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Assessment of Physico-Chemical Parameters and Water Quality Status of Lake Geriyo, Adamawa State, Nigeria

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ABSTRACT

Freshwater lakes in rapidly urbanizing regions face increasing pressures from agricultural expansion, domestic waste, and climate variability. Lake Geriyo, located near Jimeta-Yola in Adamawa State, Nigeria, is crucial for irrigation, fisheries, and local biodiversity; however, human activities threaten its water quality. This study assessed the impact of these activities on the physico-chemical parameters of Lake Geriyo to evaluate its water quality and suitability for aquatic life. Monthly water samples were collected from three stations over 18 months (n = 18 per station per parameter). Ten parameters were analyzed: temperature, turbidity, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total solids (TS), total dissolved solids (TDS), nitrite (NO_2), nitrate (NO_3), and phosphate (PO_4) using standard methods. The data were statistically examined using one-way ANOVA ($p < 0.05$) and compared against WHO and Federal Ministry of Environment (FMEnv) standards. Mean temperature (24.52-24.85 °C) and pH (7.10-7.19) fell within acceptable limits. However, turbidity varied significantly, with Station 3 exceeding the WHO guideline of 5.0 NTU, while dissolved oxygen levels were above WHO standards but below optimal FMEnv levels. Phosphate levels (0.081-0.106 mg/L) exceeded WHO guidelines but remained within FMEnv limits. Lake Geriyo is oligotrophic to mesotrophic and supports aquatic life and fisheries, but elevated turbidity and phosphate levels indicate potential eutrophication risks. Regular monitoring and nutrient management are recommended for maintaining the lake's ecological health.

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INTRODUCTION

The imperative to understand the status of freshwater ecosystems, with a particular focus on lakes, is underscored (Fierro et al., 2017). In recent decades, human activities such as agriculture, land-use changes, increased surface waterproofing that amplifies runoff and concentrates pollutants, unprocessed wastewater discharges, and the influence of climate change have collectively precipitated widespread deterioration in the quality of surface waters. The degradation we observe underscores the critical importance of effective management practices encompassing hygiene, environmental sanitation, storage, and disposal. These factors are pivotal in preserving our valuable water resources (Fabian et al., 2023).

Lake Geriyo has been a critical fluvial resource that plays a multifaceted role in supporting both human and ecological systems. Its waters serve as a primary source for irrigation, sustaining local agriculture and ensuring food security for the surrounding communities. The lake's rich aquatic life supports a thriving fishing industry, providing livelihoods for numerous households. Additionally, beyond its immediate economic and subsistence value, Lake Geriyo holds ecological significance. It offers a habitat for a diverse variety of aquatic species and plays a role in maintaining local biodiversity. Moreover, it contributes to the region's overall environmental balance, acting as a reservoir for freshwater and supporting various ecosystem services such as flood regulation and water purification.

However, the continued health and sustainability of Lake Geriyo are threatened by a range of human-induced factors, including pollution, climate change, and unsustainable resource use. Understanding and addressing these challenges are paramount to preserving the lake's importance for current and future generations." Aquatic ecosystems, including lakes, rivers, and estuaries, undergo continuous transformation due to geological factors.

These ecosystems epitomize a constant interplay of energy and matter, underscored by the actions of living organisms. The equilibrium, however, is perturbed by human interventions, ushering in pollution and its attendant consequences, manifesting in fish fatalities, repugnant odors, discoloration, and uncontrolled aquatic weed proliferation.

Of grave concern are anthropogenic sources. The repercussions are profound, yielding transformations in water quality, the loss of aquatic flora and vital ichthyofauna, and the imposition of health and ecological risks when pollutants accumulate in life-sustaining functions and ecosystem services (Oluowo and Isibor, 2016).

The primary aim of this study is to assess the impact of human activities on the physico-chemical parameters of Lake Geriyo, with a specific focus on the water quality potential of the Lake.

