A Biennial Assessment of Physicochemical Characteristics in Kalgwai Reservoir, Jigawa State, Northwestern, Nigeria

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Abstract
Monthly sampling was conducted for a period of 24 months (January 2022–December 2023) at three locations—Kalgwai, Dingare, and Marke—within Kalgwai Reservoir to examine variations in selected physicochemical properties of the water. The parameters assessed comprised temperature, transparency, hydrogen ion concentration (pH), dissolved oxygen (DO), alkalinity, ammonia, and hardness, measured using established field techniques following Dauda and Akinwole (2014) and APHA (2012). Data generated from the study were subjected to descriptive statistical analysis, analysis of variance (ANOVA), and t-test procedures. The findings indicated pronounced spatial and temporal variability in most of the measured parameters. Significant differences ($P < 0.05$) were observed across stations and months for temperature, pH, dissolved oxygen, alkalinity, and hardness. Seasonal variation was significant for temperature, dissolved oxygen, and hardness, whereas transparency, pH, alkalinity, and ammonia did not vary significantly between seasons. The results reflect the dynamic physicochemical conditions of Kalgwai Reservoir and provide essential baseline information for effective water quality monitoring and management.

Key words;
Water quality dynamics; Seasonal variability; Spatial distribution; Physicochemical assessment; Reservoir monitoring

Introduction

In many parts of Northwestern Nigeria, freshwater reservoirs constitute an important foundation for both human livelihoods and ecological stability, particularly within arid and semi-arid environments. These reservoirs provide water for household use and support fisheries, while small impoundments represent especially valuable resources that can be optimized for irrigation, livestock rearing, and aquaculture when appropriately managed (Namara et al., 2010; Pouissain et al., 2015). The condition of freshwater systems is shaped by the interaction of natural hydrological processes and human-driven land-use changes (Kazi et al., 2009; Peters, 2000). Among these influences, runoff from surrounding catchments serves as a primary route through which nutrients and contaminants are conveyed into surface waters (Tong & Chen, 2002).

Kalgwai Reservoir was established through a collaboration between the Federal Government of Nigeria and a non-governmental organization with the primary objective of supplying irrigation water to farming communities in the area (Edegbene, 2020). In recent years, however, the intended function of the reservoir has been increasingly compromised by activities along its shoreline. The reservoir is now frequently used for waste disposal, open defecation, bathing, and other domestic purposes. Such practices place considerable stress on the reservoir and negatively affect the structure and functioning of its biological communities (Ghali et al., 2020). These conditions illustrate how unmanaged human activities can accelerate the degradation of small reservoir systems.

Given these pressures, continuous and well-structured monitoring of water quality is essential for effective water resource

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management and informed policy development. Water quality refers to the condition of water in relation to its suitability for sustaining aquatic organisms and meeting various human needs (Boyd, 2019). Assessment of water quality commonly involves the measurement of physical, chemical, and biological attributes, including temperature, pH, electrical conductivity, turbidity, dissolved oxygen, nutrients, pollutants, and microbial indicators (Giri, 2021; Uddin et al., 2021). These physicochemical and microbiological characteristics are central to determining whether water can support ecosystem health and serve intended uses. When water quality deteriorates, it can pose serious threats to both biodiversity and human health (Ejigu, 2021).

This study therefore undertakes a two-year evaluation (2022–2023) of the water quality of Kalgwai Reservoir. By analyzing temporal and seasonal fluctuations in key physicochemical parameters, the research seeks to generate baseline information that will aid long-term environmental monitoring, inform sustainable reservoir management, and improve understanding of freshwater ecosystem behavior within Nigeria's semi-arid zone.

Materials and Methods

Description of the Study Area

Kalgwai Reservoir

The study was carried out at Kalgwai Reservoir, located within Auyo Local Government Area of Jigawa State, Nigeria, at an approximate distance of 25 km from Hadejia town. The reservoir was impounded in 1984 along the Hadejia River following an initiative by the Federal Government of Nigeria aimed at enhancing irrigation development under the former Hadejia Valley Irrigation Project, which was overseen by the Hadejia–Jama'are River Basin Development Authority (HJRBDA). The water body covers an estimated area of about 3,800 km^2 (Matthes, 1990) (Figure 1) and lies within the coordinates of 11°00′–13°00′ N latitude and 8°00′–13°05′ E longitude (Matthes, 1990).

