classified by size class ($<250 \text{ }\mu\text{m}$, $250\text{--}500 \text{ }\mu\text{m}$, $500 \text{ }\mu\text{m}\text{--}1 \text{ mm}$, $>1 \text{ mm}$) and morphological type (fragment, fibre, film, pellet). The lower practical size limit of reliable detection was approximately $63\text{--}100 \text{ }\mu\text{m}$, depending on filter and magnification. Counts were expressed as particles per gram wet weight (fish tissues) or particles per litre (water). Blank counts were subtracted from sample counts.

ATR-FTIR Spectroscopy

Polymer identification was performed using Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy. Representative particles (selected to cover the main morphological types and size classes observed) from each sample type were analysed on a Bruker ALPHA II FTIR spectrometer equipped with a diamond ATR crystal. Spectra were collected in the range $4000\text{--}400 \text{ cm}^{-1}$ with 32 co-added scans at 4 cm^{-1} resolution. Polymer identity was assigned by comparison with reference libraries (Bruker ATR-Polymer and Hummel Polymer Library). Only particles with library match quality factors ≥ 0.75 and displaying multiple diagnostic bands were accepted as confirmed microplastics (Ehlers et al., 2019). Key diagnostic bands used were: polyethylene (PE) – CH_2 rocking $720\text{--}730 \text{ cm}^{-1}$ and aliphatic C–H stretches $2915\text{--}2850 \text{ cm}^{-1}$; polyethylene terephthalate

(PET) – aromatic C–H bands near 870 , 1010 and 1410 cm^{-1} and carbonyl stretch $1710\text{--}1740 \text{ cm}^{-1}$; polypropylene (PP) – methyl C–H deformation near 1376 cm^{-1} and C–C stretching near 1167 cm^{-1} .

Scanning Electron Microscopy (SEM)

Morphological characterisation was performed on a subset of representative particles using a JEOL JSM-7600F Field Emission Scanning Electron Microscope. Selected particles were mounted on aluminium stubs with carbon tape and sputter-coated with gold-palladium ($\approx 5 \text{ nm}$). Imaging was conducted at accelerating voltages of $5\text{--}15 \text{ kV}$ and magnifications ranging from approximately $280\times$ to $510\times$. Surface features, edge characteristics and weathering patterns were documented.

Quality Assurance and Quality Control

Procedural blanks contained 0–2 particles per blank (mean 0.7 ± 0.9), corresponding to approximately 3 % of mean sample abundance; these values were subtracted. Recovery experiments using spiked polymer particles yielded a mean recovery of $87.3 \pm 6.2 \%$. All sample processing was performed in a clean laboratory area with limited air movement; cotton laboratory coats were avoided. Results are reported after blank correction.

Preliminary Exposure Estimate

A preliminary estimate of human exposure via fish consumption was calculated from the measured mean microplastic abundance in edible flesh. Particle counts were converted to an approximate mass intake by assuming an average particle mass of 0.01 mg (a conservative order-of-magnitude estimate for the size range observed). The estimated daily intake (EDI) was computed as:

$$EDI = (C \times IR) / BW$$

Where C is the mean concentration in flesh (particles g^{-1}), IR is the daily fish ingestion rate (g day^{-1}) and BW is adult body weight (kg). Assumptions followed FAO (2020) estimates of per-capita fish consumption in Nigeria (approximately 50 g day^{-1} for average consumers) and a reference body weight of 60 kg . Results are presented as approximate mass intake (mg day^{-1}) solely to indicate order of magnitude; they do not constitute a formal toxicological risk assessment.

Statistical Analysis

Data were analysed using IBM SPSS Statistics (Version 26). Normality was assessed with the Shapiro–Wilk test. Differences in microplastic abundance among species and tissue types were evaluated by one-way ANOVA followed by Tukey's post-hoc test ($\alpha = 0.05$). Results are presented as mean $\pm$ standard deviation (SD).

