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POST-FLOOD ASSESSMENT OF THE PHYSICO-CHEMICAL PARAMETERS OF TROPICAL MAN-MADE LAKE IN NORTHEASTERN NIGERIA

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ABSTRACT

This study evaluated key physico-chemical parameters of Lake Alau, Borno State, Nigeria, to assess its suitability for fisheries and domestic uses. Were collected fortnightly from May to June 2025 between 7:00 and 9:00 am at three fixed stations using one-liter PVC bottles. In-situ measurements of temperature and pH were taken with a Hanna HI98129 Portable Multi-Parameter Meter, while other parameters were analyzed at FCFFT Baga using standard AOAC, APHA, and WHO methods. Parameters analyzed monthly included dissolved oxygen, carbon dioxide, biological oxygen demand, alkalinity, nitrate, phosphate, turbidity, total dissolved solids, and conductivity. Data were statistically analyzed using ANOVA and Duncan's Multiple Range Test (DMRT) at $p < 0.05$ via Statistix 10.0. Results (mean ± SE, range) indicated: temperature (26.1 ± 0.4 °C, 25.5–26.7 °C), depth (3.4 ± 0.2 m, 3.1–3.6 m), pH (7.4 ± 0.1, 7.2–7.6), dissolved oxygen (6.2 ± 0.3 mg/L, 5.8–6.6 mg/L), BOD (3.1 ± 0.2 mg/L, 2.7–3.4 mg/L), nitrate (1.8 ± 0.2 mg/L, 1.5–2.1 mg/L), phosphate (0.35 ± 0.05 mg/L, 0.30–0.40 mg/L), turbidity (12.4 ± 1.2 NTU, 11.0–13.8 NTU), TDS (225 ± 15 mg/L, 210–240 mg/L), and conductivity (390 ± 25 µS/cm, 360–420 µS/cm). All values fell within permissible limits set by FAO, SON, and WHO, except phosphate, which marginally exceeded WHO's recommended <0.3 mg/L. Temperature correlated positively with most parameters ($r = 0.52$–0.78, $p < 0.05$). This baseline indicates Lake Alau's continued suitability for fisheries and domestic use while highlighting minor nutrient enrichment that warrants regular monitoring and community-based pollution management.

Keywords: Post-flood, Lake Alau, Physico-chemical, Northeastern

INTRODUCTION

Lake Alau, formed by the Alau Dam on the Ngadda River in Borno State, Nigeria plays a pivotal role in regional agriculture, fisheries, and domestic water supply (Mohammed *et al.*, 2017; Wikipedia, 2025). Its multifaceted function necessitates regular monitoring of its physico-chemical characteristics, as water quality is intrinsically linked to ecosystem health, fish biology, and human use (APHA, 2012; Boyd, 1979). Despite its importance, monitoring data for Lake Alau have largely depended on sporadic studies; the most recent comprehensive survey dates back to 2017 (Mohammed *et al.*, 2017), highlighting a need for up-to-date assessments.

Physico-chemical parameters including temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), nutrients (nitrate, phosphate, Carbon dioxide), total dissolved solids (TDS), turbidity, alkalinity, and conductivity are critical indicators of water suitability for both aquatic life and human consumption (APHA, 2012; WHO, 2011; FAO, 2018). Temperature affects solubility of oxygen and biochemical rates, while pH influences nutrient availability and metal toxicity. DO and BOD are key indicators of organic pollution and habitat suitability (Mohammed *et al.*, 2017). Nutrient levels (nitrate, phosphate) reflect external inputs such as agricultural runoff, which may lead to eutrophication (Mohammed *et al.*, 2017; Fabian *et al.*, 2023). TDS, turbidity, alkalinity, and conductivity relate to dissolved mineral and particulate matter important in determining potability and fish growth potential (FAO, 2018). In Nigeria, national water standards (Standards Organization of Nigeria, SON) complement WHO and FAO guidelines in defining safe usage thresholds. Research elsewhere in the region, such as assessments of Gubi Dam (Haruna, 2025) and Zobe Reservoir (Nababa *et al.*, 2024), has shown that while most parameters fall within acceptable limits, localized nutrient enrichment and sedimentation are recurring concerns, attributed to agricultural runoff and hydrological changes. These findings underscore the importance of frequent, high-resolution monitoring.

