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Original Article

Physicochemical Assessment of Chanchaga (Urban) and Kemi (Rural) River System in Minna, Niger State, Nigeria: Implications for Water Quality Management

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ABSTRACT

Freshwater bodies in developing nations face mounting threats from anthropogenic pollution; however, systematic physicochemical assessments comparing urban and rural river systems remain limited, particularly in North Central Nigeria. This study assessed and compared the physicochemical parameters of an urban (Chanchaga) river and a rural (Kemi) river in Minna, Niger State. Water samples were collected seasonally (dry season: March; rainy season: July) from four systematically selected stations per river and analysed for physicochemical parameters using standard American Public Health Association (APHA) methods (2017). Results revealed significant seasonal and spatial variation in physicochemical parameters. Temperature was significantly higher in the dry season (Chanchaga: 31.30 ± 0.14°C; Kemi: 32.05 ± 0.84°C) than in the rainy season. Electrical conductivity was greatest in Chanchaga River during the dry season (269.50 ± 122.36 μS/cm), indicating elevated ionic concentration attributable to urban anthropogenic activities. Biological oxygen demand (BOD) and dissolved oxygen (DO) values were highest in Chanchaga River during the rainy season (BOD: 9.25 ± 5.80 mg/L; DO: 9.50 ± 5.80 mg/L), reflecting heightened organic loading from surface runoff. Calcium concentration differed significantly between rivers, with Chanchaga recording higher values (12.63 ± 2.28 mg/L) than Kemi (6.00 ± 2.08 mg/L), possibly linked to differential geochemical substrates and anthropogenic mineral inputs. Total alkalinity was significantly higher in the dry season, while chlorine showed the opposite trend, increasing during the rainy season. pH remained within near-neutral ranges across both rivers and seasons. The findings demonstrate that urban activities significantly influence the physicochemical characteristics of Chanchaga River and underscore the need for routine water quality monitoring and integrated watershed management strategies for both river systems.

Keywords: Water quality, seasonal variation, Chanchaga River, Kemi River.

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INTRODUCTION

Freshwater bodies serve as vital ecological, economic, and social resources in developing nations. In Minna, Niger State, Nigeria, both the Chanchaga River (urban) and Kemi River (rural) perform indispensable roles in domestic water supply, agricultural irrigation, artisanal fisheries, and recreational activities [14]. Despite their socioeconomic importance, these river systems face increasing environmental pressures arising from rapid urbanisation, agricultural expansion, industrial effluent discharge, open defecation, and indiscriminate solid waste disposal [6,16].

The physicochemical characteristics of a water body serve as critical indicators of ecological status, anthropogenic impacts, and suitability for various uses [6]. Parameters such as temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), electrical conductivity, total alkalinity, hardness, calcium, and chlorine reflect both natural processes and human-induced modifications within aquatic systems [16]. Their seasonal and spatial variability is particularly important in tropical river systems, where alternating wet and dry seasons drive significant fluctuations in hydrology, water chemistry, and pollution dynamics [2].

Comparative studies of urban and rural rivers offer a powerful framework for disentangling the specific contributions of urbanisation and land use to water quality deterioration [12]. Urban rivers, like Chanchaga, are subject to continuous point-source and non-point-source pollution from settlement density, commercial activities, and infrastructure development [14]. Rural rivers, like Kemi, are generally exposed to lower industrial pressure but may still receive inputs from agricultural runoff, livestock rearing, and subsistence domestic activities [6]. However, comparative baseline data for rivers in north-central Nigeria remain limited, hampering evidence-based environmental management [6].

While extensive physicochemical studies have been conducted on Nigerian rivers in the south [9,22,10], data from rivers in the north-central region, specifically Minna, Niger State, remain insufficient. This gap constrains water resource management, risk assessments, and the design of targeted mitigation measures [3,8]. The present study, therefore, assessed the physicochemical parameters of River Chanchaga and River Kemi across dry and rainy seasons to establish baseline water quality data, characterise seasonal and spatial variation, and inform sustainable management of these vital freshwater resources.