RESULTS AND DISCUSSION

Fish Biometrics

A total of 18 fish specimens were analysed ($n = 6$ per species). Biometric data are summarised in Table 1. Mean total lengths ranged from $18.5 \pm 2.1 \text{ cm}$ (silver moony) to $32.4 \pm 4.3 \text{ cm}$ (African catfish), and mean wet weights ranged from $85.3 \pm 12.6 \text{ g}$ (silver moony) to $245.7 \pm 38.2 \text{ g}$ (African catfish).

Table 1: Biometric Data of Fish Specimens ($n = 6$ per Species)

Species	Total Length (cm)	Wet Weight (g)
African catfish (<i>Clarias gariepinus</i>)	32.4 ± 4.3	245.7 ± 38.2
Nile tilapia (<i>Oreochromis niloticus</i>)	24.2 ± 3.1	142.5 ± 22.8
Silver moony (<i>Monodactylus sebae</i>)	18.5 ± 2.1	85.3 ± 12.6

Microplastic Abundance in Fish Tissues

Microplastics were detected in all tissue types of all three species (Table 2). Mean abundances ranged from 2.3 ± 0.8

particles/g wet weight (catfish flesh) to 8.7 ± 2.1 particles/g wet weight (catfish gills). Gills consistently showed the highest abundances, followed by intestine and flesh.

Table 2: Microplastic Abundance in Fish Tissues (Particles/g Wet Weight, Mean $\pm$ SD, n = 6)

Species	Flesh	Gills	Intestine	Total per fish
African catfish	2.3 ± 0.8	8.7 ± 2.1	7.1 ± 1.9	18.1 ± 4.2
Nile tilapia	3.1 ± 1.0	6.4 ± 1.8	5.2 ± 1.5	14.7 ± 3.8
Silver moony	3.8 ± 1.2	5.8 ± 1.6	4.2 ± 1.3	13.8 ± 3.5

One-way ANOVA indicated significant differences among tissue types ($F = 24.37$, $p < 0.001$) and among species ($F = 4.12$, $p = 0.032$). Post-hoc tests showed that gill tissues contained significantly more particles than flesh ($p < 0.001$) and intestine ($p = 0.018$) across species. Silver moony had significantly lower total loads than African catfish ($p = 0.021$); no significant difference was found between catfish and tilapia ($p = 0.142$).

Microplastic Abundance in Water

Mean microplastic abundance in river water was 45.3 ± 12.6 particles/L (range 28–62 particles/L; n = 6). Dominant size fractions were 250–500 μm (34.2 %) and 500 μm –1 mm (28.7 %). Morphologically, fragments (42.3 %) and fibres (35.8 %) predominated, followed by films (15.2 %) and pellets (6.7 %).

in 67.3 % of analysed particles (library match quality 0.78–0.94). Polyethylene terephthalate (PET) accounted for 18.4 % (match quality 0.76–0.89) and polypropylene (PP) for 9.8 % (match quality 0.75–0.86). A small proportion (4.5 %) remained unidentified or produced ambiguous spectra and were excluded from confirmed counts.

Size Distribution in Fish Tissues

Across all fish tissues, particles were predominantly in the 250–500 μm range (38.4 %), followed by 500 μm –1 mm (29.1 %) and <250 μm (21.3 %). Particles >1 mm were less common (11.2 %). No significant difference in size distribution among species was detected ($\chi^2 = 3.87$, $p = 0.145$).

Representative spectra (Figures 1–7) displayed the diagnostic bands listed in Section 2.5. Figure 1 (catfish flesh) shows characteristic PE absorption at 2917.7 cm^{-1} , 1456.9 cm^{-1} and the low-wavenumber CH_2 rocking region, together with PET and PP contributions. Figure 2 (river water) exhibits a prominent carbonyl stretch at 1742.1 cm^{-1} (PET) and strong aliphatic C–H stretches (PE). Parallel PE, PET and PP signatures were recorded in tilapia and silver-moony tissues (Figures 3–7). All assignments rested on multiple diagnostic peaks and library match factors ≥ 0.75 .