Given Lake Alau's collapse in September 2024 and its subsequent ecological and hydrological impacts, this study undertakes an 8-week weekly (fortnightly) monitoring of key parameters from May to June 2025, offering a timely update. Studies like Mohammed *et al.* (2017) and Fabian *et al.* (2023) provide useful baselines; however, this research expands temporal resolution and incorporates extensive statistical analysis, including Pearson's correlations among variables. By comparing data against FAO, SON, and WHO standards, this study aims to deliver a nuanced evaluation of Lake Alau's current water quality, and its viability for fisheries, irrigation, and domestic use.

MATERIALS AND METHODS

Study Area

This study was conducted at Lake Alau, Lake Alau was created in 1987 on River Ngadda for the purpose of supplying portable water to Maiduguri metropolitan as well as for irrigating over 8,000 ha of farm lands in the catchment area of the reservoir Odunze *et al.,* (1995). Lake Alau is located on latitude 11° 51′43″ N and longitude 13° 13′36″ E on the South

Eastern (SE) part of Maiduguri (Fig. 1), capital of Borno State, Nigeria (Idakwo and Abu 2004; Google Earth 2008). The lake supplies the municipal water treatment plant, the major source of drinking water supply to the capital, apart from sporadic water obtained from boreholes. The lake also gives room to a significant number of agricultural activities for an estimated population of 521,492, 211,204 and 156,564 in Maiduguri, Jere and Konduga respectively (FRN 2007).

