

Characterization of Microplastics polymer from the water and sediment of Upper River Benue, at Yola Metropolis, Adamawa State, Nigeria

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doi: <https://doi.org/10.37745/bjmas.0614>

Published October 17, 2026

Citation: Sabo M. and Onyia L.U. (2026) Characterization of Microplastics polymer from the water and sediment of Upper River Benue, at Yola Metropolis, Adamawa State, Nigeria, *British Journal of Multidisciplinary and Advanced Studies*,7(5),15-27

Abstract: *The study presents pilot assessment of microplastics identification and characterization of different polymer classes in water and sediments from the Upper River Benue at Yola metropolis. Sampling was carried out for fourteen consecutive months at every first week of the month from February, 2025 to April, 2026. Water samples were collected in triplicates into a re-cleaned 1 L amber bottles at each of the sampling site. Sediment samples were obtained using an Ekman sediment grab. Three small portions (up to 500 g each) of the sediments were taken at each sampling site and put into an aluminium foil bags. Polymer differentiation was achieved using Fourier-Transform Infrared Spectroscopy (FTIR). The result indicates prevalence of polypropylene (PP), polyamide (nylon), polyester (PES) and polyvinyl chloride (PVC). The study demonstrates the presences of microplastics and the difference classes of polymer contamination in Upper River Benue at Yola metropolis and hence raises critical concerns about local fish population vulnerability to microplastics pollution.*

Keywords: Microplastics, polymer type, water, FTIR spectroscopy, pollution

INTRODUCTION

Microplastics (MPs) pollution is an emerging environmental threat globally, because of their ubiquitous nature, In Nigeria, however, one can aver that there is dearth of knowledge and magnitude appreciation on the effects of microplastics pollution on our freshwater water bodies. Body of literature suggests an increasing importance of research in microplastics pollution as they are repeatedly found in food and water and have shown to be transferable from across cells, accumulate in body tissues, and biomagnifies across trophic levels. Hence, the need to intensively

study microplastics pollution in freshwater environment as they originate from urban and industrial dusts and can enter inland freshwater systems from the atmospheric environment (Abbasi *et al.*, 2019). The occurrence of microplastics has been reported in a wide range of aquatic compartments, including surface water, water column of different depth, benthic sediment, and even ice core from the Polar Regions (Wang *et al.*, 2019).

Fisheries could be point sources of MPs pollution to freshwater lakes and rivers. The data for Danjiangkou Reservoir suggested that discarded ropes and/or fishing nets could be potential MPs sources in freshwater. Extensive fishery activities and detected nylon particles (Yuan *et al.*, 2019), the main component of fishing tools, strongly suggested that fishing contributes to MPs pollution in freshwater lakes. Microplastics entry into the water is mainly driven by anthropogenic activities. It was estimated that a single wash of clothes using domestic washing machines could produce > 1900 microplastic fibers into the sewage (Browne *et al.*, 2011). The concentration of plastic microbeads in facial scrubs could be up to 50391 particles/g and a typically single use of facial scrubs could release 10000–100000 primary microplastics into the domestic sewage system (Cheung and Fok, 2017), eventually ending up in aquatic ecosystems.

It was evaluated that there were > 5 trillion pieces of plastic debris afloat on the sea, with > 90% were secondary microplastics derived from fragmentation (Wang *et al.*, 2019). These suggest that the occurrence of microplastics in aquatic environments originates primarily from secondary sources. The major polymer types of microplastics include polyethylene, polypropylene, polystyrene, polyester, and polyvinyl chloride, which correspond with the mass production and extensive usage of these polymers all over the world (PlasticsEurope, 2018).

MPs are dominated by six types of polymers such as polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polyethylene terephthalate (PET) polystyrene (PS), and polyurethane (PU) (Munari *et al.*, 2021). In recent times, the study of the environmental occurrence and effects of MPs has shifted from marine ecosystems to inland waters (Wagner and Lambert, 2018) as they contribute to the diminishing aesthetic beauty of the aquatic environment and biodiversity loss (Gall and Thompson, 2015). While significant progress has been made in understanding microplastic contamination in the marine ecosystem, there are still many unanswered questions and research gaps in the freshwater environment. This study aims to provide an in – depth analysis on the characterization of MPs pollution of the Upper River Benue which essential for crafting effective mitigation measures and policies to address the effects of MPs on freshwater system.

