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## Research Article

### Distribution and Abundance of Microplastics in Surface Water of Lake Geriyo, Adamawa State, Nigeria

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#### ABSTRACT

Microplastic (MP) pollution is an emerging threat to freshwater ecosystems, yet data remain scarce across African inland waters. This study provides the first systematic assessment of microplastic distribution and abundance in the surface water of Lake Geriyo, a shallow tropical lake in the Upper Benue River Basin, Nigeria. Surface water samples were collected in triplicate from three stations over 18 months (September 2024-February 2026). Microplastics were isolated by wet sieving, wet peroxide oxidation, and density separation, and polymers were identified using attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR). Spatial and temporal differences were tested with one-way ANOVA and Duncan's multiple range test. A total of 623 microplastic particles were recovered, with mean concentrations of 6 to 19 particles/L. Stations 1 (fishing landing;  $12.67 \pm 3.48$  particles/L) and 2 (settlement runoff;  $12.89 \pm 2.35$  particles/L) recorded significantly higher concentrations than Station 3 (depositional zone;  $9.06 \pm 1.66$  particles/L) (ANOVA:  $F(2,51) = 11.88$ ,  $p < 0.001$ ). Concentrations peaked during the late wet season (September-October 2024) and the warm dry season (May-July 2025), with minima in the cool dry season (December-February). Fibres (26.30 %) and fragments (21.10 %) were the dominant morphotypes, and transparent/clear particles constituted 46.20 %. ATR-FTIR confirmed polyethylene, polystyrene, polyamide (nylon), polyethylene terephthalate, and silicone-based polymers. Fishing operations and settlement runoff are the primary drivers of contamination, with seasonal hydrology modulating distribution. These findings establish a critical baseline for microplastic pollution in a tropical African lake and underscore the need for integrated watershed management strategies.

**Keywords:** Freshwater pollution; Lake Geriyo; Microplastics; Nigeria; Spatial distribution; Seasonal variation; Surface water; Tropical Lake

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#### INTRODUCTION

The proliferation of plastic debris in aquatic environments has been identified as one of the most pervasive anthropogenic stressors facing global ecosystems (Jambeck *et al.*, 2015; Geyer *et al.*, 2017). While early research focused predominantly on marine systems, it is now recognized that freshwater ecosystems serve as major conduits for plastic pollution, receiving an estimated 1.15-2.41 million

tonnes of plastic waste annually from terrestrial sources (Lebreton and Andrady, 2019). In these environments, larger plastic items undergo photo-oxidation, mechanical abrasion, and biological weathering, fragmenting into microplastics (MPs), which are defined as synthetic polymer particles < 5 mm in diameter (Law and Thompson, 2014; GESAMP, 2015). Microplastics are further classified by origin: primary MPs are manufactured at microscopic

dimensions (e.g., cosmetic microbeads, industrial pellets), whereas secondary MPs arise from the environmental degradation of larger plastic debris (Andrady, 2011; Song *et al.*, 2017).

Freshwater lakes, in particular, serve as important sinks and reactors for microplastic pollution. Their relatively closed hydrodynamics, variable stratification regimes, and direct connectivity to terrestrial catchments create unique conditions for MP accumulation and retention (Wagner *et al.*, 2014; Eerkes-Medrano *et al.*, 2015). Once introduced, microplastics can be ingested by a broad spectrum of aquatic biota, from zooplankton to fish, with potential consequences such as physical gut blockage, false satiation, inflammatory responses, and vector-mediated transfer of sorbed pollutants (Wright *et al.*, 2013; Lusher *et al.*, 2017; Kumar *et al.*, 2020). Despite these risks, significant geographical biases persist in the literature: research has concentrated in North America, Europe, and East Asia, while African freshwater systems remain critically understudied (Blettler *et al.*, 2018; Dube and Ncube, 2020).

Empirical studies from sub-Saharan Africa, though still limited in number, have begun to document the scale of this contamination. In Nigeria, Tajudeen *et al.* (2021) reported microplastic abundances of 1.7 particles/L in the surface waters of Badagry Lagoon, Lagos State, linking contamination to domestic sewage and fishing activity, while Egbeocha *et al.* (2021) recorded 5.31 particles/L in Lake Chad, with fibres dominating the particle assemblage. Elsewhere in West Africa, Charles *et al.* (2022) detected 2.28 particles/L in the Volta Lake, Ghana, and, in East Africa, Robert *et al.* (2022) reported 2.5 particles/L in the surface water of Lake Victoria, Kenya, attributing contamination to urban runoff and shoreline settlements. Regional syntheses confirm that polyethylene and polypropylene dominate polymer assemblages across African freshwaters and that methodological inconsistency continues to hamper cross-system comparison (Dube and Ncube, 2020; Dusaucy *et al.*, 2021). Collectively, these studies indicate that microplastic pollution of African inland waters is widespread yet patchily documented, with shallow tropical lakes of the West African savanna zone remaining particularly under-represented (Blettler *et al.*, 2018; Chen *et al.*, 2025). Lake Geriyo exemplifies the anthropogenic pressures facing many tropical African lakes. To date, no systematic investigation has quantified microplastic contamination in this ecosystem. The present study addresses this knowledge gap by assessing the