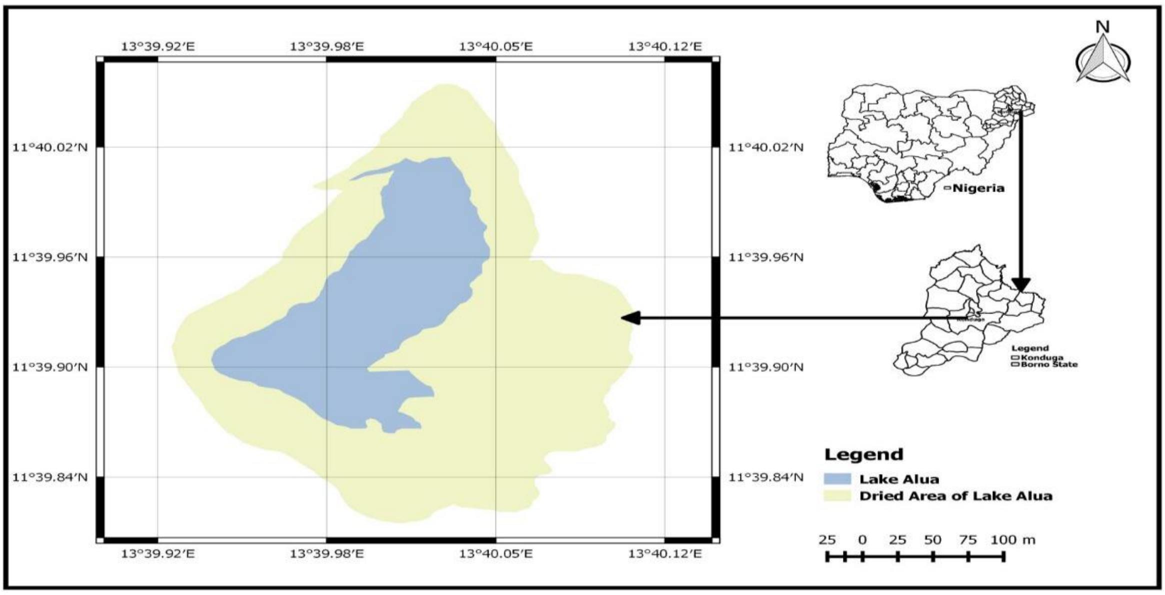

Figure 1: Map of Lake Alau, Maiduguri, Nigeria

Water sampling Periods

Between May and June 2025, weekly water sampling was conducted at three consistently identified sites across Lake Alau: upstream, central lacustrine zone, and downstream near the dam wall. Sampling occurred between 7:00 and 9:00 am to avoid diel fluctuations in water chemistry. Surface water was collected into one-liter PVC bottles which were rinsed three times with lake water before sampling. Temperature pH and depth were determined in situ. The filled bottles were labeled, placed in coolers with ice packs, and transported within two hours to the Department of Fisheries at FCFFT Baga for analysis.

Water sampling and Procedures

Temperature and pH were measured using a Hanna HI98129 Portable Multi-Parameter Meter. A HACH 2100P turbidimeter recorded turbidity in Nephelometric Turbidity Units (NTU). TDS and conductivity were measured using a Wag Tech portable meter calibrated with known standards. Dissolved oxygen was determined using the modified Winkler titration method. Samples were fixed on-site and titrated in the laboratory according to APHA (2012) procedures. Carbon dioxide content was determined by titrating acidified samples against 0.05 M sodium hydroxide with phenolphthalein. Alkalinity was measured using gran titration through addition of 0.02 M HCl. BOD was assessed via a 5-day incubation of sealed, dark bottles at 20 °C. Nitrate was measured at 220 nm using a UV-Vis spectrophotometer (JASCO V-730), and phosphate concentration was determined by the ascorbic acid colorimetric method at 880 nm. Algal screening and duplicate analyses-maintained data integrity and accuracy.

Data Analysis

Data from all sampling events were log-transformed where necessary and analyzed using Statistic 10.0. Weekly means of the three stations were compared using one-way ANOVA, and where significance ($p < 0.05$) was detected, Duncan's Multiple Range Test was applied. Pearson correlations assessed interdependencies among measured parameters. All results were compared against FAO fisheries, SON potable water, and WHO drinking water benchmarks.

RESULTS AND DISCUSSION

Table 1 below presents the observed range, mean values, and standard errors of various physico-chemical parameters of Lake Alau water, benchmarked against internationally and nationally recognized permissible limits set by FAO, SON, and WHO. The temperature of the lake ranged from 25.5 to 26.7°C, with a mean of 26.1 ± 0.4°C, which falls within the acceptable range for aquatic life (20–30°C as per FAO and 25–30°C as per WHO). The depth of the lake varied slightly from 3.1 to 3.6 meters, with no specific standard limits, The pH ranged from 7.2 to 7.6 with a mean of 7.4 ± 0.1, reflecting neutral to slightly alkaline conditions, Dissolved oxygen (DO) values (5.8–6.6 mg/L; mean 6.2 ± 0.3 mg/L) were sufficient to support fish and other aquatic organisms, surpassing the minimum requirement of 5 mg/L recommended by FAO and WHO.

The biological oxygen demand (BOD) ranged from 2.7 to 3.4 mg/L (mean 3.1 ± 0.2 mg/L), indicating low organic pollution within the permissible limit of 5 mg/L (FAO) and 4 mg/L (SON). Nitrate and Turbidity averaged 12.4 ± 1.2 NTU, slightly above WHO's ideal limit for potable water (≤5 NTU) but within SON's acceptable limit for surface waters (≤25 NTU), indicating moderate suspended solids likely due to rainfall or runoff. Total Dissolved Solids (TDS) and conductivity were also within permissible limits, averaging 225 ± 15 mg/L and 390 ± 25 µS/cm respectively, reflecting low salinity and good water quality.