MATERIALS AND METHODS

Study Area

The Upper River Benue watershed is located between latitude 6°29'N to 11°46'N and longitude 8°55'E to 13°30'E. The watershed extends 532 km from north to south and 480 km from west to east. The River covers an area of 154,328.9 km². Lake Chad Watershed bounds the upper River Benue watershed to the north, to the east and south by the Republic of Cameroon, and the west by Lower Benue and Upper River Niger (Fig. 1). The major river in the watershed is the River Benue

that has its origins in the Adamawa Plateau of Northern Cameroon and flows south-west to meet with River Niger in Lokoja. The River Benue is joined by its major tributaries; the Gongola River, the Mayo Kébbi, Taraba River, and River Katsina-Ala (Odiji, *et al.*, 2021). The altitude of the watershed ranges from 80 to 2034 m with a mean elevation of 400 m. According to the Koppen climate classification, the upper Benue River watershed is characterized by a tropical savannah climate in the south and middle and warm semi-arid climate in the north. The watershed is marked by these agro-ecological zones; mid-latitude zone, derived savannah, northern guinea savannah, southern guinea savannah, and Sahel savannah. The mean annual rainfall ranges between 700 and 1200 mm and an average annual temperature ranges from 24 to 27 °C (Odiji *et al.*, 2021).

The anthropogenic activities around the River, particularly in Jimeta Metropolis include manufacturing/production of sachet water plastics bags, bottle water containers and packaging of snacks; building construction where plastics pipes (PVC), plastics used for packaging of fittings and use of emulsion paints which contains microplastics; markets buying and selling involves exchange of goods and services, most goods are packaged in plastics bags in and out of the markets; schools where pupils/students often take snacks, sachet water and local food package in plastics eg moi-moi, and groundnut and from residential area in which case where all the domestic shopping's are packaged in plastics.. The Upper River Benue is a major transport channel that receives wastewater from its metropolitan and market places.

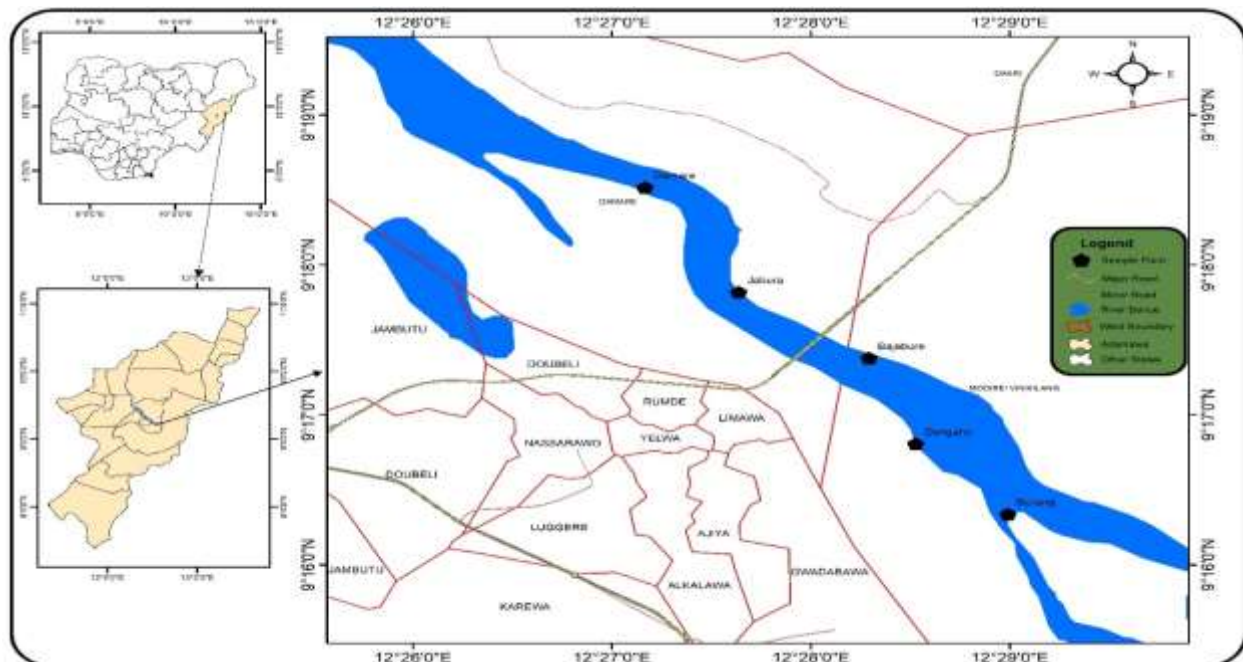


Figure 3.1 Map showing Study Area

Source; GIS, 2025

Samples Collection

Sampling was carried out for fourteen consecutive months at every first week of the month from February, 2025 to April, 2026. Five sampling sites identified with each spaced 1.5 km apart, are; 1. Buramji Latitude 9.265818°, longitude 12.44217°, and 2. Dongaho Latitude 9.271626°, longitude 12.481243°; these (2) locations are upstream relative to 3. Bajabure latitude 9.289860°, longitude 12.466734° which is adjacent to Jimeta metropolis, whereas the other two locations are downstream; 4. Jabura latitude 9.302543°, longitude 12.461624°, and 5. Damare latitude 9.308618°, longitude 12.452789°.

