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Assessment of seasonal water quality variation in River Yobe, Gashua, Northeastern Nigeria

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Abstract:
Water pollution in rivers is a growing global concern with implications for ecosystem health, public safety, and livelihoods. This study examined seasonal variations in physicochemical parameters and heavy metal contamination of River Yobe at Gashua, Nigeria, focusing on anthropogenic influences. Stratified sampling was conducted across three activity zones fishing, irrigation, and domestic during the early dry, late dry, and rainy seasons (December 2024–August 2025). A total of 54 water samples were analyzed for temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), and heavy metals (Cd, Cu, Pb, Zn) using standard procedures. Household surveys were also administered to assess river utilization and waste disposal practices. Findings revealed that 85% of respondents relied on the river for domestic and livelihood activities, while 45% disposed waste directly into it. Physicochemical parameters showed significant seasonal differences ($p < 0.05$): temperature peaked during the late dry season (28.8 °C), while DO was lowest in the rainy season (4.67 mg/L). Although most values were within WHO and NESREA guidelines, DO and BOD fluctuated beyond desirable limits in some seasons. Heavy metal analysis indicated elevated cadmium (0.043 mg/L) and lead (0.107 mg/L) concentrations during the rainy season, exceeding WHO limits, while Cu and Zn remained within safe thresholds. These results highlight increasing pollution pressure on River Yobe, driven by poor waste management and seasonal dynamics. Strengthened environmental regulation and community-based interventions are essential for safeguarding water quality and sustainable use.

***Keywords**: Heavy metals, River Yobe, Seasonal variation, Water quality*

1. Introduction

Water is one of the most essential natural resources, sustaining all forms of life, including humans [1]. With the advancement of civilization, dependence on freshwater resources, particularly rivers, has intensified [2]. Although water covers nearly 70% of the Earth's surface, pollution of rivers has emerged as a global concern, with projections indicating that by 2100, up to 5.5 billion people may face limited access to clean water [3]. The quality of river water is influenced by a wide range of natural and anthropogenic factors that accelerate its deterioration, thereby undermining its ecological, social, and economic functions [4]. Consequently, assessing water quality has become a critical aspect of water research [5]. Among the commonly employed indicators are physicochemical properties, heavy metal concentrations, and biological parameters, which together provide an integrated measure of the ecological health of aquatic systems [6].

The River Yobe, which flows through Gashua in Yobe State, Nigeria, is of particular importance as it serves as a primary source of untreated water for domestic consumption, irrigation, fishing, and agricultural practices. However, these anthropogenic activities pose significant risks to the river's water quality [7, 8]. Historically, Gashua's commercial significance attracted early settlers in the late 1970s, including farmers, fishermen, craftsmen, traders, and scholars. This stimulated rapid socio-economic development, reflected in the establishment of rice mills, surface roads, banks, and other facilities that enhanced the town's cultural and economic vitality [8]. Yet, such development has also contributed to environmental challenges, particularly the degradation of water quality through domestic effluents, agricultural runoff, and other human-induced pressures [9].

Although some studies such as Lami, *et al.*, [7], Waziri and Ogugbuaja [10] and Amoo, *et al.* [11] have examined aspects of water quality in the River Yobe and its environs, there remains a limited understanding of how seasonal variations influence both physicochemical properties and heavy metal contamination in relation to specific anthropogenic pressures in the Gashua catchment. Most existing studies are either general assessments of water resources in Yobe State or focus on single parameters, without integrating the seasonal dynamics of multiple pollutants.

Addressing these concerns is essential for safeguarding the ecological integrity of River Yobe and ensuring sustainable development in the region. Against this backdrop, the present study seeks to assess the seasonal variation in water quality and heavy metal contamination in River Yobe at Gashua, with specific emphasis on the influence of anthropogenic activities. By doing so, the study aims to provide comprehensive baseline data that can guide environmental management policies, promote public health, and support sustainable livelihood practices in Northeastern Nigeria.

