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Concentration, characterization, and risk assessment of microplastics in two main rivers in Birnin Kebbi, Nigeria

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Abstract

Background: Dukku and Kalgo rivers in Kebbi, Nigeria, provide essential ecosystem services such as drinking and domestic water, fishing, and farming. However, the safety of these rivers in terms of microplastic pollution has not been investigated. This study aimed to characterize and determine the concentration and associated risks of microplastics in both rivers.

Methods: Microplastics were extracted from water samples through filtration and analyzed using spectroscopy and microscopy.

Results: Significant concentrations of microplastics were detected in both rivers. Dukku River samples showed concentrations ranging from 125.00 to 160.30 particles/liter, while Kalgo River ranged from 119.30 to 134.70 particles/liter. Both rivers predominantly contained microplastic fibers and fragments, with fibers comprising the highest percentages (61% in the Dukku River and 56% in the Kalgo River). Microplastics in Kalgo River were predominantly sized between 0 and 100 µm, whereas in Dukku River, sizes ranged from 500 to 1000 µm. Polyamide was the dominant polymer, constituting 50% in the Dukku River and 42.50% in the Kalgo River, followed by polyethylene (34% in the Kalgo River and 25.60% in Dukku River), and polyvinyl alcohol (24.40% in Dukku River and 23.50% in Kalgo River). The predominant risk level posed by these polymers was level III (moderate risk), although polyamide posed a level IV risk (high risk). The pollution load index (PLI) for both rivers exceeded one, indicating a high risk.

Conclusion: Microplastic pollution in these rivers poses ecological and health risks. Identifying and mitigating sources of microplastic entry into the rivers is crucial to reducing exposure levels.

Keywords: Health risk assessment, Microplastics, Nylon, Polyamide, River water

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Introduction

Contamination of rivers by microplastics (plastic debris; 0.1 µm to 5 mm in size) poses a significant global challenge. Reports of this issue have surfaced across continents. Idowu et al (1) documented it in Africa, specifically in the River Osun, Nigeria, while Conard et al (2) observed it in an American river. Gao et al (3) reported findings in Europe, Sharifi et al (4) in Asia, and Leterme et al (5) in Australia. There are various sources of microplastics in rivers, including wastewater treatment plants (6), stormwater runoff (7), as well as atmospheric deposition and runoff from agricultural, recreational, industrial, and urban areas (8). Microplastics eventually enter the sea, contributing to marine microplastic pollution (9). The distribution of microplastics in water is heavily influenced by human activities, with higher concentrations typically found in areas characterized by urban land cover, high population density, and specific watershed characteristics such as slope and elevation (10). Seasonal variations also affect microplastics concentrations, with higher levels often recorded during the wet season due to increased runoff and resuspension from sediments (10). Microplastics come in various shapes, colors, and densities. They are generally categorized as primary (such as microbeads intentionally produced for use in personal care products or synthetic fibers used in clothing) and secondary (resulting from the photodegradation of larger plastic materials) (11). They also vary in polymer types, with the most commonly produced and consumed being polypropylene, polyethylene, polyvinyl chloride, polyurethane, polyethylene terephthalate (also known as polyester), and polystyrene (12).

The contamination of rivers by microplastics disrupts ecosystem services, impairs water quality, and adversely affects aquatic organisms. Microplastics can accumulate in river sediments, altering their composition, and affecting nutrient cycling. This alteration influences primary production and impacts the growth and development of indigenous flora and fauna (13). Furthermore, microplastics have the potential to be inadvertently assimilated by water and vegetation, ultimately accumulating within the food chain. Once consumed, microplastics accumulate in the digestive tracts of animals, raising various health concerns (14). In addition, microplastics can adsorb toxic compounds such as heavy metals, polychlorinated biphenyls, and pesticides from the environment. These contaminants may then be transferred to animals that ingest microplastics (15). Moreover, microplastics can serve as vectors for pathogens by providing attachment surfaces and facilitating pathogen transport (16). Humans ingest aquatic plants and animals containing microplastics carrying toxic compounds and pathogens may experience health issues including cancer, immunotoxicity, intestinal diseases, pulmonary diseases, cardiovascular diseases, inflammatory diseases, and complications during pregnancy and maternal exposure to progeny (17). Studies conducted by Ilechukwu et al (18) documented significant reductions in volume, motility, epididymal sperm count, and serum testosterone levels, as well as distorted testes with vacuolated seminiferous tubules in rats exposed to microplastics, while Yahaya et al (19) reported hematological and biochemical alterations in rats exposed to microplastic solutions.