Water samples were collected in triplicates into a re-cleaned 1 L amber bottles at each of the sampling site. The sampling bottles were held in the opposite direction to the flow of the river until full to the brim, then covered with an aluminium foil and capped. Sediment samples were obtained using an Ekman sediment grab. Three small portions (up to 500 g each) of the sediments were taken at each sampling site and put into an aluminium foil bags. Samples were transported in iced containers to Biochemistry Laboratory, Modibbo Adama University, Yola for analysis.

Sample preparation and Extraction of Microplastics from Water and Sediments

The water and sediment samples were sieved through a 5mm aluminium sieve in order to ensure no particles greater than 5 mm is retained in the sample. The extraction of microplastics from water and sediment samples were achieved by density separation (Masura *et al.*, 2015). Sieved water (250 ml) and sediment samples (250 g) were poured into 500 ml beaker each and 250 ml of sterile salt solution (NaCl) at 30% was added to cause microplastics to float and to be filtered off. Retrieved microplastics were air dried and analyzed using Photo microscope (**Coslab**, an ISO 9001 – 2008 Company; **Model:** HL – 10A) with a magnification of S40. The shapes, colours and numerical strength of microplastics in each sample were analyzed and recorded accordingly.

Further Verification Procedures for MPs

Further verification of MPs was achieved by applying the tagging method as described by Maes *et al.* (2017) and the hot needle test as described by De Witte *et al.*, (2014).

Microplastics Analysis by Fourier Transform Infra-Red (FTIR) Spectroscopy

Polymer differentiation was achieved using FTIR Spectroscopy. FTIR Spectroscopy Analysis was carried out using Agilent Technology, Model: PerkinElmer Spectrum version: 10. 4.3 as described by Ibiene *et al.*, (2013). Bits of microplastics was mixed with potassium bromide (KBr) to form a lump and then fixed on to the FTIR sample platter. Spectra were taken at 4000 to 550 wavenumbers cm^{-1} for each sample.

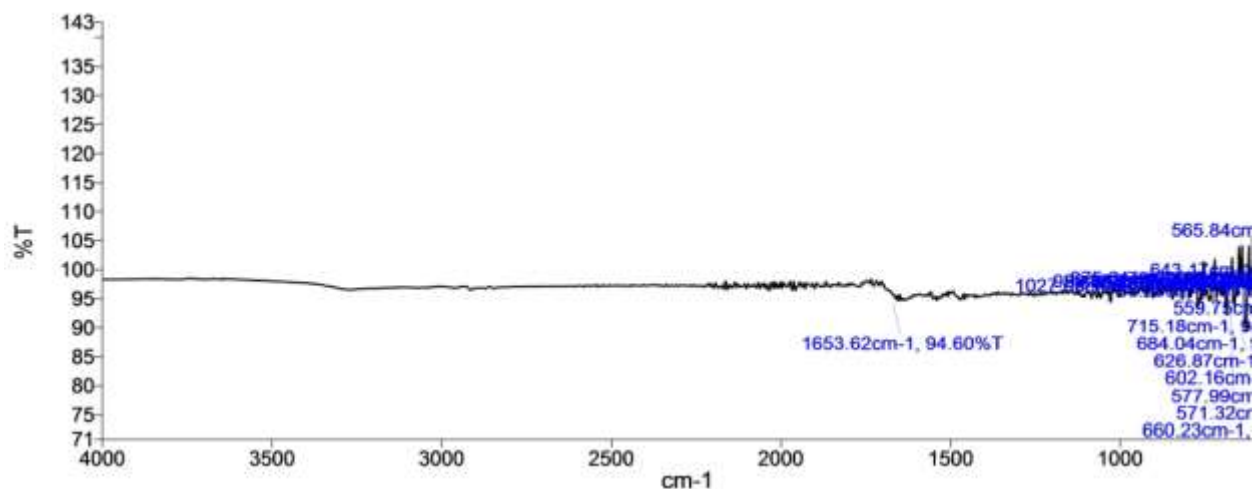
RESULTS**Composition of Different Polymer Classes Recovered in water from Upper River Benue**

Microplastics are composed of different polymers, with each having distinct physicochemical properties, which influenced their environmental behaviours.