MATERIALS AND METHODS

Study Area

The study was conducted in Niger State, located in the north-central geopolitical zone of Nigeria. The state covers approximately 76,363 km^2, sharing boundaries with Kaduna State (northeast), Kebbi State (northwest), Kwara State (southwest), and the Federal Capital Territory (southeast). The two selected rivers are located within the Minna metropolitan area.

River Chanchaga is a significant tributary of the River Kaduna flowing through Minna, the state capital. It traverses an urban corridor characterised by high human settlement density, commercial activities, and infrastructure development. The riverbed consists of coarse sands, gravels, and silty materials, with alluvial deposits on floodplains supporting irrigation farming. The river is also used for small-scale fishing and domestic water supply.

River Kemi is a rural watercourse located in the Farin Doki axis of Minna, draining into larger river systems connected to the River Niger basin. It plays a critical role in local agriculture, livestock rearing, and subsistence fishing for surrounding rural communities. The riverbanks are lined with alluvial clay, silt, and fine sands that support rice cultivation and floodplain agriculture. Both rivers flow perennially and were selected based on their ecological significance, proximity to contrasting human activities, and accessibility [13].

Study Design and Sampling Stations

A seasonal comparative study design was employed. Four sampling stations were established systematically along each river at intervals of approximately 2.5 km, selected based on observed anthropogenic inputs and ecological diversity. Sampling was conducted in two seasons: the dry season (March) and the rainy season (July).

At River Chanchaga, Station 1 (upstream) was characterised by sand excavation, irrigation farming, and cattle grazing on a silty and sandy riverbed. Station 2 had washing, swimming, and agricultural activities with mixed terrestrial and riverine vegetation. Station 3 was predominantly agricultural, with dense strawed grass on silty loamy substrate. Station 4 (downstream) exhibited bridge construction, illegal mining, washing, and swimming on a gravelly and stony riverbed transitioning to a muddy zone.

At River Kemi, Station 1 was characterized by rice plantation and deforestation on a sandy dry-season bed. Station 2 showed washing, swimming, fishing, and farming activities in a densely vegetated area. Station 3 supported animal grazing, fishing, and farming on a substrate of decayed organic matter and sandy-loamy soil. Station 4 was mainly used for farming, with a loamy substrate in both seasons.

Sample Collection

All water samples were collected in pre-rinsed bottles of at least 250 mL capacity. In situ parameters (temperature and pH) were recorded at the point of collection. Samples for dissolved oxygen (DO) were collected by immersing bottles below the water surface and corking them underwater to prevent air bubble entrapment. DO samples were immediately fixed using 1 mL of Winkler A solution (Manganese (II) Sulphate, MnSO4) and 1 mL of Winkler B solution (alkaline-iodide-azide), followed by vigorous mechanical shaking. Biological oxygen demand (BOD) samples were collected in amber-coloured reagent bottles immersed and sealed below the water surface and wrapped in black polythene bags to exclude light, then incubated at 20°C for five days (APHA, 2017). Samples for all other parameters were collected by immersing and corking bottles below the water surface to minimise contamination.

Data Analysis

Water temperature was measured in situ using a mercury-in-glass thermometer (APHA, 2017). pH was measured with a HANNA pH meter (Model HI8424) calibrated with buffer solutions of pH 4, 7, and 10. Electrical conductivity (EC) and total dissolved solids (TDS) were measured using a HACH conductivity meter (Model 44600-00), with TDS calculated as: TDS (mg/L) = Conductivity × 0.666. Turbidity was determined colorimetrically using a visible spectrophotometer (VS72IG) at 420 nm. Dissolved oxygen was quantified by the Winkler–Azide titrimetric method using 0.025 M sodium thiosulphate. BOD5 was computed as the difference between initial and five-day incubated DO values. Calcium was determined by ethylenediaminetetraacetic acid (EDTA) titrimetry, and total alkalinity and total hardness by standard titrimetric methods. All analyses followed APHA (2017) standard methods.

Statistical analyses were performed to evaluate spatial and seasonal variation. Normality of data was assessed using the Shapiro–Wilk test ($\alpha = 0.05$). Normally distributed data were compared using Welch's independent t-test (two groups) or one-way ANOVA with Tukey's HSD post-hoc test (multiple groups). Non-normally distributed data were analysed using the Mann–Whitney U test or Kruskal–Wallis H test followed by Dunn's post-hoc test. Multiple comparison p-values were adjusted using the Benjamini–Hochberg false discovery rate (FDR) procedure. Significance was accepted at $p < 0.05$. Results are expressed as mean ± standard deviation.