2. Materials and method

2.1 Study area

The Gashua is a semi-urban settlement, situated in northern Yobe State, northeastern Nigeria, covering an area of 772 sq. km, with a population of approximately 139,804 individuals. It is situated within the semi-arid zone, predominantly featuring drought-resistant shrubs and short trees, experiencing an annual rainfall between 500 and 1,000 mm over roughly 120 days [7]. The Gashua catchment area of River Yobe is positioned at coordinates 12°52'50" N and 11°1'40" E and the River Yobe, itself, is formed by the tributaries of the Hadejia and Jama'are rivers, which converge at the Hadejia-Nguru Wetlands before flowing through Gashua and draining into Lake Chad [7]. The map of the study area and the samples sites are shown in Figure 1.

2.2 Study design

A stratified random sampling technique was employed by dividing the river into three distinct strata based on dominant anthropogenic activities:

Site A: (Bakin-gada): Zone characterized by intensive fishing activities

Site B: Section of the river primarily used for irrigation practices

Site C: Area influenced largely by domestic activities

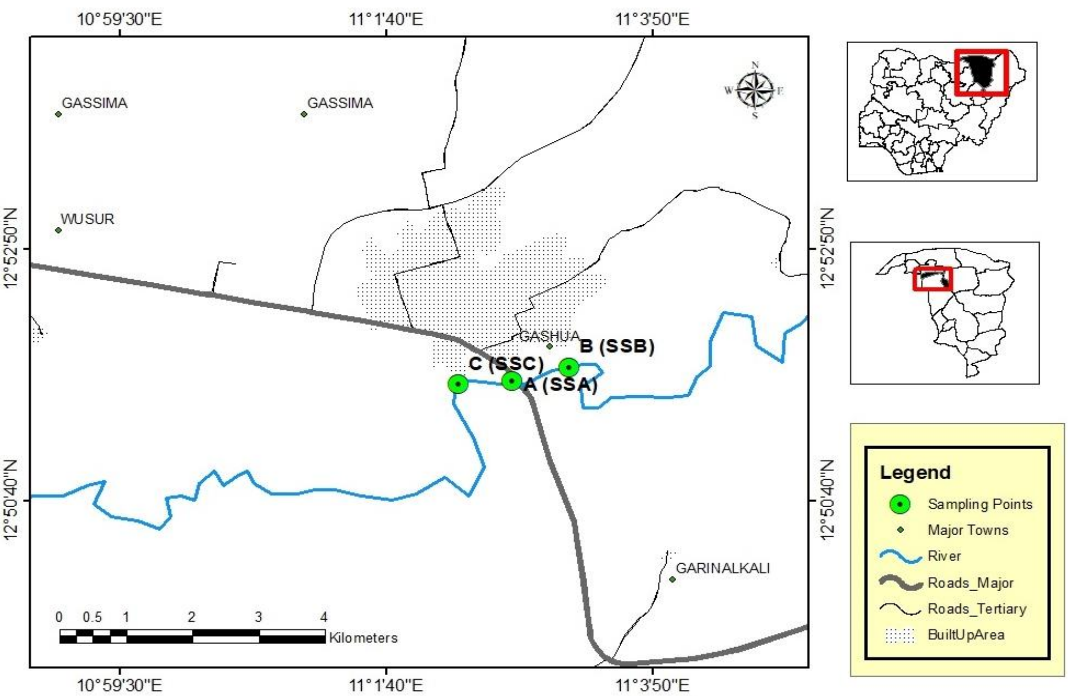

Figure 1: Map of the study area showing the sampling sites
Source: GIS LAB., BUK, 2024.

From each site, three replicate samples were collected monthly, yielding a total of 9 samples per month and 54 samples across the six-month study period. The study covers both dry and rainy seasons between December, 2024 and August 2025, from 7:30 am to 9:00 am throughout the study period to ensure consistency in data collection.