Structurally, the reservoir functions as an impoundment across the Hadejia River, with its hydrological regime influenced by controlled releases from the Challawa and Tiga Dams located upstream in Kano State. Stored water is channelled through designated control mechanisms into irrigation canals serving the project area, while the surrounding population relies on the reservoir as an additional source of water for domestic needs.

The area falls within a tropical climatic zone and experiences an average annual temperature of approximately 37.0 °C. Climatic conditions are defined by two contrasting seasons: a wet period extending from May to September and a dry period from October to April (Edegbene, 2018). During the dry season, Harmattan conditions commonly prevail between November and February, resulting in markedly cooler temperatures that may decline to about 10.0 °C, particularly in December and January (Edegbene, 2018).

Seasonal hydrological behaviour of the reservoir shows that water coverage expands to its maximum extent toward the close of the rainy season in September. Thereafter, a gradual reduction in water level occurs, with minimum levels typically observed shortly before the onset of the following rainy season in June. The extent of annual inundation varies considerably and is largely governed by rainfall intensity and distribution (Benthem, 1990). These fluctuations directly influence fish abundance and availability, often leading to increased fishing pressure in communities situated around the reservoir. Field investigations for the present study were conducted continuously over a twenty-four-month period, spanning January 2022 to December 2023

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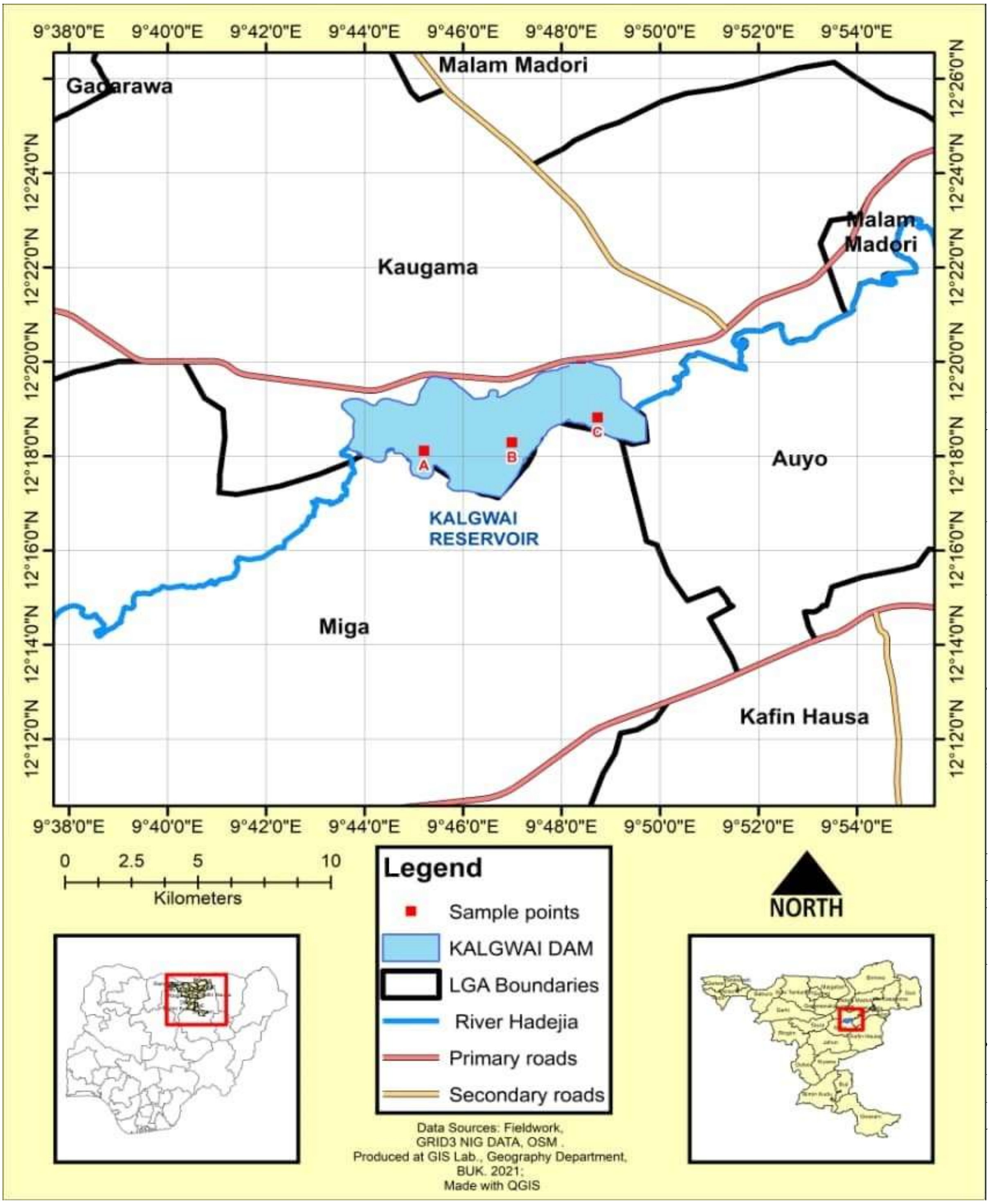