FTIR Spectroscopy of microplastics in water and sediment samples collected from Upper River Benue

Post-photo microscopic identification was conducted to identify the different polymer classes of MPs by Fourier Transform Infrared (FTIR) Spectroscopy. The results is presented on Table 3. The most abundant microplastics retrieved from water and sediment samples at five sampling sites along the Upper River Benue, (Figures 2,3 and 4) present the FTIR micrographs of some polymers classified. The analysis revealed a recurring presence of specific functional groups and polymer types, with notable spatial variation across sites.

The most consistent retrieved polymers were Polypropylene (PP), Polyamide, Polyester, (Nylon), Polyvinyl chloride (PVC), Polybutadiene, polyisoprene, Polyethylene (PE) and handfull of unclassified polymers. These suggested the strong presence of fibric polymers; polyamide (nylon), polypropylene and rubber based polymers such as polybutadiene and polyisoprene.



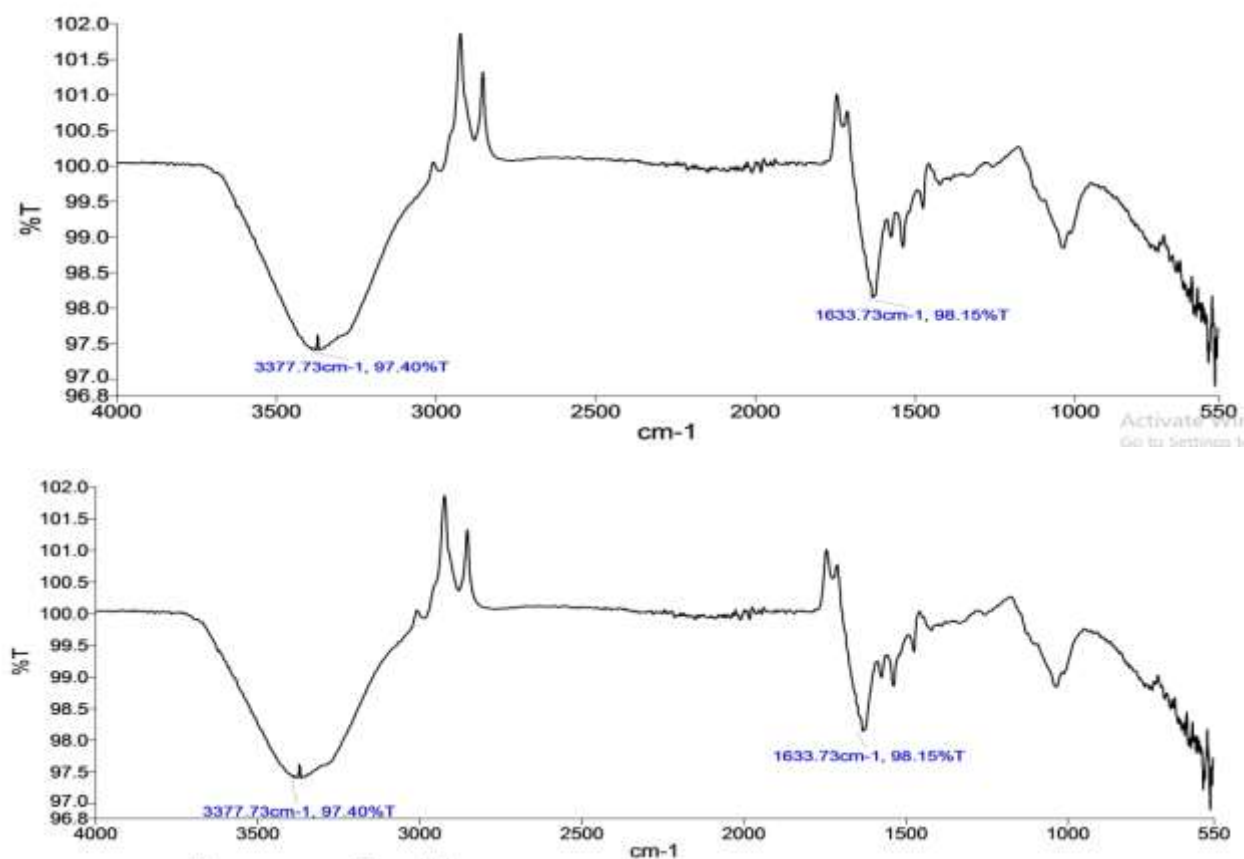


Figure2: Fourier Transform Infrared (FTIR) spectroscopy micrographs of microplastic particles in water samples from Upper River Benue

