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Evaluation of seasonal dynamics in physicochemical parameters of River Taraba, Nigeria

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ABSTRACT

This study investigated the seasonal and monthly variations in the physico-chemical parameters of River Taraba, Nigeria. Parameters measured included temperature, transparency, pH, dissolved oxygen (DO), electrical conductivity (EC), nitrate (NO_3^-), phosphate (PO_4^{3-}), and hardness. Seasonal comparison revealed statistically significant differences ($P \leq 0.01$) in transparency, DO, EC, nitrate, and phosphate levels, with higher concentrations generally recorded during the dry season. In contrast, temperature, pH, and hardness did not vary significantly between seasons ($P > 0.01$). Monthly analysis within seasons showed no significant variation across the dry months, indicating relative stability. However, all parameters exhibited significant monthly fluctuations during the wet season ($P \leq 0.01$), reflecting increased environmental dynamics due to rainfall and surface runoff. These findings underscore the importance of seasonality in water quality monitoring and suggest a greater impact of anthropogenic and natural inputs during the wet season. Continuous assessment is recommended to guide water resource management and conservation strategies in the region.

Key words: Seasonal Variations, Water Quality, Environmental Dynamics, Aquatic Ecosystem, Temperature.

INTRODUCTION

Rivers are vital freshwater resources that support a wide range of ecological, economic, and social activities (Anderson *et al.*, 2019; Bănăduc *et al.*, 2022). In many parts of the world, including Nigeria, rivers such as the River Taraba play a critical role in supporting agricultural activities, domestic water supply, and biodiversity. However, these ecosystems are highly sensitive to climatic and anthropogenic factors such as rainfall variability, pollution, urbanization, and land-use changes (Khatri & Tyagi, 2015; Ekka *et al.*, 2020; Yu *et al.*, 2021; Siddha & Sahu, 2022).

Seasonal variations, particularly the alternation between wet and dry seasons, significantly affect the physicochemical parameters of river systems in tropical regions like Nigeria (Adeyemo *et al.*, 2008; Agbasi *et al.*, 2023; Ayejoto *et al.*, 2023). During the rainy season, increased rainfall leads to higher runoff, which can carry nutrients, sediments, and pollutants into rivers, altering parameters such as turbidity, temperature, pH, dissolved oxygen, and nutrient concentrations (e.g., nitrates, phosphates) (Adeyemo *et al.*, 2008; Wang *et al.*, 2017; Coffey *et al.*, 2019; Razali *et al.*, 2020). Conversely, the dry season often results in reduced water volume, increased concentration of dissolved substances, and changes in water temperature and hardness (Ouyang *et al.*, 2006; Anhwange *et al.*, 2012; Mosley, 2015; Xu *et al.*, 2019).

Studies on rivers in Nigeria, such as the River Benue and Warri Rivers, have highlighted the impact of seasonal rainfall patterns on water discharge, quality, and ecosystem health

(Anhwange *et al*., 2012; Okoye & Iteyere, 2014; Joyce, 2019; Aondoakaa & Jewitt, 2022; Ezra *et al*., 2023; Patricia *et al*., 2024). River Taraba and similar river systems in Nigeria have demonstrated that seasonal fluctuations in physicochemical parameters are closely linked to both natural hydrological cycles and human activities. For example, research on River Kashimbila in Taraba revealed that zooplankton diversity and abundance are influenced by seasonal changes in water quality, with higher turbidity and nutrient loads observed during the rainy season due to runoff and anthropogenic inputs. These changes can affect aquatic food webs, fisheries productivity, and the suitability of river water for various uses (Bonjoru *et al*., 2020; Usman *et al*., 2023). Taraba State experiences distinct wet and dry seasons that significantly influence river dynamics (Gabriel *et al*., 2018; Gabriel *et al*., 2020; Asa & Zemba, 2024). Previous studies in the River Taraba basin have shown that rainfall peaks between July and October, with a sharp decline afterward. This seasonal pattern directly affects river discharge, water levels, and physicochemical properties such as pH, turbidity, and dissolved oxygen (Gabriel *et al*., 2018; Adamu *et al.,* 2024). Furthermore, climate change has introduced variability in rainfall onset and cessation, leading to challenges such as flooding during heavy rains or reduced water availability during prolonged dry periods (Trenberth, 2005; Wasko *et al*., 2021).