pH readings ranged from 6.52 to 6.64 over the study period. Significant differences were identified between stations and months ($P < 0.05$) (Table 1). The highest pH, 7.95, occurred at Kalgwai in February 2023, while the lowest, 6.02, was recorded at Dingare in January 2022 (Fig. 4). T-test results indicated no significant seasonal differences ($P > 0.05$), with 6.61 during the rainy season and 6.53 in the dry season (Table 2).

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Dissolved Oxygen (DO)
DO concentrations ranged between 6.03 mg/L and 6.09 mg/L. ANOVA highlighted significant spatial and monthly differences ($P < 0.05$) (Table 1). The highest value, 6.41 mg/L, was observed at Marke in January 2022, whereas the lowest, 5.49 mg/L, occurred at Kalgwai in February 2023 (Fig. 5). Seasonal t-test results indicated a significant difference ($P < 0.05$), with 6.11 mg/L during the rainy season and 6.02 mg/L in the dry season (Table 2).

Alkalinity
Alkalinity readings ranged from 24.93 ppm to 25.26 ppm. ANOVA detected significant monthly differences ($P < 0.05$), though differences between stations were minor (Table 1). The peak alkalinity, 28.18 ppm, occurred at Marke in December 2022, while the lowest, 22.05 ppm, was recorded at Dingare in February 2022 (Fig. 6). Seasonal t-test comparison revealed no notable difference ($P > 0.05$), with 25.13 ppm during the rainy season and 25.07 ppm in the dry season (Table 2).

Ammonia
Ammonia concentrations ranged narrowly from 1.55 ppm to 1.56 ppm. ANOVA indicated non-significant differences across stations ($P > 0.05$) but significant differences across months ($P < 0.05$) (Table 1). The maximum value, 2.50 ppm, was observed at Kalgwai in December 2022, and the minimum, 1.01 ppm, at all stations in January 2022 (Fig. 7). T-test analysis found no significant seasonal difference ($P > 0.05$), with 1.56 ppm in the rainy season and 1.55 ppm in the dry season (Table 2).

Hardness
Hardness readings varied from 78.56 ppm to 80.25 ppm. ANOVA indicated significant differences between stations and months ($P < 0.05$) (Table 1). The highest hardness, 96.57 ppm, was observed at Kalgwai in January 2023, while the lowest, 62.38 ppm, occurred at Dingare in August 2022 (Fig. 8). Seasonal comparison using t-test revealed a significant contrast ($P < 0.05$), with higher values during the dry season (84.91 ppm) and lower values in the rainy season (74.31 ppm) (Table 2).

Results
The physicochemical characteristics of Kalgwai Reservoir recorded during the study period are summarized in Table 1.