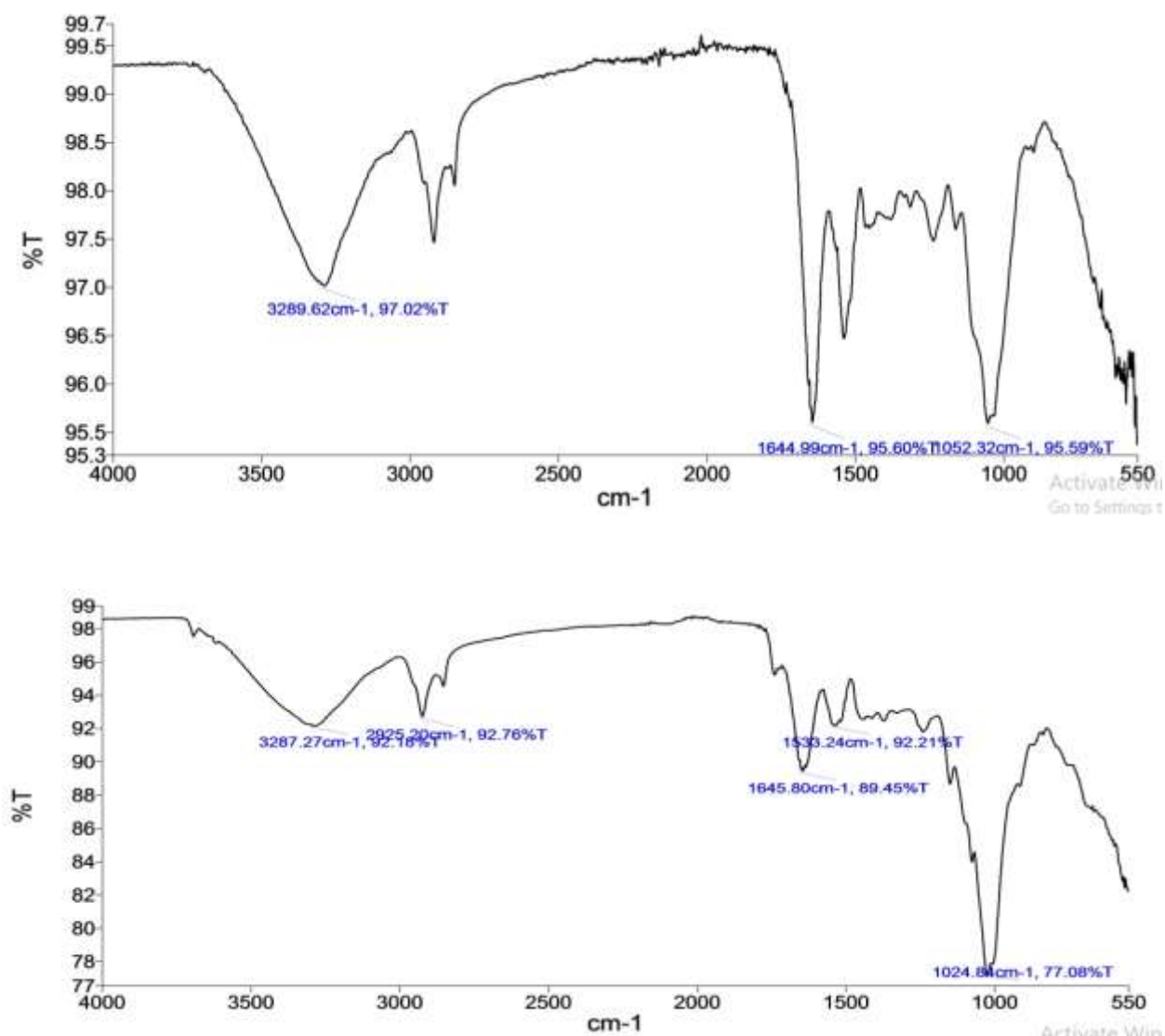


Figure 3: Fourier Transform Infrared (FTIR) spectroscopy micrographs of microplastic particles in sediment samples from Upper River Benue