2.3 Water sample collection

Prior to collection, sampling containers were rinsed three times with river water at the site to minimize contamination. Each container was labeled with the date, time, location, and field observations following the procedure of Amoo, *et al.* [11]. Samples were collected by submerging sterilized plastic bottles approximately 15 cm below the water surface, as outlined by Adeleye, *et al.* [12]. Collected samples were stored in cool boxes and transported to the laboratory for further analysis.

2.4 General survey

A detailed questionnaire was developed to obtain data on water usage, waste disposal method, agricultural inputs and environmental management. The questionnaire was administered to the identified and selected households, farmers, fishermen and businesses in the Gashua catchment area through face-to-face interviews.

2.5 Determination of physicochemical parameters

Field measurements of temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS) were conducted in situ using a Hanna Multiparameter Instrument (Model HI 98129). Data were recorded instantly at each sampling site. Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were analyzed using a DO probe following the Standard Methods for the Examination of Water and Wastewater (Methods 4500-O and 5210 B) [13].

2.6 Heavy metal analysis (Cd, Cu, Pb, Zn)

Heavy metals were determined using Atomic Absorption Spectrophotometry (AAS) (Perkin Elmer, Model VGP 210, USA) after acid digestion. For each sample,100 mL of water was measured into a labeled cylinder and treated with 5 mL concentrated nitric acid (HNO_3) to convert metals into soluble forms. The mixture was heated on a hot plate until approximately 70 mL of water had evaporated. After cooling, the residue was diluted to 100 mL with distilled water, filtered, and analyzed using AAS, following the method of Tasiu and Dabo [14].

2.7 Statistical analysis

Data were analyzed using IBM SPSS Statistics version 25. Descriptive statistics were applied to summarize physicochemical and heavy metal concentrations. One-way Analysis of Variance (ANOVA) was used to assess seasonal and spatial variations. Statistical significance was determined at $p < 0.05$.

3. Results and discussions

3.1 Gashua river utilization patterns

The data presented in Table 1 shows that 35% of respondents were 21–40 years, 30% were 41–60 years, 20% were 18–20 years, and 15% were above 60 years. Thus, the working-age group (21–60 years) constituted 65%, indicating active engagement in water-related occupations and domestic activities. Occupations included fishermen (37%), domestic laborers (33%), farmers (23%), and rice mill workers (7%), with fishing being dominant, thereby heightening exposure to contaminated water [15]. In addition, river dependence was high (table 1): 85% reported usage, while 15% did not. Among users, 37% relied on it for fishing, 25% for direct consumption, 20% for irrigation, 15% for cooking, and 3% for other activities.

Table 1: Pattern of the interaction with population of the Gashua catchment area of River Yobe on relevant water issues using questionnaire.

Variables	(%=100)	Variables	(%=100)	Variables	(%=100)
Age Group		**Types of Waste**		**Rules For Waste Disposal**	
18 – 20	20	Organic wastes	32	Yes	27
21 – 40	35	Plastics	10	No	48
41 – 60	30	Human waste	28	Not aware	25
> 60	15	Agricultural waste	30	**Rules For Fishing**	
Occupation		**Method of Wastes Disposal**		Yes	45
Fishing	37	Dumping	37	No	25
Farming	23	Burning	8	Not sure	15
Domestic labor	33	Burying	0	No rules exits	15
Industry	7	Throwing into river	45	**Rules For irrigation**	
River Water Usage		Others	10	Yes	10
Yes	85	**Purpose of waste disposal near the river**		No	40
No	15	Poor collection service	58	Sometimes	25
Purpose of using river		Lack of awareness	22	Don't know	25
Direct consumption	25	Lack of law enforcement	20	**Community Involvement in Protecting the River**	
Fishing	37	**Effects of Wastes on the River**		Very active	20
Irrigation	20	Yes	28	Rarely active	45
Cooking	15	No	57	Not active at all	35
Others	3	Not aware	15		

Key: % = Percentage

These findings agree with Alhassan and Yusuf [16], who stressed the river's centrality to livelihoods and public health. Furthermore, waste management practices were poor: 45% disposed waste directly on the riverbank, 37% at nearby dump sites, and 8% by burning. Furthermore, 58% disposed on the riverbank due to poor collection services, 20% due to lack of awareness, and 22% due to weak law enforcement, consistent with findings by Wang and Zhang [15], Alhassan and Yusuf [16] and Adizua, *et al.* [17].