To mitigate the ecosystem effects and health risks associated with microplastics, it is crucial to assess the safety of rivers, with the ultimate goal of prevention and remediation. In Birnin Kebbi, northwestern Nigeria, the Dukku and Kalgo rivers play pivotal roles in providing essential ecosystem services such as drinking and domestic water and supporting farming, fishing, and laundry activities. However, there are few documented studies on the microplastic pollution status of these water bodies, or indeed any river in northwestern Nigeria. Such studies are imperative considering the numerous reports of microplastic occurrence and risk in various water bodies worldwide, including Nigeria. Therefore, this study was conducted to provide primary information about the concentrations, characteristics, and risks of microplastics in the Dukku and Kalgo rivers in Birnin Kebbi, aiming to determine the safety of the rivers and raise public awareness.

Materials and Methods

Description of the study area

The study was conducted along the Dukku and Kalgo rivers in Birnin Kebbi, Kebbi State, North-West Nigeria (Figure S1, Supplementary file 1). Birnin Kebbi serves as the capital city of Kebbi State and the headquarters of Gwandu Emirate. Situated along the Sokoto River, it stands at the convergence of roads from Argungu, Jega, and Bunza. The geographical coordinates of Birnin Kebbi city are 12° 27’ 7.79” N latitude and 4° 12’ 0.60” E longitude. Kebbi State is home to various ethnic groups, including the Fulani, Hausa, Zarma, Dakarki, Kamberi, Yoruba, Igbo, and Nupe. The predominant religion in the city is Islam. The climate of the state is semi-arid, characterized by a savannah vegetation zone within the sub-Saharan Sudan belt of West Africa. Shrubs, grasses, and scattered trees adorn the landscape. The wet season is brief, spanning from mid-May to mid-September, while the remaining months are dry. Kebbi typically receives around 69.76 mm (2.75 inches) of precipitation annually, with 94.53 rainy days (20). The city’s average temperature is 31.26 ^{o}C but can soar above 40 ^{o}C during hot spells and drop below 20 ^{o}C during colder periods.

The Dukku River originates from the Rima River in Sokoto State and traverses several villages and towns in Kebbi State, including Argungu, Zauro, Birnin Kebbi, Tilli, and Kalgo, before eventually emptying into the Bunza River. It shares similar climatic conditions with Kebbi State and provides various ecosystem services such as laundry, vehicle and motorcycle washing, agriculture, irrigation, fishing, and animal husbandry. Conversely, the Kalgo River is an extension of the Jega River and flows into the River Niger. It offers essential ecosystem services similar to those of the Dukku River. The provision of these ecosystem services by both rivers could potentially impact their water quality and have adverse effects on their flora and fauna populations, ultimately, affecting humans through the food chain or the services they provide. In particular, alongside urban runoff and domestic wastewater, these ecosystem services may serve as entry points for microplastics.

Sample collection

Three locations (named A, B, and C), representing the lower, middle, and upper courses of the rivers, respectively, were randomly selected from each river. The upper course corresponds to the river’s entry into the city; the middle course is situated behind the metropolis; and the lower course is positioned at the city’s end. Triplicate samples were collected at each location using a 10 dm^3 metal bucket. Water was collected by scooping from the surface layer at depths ranging from 5 to 20 cm (21). Sampling occurred between August 2023 and September 2023, during the rainy season when microplastic pollution reportedly peaks (10). In total, nine samples were collected from each river and transported to the laboratory in non-plastic jars that had been pre-cleaned with ultrapure water.

Microplastics extraction

The water samples were first oxidized using wet peroxide oxidation (WPO) to remove organic materials (22). Thereafter, 50 mL of each sample was sequentially vacuum-filtered using a suction pump and cellulose-based filter paper, with a pore size of 0.2 µm to isolate the microplastics (22). The filtered materials were covered, and stored in an airtight container to prevent contamination.