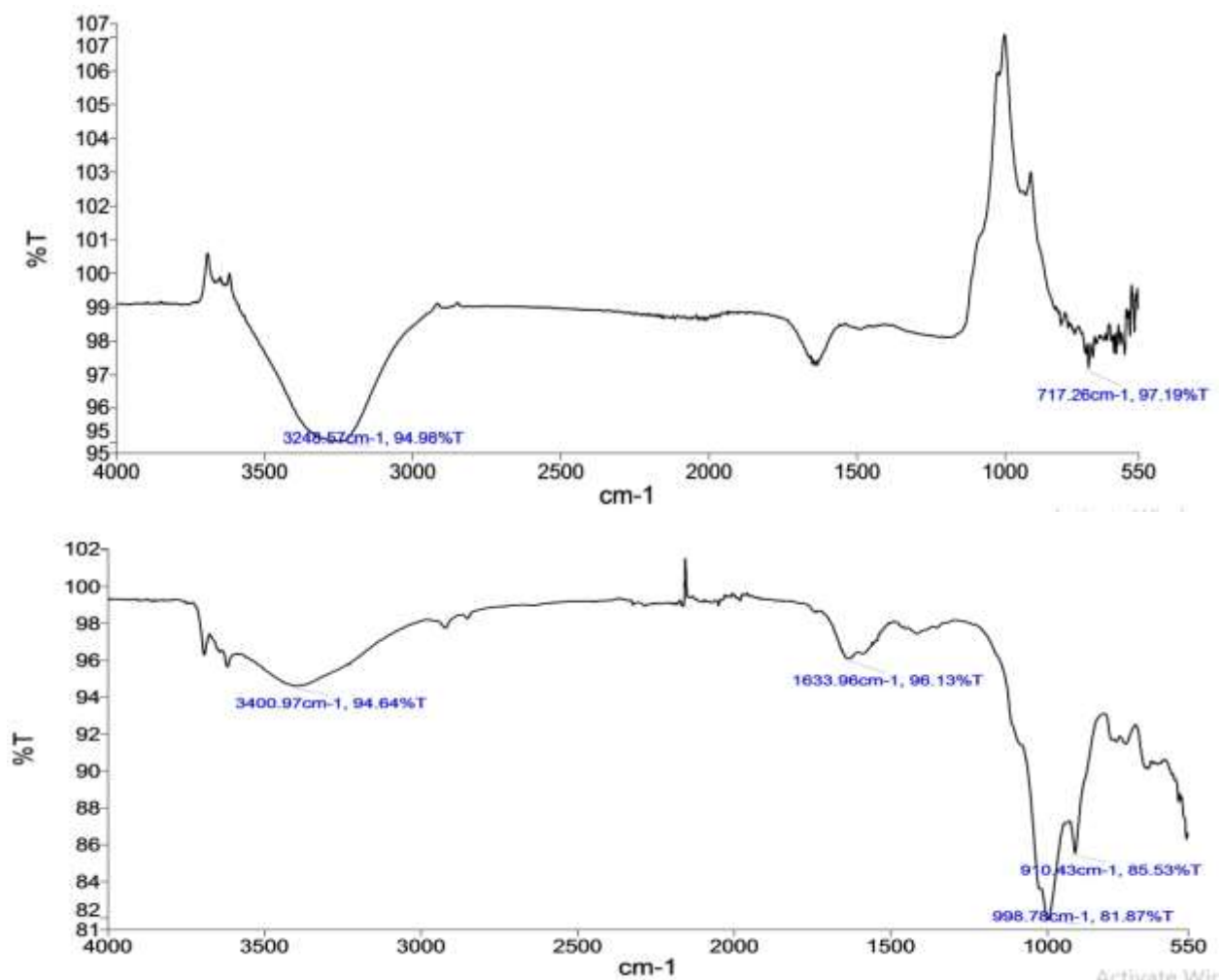


Figure 4: Fourier Transform Infrared (FTIR) spectroscopy analysis of some microplastic particles in sediment samples from Upper River Ben

SPECTRAL AND FUNCTIONAL GROUPS OF MPs

The spectral and functional groups of polymers detected in the water samples are presented on Table 1. Water and sediment Samples collected from Upper River Benue exhibited peaks at 1,533.24 cm⁻¹ C-N stretch typical of Nitro compounds, indicating the presence of polyamide (nylon). Exhibited peaks at 1,644.90 and 1,652.62 cm⁻¹, correspond to C=C stretching, suggested the presence of polybutadiene, polyisoprene, polyethylene (PE) and polypropylene (PP). An absorption peak at approximately 2,915.18 cm⁻¹, C=C stretching is characteristics of alkenes pointing to the presence of polybutadiene and polyisoprene. Additional absorption peak at 2,925.26 cm⁻¹, typical to alkene, aliphatic suggested the presence of polyethylene (PE) and

polypropylene (PP). Additional absorption peak at $3,289.62\text{ cm}^{-1} \equiv \text{C-H}$ stretch typical to alkenes which could be attributable to polybutadiene, and polyisoprene. Another absorption peak at $3,377.73\text{ cm}^{-1}$ C-H stretching characteristic of alcohols, Esters and carboxylic acids suggested the strong presence of polyvinyl alcohol (PVA) and polyamide (nylon). Additionally, an intense vibration peak at $32,400.49\text{ cm}^{-1}$, typical with the stretching region of the N-H amine group, indicated the presence of polyamide.

Table 1: FTIR Spectroscopy of Microplastics in water and sediment collected from Upper River Benue.