The dominant respondents (57%) believed that the wastes have zero effects on the river whereas the minorities (15%) are not aware of the effects. On the other hand, 28% are sure that the wastes have negative consequences on the river. Moreover, perceptions of regulatory enforcement were low: 48% believed no rules exist for waste disposal, 40% for irrigation, while 45% acknowledged fishing regulations. Additionally, 25% (waste disposal) and 15% (fishing) were unsure of regulatory presence, and only 10% believed irrigation rules were enforced, underscoring weak governance and poor community engagement.

3.2 Mean values of physicochemical parameters

The analysis of mean values of physicochemical parameters revealed distinct seasonal variations in the study area as shown in Table 2, indicating the influence of temporal and environmental factors on the water quality.

3.2.1 Temperature

The seasonal variation in water temperature observed ranged from 20.50 °C in the early dry season, rising sharply to a peak of 28.83 °C in the late dry season, and then moderating to 23.44 °C during the rainy season, indicating a significant seasonal difference ($P < 0.05$) in temperature, suggesting a significant influence of temporal variation on temperature in the study area as shown in Table 2. The elevated temperature observed during the late dry season can be attributed to higher solar radiation, reduced water volume, and prolonged water residence time, whereas the lower temperature in the early dry season aligns with cooler atmospheric conditions. The rainy season value of 23.4 °C appears to be moderated by increased rainfall, runoff, and mixing, which buffer the extremes of the dry season [18, 19]. This result is in conformity with 22°C – 28°C revealed by Ahmad and Indabawa [20]. In contrast, it lower than 24.0°C to 33.7°C revealed by Saifullah, *et al.* [21] and <30°C recommended by WHO [22]. However, it is higher than 22.47 °C - 22.77 °C) revealed by Ahmad, *et al*. [23].

3.2.2 pH

The pH recorded values ranged from 6.8 in the rainy season, 7.11 in the early dry season to 7.4 in the late dry season (table 2), indicating a significant seasonal difference ($P < 0.05$), suggesting a significant influence of seasonal variation on pH in the study area. Fortunately, all the pH mean values in this study remained within the WHO [22] and NESREA [24] recommended range of 6.5 – 8.5 for surface and drinking waters, implying that none of the seasons exhibited problematic acidity or alkalinity. However, it is slightly lower than 7.3 to 7.7 researched by Lurwan, *et al* [25] and 6.1 – 9.2 revealed by Ahmad and Indabawa [20]. In contrast, it is higher than 6.2 – 6.9 mg/L revealed by Jonah, *et al*. [26].

3.2.3 Electrical conductivity (EC)

Electrical conductivity (EC) ranged seasonally as can be seen in Table 2 from 100.67 µS/cm (rainy) to 271.78 µS/cm (late dry), signaling that seasonal variation was significant ($P < 0.05$), suggesting a significant influence of temporal differences on EC in the study area. All values were below the irrigation safety limit of 700 µS/cm [27, 28]. These values were comparable to Ahmad and Indabawa [20] (38.2–135.3 µS/cm), lower than Lurwan, *et al.* [25] (617–628 µS/cm) and WHO [22] (1000 µS/cm), but higher than Jonah *et al.* [26] (57.0–62.6 µS/cm).