Microplastic observation and identification

The particles collected on the filter paper were dried, after which microplastics were picked with a hot needle and counted using the AmScope Trinocular Stereo Zoom Microscope SM-1TY-144-18M3 equipped with an 18.0 MP digital camera (23). The particle counts were recorded as particles per 50 mL (23). Microplastics were categorized based on shape (fibers, fragments, pellets, and films), color (black, yellow, grey, red, etc), and size ranges (0-100, 100-500, and 500-1000 µm), following the protocol outlined by Yahaya et al (11). Photographs of the particles were taken using an 18.0 MP digital camera. Identification, confirmation, and characterization of the microplastics were conducted using a Nicolette Nexus 470 Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR) instrument by Therm, the USA, with Omic software. The spectral range for the study was set at 650-4000 cm^{-1} with a resolution of 4 cm^{-1}. A background air spectrum was regularly checked throughout the process to correct the errors. The obtained spectra were compared with those from published studies referenced in the results section of this study. Polymer types were identified as polypropylene, polyethylene, polyvinyl chloride, polyamide (nylon), polystyrene, and ethylene-vinyl acetate based on absorbance peaks and functional groups.

Contamination control

All equipment and materials used were free of plastic and prewashed with ultrapure water to maintain a clean laboratory environment. Throughout the analyses, plastic-free laboratory attire, including coats, gloves, and goggles, was worn. Each sample was meticulously labeled with detailed information, such as GPS coordinates and locations. Furthermore, to prevent background contamination during sample extraction, blank samples consisting of ultrapure water were periodically tested.

Microplastic health risk assessment

The polymer risk index (PRI) was used to assess the associated risk of microplastics in the water samples, as shown in equation 1 (11). The pollution load index (PLI) was calculated using equations 2 and 3.

$$PRI = \sum PMP \times PS \quad (1)$$

$$PLI = Cn/Cb \quad (2)$$

$$PLIzone = \sqrt{PLI1 \times PLI2 \times PLI3} \quad (3)$$

In equation 1, *PMP* represents the percentage of each microplastic polymer in the water samples, and *PS* denotes the polymer score of each polymer, which is a constant obtained from the literature. These scores are as follows: polyethylene (PE) = 11, polyamide (PA) = 47, and polyvinyl alcohol (PVA) = 36 (11). The risk level (PRI) was categorized based on the following scoring ranges: less than 10 was designated as risk level I, 10-100 as risk level II, 100-1000 as risk level III, and greater than 1000 as risk level IV (11).

In equation 2, *Cn* represents the concentration of the sample, and *Cb* represents the background concentration (the lowest concentration in the study). Water with a PLI greater than 1 is regarded as polluted (24).

Data analysis

Microplastic concentrations in the water samples were expressed as the number of microplastic particles per liter of water (P/L). All values were presented as mean ± standard error of the mean (mean ± SEM) using Excel software version 22. Excel was also used to calculate the PRI. Mean differences were compared using a one-way ANOVA analysis followed by a post-hoc LSD (least significant difference) test. A confidence interval of 95% was set to indicate significance among the groups using SPSS Statistics version 22.

Results

Concentrations and characteristics of microplastics in the water samples

Figure 1 presents the concentrations of microplastics in the water samples collected from the Dukku and Kalgo rivers at three different locations in mean and standard error mean. Statistical mean comparison of the samples among the groups showed no significant difference from one another ($P \geq 0.05$) despite the highest concentrations of microplastics (ranging from 125.00 to 160.30 particles per liter) exhibited from the Dukku River at location A (Figure 1).

The percentage distribution of microplastic shapes in the water samples is outlined in Table 1. Only fibers and fragments were detected in both rivers, with fibers having the highest percentages in both cases: 56% in the Kalgo River and 61% in the Dukku River. Photomicrographs illustrating these microplastic shapes are provided in Figure 2.

Figure 3 presents the percentage distribution of microplastics sizes in the water samples. In the Kalgo River, the size of the majority of microplastics was 0-100 µm, followed by 100-500, 500-1000, and 1000-5000 µm, respectively. In Dukku River, the predominant size is 500-1000 µm, followed by 1000-5000, and 0-100 µm, respectively.

The percentage distribution of microplastics colors in both rivers is shown in Figure 4. Black was the dominant color in both rivers, followed by yellow, red, and transparent.

Polymer type distribution in the water samples

Table 2 presents the spectral and functional groups of polymers detected in the water samples. Samples collected from the Kalgo River exhibit peaks at 3697.51 and 3615.51 cm^{-1}, corresponding to O-H stretching, suggesting the presence of polyvinyl alcohol. Additionally, an absorption peak at approximately 1941.94 cm^{-1}, characteristic of C-H bending, indicates the presence of polyethylene. An intense peak at 2292.31 cm^{-1} is attributable to the CH_2 stretching group, suggesting polyamide. These spectra are depicted in Figure S2a.