The seasonal changes in temperature, rainfall, and land use patterns significantly impact the river's physicochemical properties (Lee *et al*., 2012; Yu *et al*., 2016). Moreover, seasonal changes impact critical water quality parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, and nutrient concentrations (e.g., nitrates and phosphates). These fluctuations can affect aquatic life and water usability for human consumption (Odjadjare & Okoh, 2010; Zhang *et al*., 2017; Ibrahim *et al*., 2021).

River Taraba is one of the major tributaries of River Benue, located in northeastern Nigeria. The river traverses Taraba State, supporting diverse ecological and socio-economic activities, including fishing, irrigation, and drinking water supply. However, due to increasing human activities such as farming, mining, and urbanization, the river's water quality is at risk of degradation. While there is extensive research on climatic trends and hydrology in Taraba State, there is limited data specific to the seasonal dynamics of physicochemical parameters in River Taraba itself. Addressing this gap is essential for sustainable water resource management and mitigating the impacts of climate change on local communities. Therefore, this study aims to assess the seasonal dynamics of key physicochemical parameters in River Taraba.

MATERIALS AND METHODS

The Study Area

River Taraba is situated at 8°34'N latitude and 10°15'E longitude. It originates from the high-altitude Alantica Hills along the Nigeria-Cameroon border in the mid-eastern part of Taraba State. Flowing westward through the Mambilla Plateau in Sardauna Local Government Area, the river spans approximately 265 kilometers before joining the Upper Benue River Basin (Danba *et al*., 2020). Along its course, the river traverses Gashaka, Bukundi, and Gassol districts within Gashaka, Bali, and Gassol Local Government Areas of Taraba State.

Taraba State experiences a tropical climate with distinct wet and dry seasons. The wet season spans from April to October, with annual rainfall ranging from 1,058 mm in northern areas like Jalingo and Zing to over 1,300 mm in the Central and Southern regions such as Gembu, Serti and Takum. August and September are typically the wettest months (Danba *et al*., 2020; Bingari, 2014). The dry season extends from November to March, with December and January being the driest months, during which the relative humidity falls to approximately 15%. In Jalingo, the average annual temperature is around 28°C, with highs fluctuating

between 30°C and 39.4°C and lows ranging from 15°C to 23°C. The Mambilla Plateau experiences a climate similar to temperate regions (Bingari, 2014; Danba *et al.*, 2020). Vegetation in Taraba State is influenced by rainfall patterns and topography, categorized into Northern Guinea Savannah, Southern Guinea Savannah, and Mountain Grassland/Forest vegetation types (Bako *et al.*, 2016; Riki *et al.*, 2021). The fish sampling site for this study is situated in the Northern Guinea Savannah zone.