FTIR (cm-1)	PEAKS	Characteristics (vibration)	Assignments	Type of polymer/Functional Groups
1653.62		C=C stretch	Alkene conjugated	Polybutadiene, polyisoprene
1633.73		C=C stretch	Alkene saturated	Polybutadiene, polyisoprene
3377.73		O=H stretch	Alcohols, Esters & Carboxylic acid	Polyvinyl alcohol (PVA), Polyamide (Nylon)
2915.18		C=C stretch	Alkenes	Polyethylene (PE), Polypropylene (PP)
3289.62		$\equiv \text{C-H stretch}$	Alkenes	Polybutadiene, polyisoprene
1644.90		C=C stretch	Alkene saturated	Polybutadiene, polyisoprene, polyamide (Nylon)
3287.27		C-H stretch	Alkene	Polyvinyl alcohol (PVA)
2925.26		C-H stretch	Alkanes, Aliphatic	Polyethylene (PE), polypropylene (PP)
1645.86		C=C stretch	Alkene saturated	Polybutadiene, polyisoprene
1533.24		C-N stretching	Nitro compounds	Polyamide (Nylon)
3245.57		O-H stretch	Free hydroxyl	Polyvinyl alcohol (PVA)
3400.49		N-H stretch	Amines	Polyamide (Nylon)
1633.96		C=C stretch	Alkene unsaturated	Polyethylene, polystyrene

Abundance (%) of Polymer Class Distribution across the Sampling Sites

A total of 1,699 microplastics retrieved from water and sediment samples were analyzed by FTIR spectroscopy. Twelve different polymer types and other unclassified polymer types were detected during the study. The predominant polymers were polypropylene (PP) 20.84%, polyamide (nylon) recorded 16.83% and polyester had 10.54% concentration. Whereas, High density polyethylene (HDPE) and polyvinyl chloride (PVC), polybutadiene, and polyisoprene were the least concentrations observed. The abundance (percentage and particles) of the total observations recorded are presented on figure 5. Polypropylene and polyamide were predominant at Jabura respectively. Polyester was the dominant polymer at Damare site and polyvinyl chloride (PVC) had the highest observation at Buramji and polyvinyl alcohol was observed predominantly at Dongaho site.