Samples from the Dukku River display an absorption peak at around 3693.79 and 3332.24 cm^{-1}, typical of the amine group, indicating polyamide. Another absorption peak at 2896.14 cm^{-1}, characteristic of C-H asymmetrical stretching alkane, suggests the presence of polyethylene. Additionally, an intense vibration peak at 3280.05 cm^{-1}, synonymous with the stretching region of the O-H alcohol group, indicates the presence of polyvinyl alcohol. These spectra are depicted in Figure S2b.

Figure 5 illustrates the percentage distributions of polymer types in the water samples. Polyamide emerges as the dominant polymer, constituting 50.00% in the Dukku River and 42.50% in the Kalgo River. Followed by polyethylene, with percentages of 34.00% in the Kalgo River and 25.60% in the Dukku River. Polyvinyl alcohol accounts for 24.40% in the Dukku River and 23.50% in the Kalgo River.

Risk of microplastics in the water samples

Table 3 shows the PRI of the polymers in the water samples. Polyethylene and polyvinyl alcohol, in all locations, registered a risk level III and polyamide demonstrated a risk level IV.

The PLI of the microplastics in the two rivers is revealed in Table 4. Both rivers recorded a PLI greater than 1.

Discussion

Characteristics of microplastics in the water samples

The analysis of water samples from the two rivers revealed microplastic concentrations ranging from 125.00 to 160.30 particles per liter in the Dukku River and 119.30 to 134.70 particles per liter in the Kalgo River. However, there were no significant mean ($P \geq 0.05$) differences in the concentrations of microplastics between the two rivers, indicating similar levels of contamination by these pollutants. Location A contained more microplastics than other locations in both rivers because it is on the lower course of the rivers, where water flow is slower.

Table 1. Percentage distribution of microplastic shapes in the water samples

Shape	Kalgo River (%)	Dukku River (%)
Fibers	56%	61%
Fragments	44%	39%

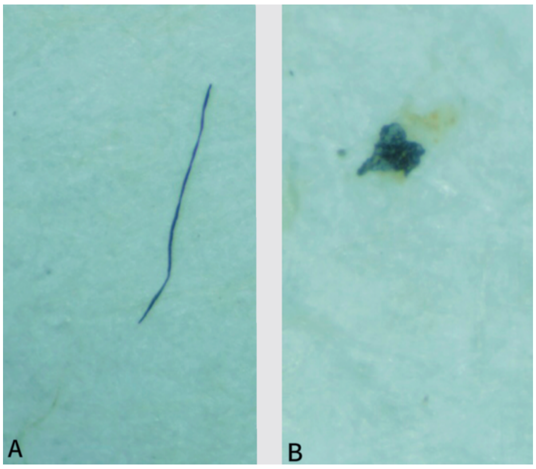

Figure 2. Microplastic shapes identified in the water samples: A = fiber and B = fragment

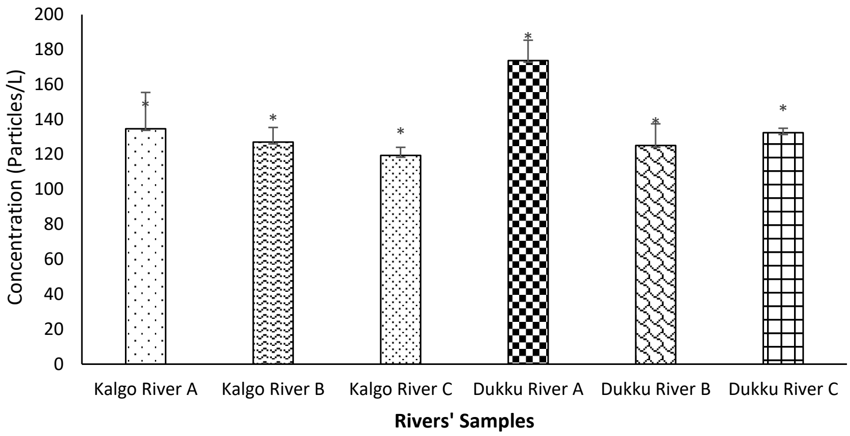

Figure 1. Concentrations of microplastics in the water samples (n = 3); * = means are not significantly different among the groups.