Polymer Identification by ATR-FTIR

ATR-FTIR analysis confirmed multiple polymer types (Table 3). Polyethylene (PE) was the dominant polymer, identified

Table 3: Summary of FTIR Peak Assignments and Polymer Identification

Sample	Key peaks (cm^{-1})	Polymer	Match quality	Relative abundance (%)
Catfish flesh	2920, 2850, 1460, 720	PE	0.89	72.3
	1715, 1410, 1010, 870	PET	0.82	18.5
	1376, 1167	PP	0.78	9.2
Catfish gills	2920, 2850, 1460, 720	PE	0.92	68.7
	1718, 1410, 1010	PET	0.85	22.4
Water	2922, 1742, 1458, 1376	PE/PET/PP	≥ 0.78	PE dominant

Morphological Characterisation by SEM

SEM imaging of selected particles revealed irregular fragments, fibres and sheet-like particles with sharp edges, surface cracks, pitting and other weathering features

consistent with secondary microplastics of environmental origin (Figures 8–11). Table 4 summarises the principal morphological observations.

Table 4: SEM Morphological Features of Selected Microplastic Particles

Sample	Observed features	Inferred type	Abundance*
Catfish flesh	Elongated/oval particles, rough pitted surface	Fragments (PE)	2.3 ± 0.8
Catfish gills	Irregular flaky layered structures, sharp edges, embedded fibres	Fibres & fragments	8.7 ± 2.1
Catfish intestine	Fibrous networks, elongated strands with surface cracks	Microfibres	7.1 ± 1.9
Silver moony flesh	Cracked plate-like surface, weathering features	Film fragments	3.8 ± 1.2
Water	Rod-like, fibrous and sheet-like particles	Fibres & fragments	$45.3 \pm 12.6\text{ /L}$

*Abundance values (particles/g ww or particles/L) are those reported for the corresponding sample type in Tables 2 and Section 3.3.

Procedural Blanks and Recovery

Procedural blanks contained 0–2 particles (mean 0.7 ± 0.9). After subtraction, residual blank contribution was approximately 3 % of mean sample abundance. Mean recovery of spiked particles was $87.3 \pm 6.2\%$, indicating satisfactory method performance for the size range examined.

Preliminary Exposure Estimate

Using the mean microplastic abundance in edible flesh (approximately 3.1 particles/g wet weight across species) and an assumed average particle mass of 0.01 mg, the estimated daily intake for a consumer eating 50 g of fish per day is of the order of 0.16 mg day^{-1} . For a higher consumption rate of 100 g day^{-1} the corresponding figure is approximately 0.31 mg day^{-1} . These values are order-of-magnitude estimates only

and are intended solely to illustrate potential exposure; they do not imply demonstrated toxicological risk.

Discussion

Microplastic Abundance and Tissue Distribution

This study provides quantitative evidence of microplastic occurrence in fish and water from Yusuf Bage River, Kaduna State, Nigeria. Microplastics were detected in every sample examined, with mean tissue abundances of 2.3–8.7 particles/g wet weight and a water concentration of 45.3 ± 12.6 particles/L.

The higher abundances recorded in gills and intestine relative to flesh are consistent with the physiological roles of these organs: gills continuously filter water, while the intestine is the primary site of dietary intake. Detection of particles in flesh indicates that a fraction of ingested or entrapped material can reach edible muscle tissue. The predominance of the 250–500 μm size class is compatible with secondary fragmentation of larger debris and with the filtration and retention characteristics of the tissues examined.

Polymer Composition

Polyethylene was the most frequently identified polymer (67.3 % of confirmed particles), followed by PET (18.4 %) and PP (9.8 %). This pattern mirrors reports from other Nigerian freshwater and coastal studies in which PE derived from packaging films and bags is typically dominant (Ndibe et al., 2023; Olarinmoye et al., 2020; Akindele et al., 2020).