RESULTS

Physicochemical Parameters of River Chanchaga and River Kemi by Season

The physicochemical parameters of both rivers across dry and rainy seasons are summarized in Table 1. Clear seasonal and spatial variation was observed across all measured parameters.

Table 1: Physicochemical Parameters of Chanchaga and Kemi Rivers by Season.

Parameter	River Chanchaga		River Kemi	
	Dry season	Rainy season	Dry season	Rainy season
BOD (mg/L)	5.5 ± 1.59ab	9.25 ± 5.80b	2.35 ± 0.52a	6.9 ± 3.42ab
Calcium (mg/L)	13.88 ± 2.21b	11.38 ± 1.75b	5.05 ± 2.66a	6.95 ± 0.82a
Chlorine (mg/L)	9.85 ± 6.98a	21.7 ± 1.63b	9.12 ± 2.18a	24.92 ± 5.27b
DO (mg/L)	5.75 ± 1.71ab	9.5 ± 5.80b	2.5 ± 0.58a	7.25 ± 3.40b
EC (µS/cm)	269.5 ± 122.36b	173.05 ± 4.63ab	172.45 ± 39.51ab	125.05 ± 27.32a
Temperature (°C)	31.3 ± 0.14a	26.0 ± 0.00c	32.05 ± 0.84a	25.0 ± 0.00b
Total Alkalinity (mg/L)	54.0 ± 4.90c	26.0 ± 7.83ab	34.0 ± 8.49a	15.5 ± 1.91b
Total Hardness (mg/L)	56.0 ± 1.63a	57.5 ± 10.75a	56.0 ± 1.63a	61.0 ± 16.69a
pH	7.58 ± 0.09b	7.22 ± 0.08b	6.48 ± 0.31a	7.33 ± 0.24b

Different superscript letters within rows indicate statistically significant differences ($p < 0.05$).

Biological oxygen demand (BOD) ranged from 2.35 ± 0.52 mg/L (Kemi River, dry season) to 9.25 ± 5.80 mg/L (Chanchaga River, rainy season), indicating increased organic loading during high-runoff periods. Dissolved oxygen (DO) followed a similar pattern, rising from 2.50 ± 0.58 mg/L (Kemi River, dry season) to 9.50 ± 5.80 mg/L (Chanchaga River, rainy season). Electrical conductivity was highest in Chanchaga River during the dry season (269.50 ± 122.36 µS/cm) and lowest in Kemi River during the rainy season (125.05 ± 27.32 μS/cm), reflecting dilution effects and differential ionic concentration. Temperature was significantly higher during the dry season in both rivers (Chanchaga: 31.30 ± 0.14°C; Kemi: 32.05 ± 0.84°C) compared to the rainy season (26.00 ± 0.00°C and 25.00 ± 0.00°C, respectively). pH ranged from 6.48 ± 0.31 (Kemi, dry) to 7.58 ± 0.09 (Chanchaga, dry), indicating slightly acidic to neutral conditions.

Seasonal Variation in Physicochemical Parameters for Chanchaga and Kemi Rivers

Seasonal variation across both rivers is presented in Table 2. Temperature was significantly lower in the rainy season (25.50 ± 0.53°C) than in the dry season (31.67 ± 0.69°C), reflecting the moderating influence of rainfall and cloud cover. Electrical conductivity was significantly higher in the dry season (220.98 ± 98.88 μS/cm) than in the rainy season (149.05 ± 31.42 μS/cm), consistent with reduced dilution. Chlorine concentration was significantly higher during the rainy season (23.31 ± 4.00 mg/L) than the dry season (9.49 ± 4.80 mg/L), likely reflecting increased surface runoff carrying chlorinated compounds. Total alkalinity was also significantly higher in the dry season (44.00 ± 12.47 mg/L) than in the rainy season (20.75 ± 7.70 mg/L), indicating seasonal shifts in buffering capacity.