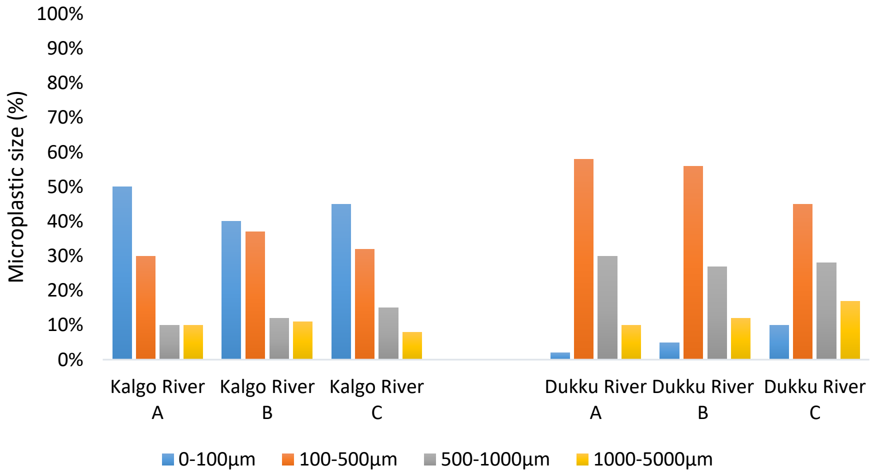

Figure 3. Percentage of microplastic size in the water samples

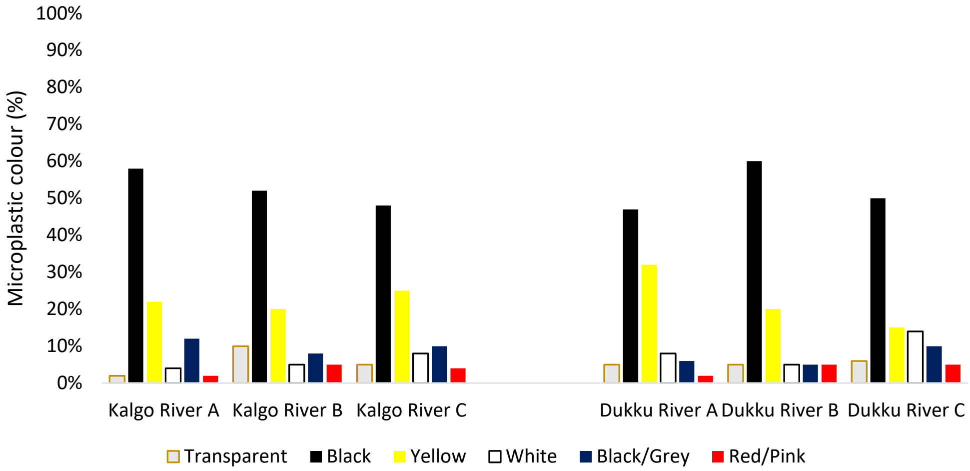

Figure 4. Percentage of microplastics colors in the water samples

Table 2. Absorbance peaks and functional groups of polymers identified in the water samples

Sample	Absorbance Peak	Functional Group	Polymer Type	Referenced Studies
Kalgo River	3697.51, 3615.51, 2292.31, 1941.94	OH, C-H, CH_2	PE, PA PVA	(25)
Dukku River	3693.79, 2896.14, 3332.24, 3280.05	CH, O-H Amine group	PA, PE PVA	(25)

Microplastics accumulate quicker and stay longer in slow-flowing stretches of rivers compared to faster-flowing areas (26). The lower course is at the exit of the city, and the higher concentrations compared to other locations indicate that human activities in the city contributed to the microplastic pollution of the rivers. The detection of microplastics in both rivers underscores their contamination with these particles, with concentrations falling within a range consistent with the levels (153 particles per liter) found in the Kaduna River (27), situated in Kaduna State within the same northwestern region as the present study. However, these concentrations are lower than the 22,079 ± 134 particles per liter detected in water samples from the Osun River in Osogbo, Osun State, southwestern Nigeria, as reported by Idowu et al (1). Similarly, Ebere et al (28) reported higher concentrations of microplastics, ranging from 440 to 1556 particles per liter, in Imo, southeastern Nigeria. Conversely, the levels detected in the Cross River, south-south Nigeria, by Nwonumara et al (29) were lower, at 104 particles per liter. Furthermore, when compared with the findings from rivers in advanced countries, the concentrations observed in the Kalgo and Dukku rivers were higher. For instance, Zhao et al (30) reported concentrations ranging from 4.67 to 12.30 particles per liter in the Wei River in Plain, China, while Rami et al (31) documented levels ranging from 0 to 50 particles per liter in some rivers in India. The concentrations of microplastics in rivers vary worldwide and depend on various factors, primarily anthropogenic activities and environmental conditions, such as population density, industrialization, types of industries, geographic features of the river, and land use patterns (9). Other contributing factors include climatic elements like rainfall, biological factors such as vegetation distribution, and microplastic