distribution and abundance of microplastics in the surface water of Lake Geriyo, with the specific objectives of characterizing their spatial heterogeneity, temporal dynamics, physical attributes, and polymer composition.

## **MATERIALS AND METHODS**

### **Study Area**

Lake Geriyo is situated on the outskirts of the Jimeta Yola metropolis in the northeast region (longitude 120 25' E, between latitude 90 81' N and 90 17' N). It covers an area of approximately 750 hectares at a high level and 200 hectares at a low level, with a storage capacity of about 7,500,000 cubic meters and a mean depth of about 2 to 3 meters (with seasonal low points around 0.7 meters). Its maximum length reaches over 3 kilometers. The portion suitable for fisheries development is roughly 250 hectares. Most of the inhabitants around the lake are associated with the Upper Benue River Basin Development Authority. Lake Geriyo is a small body of water that originally formed from a tiny gully, later filling with rainwater and some inflow from the River Benue. It became a recognizable lake around 1950. Initially, it was not used for fishing, but now it has developed into a significant fishery with year-round fishing activities. Additionally, it serves as a major water source for irrigation during the dry season for farming around the lake. The lake's water level remains relatively stable, allowing for balanced inflow and outflow. This stability has supported the growth of aquatic plants, giving the basin the characteristics of a typical lake. (Yonnana *et al.*, 2015).

Lake Geriyo is a shallow, rain-fed lake in northwestern Adamawa State, Nigeria, originally formed from a gully system that filled with rainwater and River Benue inflow around 1950. The lake covers approximately 750 ha at high level and 200 ha at low level, with a storage capacity of roughly 7.5 million cubic meters. The portion suitable for fisheries development is approximately 250 ha. The lake experiences a tropical climate with a rainy season (May-October) and a dry season (late October-April), during which strong harmattan winds and intense heat (up to 40 °C) prevail. Three sampling stations were established: Station 1 (fishing landing site, primary hub for fish processing and marketing); Station 2 (settlement runoff zone, receiving surface drainage from adjacent residential and agricultural land); and Station 3 (depositional zone, a comparatively undisturbed area with minimal direct anthropogenic influence).



**Figure 1: Map showing Lake Geriyo**

### Sample Collection

Surface water samples were collected monthly from September 2024 to February 2026 (18 months) at the three stations using a simple randomized design. At each station, triplicate 1-L samples were collected at a depth of 10 cm below the water surface at 08:00 h local time. All sample bottles were thoroughly pre-cleaned by soaking in 1:3 nitric acid for 48 h, followed by repeated rinsing with deionized distilled water acidified to pH < 1, to eliminate background plastic contamination (Streumpler, 1973). Bottles were rinsed three times with lake water before final sample collection, filled completely to exclude air bubbles, and transported on ice blocks to the Modibbo Adama University Central Laboratory within 60 min of collection.

### Sample Processing and Microplastic Extraction

Microplastic extraction followed the NOAA protocol described by Masura *et al.* (2015) with minor modifications. Each sample was poured through a stacked set of stainless-steel sieves (5.6 mm and 0.3 mm apertures) and rinsed with distilled water to transfer residual solids and remove salts. The 0.3-mm size fraction was transferred to a pre-weighed 500-mL beaker and dried at 90 °C for ≥ 24 h. Wet peroxide oxidation (WPO) was performed by adding 20 mL of 0.05 M Fe (II) solution and 20 mL of 30 % hydrogen peroxide, heating the mixture to 75 °C on a hotplate for 30 min to digest organic matter. Density separation was achieved by adding NaCl (6 g per 20

mL of sample, ≈ 5 M) to raise the aqueous density, allowing less dense plastic particles to float. Floating solids were collected on a custom 0.3-mm sieve, air-dried for 24 h, and examined under a dissecting microscope at 40× magnification. Suspected microplastics were manually extracted using stainless steel forceps, placed in pre-weighed 4-mL glass vials, and stored for further analysis.