MATERIALS AND METHODS

Study Area

Figure 1: Map Showing Lake Geriyo (Bawuro *et al.,* 2018)

The study area, Lake Geriyo, is situated on the outskirts of the Jimeta Yola metropolis in the northeast region (longitude 120 25' E, between latitude 90 81' N and 90 17' N). It covers an area of approximately 750 hectares at a high level and 200 hectares at a low level, with a storage capacity of about 7,500,000 cubic centimeters. The portion suitable for fisheries development is roughly 250 hectares. Lake Geriyo is a small body of water that originally formed from a tiny gully, later filling with rainwater and some inflow from the River Benue. It became a recognizable lake around 1950. Initially, it was not used for fishing, but now it has developed into a significant fishery with year-round fishing activities. Additionally, it serves as a major water source for irrigation during the dry-season farming around the lake. The lake's water level remains relatively stable, allowing for balanced inflow and outflow. This stability has supported the growth of aquatic plants, giving the basin the characteristics of a typical lake.

The lake experiences two seasonal periods: the rainy season and the dry season. The rainy season typically occurs from May to October, characterized by heavy rainfall that can sometimes lead to severe flooding. Conversely, the dry season spans from late October to April and features cold, dusty winds during December and January (harmattan), along with intense heat from February through April. Temperatures can drop to around 20°C in December and January and rise to as high as 40°C in March and April.

Determination of Physico-Chemical Parameters

In this study, water samples were meticulously collected and preserved in labeled 100ml containers. Various key water characteristics were directly measured at the sampling sites. Specifically, water temperature, pH levels, and Dissolved Oxygen (DO) concentrations were assessed on-site using specialized instruments. Temperature readings were obtained using an in-situ Mercury bulb thermometer (Glasweikwer Tien Model), while pH measurements were conducted with a pH meter (Model: Hanna Instrument Model No H18915ATC). Additionally, the concentration of Dissolved Oxygen (DO) was determined utilizing a digital Dissolved Oxygen meter (Model: FT 607.

The analysis of total solids involved determining the residues left behind after evaporating unfiltered water samples, while total dissolved solids were ascertained by evaporating filtered water samples. Furthermore, Dissolved Oxygen measurements were recorded after a five-day incubation period, and Biochemical Oxygen Demand (BOD) was calculated using the formula:

BOD = DO1 - DO2 (mg/l)

To assess the concentrations of nitrates ($NO3^-$), the Cadmium Reduction Method as outlined in APHA (1998) was employed. The determination of nitrite and phosphate (PO4-3) concentrations was carried out using a spectrophotometer. Statistical analyses were performed using the SPSS software package. The collected data on water quality parameters underwent ANOVA.

RESULTS AND DISCUSSION

The water quality assessment of Lake Geriyo was conducted across three sampling stations (Stations 1, 2, and 3) over 18 months (n = 18 per station per parameter), as shown in Table 1 below. Ten physicochemical parameters were measured: temperature, turbidity, pH, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Total Solids (TS), Total Dissolved Solids (TDS), Nitrite (NO_2), Nitrate (NO_3), and Phosphate (PO_4). The results are presented as mean ± standard error (standard deviation), with statistical significance determined by one-way ANOVA ($p < 0.05$).

Table 1: Showing the Physicochemical parameters of Lake Geriyo

Parameters	Station 1 $\bar{X} \pm S.E\ (S.D)$	Station 2 $\bar{X} \pm S.E\ (S.D)$	Station 3 $\bar{X} \pm S.E\ (S.D)$	p Value	Standard FMEnv. Permissible Limit	WHO Permissible Limit
Temperature (^{O}C)	24.52 ±0.83 (3.54)	24.85 ±0.79 (3.37)	24.56 ±0.78 (3.31)	0.952	<40	25
Turbidity (NTU)	20.10 ±1.16(4.93)	20.32 ±1.05(4.45)	27.06±1.63(6.93)	<0.001	5	5.0
pH	7.19 ±0.16(0.69)	7.13 ±0.08 (0.35)	7.10±0.03(0.12)	0.642	6.0 9.0	6.5 8.5
DO (mg/l)	6.16 ± 0.16 (0.69)	6.05 ±0.13 (0.56)	6.60 ±0.17 (0.73)	0.044	>10	>5
BOD (mg/l)	3.68 ±0.11 (0.46)	3.76 ±0.10 (0.43)	3.78 ±0.10 (0.43)	0.796	10	-
TS (mg/l)	373.45 ±16.75 (71.06)	365.27±17.21(73.01)	358.88 ±16.86(71.55)	0.831	-	-
TDS (mg/l)	199.43 ±14.93 (61.55)	195.42 ±14.46 (59.62)	194.87 ±14.92(61.53)	0.972	500	500
NO_2 (mg/l)	0.073 ±0.010 (0.044)	0.065 ±0.008 (0.035)	0.063 ±0.008 (0.032)	0.718	1.0	0.2