3.2.4 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) were 70.89 mg/L (rainy), 106.44 mg/L (early dry), and 201.33 mg/L (late dry) as illustrated in Table 2. Seasonal variation was significant ($P < 0.05$), indicating a significant influence of seasonal differences on TDS in the study area. All values were within WHO [22] limits (<500 mg/L) but exceeded Jonah, *et al*. [26] (12.3–18.3 mg/L).

3.2.5 Dissolved oxygen (DO)

Dissolved oxygen (DO) (table 2) peaked at 8.32 mg/L (early dry), declined to 7.2 mg/L (late dry), and was lowest in the rainy season (4.67 mg/L), showing significant seasonal variation ($P < 0.05$), indicating a significant influence of temporal variation on temperature in the study area. Values exceeded Lurwan, *et al.* [25] (3.73–4.10 mg/L), Jonah, *et al*. [26] (2.3–5.2 mg/L), and Saifullah, *et al.* [21] (2.59–3.91 mg/L), but were consistent with WHO [22] (>5 mg/L) and Ahmad and Indabawa [20] (2.0–9.8 mg/L).

3.2.6 Biological oxygen demand (BOD)

Biological oxygen demand (BOD) ranged from 1.17 mg/L (early dry) to 3.07 mg/L (rainy), with 1.93 mg/L in late dry as shown in Table 2. Seasonal variation was significant ($P < 0.05$), suggesting a significant influence of temporal variation on BOD in the study area. All values were below WHO [22] (<6 mg/L) and aligned with Lurwan, *et al.* [25] (1.96–2.23 mg/L), Ahmad and Indabawa [20] (0.5–4.9 mg/L), and Jonah, *et al*. [26] (1.1–3.8 mg/L).

Table 2: Temporal variation in concentration of physicochemical parameters across the seasons in the Gashua Catchment area of River Yobe (December, 2024 - August, 2025)

Season	Temp (°C)	pH	EC (µS/cm)	TDS (MgL^{-1})	DO (MgL^{-1})	BOD (MgL^{-1})
EDS	20.50 ± 0.87^a	7.11 ± 0.17^b	132.44 ± 18.30^b	106.44 ± 8.31^b	8.32 ± 0.38^c	1.17 ± 0.43^a
LDS	28.83 ± 1.20^c	7.44 ± 0.22^c	271.78 ± 33.04^c	201.33 ± 16.40^c	7.22 ± 0.93^b	1.93 ± 0.67^b
RS	23.44 ± 1.10^b	6.77 ± 0.15^a	100.67 ± 23.61^a	70.89 ± 11.68^a	4.67 ± 0.56^a	3.07 ± 0.59^c

Values are expressed as mean **±** SD, (N = 3.) Means with different superscripts in the same column are statistically significantly different ($P < 0.05$). EDS: Early dry season, LDS: Late dry season, RS: Rainy season.

3.3 Heavy metal concentrations

The mean value of the concentrations of the heavy metals showed significant seasonal variations ($P < 0.05$) as depicted in Table 3, indicating that temporal factors greatly influenced their levels in the study area.

3.3.1 Cadmium (Cd)

The Cd concentrations were lowest in the early dry season (0.005 mg/L) and peaked in the rainy season (0.043 mg/L), it remains moderate in late dry season (0.014 mg/L) as depicted in table 3. This indicates a significant difference variation ($P < 0.05$) across the seasons, which shows a significant influence of temporal variation on Cd concentration in the study area. The Cd result (with the exception of 0.043 mg/L in rainy season) is lower than 0.04 - 0.05 mg/L revealed by Kluska, *et al.* [3] and 0.10 - 0.50 mg/L revealed by Pratyush, *et al.* [29]. However, it is higher than 0.003 recommended by WHO [22] and 0.003 mg/L researched by Odongo, *et al.* [30]. In contrast, early dry season corresponded with NESRESA [24] recommended limit of 0.005 mg/L. It was also noted that, the result is similar to 0.01 – 0.02 mg/L determined by Oiganji, *et al.* [31] and 0.0218 - 0.0561 mg/L observed by Aliyu, *et al*. [32].