### Polymer Identification

Polymer characterization was conducted using a PerkinElmer Spectrum Two ATR-FTIR spectrometer equipped with a single-reflection diamond ATR accessory and a lithium tantalate (LiTaO<sub>3</sub>) detector. A background spectrum was collected against the clean diamond crystal under ambient conditions. Each microplastic sample was placed directly on the diamond crystal and secured with the built-in pressure clamp. Spectra were recorded in absorbance mode from 4000 to 550 cm<sup>-1</sup>, averaging 4 co-added scans at 4 cm<sup>-1</sup> resolution. Atmospheric compensation, baseline correction, ATR correction, and min-max normalization were applied using Spectrum software. Polymers were identified by comparing characteristic absorption bands against standard spectral libraries.

### Quality Assurance and Control

Procedural blanks (deionized water processed identically to field samples) were run in parallel with each batch to monitor laboratory contamination. All glassware was rinsed with distilled water before use,

and cotton laboratory coats were worn during processing to minimize fibre contamination. No microplastic contamination was detected in blank samples.

#### Data Analysis

All analyses were performed in triplicate. Descriptive statistics (mean, standard deviation, standard error) were calculated for each station. Spatial differences in microplastic concentrations were evaluated using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test for post-hoc comparison of means. Statistical significance was set at  $p \leq 0.05$ . All analyses were conducted using SPSS version 26.0.

#### RESULTS

Over the 18-month monitoring period, a total of 623 microplastic particles were detected in the surface water of Lake Geriyo. Mean monthly concentrations across all stations ranged from 6 to 19 particles/L. The highest monthly totals were recorded in September 2024 (47 particles), November 2024 (41 particles), July 2025 (41 particles), and August 2025 (42 particles), while the lowest totals occurred in December 2025 and January 2026 (27 particles each). Microplastic concentrations exhibited pronounced and statistically significant spatial heterogeneity (ANOVA:  $F(2,51) = 11.88$ ,  $p < 0.001$ ). Station 2 recorded the highest mean concentration ( $12.89 \pm 2.35$  particles/L), closely followed by Station 1 ( $12.67 \pm 3.48$  particles/L). Station 3 displayed significantly lower levels ( $9.06 \pm 1.66$  particles/L). Duncan's posthoc test grouped Stations 1 and 2 into a single homogeneous subset, both significantly different from Station 3 ( $p < 0.05$ ) (Table 1). The cumulative particle count mirrored this pattern: Station 1 = 228 particles, Station 2 = 232 particles, and Station 3 = 163 particles.

The temporal record revealed a distinct seasonal pattern characterized by two concentration peaks.

The first peak occurred during the late wet season (September-October 2024), coinciding with maximum rainfall and surface runoff. The second, more pronounced peak was observed during the warm dry season (May-July 2025), a period associated with strong winds and intensified fishing activity. Conversely, concentrations were consistently lowest during the cool dry season (December-February), when reduced runoff, lower wind speeds, and diminished anthropogenic inputs allowed gravitational settling to dominate (Table 2).

Colour analysis revealed a markedly uneven distribution across six categories. As shown in fig. 2 Transparent/clear microplastics dominated the assemblage (46.20 %), followed by yellow (20.54 %), blue (13.19 %), green (9.62 %), red (6.11 %), and black (4.30 %). As shown in fig. 3 Morphological classification identified fibres as the most abundant type (26.30 %), followed by fragments (21.10 %), film (16.62 %), nylon (13.94 %), foam (12.02 %), and pellets (10.02 %).

ATR-FTIR analysis of representative microplastic samples identified a diverse polymer suite. G2 shows High-density polyethylene (HDPE) was confirmed by characteristic aliphatic C-H stretches ( $2915$  and  $2848$   $\text{cm}^{-1}$ ) and  $\text{CH}_2$  rocking at  $718$   $\text{cm}^{-1}$ . G3 shows Polystyrene variants were identified by aromatic C-H stretches ( $\sim 3025$   $\text{cm}^{-1}$ ) and out-of-plane bending ( $\sim 695$   $\text{cm}^{-1}$ ). Administration 70 shows Polyamide (nylon 666) was distinguished by amide I ( $1635$ - $1637$   $\text{cm}^{-1}$ ) and amide II ( $1535$ - $1542$   $\text{cm}^{-1}$ ) bands. G10 shows Polyethylene terephthalate (PET) exhibited ester carbonyl stretching at  $\sim 1715$   $\text{cm}^{-1}$  and C-O stretching at  $\sim 1239$   $\text{cm}^{-1}$ . Notably, G9.2 shows silicone/siloxane polymers were also detected, indicated by Si-O-Si asymmetric stretches ( $\sim 1030$   $\text{cm}^{-1}$ ) and vinylidene C-H out-of-plane bending ( $\sim 910$   $\text{cm}^{-1}$ ), suggesting inputs from medical or industrial waste streams.