Parameters	Station 1 $\bar{X} \pm S.E\ (S.D)$	Station 2 $\bar{X} \pm S.E\ (S.D)$	Station 3 $\bar{X} \pm S.E\ (S.D)$	p Value	Standard FMEnv. Permissible Limit	WHO Permissible Limit
NO_3 (mg/l)	0.374 ±0.020 (0.085)	0.369 ±0.017 (0.072)	0.356 ±0.018 (0.076)	0.767	10	<10
PO_4 (mg/l)	0.081 ±0.011 (0.045)	0.106 ±0.015 (0.064)	0.104 ±0.024 (0.101)	0.534	5.0	<0.05

The water quality assessment of Lake Geriyo reveals that most physicochemical parameters: temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total solids (TS), total dissolved solids (TDS), nitrite (NO_2), nitrate (NO_3), and phosphate (PO_4) showed no statistically significant differences among the three stations (all $p > 0.05$). The sole exception was turbidity, which exhibited significant spatial variation ($p < 0.001$), with Station 3 recording the highest mean value (27.06 NTU) compared to Stations 1 (20.10 NTU) and 2 (20.32 NTU). The mean water temperatures recorded across the three stations fall within the typical range for tropical freshwater systems in Nigeria. Comparable values have been reported for Lake Geriyo by Vandi *et al.* (22.7 ± 0.78°C to 28.5 ± 0.04°C), Anyanwu *et al.* (2025) reported a flood retention lake in Benin City (24.00-28.00°C), and Abasiryu *et al. (*2022) reported Luhu Dam, Adamawa State (18.63°C to 27.45°C). Ahiarakwem *et al.* (2012) reported that Oguta Lake exhibits a wider seasonal range of 24.0-31.0°C, reflecting its larger surface area and more pronounced thermal stratification. The relatively narrow temperature range observed in Lake Geriyo (approximately 0.3°C difference among stations) and the absence of significant spatial variation ($p = 0.952$) indicate that the lake is well mixed and thermally homogeneous. All values are within the FMEnv permissible limit of <40°C and the WHO guideline of 25°C. The temperature regime is suitable for the survival and reproduction of tropical fish species.

The pH values recorded (7.10-7.19) indicate slightly alkaline conditions, which are typical of many Nigerian freshwater systems. These values are within the WHO permissible range of 6.5-8.5 and the FMEnv standard of 6.0-9.0. Comparative studies show similar pH ranges: Adamu *et al.* (2021) reported Dangana Lake (6.10-7.5), Adedire *et al.* (2024) reported Lake Tunari, Taraba State (6.50-7.20), and Gasma *et al.* (2025) reported Nguru Lake, Jigawa/Yobe States (7.0-7.6). Oguta Lake, however, exhibits more acidic conditions (pH 5.1-6.5), likely due to the influence of organic acids from surrounding vegetation and wetland soils in the Niger Delta. The absence of significant spatial variation in pH ($p = 0.642$) across Lake Geriyo suggests that acid-base buffering capacity is relatively uniform throughout the lake. The neutral to slightly alkaline pH is favorable for aquatic life, as extreme acidity or alkalinity can stress aquatic organisms and influence the bioavailability of contaminants.

Turbidity was the only parameter showing statistically significant spatial variation ($p < 0.001$), with Station 3 exhibiting the highest mean value compared to Stations 1 and 2. This spatial pattern, higher turbidity at Station 3.