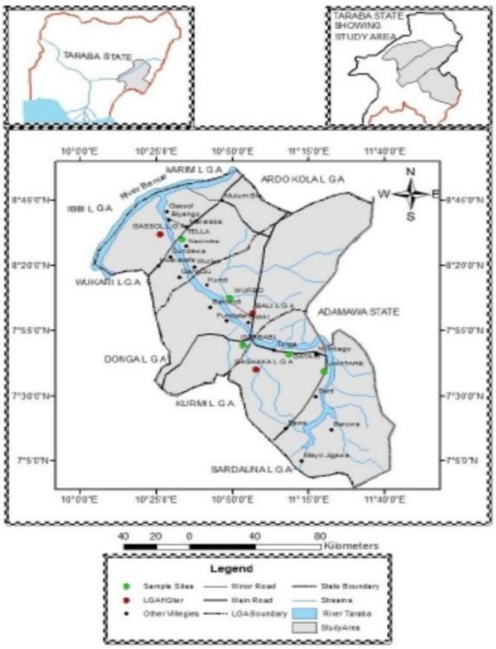

Fig. 1: Map showing River Taraba

Physico-Chemical Analysis of Water Sample

The water samples were collected every month between 9 and 11 a.m. from the sampling stations along River Taraba between November 2021 and April 2023. The River is categorized into four stations, namely: Station I (Tella) is mainly occupied by anthropogenic activities like fishing, farming, washing, bathing, and other activities such as dumping of rice chaff, household and animal waste. The water is comparatively polluted. It is a densely populated human settlement. Station II (Wurbo) has natural vegetation and scattered trees, which are planted at the riverbank. Grazing, bathing, fishing, irrigation, and commercial activities are common in this station. There is a scattered human settlement nearby. This station is relatively less impacted. Station III (Garbabi) is surrounded by grazing lands. Anthropogenic activities such as irrigation farming and grazing, cattle watering, bathing, and washing are common practices in the area. Station IV (Gayam), anthropogenic activities such as farming and grazing, herbicide spraying, washing clothes, and bathing are common activities in this station. The Water samples were collected in 250ml bottles from the four (4) sampling stations. During analysis of the physico-chemical properties of the water, the bottles were rinsed before being filled with water for physico-chemical analysis in the laboratory according to the methods suggested by the American Public Health Association (APHA, 2017)

Determination of temperature

Water temperature was determined at the sampling station (*in situ*) using a digital portable dissolved oxygen/temperature meter model 407510A) to measure the temperature values at each station by dipping the electrode into the water and allowing it to stabilize; then the reading was immediately taken (Suzie, 2015).

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Determination of transparency

The transparency of the water was measured using a Secchi disk as described by Suzie (2015). The disk was dipped into the water till the disk disappeared, and the depth was recorded (d_1). It was then withdrawn carefully, and the depth at which it became visible was also recorded (d_2). Actual measurement was obtained by taking the average of the two readings (d_1+ d_2/2).

Determination of pH

The pH was determined directly at the sampling station (in situ) using a pH meter (model: Pen type pH meter). The electrode of the meter was first standardized using a buffer solution that had the same temperature as the water. After calibration of the electrode in the solution, it was washed in distilled water before dipping it into the water for about two minutes for equilibrium. The reading was standardized with buffer solution before measurement was taken (Suzie, 2015).

Determination of dissolved oxygen

A digital portable dissolved oxygen/temperature meter model (EXTECH INSTRUMENTS-407510A) was used to measure the DO values at each station. For each sampling station, the probe was inserted into the water, and the reading displayed on the LCD dial was recorded; subsequently, the same procedure was applied for all the stations after rinsing the probe in distilled water (Higgins *et al.,* 2008).

Determination of Electrical Conductivity

Electrical Conductivity was determined at the station (in situ) using a conductivity meter. The electrode of the conductivity meter was dipped into the water and allowed to stabilize; the reading was immediately taken (Ahmed, 2015).

Determination of Nitrate-Nitrogen

Nitrate was measured using a Testab water investigation kit as recommended by Campbell and Weinberger (2001). A test tube was filled with water to 5ml line. One Nitrate Testab 1 (2799A) was added. The test tube was capped and mixed until the tablet was fully disintegrated. One tablet of Nitrate CTA testab 2 (NN-3703A) was added again, and immediately the test tube was slid under a protective sleeve; the test tube was capped and mixed for 2 minutes in order for the tablet to disintegrate. It was then allowed to wait for 5 minutes; the tube was removed from the protective sleeve. The colour of the sample was compared with the Nitrate colour chart (5891-CC). The result was recorded in milligrams per litre (mg/l) Nitrate.

Determination of Phosphorus-phosphate

Phosphate was determined by a method adopted by Ibrahim (2009). 5 mL of the sample was measured into a test tube. 1mls ammonium Molybdate solution was added and allowed to stand for 20 seconds. 1ml of hydroquinone solution was also added, and the flask was rotated to mix, and 1 mL of Na_2SO_4 solution was also added. 2 mL of distilled water was then added. The test tube was stopped with a thumb and was shaken to mix thoroughly. The mixture was allowed to stand for 30 minutes and then measured with a spectrophotometer set at 650nm, alongside a blank. A calibration curve was prepared using standard phosphorus concentrations.