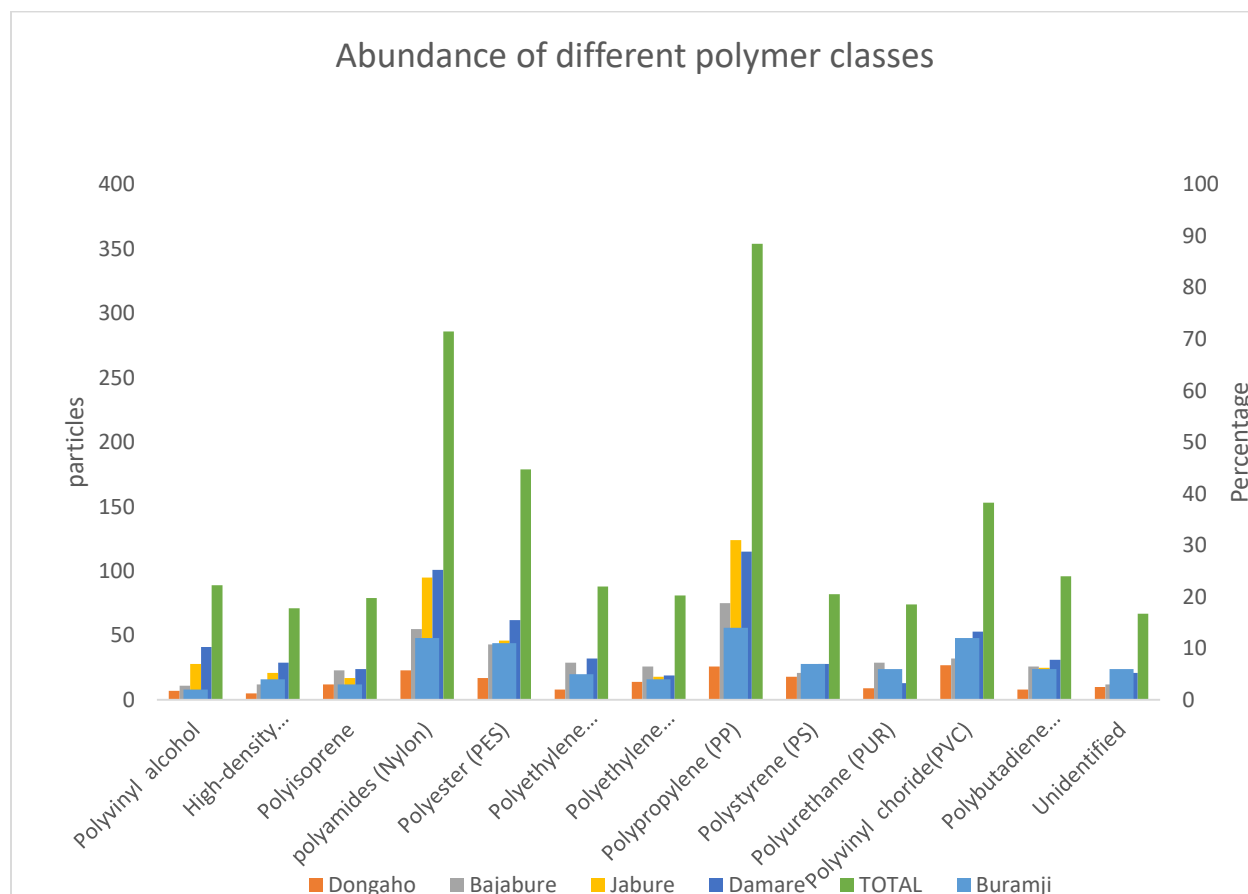


Figure 9: Abundance of different polymer classes retrieved from five sampling sites of Upper River Benue

DISCUSSION

Research into aquatic environments have clearly established the widespread of microplastics pollutants. Microplastics can enter all the spheres of the environments as minute plastics pieces or can be fragmented from larger plastics. However, vast majority of the published studies on microplastics pollution were carried out in the marine environment, though, an increasing number of freshwater studies have been reported in the recent past across the continents (Lu *et al.*, 2021). Although, freshwater ecosystems are generally closer and most accessible to the various sources of microplastics pollutants, such as wastewater treatment, market places, household refuse disposal points, industrial plants, storm water runoffs and atmospheric deposition that are identified as major contributors of heavier loads to water and sediment (Alimba and Faggio, 2019). Additionally, two major African rivers (Niger and Nile) are documented among the ten rivers

globally that contribute about 90% of plastic waste into the world oceans, having a tonnage of 35,196 and 84,792 tons yearly, respectively, (Okeke *et al.*, 2022).

Eleven different polymer classes were confirmed with different percentages. The most abundant were Polypropylene (PP) polyamide (nylon) and polyester (PES). High density polyethylene (HDPE) and polyvinyl alcohol (PVA) are among the least abundant polymer classes observed. Their prevalence is consistent with MPs from secondary sources as they are often used in single-use plastics, packaging, textiles, and containers, as well as for industrial, domestic, and agricultural applications (Qian *et al.*, 2023).

Polyamide, polyethylene, and polyvinyl alcohol were the dominant polymers detected in the two rivers, in that order. The first study that reported the predominance of polyamide and polyvinyl alcohol in Nigerian rivers was by Aliyu *et al.*, 2023. Therefore, it was not consistent with the findings of this study. These findings contrast with those of Aliyu *et al.*, 2023), Anyaegbu *et al.*, 2024, and Ololade *et al.*, 2024, that reported the prevalence of polypropylene, polyester, polyvinyl chloride, and polyethylene terephthalate polymers in Nigerian rivers, which is in total agreement with this study. Polyamide is a synthetic polymer released during the washing of woven polyamide fabrics (Qian *et al.*, 2023). This highlighted that home laundering or washing straight into the rivers is a major source of microplastics pollution in the rivers. Polyamide is also used in the production of various plastic materials (Qian *et al.*, 2023), further signifying that the indiscriminate dumping of plastic wastes in the environment is a substantial entry point for microplastics in the rivers.

Polyethylene is used in the production of fishing nets and ropes (Kye *et al.*, 2023), reaffirming that leaching from or photo-degradation of abandoned fishing gears are important sources of polyethylene microplastics in the rivers. Polyethylene is likewise frequently utilized in the food packaging industry, the production of plastic bottles, and textiles (Dhaka *et al.*, 2022), signifying that textile laundry and the undiscerningly dumping of large plastic materials are possible sources of microplastics in the rivers. Polyvinyl alcohol is a biodegradable synthetic resin derived from petroleum-based sources (Liu *et al.*, 2022), suggesting that some microplastics in the rivers could have originated from petroleum products from boats and automobile washing, that are prominent activities along the river banks.

CONCLUSION

The study provides preliminary data on the distribution and polymer classes from Upper River Benue at Yola metropolis on microplastics contamination in water and sediment. The composition mainly included polymers like polyethylene, polypropylene, polyester and polyvinyl chloride widely used in packaging and commercial products. This finding underscores the importance of continued monitoring and development of policy framework to mitigate microplastics pollution in our freshwater systems.

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