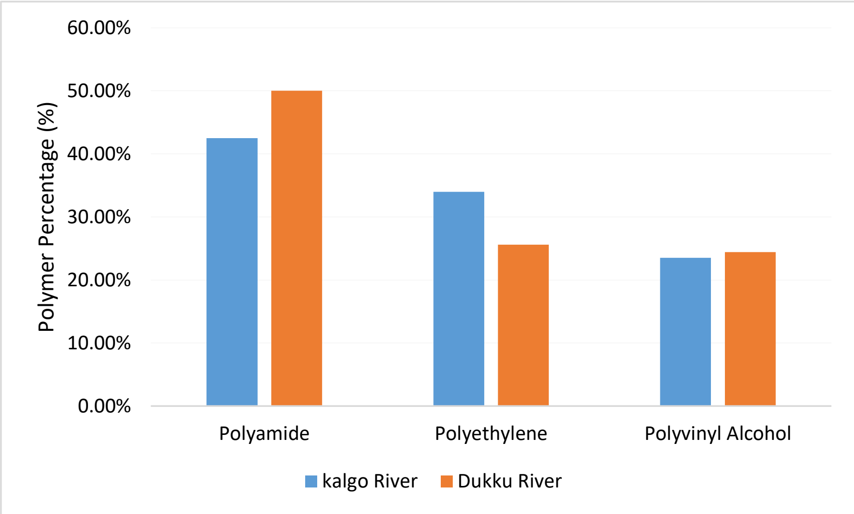

Figure 5. Percentages of polymer types in the water samples

Table 3. Risk index of polymers in the water samples

Location	Polyethylene	Polyvinyl Alcohol	Polyamide
Kalgo River	374.00	846.00	1997.50
Dukku River	281.60	878.40	2350.00
Risk Level	III	III	IV

Note: I = very low risk, II = low risk, III = moderate, IV = high, and V = very high (11).

Table 4. Pollution load index (PLI) of the water samples

Location	PLI	PLI zone
Kalgo River		
A	1.13	
B	1.07	1.10
C	1.00	
Dukku River		
A	1.39	
B	1.00	1.22
C	1.06	
Risk level	< 1	< 1

Note: Pollution load index greater than > 1 signifies water pollution (24).

properties like size and density (32). Environmental pollution control measures and enforcement, which vary widely, can also influence the abundance of microplastics in the environment. For example, eight American states have initiated bans on single-use plastic bags, starting with Hawaii in 2011, followed by California in 2014 (33). Similarly, Lagos, Nigeria, enforced a ban on Styrofoam and single-use plastics in early 2024. In June 2024, the Nigerian government banned single-use microplastics across ministries, departments, and agencies in the country. Such legislative actions may ultimately lead to reduced microplastic pollution in the environment. Birnin Kebbi, the focal area of the present study, is neither densely populated nor heavily industrialized, which partly explains the relatively mild microplastic pollution observed in the evaluated rivers compared to the regions with significantly higher microplastic abundance. Like many other parts of the country, enforcement of environmental protection laws in Birnin Kebbi is lax or virtually non-existent, which could account for the higher levels of microplastics detected in the rivers investigated in this study compared to the rivers in developed countries, despite the latter being more industrialized.

Most of the microplastics detected are light particles (0 to 100 µm in size). This suggests that microplastics in the water have a strong potential to induce toxicity. According to the study by Schmid and Stoeger (34), smaller particles have a large surface-to-volume ratio and are thus more likely to interact with cells and tissues, leading to stronger responses at exposure sites. Moreover, the wide variety of microplastic colors detected in the water indicates diverse sources of pollutants. The dominance of black could be due to the widespread use of polythene bags. Polythene bags of various sizes are often used for shopping and packaging in the country and are frequently disposed of indiscriminately, with many ending up in water bodies. According to the study by Idowu et al (1), another possible source of black microplastics in rivers is particles emanating from the wear and tear of automobile tires, which are carried by runoff water to the drainages and subsequently to the rivers. Yellow microplastics originate from plastics degraded by weathering, causing yellowing, as pointed out by Liu et al (35). Grey particles could have originated from the degradation of white nylon, especially pure water sachets, which are often carelessly disposed of in the environment, ending up in water bodies. Red could have been introduced through colored products such as fabrics and fishing nets.