Statistical Analysis

The data recorded from the present investigation were analyzed using the methodology described by Gomez and Gomez (1984). The data collected for different parameters were statistically analyzed using ANOVA (Analysis of Variance). Statistical significance was assessed using an 'F' test, and differences in means across treatments were examined using the least significant difference (LSD) at the 5% level of significance.

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RESULTS

The Physico-Chemical Parameters of River Taraba showed seasonal mean variation (Table 1). The water temperature variation indicated mean ± SE value of (27.99±0.29^{o}C); Transparency of the River fluctuated with mean ± SE value of 28.22±1.07cm, the pH values ranged between (7.41-7.57) with mean ± SE value of 7.49±0.08; The Dissolved Oxygen values in the River ranged from 2.40 mgL^{-1}to 6.81 mgL^{-1} with the mean ± SE of 4.74±0.15 mgL^{-1}.

The electrical conductivity ranged from 38.20µS/cm to 64.20µS/cm with a mean ± SE of 54.75±1.17µS/cm. Nitrate-nitrogen indicated mean ± SE values of 0.24±0.01mg^{L-1}during the period of study, Phosphate-phosphorus was 0.14±0.01mg^{L-1} while the hardness in the River showed a mean ± SE of 13.8±4.4mg^{L-}1(CaCO3). Tables 2 and 3 showed results on physico-chemical parameters of the River based on seasons. It indicated that all the parameters were non-significant for the dry season, while the results for the wet seasons indicated high significance for all the parameters.

Table1: Seasonal Variation of the Physico-chemical Parameters of River Taraba

Parameter	Season		Total	P value
	Dry	**Wet**		
Temp (oC)	27.8±0.49	27.99±0.29	27.99±0.29	**0.497ns**
Transparency (cm)	31.8±2.74	28.22±1.07	28.22±1.07	**0.001****
pH	7.40±0.08	7.49±0.08	7.49±0.08	**0.329ns**
DO (mg/L)	5.50±0.20	4.74±0.15	4.74±0.15	**0.000****
EC (µS/cm)	59.0±2.05	54.75±1.17	54.75±1.17	**0.000****
NO3- (mg/L)	0.30±0.05	0.24±0.01	0.24±0.01	**0.000****
PO4-(mg/L)	0.20±0.02	0.14±0.01	0.14±0.01	**0.000****
Hardness (mg/L)	**112.70±8.11**	**3.27±0.11**	**13.8±4.4**	**0.311ns**

**- highly significant at P≤0.01, Non-significant at P>0.01

Table 2: Physico-chemical Parameters of River Taraba Based on Dry Season

Physico-chemical Parameters	Dry Season						Total	P value
	October	**November**	**December**	**January**	**February**	**March**		
Temp (^{o}C)	26.46±0.74^{c}	26.90±0.60^{c}	26.20±0.72^{c}	26.90±0.53^{c}	28.76±0.19^{b}	31.48±0.19^{a}	27.8±0.49	**0.765ns**
Transparency	40.10±0.39^{a}	28.10±1.54^{bcd}	30.20±1.85^{bc}	30.40±1.81^{bc}	34.30±5.09^{ab}	27.60±5.75^{bcd}	31.8±2.74	**0.905ns**
pH	7.30±0.10^{bc}	7.60±0.07^{bc}	7.47±0.07^{bc}	7.44±0.05^{bc}	7.41±0.12^{bc}	7.24±0.07^{c}	7.4±0.08	**0.485ns**
DO (mg/L)	6.71±0.26^{a}	6.08±0.25^{ab}	5.33±0.11^{bc}	5.08±0.14^{c}	6.81±0.27^{a}	6.35±0.14^{e}	5.5±0.20	**0.309ns**
EC (µS/cm)	61.60±0.51^{a}	64.20±1.53^{a}	63.20±0.97^{a}	60.60±0.68^{ab}	52.20±3.50^{bc}	52.00±5.10^{bc}	59.0±2.05	**0.965ns**
NO3 (mg/L)	0.30±0.01^{a}	0.30±0.01^{a}	0.28±0.03^{ab}	0.27±0.19^{abc}	0.27±0.02^{abc}	0.20±0.02^{def}	0.3±0.05	**0.165ns**
PO4-(mg/L)	0.15±0.01^{bcd}	0.20±0.03^{ab}	0.24±0.02^{a}	0.17±0.03^{bc}	0.15±0.03^{bc}	0.14±0.01^{bcd}	0.2±0.02	**0.136ns**
Hardness	**145.6±9.6^{abc}**	**142.4±12^{abc}**	**143.2±10^{abc}**	**3.48±0.25^{bc}**	**144±10.8^{abc}**	**97.6±6de**	**112.7±8.11**	**0.904ns**