The elevated turbidity at Station 3 may reflect localized inputs of suspended solids from runoff, sediment resuspension, or differences in substrate composition. Turbidity values in Nigerian lakes vary considerably: Niger Delta lakes range from 7.83 to 27.7 NTU, Mid Lagos Lagoon ranges from 27.09 to 32.71 NTU, and Umar *et al.* 2025 reported that Lake Alau recorded 12.4 ± 1.2 NTU. The values at Lake Geriyo exceed the WHO guideline of 5.0 NTU, indicating elevated suspended solids loads. Lake Geriyo's turbidity is notably higher than that of the flood retention lake in Benin City, but comparable to Niger Delta lakes. The elevated turbidity may reflect higher suspended sediment loads from runoff or differences in catchment characteristics.

DO concentrations varied greatly, with Station 3 recording the highest mean value. These values are within the WHO guideline of >5 mg/L but fall short of the FMEnv standard of >10 mg/L for optimal aquatic life support. The p-value of 0.044 indicates a statistically significant difference among stations, although all three stations remain within acceptable ranges. Comparison with other Nigerian lakes reveals that Lake Geriyo's DO levels are moderate: Oguta Lake ranges from 5.6 to 8.0 mg/L (mean 7.01 mg/L), Ayoade et *al.* (2025) reported Oyan and Asejire lakes (6.9 to 7.1 mg/L), and Dangana Lake ranges from 3.40 to 4.70 mg/L. The relatively higher DO at Station 3 may be associated with lower organic load or greater water circulation at that location. Lake Geriyo's DO (6.05- 6.60 mg/L) is higher than Dangana Lake but lower than Oguta Lake. These differences may reflect variations in organic loading, water depth, and photosynthetic activity. DO is critical for aerobic aquatic life, and levels below 5 mg/L can stress fish and benthic organisms. The values observed are sufficient to support the lake's fish populations, although the marginal significance ($p = 0.044$) suggests that subtle spatial differences in oxygen dynamics warrant continued monitoring.

BOD values ranged narrowly from 3.68 to 3.78 mg/L, with no significant spatial differences ($p = 0.796$). All values are well within the FMEnv permissible limit of 10 mg/L. These relatively low BOD levels indicate that the lake is not under severe organic pollution stress. Comparative data show that Lake Geriyo's BOD is comparable to Dangana Lake (2.30 3.91 mg/L), slightly higher than Oguta Lake (1.6 3.0 mg/L, mean 2.95 mg/L), and lower than some impacted systems such as Ibadan lakes (5.7 11.0 mg/L). The narrow range across stations suggests uniform organic matter loading throughout the lake.

Total Solids (358.88 373.45 mg/L) and Total Dissolved Solids (194.87 199.43 mg/L). TS and TDS values showed no significant spatial variation ($p = 0.831$ and $p = 0.972$, respectively), indicating that suspended and dissolved mineral loads are spatially uniform. TDS values are well below the WHO guideline of 500 mg/L and the FMEnv standard of 500 mg/L. Comparison with other Nigerian lakes reveals that Lake Geriyo's TDS is moderate: a flood retention lake in Benin City ranges from 113 to 279 mg/L, Lake Alau ranges from 210 to 240 mg/L, and Niger Delta lakes range from 33.8 to 187.0 mg/L. The relatively higher TDS in Lake Geriyo compared to Niger Delta lakes may reflect differences in catchment geology, evaporation rates, and anthropogenic inputs.