The elevated PET signature in the water samples is consistent with inputs from discarded beverage bottles and synthetic textile fibres. All polymer assignments were based on multiple diagnostic infrared bands and library match factors ≥ 0.75 , reducing the likelihood of misidentification.

Morphological Features

SEM images showed irregular fragments, fibres and sheet-like particles bearing sharp edges, surface cracks and pitting—features characteristic of weathered secondary microplastics (Lusher et al., 2017; Veerasingam et al., 2021). Such surface roughening increases the specific surface area available for adsorption of hydrophobic pollutants, although the present study did not quantify adsorbed chemicals.

Comparison with Other African Studies

Tissue abundances recorded here (2.3–8.7 particles/g) fall within the lower to mid-range of values reported for African freshwater biota (Table 5). Higher loads have been documented in aquatic insects from the Osun and Ogun Rivers (Akindele et al., 2020) and in some Egyptian and South African fish populations. Differences among studies may reflect local pollution intensity, species-specific feeding ecology, analytical size limits and extraction protocols. The consistent detection of microplastics in Yusuf Bage River nevertheless demonstrates that this northern Nigerian system is not exempt from the widespread plastic contamination observed elsewhere on the continent.

Table 5: Comparison of microplastic abundances reported for selected African freshwater systems

Location	Matrix	Abundance	Reference
Osun/Ogun Rivers, Nigeria	Aquatic insects	up to 291 particles/g	Akindele et al. (2020)
Yusuf Bage River, Nigeria	Fish tissues	2.3–8.7 particles/g	This study
Nile River, Egypt	Tilapia (gut/gills)	0.5–7.7 particles/indiv.	Hassan et al. (2025)
South African rivers	Various fish	10–119 particles/fish	Dahms et al. (2020)

Implications for Exposure Assessment

The presence of microplastics in edible flesh confirms a potential dietary exposure pathway for local consumers. The preliminary mass-based intake estimates (approximately $0.16\text{--}0.31\text{ mg day}^{-1}$ under the stated assumptions) are intended only to indicate order of magnitude. Formal risk characterisation would require particle-size-resolved mass data, toxicological benchmarks for the relevant polymers and additives, and detailed local consumption surveys—none of which were available in the present study. Consequently, no claim of demonstrated human health risk is made.

Methodological Considerations

The KOH digestion protocol proved effective for the lipid-rich tissues examined, and recovery and blank results were acceptable. The practical lower size limit of approximately 63–100 μm means that smaller microplastics and nanoplastics were not quantified; total contamination may therefore be underestimated. Future work should incorporate finer filters or complementary techniques (for example, micro-Raman or pyrolysis-GC/MS) to extend the size spectrum and to quantify polymer mass more rigorously.

CONCLUSION

This study documents the occurrence of microplastics in fish tissues and water from Yusuf Bage River, Kaduna State, Nigeria. Mean abundances ranged from 2.3 to 8.7 particles/g wet weight in flesh, gills and intestine, and 45.3 ± 12.6 particles/L in surface water. Polyethylene was the dominant polymer (approximately 67 %), followed by PET and PP.

Particles exhibited morphological features consistent with secondary, environmentally weathered microplastics. Higher abundances were recorded in gills and intestine than in edible flesh. The data provide a useful baseline for this previously unstudied northern Nigerian river and highlight the need for continued monitoring and improved waste-management practices along the catchment.

- Relevant authorities should strengthen regulation of single-use plastics (especially polyethylene bags and PET bottles) and improve solid-waste collection and disposal infrastructure along the river corridor.
- Routine monitoring of microplastics in commercially important fish species and freshwater bodies should be established, using standardised protocols that permit temporal and spatial comparison.
- Public-awareness programmes on hygienic fish processing (removal of gills and viscera, thorough rinsing) and responsible waste disposal should be promoted.
- Further research should address smaller size fractions ($<100\text{ }\mu\text{m}$), histopathological and biomarker responses, and more refined human-exposure assessments based on local dietary surveys.

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