Table 3: Physicochemical Parameters of River Taraba Based on the Wet Season

Physico-chemical Parameters	Wet Season						Total	P value
	April	May	June	July	August	September		
Temp (°C)	31.20±0.36^{a}	31.54±0.18^{a}	25.94±0.07^{c}	26.30±0.07^{c}	27.04±0.13^{c}	27.10±0.49^{c}	27.99±0.29	0.000**
Transparency	28.10±3.23^{bcd}	27.10±2.05^{bcd}	23.10±1.78^{cd}	20.80±1.21^{cd}	19.40±1.22^{d}	29.40±3.61^{bcd}	28.22±1.07	0.002**
pH	6.19±0.21^{d}	7.51±0.13^{bc}	7.65±0.17^{bc}	7.62±0.10^{bc}	8.63±0.31^{a}	7.79±0.26^{b}	7.49±0.08	0.000**
DO (mg/L)	3.86±0.24^{d}	2.40±0.28^{e}	3.89±0.34^{d}	5.22±0.22^{c}	2.80±0.12^{e}	5.81±0.57^{bc}	4.74±0.15	0.000**
EC (µS/cm)	52.00±1.10^{bc}	55.80±1..36^{abc}	50.20±2.06^{c}	55.80±1.77^{abc}	38.20±1.80^{d}	51.20±6.63^{c}	54.75±1.17	0.000**
NO3 (mg/L)	0.24±0.02^{bcd}	0.17±0.02^{ef}	0.15±0.02^{f}	0.22±0.004^{cde}	0.18±0.01^{ef}	0.26±0.03^{abc}	0.24±0.01	0.000**
PO4-(mg/L)	0.12±0.01^{cd}	0.15±0.03^{bc}	0.09±0.01^{de}	0.04±0.02^{e}	0.13±0.01^{cd}	0.14±0.01^{cd}	0.14±0.01	0.000**
Hardness	124±16^{cd}	87.2±8.4^{e}	80±6.8^{e}	133.6±5.2^{bc}	174.4±14^{a}	158.4±5.6^{ab}	3.27±0.11	0.000**

DISCUSSION

The highest value for temperature was observed in the wet season. The mean monthly variation of temperature was higher in May (31.54°C). The lower temperature recorded in the wet season could be a result of seasonal changes in air temperature, humidity, and solar radiation. Adelalu *et al.* (2020) and Ezra *et al.* (2020) observed that the temperature of River Taraba in Nigeria is influenced by various climatic factors, which can vary significantly throughout the year. The results for temperature in these findings were also similar to the findings of David *et al.* (2020) and Nasiru (2020). The low water temperature values recorded during the wet season were attributed to the rainy season due to the effect of cloud cover and the extensive submerged macrophytes. The turbid nature of the River contributed to the reduction in temperature due to absorption of heat by the silts.

The highest value for transparency was recorded to be high in dry season (31.8cm) which was highly significant from the wet season (28.22cm). Bichi and Ibrahim (2009) reported that higher transparency occurred during the dry season due to the absence of rain runoff and low flow of water, as well as gradual settling of suspended particles. Inuwa (2017) reported high water transparency as a result of the dry season, and that temperature increases the euphotic zone in an aquatic ecosystem, which in turn favours phytoplankton growth and primary productivity.

pH value recorded was high in the month of August, which was non-significant (P>0.05) compared with September, June, July, and November, and the lowest was recorded in the month of April. This was probably within the recommended range (6.0 - 9.0) for aquatic life (Chapman and Kimstach, 2019). The highest value recorded in the wet season could be attributed to an enhanced rate of evaporation coupled with human interference and partly to enhanced photosynthetic activity. Also, low pH indicates low acidity, possibly due to the presence of CO_2 in the water; this was also in congruence with the findings of Inuwa (2017) and Mustapha (2018a and 2018b).