Calcium, pH, total hardness, dissolved oxygen, and BOD showed no statistically significant seasonal differences. DO was higher in the rainy season (8.38 ± 4.57 mg/L vs. 4.13 ± 2.10 mg/L in dry season), and BOD likewise showed higher rainy season values (8.08 ± 4.58 mg/L vs. 3.93 ± 2.01 mg/L in dry season), but substantial within-season variability precluded statistical significance.

Table 2: Seasonal Variation in Physicochemical Parameters for Chanchaga and Kemi Rivers.

Parameter	Rainy Season	Dry Season
Temperature (°C)	25.50 ± 0.53a	31.67 ± 0.69b
Calcium (mg/L)	9.16 ± 2.68a	9.46 ± 5.23a
Chlorine (mg/L)	23.31 ± 4.00a	9.49 ± 4.80b
pH	7.28 ± 0.17a	7.03 ± 0.62a
Electrical Conductivity (μS/cm)	149.05 ± 31.42a	220.98 ± 98.88b
Total Alkalinity (mg/L)	20.75 ± 7.70a	44.00 ± 12.47b
Total Hardness (mg/L)	59.25 ± 13.13a	56.00 ± 1.51a
Dissolved Oxygen (mg/L)	8.38 ± 4.57a	4.13 ± 2.10a
BOD (mg/L)	8.08 ± 4.58a	3.93 ± 2.01a

Different superscript letters indicate statistically significant differences ($p < 0.05$).

Comparative Physicochemical Characteristics for Chanchaga and Kemi Rivers.

The comparative assessment of both rivers is presented in Table 3. Calcium concentration was the only parameter that differed significantly between the rivers, with Chanchaga River recording a substantially higher mean (12.63 ± 2.28 mg/L) than Kemi River (6.00 ± 2.08 mg/L), possibly reflecting geological substrate differences or anthropogenic mineral inputs. Electrical conductivity was higher in Chanchaga River (221.27 ± 95.31 μS/cm) than in Kemi River (148.75 ± 40.38 μS/cm), although the difference was not statistically significant due to high within-site variability. Total alkalinity was similarly higher in Chanchaga River (40.00

± 16.14 mg/L) than in Kemi River (24.75 ± 11.41 mg/L), but not significantly so. Temperature, pH, chlorine, total hardness, DO, and BOD did not differ significantly between the two rivers.

Table 3: Comparative Physicochemical Characteristics for Chanchaga and Kemi Rivers.

Parameter	River Kemi	River Chanchaga
Temperature (°C)	28.53 ± 3.81a	28.65 ± 2.83a
Calcium (mg/L)	6.00 ± 2.08a	12.63 ± 2.28b
Chlorine (mg/L)	17.03 ± 9.23a	15.78 ± 7.88a
pH	6.91 ± 0.52a	7.40 ± 0.20a
Electrical Conductivity (μS/cm)	148.75 ± 40.38a	221.27 ± 95.31a
Total Alkalinity (mg/L)	24.75 ± 11.41a	40.00 ± 16.14a
Total Hardness (mg/L)	58.50 ± 11.30a	56.75 ± 7.17a
Dissolved Oxygen (mg/L)	4.88 ± 3.40a	7.63 ± 4.44a
BOD (mg/L)	4.63 ± 3.32a	7.38 ± 4.42a

Different superscript letters indicate statistically significant differences ($p < 0.05$).

DISCUSSION

The results of this study suggested clear seasonal and spatial patterns in the physicochemical characteristics of Chanchaga and Kemi Rivers, consistent with the influence of urban land use and tropical seasonal hydrology on freshwater quality.

The significantly higher temperatures recorded during the dry season in both rivers are consistent with reduced cloud cover, lower water volumes, and intensified solar radiation, conditions known to elevate surface water temperatures in tropical systems [2]. Elevated dry-season temperatures can accelerate metabolic processes and biochemical reactions in the water column, including the degradation of organic matter, which may partly explain the lower DO values observed during this period [18]. Lower dissolved oxygen during the dry season at Kemi River in particular suggests stagnant flow conditions and reduced hydraulic recharge, which promote oxygen depletion at the sediment–water interface [15].