**Table 1. Spatial variation of microplastic concentrations in the surface water of Lake Geriyo (September 2024-February 2026)**

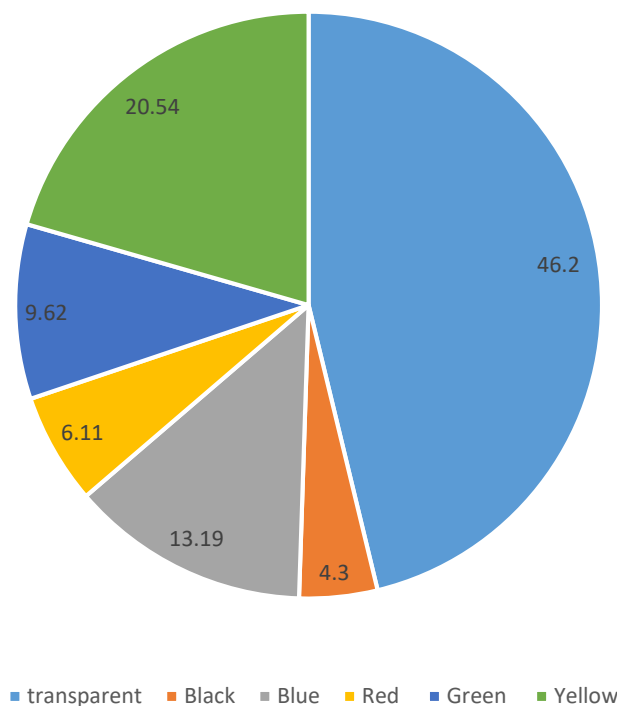
| Station                       | N  | Mean (particles/L) | SD   | SE   | Duncan grouping |
|-------------------------------|----|--------------------|------|------|-----------------|
| Station 1 (Fishing landing)   | 18 | 12.67              | 3.48 | 0.82 | A               |
| Station 2 (Settlement runoff) | 18 | 12.89              | 2.35 | 0.55 | A               |
| Station 3 (Depositional zone) | 18 | 9.06               | 1.66 | 0.39 | B               |

Note. Means sharing the same letter are not significantly different at  $p < 0.05$ .

**Table 2. Monthly summation of microplastic particles across all sampling stations in Lake Geriyo surface water**

| Month    | Station 1 | Station 2 | Station 3 | Monthly Total |
|----------|-----------|-----------|-----------|---------------|
| Sep 2024 | 19        | 19        | 9         | 47            |
| Oct 2024 | 17        | 11        | 10        | 38            |
| Nov 2024 | 18        | 13        | 10        | 41            |
| Dec 2024 | 17        | 11        | 8         | 36            |
| Jan 2025 | 12        | 11        | 9         | 32            |
| Feb 2025 | 11        | 13        | 9         | 33            |
| Mar 2025 | 10        | 11        | 8         | 29            |
| Apr 2025 | 8         | 11        | 9         | 28            |
| May 2025 | 14        | 16        | 10        | 40            |
| Jun 2025 | 13        | 14        | 11        | 38            |
| Jul 2025 | 14        | 14        | 13        | 41            |
| Aug 2025 | 15        | 16        | 11        | 42            |
| Sep 2025 | 13        | 14        | 9         | 36            |
| Oct 2025 | 9         | 13        | 9         | 31            |
| Nov 2025 | 8         | 13        | 8         | 29            |
| Dec 2025 | 9         | 11        | 7         | 27            |
| Jan 2026 | 10        | 10        | 7         | 27            |
| Feb 2026 | 11        | 11        | 6         | 28            |