The detection of microplastics in the rivers raises concerns about the presence of associated toxic metals, compounds, and biological agents in the water. Unfortunately, these aspects were not investigated in the present study. However, Tilli et al (36) and Bunza et al (37) reported that the physicochemical properties of water samples from the Dukku River were within acceptable limits, except for the slightly elevated temperature of the water. Similarly, Bawa et al (38) reported acceptable physicochemical properties and heavy metal concentrations in water samples from the Jega River (the upper course of the Kalgo River). Interpreting the results of these studies alongside the present study suggests a lack of association between microplastics and associated pollutants in the rivers, which could stem from several factors. According to the study by Chen et al (39), the adsorption of heavy metal ions by microplastics is influenced by various factors, including the type and concentration of heavy metal ions, as well as the functional groups and chemical bonds on the surface of different microplastics. Other factors include pH, temperature, and salinity of the water; contact time; ionic strength; aging, and particle size (40). Aging and an increase in pH levels enhance the adsorption capacity of microplastics for heavy metals (40). Additionally, the growth of biofilms can positively affect the adsorption of heavy metals, and the concentration of heavy metals on microplastics will increase as the biofilm matures (40). These findings illustrate the complexity of interactions between microplastics and other pollutants in the environment, warranting further studies to determine the reasons behind the lack of association between microplastics and associated pollutants in the two rivers investigated in the present study.

The detection of fibers and fragments as the dominant microplastic shapes in the two rivers is consistent with the findings of Olarinmoye et al (41) and Ololade et al (42), who reported the prevalence of fibers and fragments in some rivers in southwestern Nigeria. However, Ebere et al (28) and Aliyu et al (27) reported the dominance of fragments and fibers, respectively, in rivers in southeastern and northwestern Nigeria. The prevalence of microplastic fibers in the water suggests that a significant portion of the microplastics in the rivers originate from garment washing and sewage disposal into the waterways. As noted by Acharya et al (43), microfibers are released in large quantities from textile garments during home laundering, often entering sewage effluents and/or sludge. It is worth noting that clothes washing frequently occurs directly in the rivers investigated in the present study, serving as a major entry point for microplastics. Additionally, synthetic fibers are commonly used in fishing gear production (nets, ropes, and lines) due to their cost-effectiveness, high tensile strength, and resistance to degradation (44). Therefore, abandoned fishing gear, which is a noticeable occurrence in the rivers, can also serve as an entry point for microplastics through leaching. On the other hand, the detection of fragments in the water suggests that some microplastics result from the photodegradation of large plastic materials indiscriminately dumped in the environment or rivers (1). Although fishing nets are made from synthetic fibers, it is important to note that fishing gear can degrade into fragments through photodegradation (45). Hence, the detection of microplastic fragments further underscores that abandoned fishing gear may represent a significant entry point for microplastics in the rivers. Fragments pose health threats to aquatic life and humans that ingest them because of their irregular shape and coarse edges, making them more physically injurious to aquatic organisms (1). They may cause lacerations on both the external and internal (digestive) parts of an organism's body. Fibers can be ingested by aquatic organisms and subsequently passed on to larger animals higher up in the food chain, including humans.

Polyamide, polyethylene, and polyvinyl alcohol were the dominant polymers detected in the two rivers, in that order. This study is the first one to report the predominance of polyamide and polyvinyl alcohol in Nigerian rivers. The dominance of polyamide was also observed in groundwater within the city (46). These findings contrast with those of Aliyu et al (27), Anyaegbu et al (47), and Ololade et al (42), who reported the prevalence of polyethylene, polypropylene, polyester, polyvinyl chloride, and polyethylene terephthalate polymers in Nigerian rivers. Polyamide is a synthetic polymer released during the washing of woven polyamide fabrics (48). This underscores that home laundering or washing directly in the rivers is a major source of microplastics in these waterways. Polyamide is also used in the manufacturing of various plastic materials (49), further suggesting that the indiscriminate dumping of plastic waste in the environment is a significant entry point for microplastics in the rivers.