The highest value for Dissolved Oxygen was obtained in the month of February (dry). A similar value for D.O. was also observed by Ibrahim *et al.* (2019), who reported that the cool harmattan wind, which increases wave action and decreases surface water temperature, might have contributed to the increased oxygen concentration during the dry season. The high oxygen value for the dry season

coincides with periods of lowest turbidity and temperature. The amount of dissolved oxygen in water has been reported not to be constant but to fluctuate, depending on temperature, depth, wind, and the amount of biological activities such as degradation. In this study, the cool harmattan wind, which increases wave action and decreases surface water temperature, might have contributed to the increased oxygen concentration during the dry season, while the torrential rains created increased turbidity and decreased oxygen concentration during the rainy season. Oniye *et al.* (2016) made similar observations for Zaria Dam. The higher fluctuations of dissolved oxygen during the dry season than in the rainy season periods could also be attributed to the peak of human activities along the catchment area during this season. The decomposition of organic matter and metabolic activities of epiphytic organisms could also be responsible for reduced oxygen concentration in the river (Ibrahim, 2019). This also agrees with the report of Araoye (2018) that high O_2 concentration recorded during the dry season was due to enhanced photosynthetic activities during this season.

The concentration of Electrical Conductivity (EC was highest in the dry season (59.0µS/cm). Electrical Conductivity was maximum in the month of November (dry) while the lowest was recorded in the month of August (wet). The high dry season value may be due to the reduction in the water level and an increase in nutrients due to runoff of inorganic fertilizer from nearby farmland. Atobatele and Ugwumba (2018) suggested that a decrease in conductivity values during raining season might be due to dilution by rainfall. The higher values may be due to dilution of rainfall. The higher values may be due to chemical fertilizers from irrigated farmlands around the reservoir coupled with a higher rate of evaporation that reduces the level of water during the dry season. Thus, conductivity of water depends upon the concentration of ions and its nutrient status.

The maximum value for nitrate was obtained in the months of October and November (dry), while the lowest value was obtained in the month of June. These findings are similar to the findings of Dimowo (2013) in Ogun River, Kolo, and Ogugbuaja (2014) in Lake Chad Basin of Borno State, who revealed lower water levels and higher evaporation rates during the dry season that lead to an increase in the concentration of nitrates in the remaining water. Moreover, as water evaporates, the dissolved substances, including nitrates, become more concentrated, resulting in higher nitrate-nitrogen levels. This effect can be particularly pronounced in shallow water bodies where evaporation is more significant.

The high dry season mean value for phosphate could be due to a concentration effect because of reduced water volume. The relatively high values of Phosphate recorded in this study could be attributed to incoming effluents and human activities such as washing, bathing, fishing, and fish farming. The values of phosphate in Station 1 were considerably higher than those in other Stations. This may be due to the biodegradation of organic matter by bacteria. It could also be due to lower water hardness, thus less co-precipitation of phosphate with calcium carbonate, a phenomenon that has often been reported to occur in many freshwaters. Kolo and Ogugbuaja (2014) made similar observations in Borno State in North-eastern Nigeria.

Water hardness was higher during the dry season than the rainy season. This could be as a result of low levels and concentration of ions, and the lower rainy season value could be due to dilution. It could be attributed to the decrease in water volume and increase in the rate of evaporation at high temperatures. This agrees with the findings of Fahmy *et al.* (2022) for Manzala Lake, Kolo and Oladimeji (2016) for Shiroro Lake, and Shehata *et al.* (2018)

CONCLUSION AND RECOMMENDATIONS

The tables collectively demonstrate a clear seasonal pattern in physicochemical water quality parameters, with the wet season characterized by increased runoff-driven pollution (higher turbidity, BOD, nutrients) and the dry season showing concentration effects (higher temperature, EC, hardness). The significant statistical results validate that these seasonal changes are not random but driven by climatic and anthropogenic factors. These findings underscore the importance of seasonality in water quality monitoring and suggest a greater impact of anthropogenic and natural inputs during the wet season. Continuous assessment is recommended to guide water resource management and conservation strategies in the region.

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