Percentage of microplastics based on colour in Lake Geriyo



**Figure 2: Percentage of microplastics based on colour in Lake Geriyo (September 2024 to February 2026)**

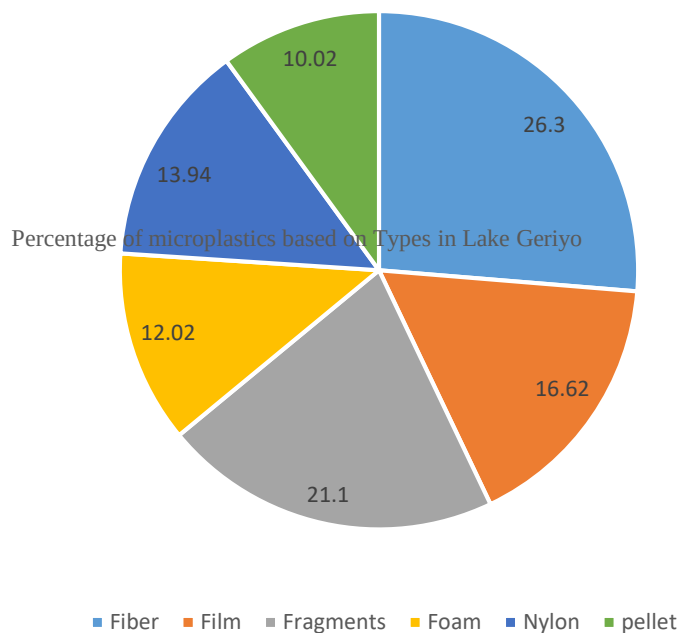


Figure 3: Percentage of microplastics based on Types in Lake Geriyo (September 2024 to February 2026)

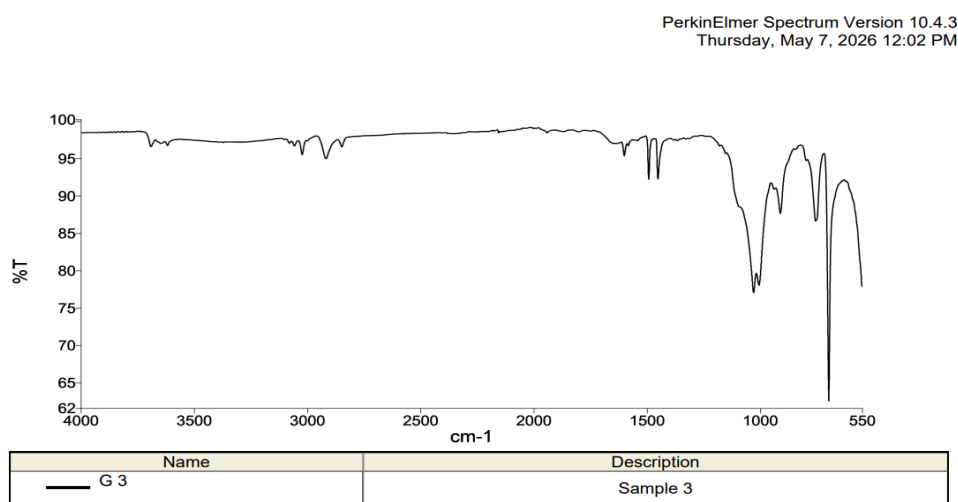
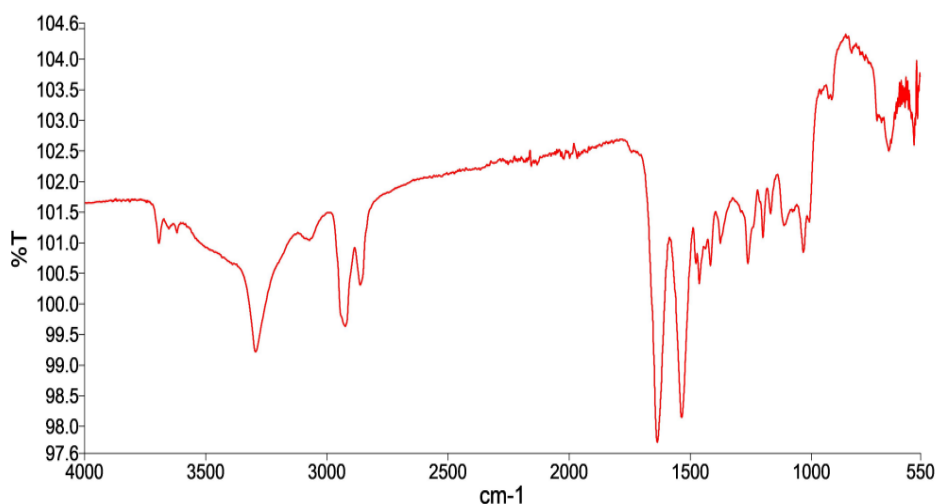