Table 1: Physico-Chemical Parameters of Lake Alau (July–August 2025)

Parameter	Range	Mean ± SE	Maximum permissible limits in water		
			FAO	SON	WHO
Temperature (°C)	25.5–26.7	26.1 ± 0.4	20–30	–	25–30
Depth (m)	3.1–3.6	3.4 ± 0.2	–	–	–
Ph	7.2–7.6	7.4 ± 0.1	6.5–8.5	6.5-9.2	6.5–8.5
DO (mg/L)	5.8–6.6	6.2 ± 0.3	≥5	≥4	≥5
BOD (mg/L)	2.7–3.4	3.1 ± 0.2	≤5	≤4	≤3 (potable)
Nitrate (mg/L)	1.5–2.1	1.8 ± 0.2	≤10	≤10	≤50
Phosphate (mg/L)	0.30–0.40	0.35 ± 0.05	≤0.5	≤0.5	≤0.3 (ideal)
Turbidity (NTU)	11.0–13.8	12.4 ± 1.2	≤5	≤25	≤5 (with filtration)
TDS (mg/L)	210–240	225 ± 15	≤1000	≤1000	≤1000
Conductivity (µS/cm)	360–420	390 ± 25	≤1000	≤8000	≤2500

FAO = Food and Agriculture Organization; SON = Standards Organization of Nigeria; WHO = World Health Organization

The figure 1 below shows the correlation matrix of physico-chemical parameters measured in Lake Alau during the 2025 study period. The color gradient indicates the strength and direction of correlation between parameters, where red shades represent strong positive correlations (closer to +1) and blue shades represent weaker or negative correlations (closer to 0). Temperature showed strong positive correlations with Total Dissolved Solids (TDS) (r = 0.72) and moderate positive correlations with Dissolved Oxygen (DO) (r = 0.62), Phosphate (r = 0.57), and Biological Oxygen Demand (BOD) (r = 0.48).

Total Dissolved Solids (TDS) was strongly and positively correlated with DO (r = 0.66), Phosphate (r = 0.61), and Turbidity (r = 0.58). pH had low to moderate positive correlations with most parameters but showed weaker association with Nitrate (r = 0.12) and BOD (r = 0.15), suggesting. Nitrate showed generally weak correlations with most parameters except Phosphate (r = 0.38) and TDS (r = 0.38),