All three nutrient parameters showed no significant spatial variation (p = 0.718, 0.767, and 0.534, respectively) and remained well within permissible limits. Nitrite levels are below the WHO guideline of 0.2 mg/L and the FMEnv standard of 1.0 mg/L. Nitrate levels are far below the WHO guideline of <10 mg/L and the FMEnv standard of 10 mg/L. Phosphate levels are within the FMEnv standard of 5.0 mg/L but marginally exceed the WHO guideline of <0.05 mg/L for drinking water. The low nitrate concentrations are consistent with findings from other relatively pristine Nigerian lakes, such as Alau Lake (0.18 0.55 mg/L). However, they contrast sharply with eutrophic systems where nitrate levels are elevated; for example, Lake Alau has been reported to have nitrate concentrations of 12 22 mg/L and phosphate of 15-18 mg/L. Oguta Lake exhibits much higher nitrate levels (13.16-36.17 mg/L), reflecting significant nutrient enrichment from surrounding agricultural and domestic sources. Lake Geriyo's nitrate and phosphate levels are substantially lower than those reported for Lake Alau (nitrate 12-22 mg/L; phosphate 15-18 mg/L), Oguta Lake (nitrate 13-36 mg/L), and Lelei *et al* (2024) reported Igbeba Ago and OxBow lakes in Bayelsa State (nitrate 6.87-10.32 mg/L; phosphate 1.98-4.46 mg/L). These differences likely reflect lower agricultural runoff and domestic waste inputs into Lake Geriyo compared to these more impacted systems. The low nutrient levels in Lake Geriyo suggest that the lake is oligotrophic to mesotrophic and not currently experiencing significant eutrophication pressure. However, the marginal exceedance of the WHO phosphate guideline at all stations warrants attention, as phosphate is often the limiting nutrient in freshwater systems and can trigger algal blooms if concentrations increase further.

Ecological Significance of the Findings shows suitability for aquatic life because the water quality parameters measured in Lake Geriyo indicate that the lake is generally suitable for aquatic life. DO levels (>5 mg/L) are sufficient to support fish populations, pH is within the optimal range for most freshwater organisms, and nutrient levels are low enough to prevent eutrophication. The lake supports all species of fishes which are commercially important, and the water quality conditions appear conducive to their survival and reproduction. The low nutrient concentrations (nitrate <0.4 mg/L, phosphate <0.11 mg/L) suggest that Lake Geriyo is oligotrophic to mesotrophic, with limited primary productivity. While this is favorable for water clarity and oxygen dynamics, it also means that the lake may be sensitive to nutrient inputs. Any increase in anthropogenic nutrient loading from agricultural runoff, domestic waste, or urban development could rapidly push the lake toward eutrophication, with associated problems such as algal blooms, oxygen depletion, and fish kills. The marginal exceedance of the WHO phosphate guideline (<0.05 mg/L) at all stations is a warning sign that should not be overlooked. Even at these low levels, phosphate is the limiting nutrient in many freshwater systems, and small increases can trigger significant ecological changes.

CONCLUSION

This study provides a comprehensive assessment of the physico-chemical water quality of Lake Geriyo, Adamawa State, Nigeria, across three sampling stations over 18 months. The findings indicate that the lake maintains a relatively stable and homogeneous water chemistry, with temperature, pH, BOD, TS, TDS, nitrite, and nitrate showing no significant spatial variation and falling within the permissible limits set by WHO and the Federal Ministry of Environment (FMEnv). The neutral to slightly alkaline pH and adequate dissolved oxygen concentrations (>5 mg/L) create a conducive environment for the survival and reproduction of tropical fish species, supporting the lake's role as a significant fisheries resource. However, two parameters warrant particular attention. First, turbidity was significantly elevated at Station 3 (27.06 NTU), markedly exceeding the WHO guideline of 5.0 NTU and suggesting localized inputs of suspended solids from surface runoff, sediment resuspension, or catchment disturbances. Second, phosphate concentrations marginally exceeded the WHO guideline for drinking water (<0.05 mg/L) at all stations, representing a potential early signal of nutrient enrichment. While the lake currently exhibits oligotrophic to mesotrophic conditions with low overall nutrient loads, phosphate is frequently the limiting nutrient in freshwater systems, and even small increases can trigger algal blooms, oxygen depletion, and cascading ecological impacts. In light of these findings, Lake Geriyo is presently classified as ecologically suitable for aquatic life, but it is not immune to anthropogenic pressure. The absence of severe organic pollution (low BOD) and the spatial uniformity of most parameters are positive indicators; nonetheless, the warning signs of elevated turbidity and marginal phosphate enrichment necessitate proactive management. It is recommended that: (1) continuous long-term monitoring of turbidity, phosphate, and dissolved oxygen be instituted; (2) catchment-level interventions be implemented to control sediment and nutrient runoff from agricultural and urban sources; and (3) regulatory frameworks be enforced to safeguard the lake from future eutrophication. Preserving the water quality of Lake Geriyo is essential to maintaining its fisheries.

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