Figure 4: Showing the G3 FTIR spectrum

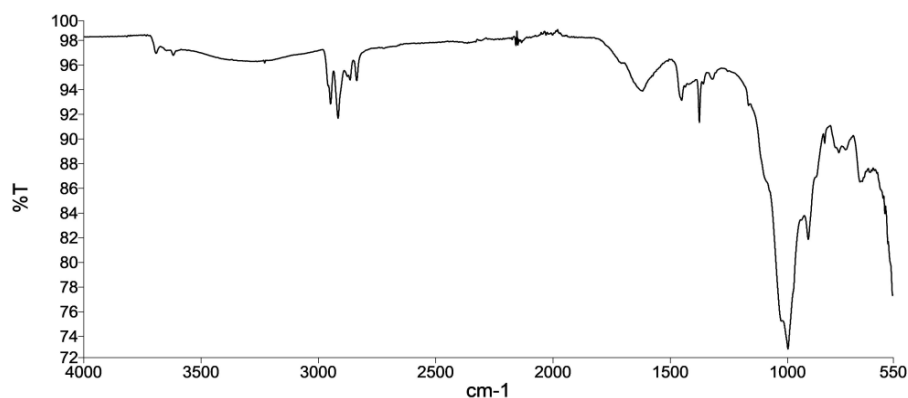
PerkinElmer Spectrum Version 10.4.3  
Thursday, May 7, 2026 12:40 PM



| Name             | Description                                            |
|------------------|--------------------------------------------------------|
| Administrator 70 | Sample 070 By Administrator Date Thursday, May 07 2026 |

Figure 5: Showing the Administration 70 FTIR spectrum

PerkinElmer Spectrum Version 10.4.3  
Thursday, May 7, 2026 12:54 PM



| Name  | Description |
|-------|-------------|
| G 9.2 | Sample 9.2  |

#### Summary

| Sample Name | Description | Quality |
|-------------|-------------|---------|
|-------------|-------------|---------|