Polyethylene is used in the production of fishing nets and ropes (9), reaffirming that leaching from or photodegradation of abandoned fishing gear are important sources of microplastics in the rivers. Polyethylene is also commonly utilized in the food packaging industry, the manufacture of plastic bottles, and textiles (50), indicating that textile laundry and the indiscriminate dumping of large plastic materials are likely sources of microplastics in the rivers. Polyvinyl alcohol is a biodegradable synthetic resin derived from petroleum-based sources (51), suggesting that some microplastics in the rivers could have originated from petroleum products from boats and automobile washing, which are prominent activities along the rivers.

Risk of microplastics in the water

The risk assessment of the polymers detected in the rivers indicates that polyethylene and polyvinyl alcohol registered a risk level III (moderate risk) in all locations, while polyamide demonstrated a risk level IV (high risk). This suggests that the predominant risk in the water was level III, with polyamide posing the greatest risk at level IV. Polyamide is immunotoxic, genotoxic, and an endocrine disruptor (52). Ingestion of high concentrations of polyethylene, with its rough structures, increases the risk of cytotoxicity in epithelial cells and triggers the release of pro-inflammatory cytokines (53). While polyvinyl alcohol is believed to be harmless (54), it has a high potential for mobilizing heavy metals and other hydrophilic contaminants from the environment (55). Moreover, the PLI of water samples from the two rivers, which was greater than 1, indicates that the rivers were polluted and could cause ecological damage. The findings of the present study are consistent with those of Yahaya et al (11), who reported the dominance of risk level III for polymers in water and sediments obtained from Badagry Lagoon in Lagos, Nigeria. Additionally, Xu et al (56) reported risk level III as the dominant polymer risk in the Changjiang Estuary in China. In contrast, Fred-Ahmadu et al (57) reported the dominance of risk level I in water samples obtained from different sampling locations in the Atlantic Ocean, Lagos. Similarly, Ranjani et al (58) reported high-risk polymers in sediments obtained from the southeast coast of India.

One of the limitations of the present study is its failure to determine seasonal variations in the abundance of microplastics in the rivers. While the study was conducted during the wet season when the concentrations are believed to peak, investigating microplastic abundance during the dry season is necessary to confirm this assertion. Moreover, microplastic abundance is influenced by several factors, which might favor drier conditions in the two rivers evaluated. Furthermore, better results could have been achieved if more water samples had been evaluated. It is worth mentioning that these limitations were due to financial constraints, which limited access to some equipment and materials.

Conclusion

Water samples from Dukku and Kalgo rivers in Birnin Kebbi, Nigeria, were found to contain microplastics, with samples from Dukku exhibiting the highest concentrations. Samples from Dukku River had 125.00 to 160.30 particles per liter, while Kalgo River had 119.30 to 134.70 particles per liter. Fibers and fragments were the only microplastic shapes present in the water, with fibers being the dominant type (constituting 56% in the Kalgo River and 61% in the Dukku River). The most prevalent polymer types detected in the water from the two rivers were polyamide (50% in the Dukku River and 42.50% in the Kalgo River), followed by polyethylene and polyvinyl alcohol. The dominant risk level in the water samples was level III (moderate risk), with polyamide posing the greatest risk among the polymers, demonstrating a level IV (high risk). Based on the findings of this study, there is a pressing need to implement microplastic pollution control measures in the city. Indiscriminate dumping of plastic materials in the environment should be discouraged, and efforts to recover and recycle plastics should be promoted to prevent plastic materials from entering the environment. Wastewater, particularly from fabric laundry and home sludge, should undergo treatment before being discharged. Washing of garments and automobiles in the rivers should be prohibited, and the rivers should be cleared of abandoned fishing gear. Further studies are necessary to verify the findings of this study, particularly those with larger sample sizes and that consider the influence of seasonal variations.

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Competing interests

All authors declared no competing interest.

Ethical issues

The study was approved by the Ethics and Animal Committee of Federal University Birnin Kebbi, Nigeria in line with the National Institutes of Health guide for the care and use of Laboratory animals (NIH Publications No. 8023, revised 1978). Approval for the experimental procedures was obtained with the ethical code FUBK/AEC/FS/M1056.

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Supplementary Files

Supplementary file 1 contains Figure S1, Figure S2a and Figure S2b.

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