3.3.2 Copper (Cu)

Seasonally, Copper (Cu) rose from 0.016 mg/L (early dry) to 0.115 mg/L (late dry) and 0.156 mg/L (rainy), indicating a significant difference ($P < 0.05$) across the seasons (table 3), suggesting a crucial influence of temporal variation on Cu concentration in the study area. All values were well below WHO [22] (2.0 mg/L) and Oiganji, *et al.* [31] (0.06–0.36 mg/L).

3.3.3 Lead (Pb)

Lead (Pb) increased seasonally from 0.045 mg/L (early dry) to 0.073 mg/L (late dry) and 0.107 mg/L (rainy) indicating significant variation ($P < 0.05$) across the seasons, indicating a significant influence of seasonal variation on Pb in the study area shown in Table 3. All values exceeded WHO [22] (0.01 mg/L) recommended limit, posing health risks. However, they were lower than Kluska, *et al*. [3] (5.3–6.1 mg/L) and Aliyu, *et al*. [32] (0.05–0.226 mg/L), but consistent with Oiganji, *et al*. [31] (0.08–0.46 mg/L) and Odongo, *et al*. [30] (0.054 mg/L).

3.3.4 Zinc (Zn)

Zinc (Zn) ranged from 0.059 mg/L (early dry) to 0.090 mg/L (late dry) and 0.152 mg/L (rainy) as depicted in Table 3, indicating a great significant variation ($P < 0.05$) across the seasons, which shows a significant influence of seasonal differences on Zn concentration in the study area. Values exceeded Oiganji, *et al*. [31] (0.01 mg/L) but were well below WHO [22] (3.0 mg/L).

Table 3: Temporal variation in heavy metal concentrations across the seasons in the Gashua catchment area of River Yobe (December, 2024 - August, 2025)

Season	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Zn (mg/L)
EDS	0..005 ±0.003^{a}	0.016 ±0.015^{a}	0.045±0.011^{a}	0.059 ±0.018^{a}
LDS	0.014±0.005^{b}	0.115 ±0.014^{b}	0.073 ±0.004^{b}	0.090 ±0.011^{b}
RS	0.043 ±0.003^{c}	0.156 ±0.009^{c}	0.107 ±0.013^{c}	0.152 ±0.034^{c}

Values are expressed as mean **±** SD, (N = 3.) Means with different superscripts in the same column are statistically significantly different ($P < 0.05$).

Keys: EDS: Early dry season, LDS: Late dry season, RS: Rainy season.

4. Conclusion

The study revealed that the River Yobe is heavily relied upon by local communities for domestic and livelihood activities, yet poor waste disposal practices, with nearly half of respondents discharging waste directly into the river, have contributed to water quality deterioration. Although basic physicochemical parameters were largely within WHO [22] and NESREA [24] standards, seasonal fluctuations and elevated levels of cadmium and lead far above permissible limits indicate serious health and ecological risks.

Overall, the findings highlight that while the river retains some ecological balance, its quality is increasingly threatened by human activities and seasonal pressures. This underscores the urgent need for improved community awareness, enforcement of waste management regulations, and strengthened monitoring of heavy metals and microbial contaminants to safeguard both human health and the ecological integrity of the River Yobe.

Recommendation

a. Regulated waste collection systems should be established in the River Yobe's communities to strengthen waste management.
b. Environmental laws on waste disposal and irrigation should be enforced through community-level monitoring and penalties to strengthen low enforcement.
c. Further researches should be carried out to include turbidity, nitrates, phosphates, and pesticides, resulting from fishing, agricultural and domestic wastes, to fully capture the physicochemical properties of the river.
d. Further studies should be conducted to assess the bioaccumulation and the toxicological impact of heavy metal pollutants on aquatic fauna, especially fish consumed by local communities.

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