Figure 6: Showing the G9.2 FTIR spectrum

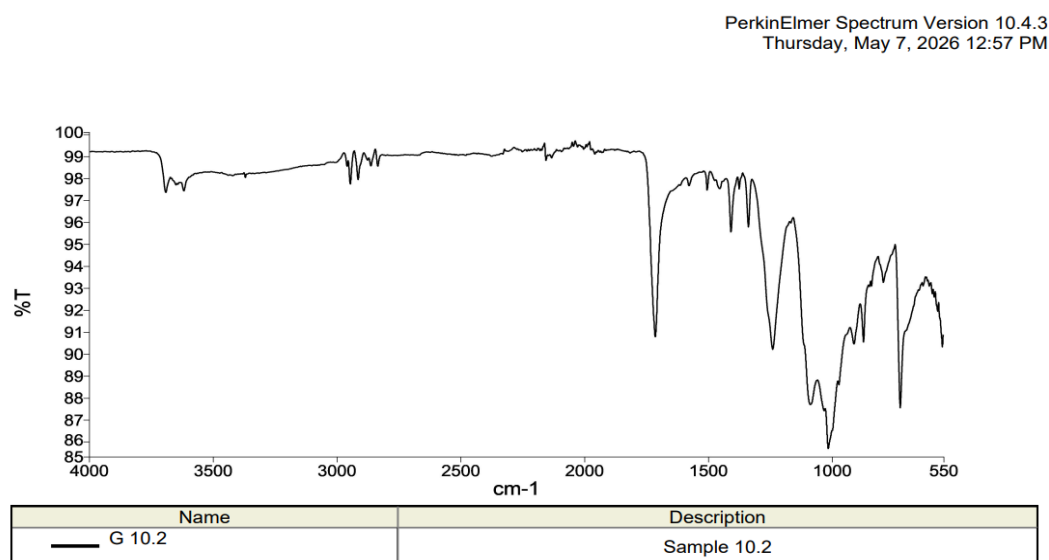


Figure 7: showing G10.2 FTRIR spectrum

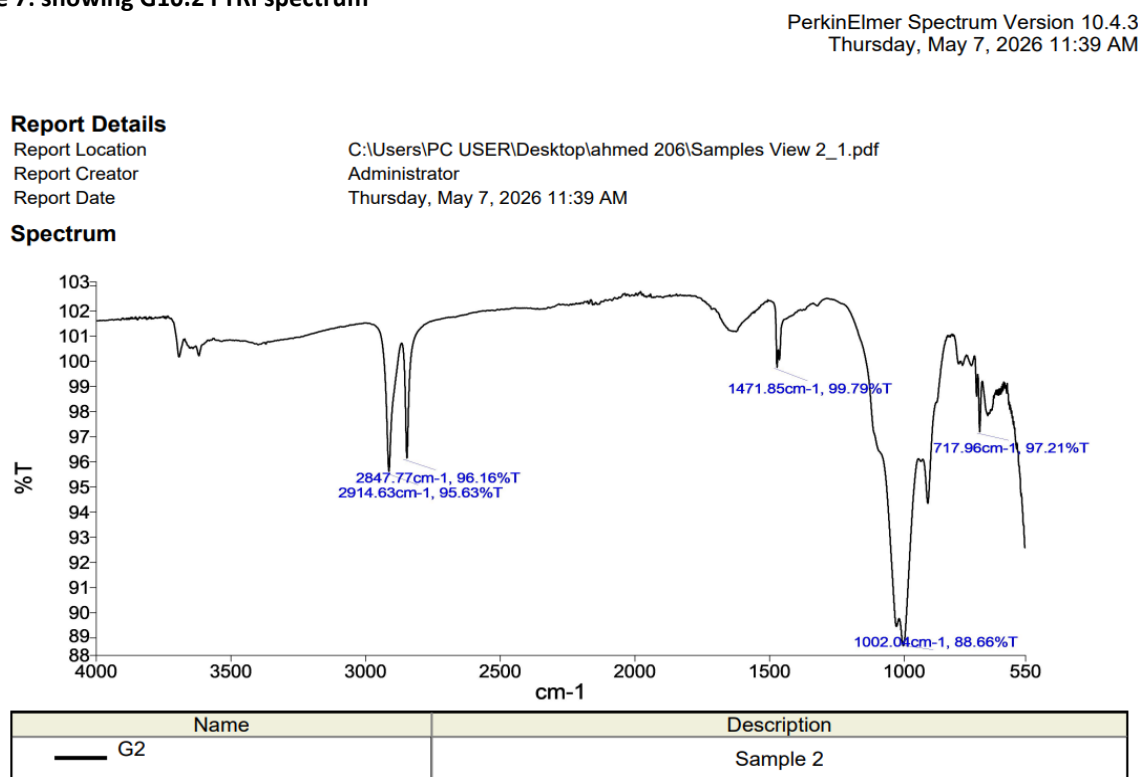


Figure 8: Showing the G2 FTRIR spectrum

## DISCUSSION

The significant spatial heterogeneity observed in Lake Geriyo surface waters ( $p < 0.001$ ) reflects the strong influence of localized anthropogenic activity on microplastic distribution. Stations 1 and 2, situated proximal to the primary fishing landing and settlement runoff zones, consistently recorded

concentrations approximately 40 % higher than Station 3. This pattern aligns with the conceptual model of source-proximal accumulation in freshwater systems, where nearshore areas adjacent to human activity act as primary entry points for plastic debris (Nel *et al.*, 2018; Hurley *et al.*, 2018).

Station 1 receives direct inputs from fishing operations, including abandoned or degraded nets, ropes, floats, and post-harvest packaging materials. The high prevalence of nylon fibres (13.94 % of total morphotypes) and blue/green-coloured particles at this station strongly implicates fishing gear as a dominant source. Station 2, by contrast, is influenced by surface runoff from residential areas and agricultural fields, likely contributing transparent films (agricultural mulch) and fragments from domestic packaging. The morphological dominance of fibres and fragments, which collectively accounting for nearly half of all particles, further supports a mixed source profile combining fisheries-derived fibres and secondary fragmentation of land-based plastics (Chen *et al.*, 2025).

Station 3's lower concentrations, despite its role as a depositional zone for inorganic sediments, highlight an important decoupling between mineral sedimentation and plastic accumulation. Microplastics, with densities typically ranging from 0.9 to 1.4 g/cm<sup>3</sup>, settle more slowly than silicate minerals (~2.6 g/cm<sup>3</sup>) and remain susceptible to wind-driven resuspension and lateral advection in shallow lakes (Hess *et al.*, 2021; Amadori *et al.*, 2025). Consequently, less dense plastics may be transported away from quiescent depositional zones before incorporation into the sediment bed, resulting in lower standing stocks in the water column at Station 3.

The bimodal temporal pattern, peaking in the late wet season and again in the warm dry season reflects the interplay of hydrological mobilization and wind-induced resuspension in shallow lacustrine systems. The September-October 2024 peak coincided with maximum rainfall, which mobilized terrestrial microplastics from agricultural fields, roads, and informal waste dumps via surface runoff. This mechanism is well documented in tropical catchments, where the first flush of the rainy season delivers accumulated dry-season debris to receiving waters (Dusaucy *et al.*, 2021; Tajudeen *et al.*, 2021). The second peak (May-July 2025) occurred during the hot, windy dry season. Strong winds exert significant shear stress on the shallow lake bed, resuspending sediment-bound microplastics into the water column. This interpretation is supported by concurrent turbidity maxima (> 25 NTU) and the documented susceptibility of shallow African lakes to wind-driven mixing (Hess *et al.*, 2021). Additionally, this period coincides with peak fishing activity, introducing fresh debris directly to the water surface. The lowest concentrations during December-February reflect

seasonal attenuation: reduced runoff, diminished wind energy, and lower fishing activity allow particles to settle, temporarily depleting the water-column inventory.