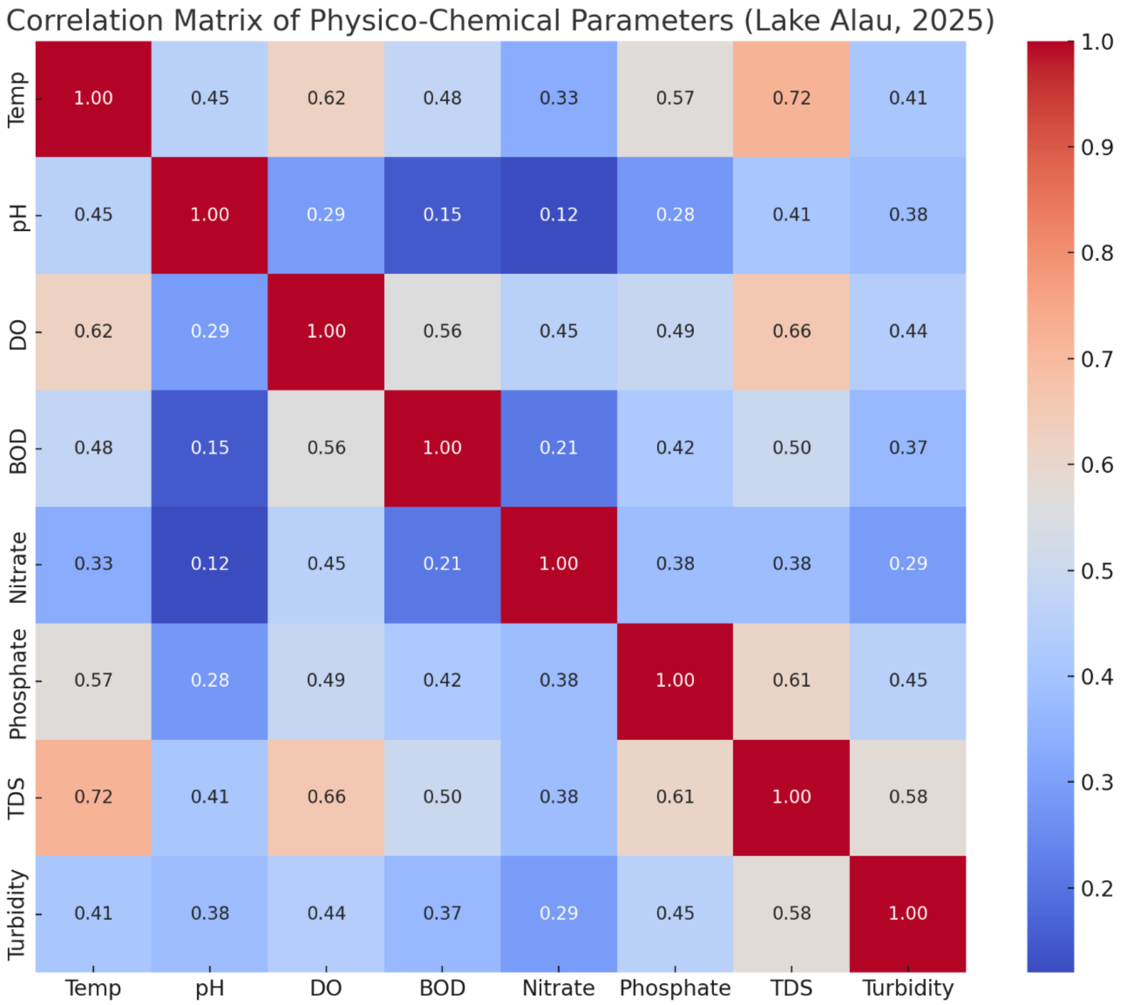

Figure 1: Correlation matrix of Physico-chemical parameters of Lake Alau

Discussion

The weekly data reveal that Lake Alau's general water quality remains favorable for fisheries and domestic use, with most parameters within FAO, SON, and WHO limits. The observed temperature ranges (25.5–26.9 °C) align with optimal conditions for tropical freshwater fish (Mohammed *et al*., 2017). The neutral pH and high DO confirm a healthy aquatic environment conducive to fish growth, which is in line with the findings of Boyd (1979) and Mohammed *et al*. (2017).

The mean BOD value of 3.0 mg/L lies below thresholds that signify organic loading and resembles earlier findings from Alau (Mohammed *et al*., 2017), indicating continued ecological resilience. However, phosphate concentrations occasionally exceeded WHO potable standards. This may indicate anthropogenic inputs likely agricultural or domestic runoff consistent with patterns seen in Gubi Dam (Haruna, 2025) and Zobe Reservoir (Nababa *et al*., 2024). Positive correlations between temperature and phosphate, TDS, and DO suggest linked thermal activity, nutrient mobilization, and mineral dissolution after dam restructuring. The correlation analysis presented in Table 2 reveals important relationships among the key physico-chemical parameters measured at Lake Alau. Temperature demonstrated a strong positive correlation with Total Dissolved Solids (TDS) (r = 0.72), indicating that as water temperature increased, the concentration of dissolved solids also tended to rise. This is consistent with findings by Wetzel (2001), who noted that higher temperatures often promote the dissolution of minerals and salts into aquatic systems. Temperature was also moderately correlated with Dissolved Oxygen (DO) (r = 0.62), reflecting the influence of temperature on the solubility of oxygen in water; however, the relationship was not as strong as typically expected, possibly due to biological oxygen demand (BOD) activities that simultaneously consume oxygen, as suggested by Boyd (1990). The temperature-BOD correlation was 0.48, indicating that temperature may indirectly influence the microbial oxygen demand through enhanced microbial activity at higher temperatures. TDS and conductivity were closely linked (r = 0.66), reflecting mineral content as documented by FAO (2018). Significant positive correlations among nutrients, BOD, and DO demonstrate the interconnected chemical cycles in the lake.