The significantly elevated electrical conductivity in Chanchaga River during the dry season (269.50 ± 122.36 μS/cm) reflects heightened ionic concentrations, commonly associated with evaporative concentration of dissolved salts and sustained inputs from municipal and commercial activities along the urban corridor. This aligns with findings from [4] and [7], who documented elevated conductivity in urban-influenced Nigerian rivers. The higher ionic strength observed in Chanchaga River may further influence physicochemical processes such as the aggregation of colloidal particles and the speciation of dissolved contaminants [24]. Elevated conductivity during the dry season has also been linked to reduced dilution and prolonged residence times of dissolved ions in aquatic systems [1].

Higher Biological Oxygen Demand and chlorine concentrations during the rainy season indicate enhanced mobilization of organic matter and dissolved compounds from terrestrial sources through surface runoff [17]. This pattern is consistent with findings from [23], who demonstrated that rainfall events significantly increase the flux of organic pollutants from catchment areas into river systems. Although DO was higher in the rainy season (8.38 ± 4.57 mg/L) than in the dry season (4.13 ± 2.10 mg/L), the difference was not statistically significant, suggesting that elevated organic inputs during the rainy season counterbalance the oxygen replenishment capacity of increased flow and rainfall-induced mixing.

Total alkalinity was significantly higher in the dry season across both rivers, indicating greater buffering capacity and elevated carbonate concentrations during low-flow conditions. This is consistent with seasonal evaporative concentration of dissolved inorganic carbon, as documented by [19] and [10]. The significantly different calcium concentrations between Chanchaga (12.63 ± 2.28 mg/L) and Kemi (6.00 ± 2.08 mg/L) likely reflect differences in the geological substrates of their catchments, as well as the influence of anthropogenic mineral inputs associated with urban construction, sand mining, and cement-related runoff in the Chanchaga watershed.

The pH values recorded in both rivers (6.48–7.58) remained within ranges considered acceptable for aquatic life and, in most instances, within WHO guidelines for drinking water [25]. Near-neutral pH values suggest adequate buffering capacity in both systems, despite varying levels of anthropogenic stress. Total hardness did not differ significantly between rivers or seasons (56.00–61.00 mg/L), indicating consistent contributions from divalent cations irrespective of hydrology or location [11].

Comparing the two rivers, Chanchaga consistently exhibited higher mean values for most physicochemical parameters, reflecting the cumulative impact of urban anthropogenic activities, including municipal wastewater discharge, domestic waste disposal, commercial agriculture, and construction activities [20]. River Kemi, though shielded by lower population density and industrial pressure, nevertheless recorded elevated BOD and chlorine during the rainy season, suggesting that agricultural runoff and domestic inputs from surrounding communities contribute meaningfully to its water chemistry. These findings corroborate the observations of [14] and [22], who documented similar patterns of water quality variation in rivers across Niger State and the north-central region of Nigeria.

CONCLUSION

This study established baseline physicochemical profiles for Rivers Chanchaga and Kemi in Minna, Niger State, across dry and rainy seasons. Clear seasonal variation was documented, with elevated temperature, electrical conductivity, and total alkalinity during the dry season, and increased BOD, dissolved oxygen, and chlorine during the rainy season. Spatially, Chanchaga River displayed significantly higher calcium concentrations and consistently elevated physicochemical parameters relative to Kemi River, reflecting the greater anthropogenic influence of urban land use on water quality. While most parameters remained within WHO guideline limits, the observed trends signal ongoing deterioration driven by urbanization, inadequate waste management, and seasonal hydrological dynamics. The findings highlight the urgent need for routine physicochemical monitoring programmes, integrated watershed management, and targeted pollution control policies for both river systems. Future research should incorporate biological indicators and contaminant analyses to provide a more comprehensive assessment of ecological health in these important freshwater systems.

Declarations

Authors' contributions: F.O, Y.I, and S.O conceptualized and designed the study; S.O and Y.I participated in fieldwork and data collection. S.O prepared the manuscript, reviewed by F.O, V.I, and Y.I. All authors contributed to the development of the final manuscript and approved its submission.

Conflict of Interest: There is no conflict of interest.

Ethical Approval: This study involved the collection of water and sediment samples from public river systems. No human subjects or animals were used. Sampling complied with applicable national environmental regulations. Therefore, ethical consideration was not applicable.

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Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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