The polymer assemblage provides robust evidence for multiple, distinct source pathways. Polyethylene (HDPE) and polypropylene, the most widely produced plastics globally (Geyer *et al.*, 2017), are ubiquitous in packaging and container applications. Their dominance in Lake Geriyo indicates substantial input from domestic and commercial packaging waste. The identification of polystyrene with both general-purpose and expanded forms, points to food containers and disposable cups commonly used in local markets. Polyamide (nylon) fibres are unequivocally linked to fishing nets, ropes, and synthetic textiles, corroborating the visual evidence of fibre dominance.

Perhaps most concerning is the detection of silicone-based polymers, including vinyl-functional silicone consistent with medical-grade materials. These are not typical environmental microplastics and suggest improper disposal of clinical or industrial waste into the lake catchment (Horvatits *et al.*, 2021). The presence of such specialized polymers underscores the diversity of anthropogenic pressures on Lake Geriyo and the inadequacy of current waste management infrastructure.

Direct comparisons across African lakes are complicated by methodological differences in sampling, extraction, and reporting units. Nevertheless, the concentrations observed in Lake Geriyo (6-19 particles/L; mean ≈ 11.5 particles/L) are moderately high relative to published benchmarks. Tajudeen *et al.* (2021) reported 1.7 particles/L in Lagos Lagoon, Nigeria; Egbeocha *et al.* (2021) recorded 5.31 particles/L in Lake Chad; Charles *et al.* (2022) found 2.28 particles/L in Volta Lake, Ghana; and Robert *et al.* (2022) observed 2.5 particles/L in Lake Victoria, Kenya. The elevated levels in Lake Geriyo likely reflect the combined effects of intense local fishing pressure, proximity to an urban centre (Jimeta-Yola), and the lake's shallow, wind-exposed morphology, which promotes continuous resuspension and retention of particles. The use of a 0.3-mm mesh sieve also captures smaller particles than some prior studies, potentially inflating counts relative to coarser screening protocols.

Microplastic concentrations of 6-19 particles/L represent a chronic exposure risk for the Lake Geriyo food web. The water column serves as the primary vector for microplastic uptake by pelagic and filter-feeding organisms, including the commercially

important Nile tilapia (*Oreochromis niloticus*). Although acute toxicity is unlikely at these concentrations, sublethal effects which includes oxidative stress, gut microbiome disruption, and reduced feeding efficiency may manifest under chronic exposure, particularly when microplastics act as vectors for co-contaminants such as heavy metals and persistent organic pollutants (Rai *et al.*, 2022; Hayat *et al.*, 2025).

From a management perspective, the spatial concentration gradient (Stations 1, 2 > Station 3) offers a clear targeting framework for intervention. Source-control measures, such as provision of waste collection infrastructure at fishing landings, prohibition of abandoned gear, and installation of runoff interception systems should be prioritized in the Northeastern littoral zones where anthropogenic pressure is greatest. The seasonal pattern further suggests that intervention efficacy will vary temporally; for example, floating debris barriers may be most critical during the late wet season when runoff-driven inputs peak.

## CONCLUSION

This study demonstrates that Lake Geriyo is pervasively contaminated with microplastics in its surface waters, with significant spatial heterogeneity driven by anthropogenic activity and pronounced temporal variation governed by seasonal hydrology and wind-driven resuspension. Spatial distribution: Microplastic concentrations are significantly elevated at the fishing landing (Station 1) and settlement runoff (Station 2) sites compared to the depositional zone (Station 3), confirming localized anthropogenic sources. Temporal dynamics: A bimodal seasonal pattern peaks during the late wet season (runoff mobilization) and the warm dry season (wind resuspension and fishing activity), with minima during the cool dry season. Particle characteristics: Fibres and fragments dominate the assemblage, with transparent particles most abundant. Polymer identification reveals inputs from packaging (PE, PS, PET), fishing gear (nylon), and potentially medical or industrial waste (silicone). Baseline value: Mean surface water concentrations ( $\approx 11.5$  particles/L) place Lake Geriyo in the moderate-to-high range of reported African freshwater systems, necessitating proactive monitoring and mitigation. These findings provide the first quantitative baseline for microplastic pollution in Lake Geriyo and contribute to the growing, but still limited, body of evidence on freshwater microplastic contamination in sub-Saharan Africa. We recommend the establishment of

a long-term monitoring programme, enforcement of waste management regulations at fishing landings, and community-based interventions to reduce plastic input at identified hotspots.

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