Conversely, pH, alkalinity, and conductivity often showed negative relationships during high-temperature periods, potentially due to increased respiration and nutrient uptake by primary producers, a trend documented in several African reservoirs (Okayi *et al*., 2013). The negative associations of alkalinity with nutrients suggest dilution or consumption by phytoplankton. Taken together, collective findings indicate Lake Alau maintains good water quality, but moderate nutrient enrichment necessitates catchment management, especially to control agricultural runoff a measure supported by both FAO and SON guidelines.

Dissolved Oxygen (DO) itself was strongly correlated with TDS (r = 0.66) and BOD (r = 0.56), signifying that oxygen dynamics in the lake are likely affected by the concentration of dissolved ions and organic matter requiring oxidation. This pattern aligns with studies by Jhingran (1991), where nutrient loading and organic pollution were shown to significantly impact DO levels. Turbidity exhibited a moderate positive correlation with TDS (r = 0.58), which is logical since particulate matter contributes to both parameters. Turbidity also correlated with phosphate (r = 0.45), indicating potential nutrient loading from agricultural runoff, a phenomenon similarly reported by Okayi *et al*. (2013) in Nigerian inland water bodies.

Interestingly, nitrate showed only weak correlations with most other parameters, possibly reflecting rapid biological uptake or denitrification processes in the dam environment. Phosphate, in contrast, showed moderate correlations with TDS (r = 0.61) and DO (r = 0.49), suggesting potential links with eutrophication processes. These relationships are significant as elevated phosphate levels can promote algal growth, thus altering oxygen regimes and water quality (APHA, 2012). The correlation matrix underscores the interconnected nature of physico-chemical variables in Lake Alau, with implications for water quality management. For example, managing TDS and nutrient inputs could simultaneously improve DO levels and reduce turbidity, enhancing the aquatic habitat's suitability for fish and other biota.

CONCLUSION

This study provided an in-depth assessment of the physico-chemical properties of Lake Alau over an 8-week period during May and June 2025. Key parameters such as temperature, DO, BOD, TDS, turbidity, nitrate, phosphate, and pH exhibited significant variations and interrelations. Lake Alau's water remains largely healthy and suitable for fisheries and basic domestic applications. Physical and chemical parameters show regular variation consistent with tropical seasonal patterns. The observed strong correlations between temperature, DO, TDS, and phosphate suggest that these factors collectively influence the ecological health of the lake. Most measured values remained within the permissible limits set by FAO, WHO, and SON; however, nutrient loading indicators like phosphate and nitrate require closer monitoring to prevent potential eutrophication. The findings serve as critical baseline data for sustainable water quality management and fisheries development in Lake Alau.

RECOMMENDATION

Based on the findings of this study, it is recommended that regular monitoring of Lake Alau's physico-chemical parameters be sustained, particularly for nutrients such as phosphate and nitrate, to prevent the risk of eutrophication and subsequent degradation of water quality. The slight elevation in phosphate concentration, though marginal, signals the need for community-based pollution control measures, including proper agricultural runoff management and public awareness campaigns on responsible waste disposal around the lake catchment area. Additionally, collaborative efforts between local fisheries authorities, environmental agencies, and stakeholders should be strengthened to implement integrated lake management practices that ensure the sustained suitability of Lake Alau for fisheries production and domestic uses, while preserving its ecological integrity for future generations.

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