Temperature
Water temperature fluctuated across the sampling period, with average readings ranging from 25.51 °C at Marke to 25.87 °C at Kalgwai (Table 1). Differences in temperature among stations and months were apparent ($P < 0.05$). The highest temperature, 29.20 °C, occurred at Kalgwai in July 2022, while the lowest, 17.90 °C, was recorded at the same station in January 2022 (Fig. 2). Seasonal comparison using the Student's t-test revealed a clear contrast ($P < 0.05$), with 24.59 °C during the dry season and 26.67 °C in the rainy season (Table 2).

Transparency
Average transparency ranged from 0.25 m to 0.28 m. ANOVA indicated differences across stations and months ($P < 0.05$). The maximum transparency, 0.32 m, was observed at Marke in October 2023, while the minimum, 0.23 m, occurred at Dingare in January 2022 (Fig. 3). Seasonal t-test results did not reveal noticeable changes ($P > 0.05$), with 0.26 m during the dry season and 0.27 m in the rainy season (Table 2).

PH
PH readings ranged between 6.52 and 6.64. Differences across stations and months were observed ($P < 0.05$) (Table 1). The highest pH, 7.95, was recorded at Kalgwai in February 2023, whereas the lowest, 6.02, occurred at Dingare in January 2022 (Fig. 4). Seasonal comparison with t-test showed minimal change ($P > 0.05$), with 6.61 during the rainy season and 6.53 in the dry season (Table 2).

Dissolved Oxygen (DO)
DO concentrations ranged from 6.03 mg/L to 6.09 mg/L. ANOVA revealed differences between stations and months ($P < 0.05$) (Table 1). The highest DO, 6.41 mg/L, was observed at Marke in January 2022, and the lowest, 5.49 mg/L, at Kalgwai in February 2023 (Fig. 5). Seasonal t-test indicated a clear seasonal change ($P < 0.05$), with 6.11 mg/L in the rainy season and 6.02 mg/L in the dry season (Table 2).

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Alkalinity

Alkalinity ranged from 24.93 ppm to 25.26 ppm. ANOVA indicated fluctuations across months ($P < 0.05$), while differences between stations were less pronounced (Table 1). The peak alkalinity, 28.18 ppm, occurred at Marke in December 2022, and the lowest, 22.05 ppm, at Dingare in February 2022 (Fig. 6). Seasonal t-test revealed minimal difference ($P > 0.05$), with 25.13 ppm during the rainy season and 25.07 ppm in the dry season (Table 2).

Ammonia

Ammonia values ranged narrowly from 1.55 ppm to 1.56 ppm. ANOVA indicated small differences across stations ($P > 0.05$) and fluctuations across months ($P < 0.05$) (Table 1). The highest value, 2.50 ppm, was recorded at Kalgwai in December 2022, and the lowest, 1.01 ppm, at all stations in January 2022 (Fig. 7). Seasonal t-test indicated little change between dry and rainy seasons ($P > 0.05$), with 1.56 ppm in the rainy season and 1.55 ppm in the dry season (Table 2).

Hardness

Hardness ranged from 78.56 ppm to 80.25 ppm. ANOVA revealed differences between stations and months ($P < 0.05$) (Table 1). The highest hardness, 96.57 ppm, occurred at Kalgwai in January 2023, and the lowest, 62.38 ppm, at Dingare in August 2022 (Fig. 8). Seasonal comparison using t-test indicated a noticeable seasonal change ($P < 0.05$), with 84.91 ppm during the dry season and 74.31 ppm in the rainy season (Table 2)

Table 1: Physicochemical parameters of Kalgwai Reservoir from January 2022 to December 2023

Parameter	Kalgwai	Dingare	Marke	P-value ANOVA
				Station
Temperature (°C)	25.87 ± 2.52^{a}	25.52 ± 2.55^{b}	25.51 ± 2.45^{b}	0.025*
Transparency (m)	0.28 ± 0.02^{a}	0.25 ± 0.03^{b}	0.28 ± 0.02^{a}	0.001*
pH	6.64 ± 0.58^{a}	6.52 ± 0.49^{b}	6.56 ± 0.49^{ab}	0.022*
Dissolved oxygen (mg/l)	6.03 ± 0.27^{c}	6.07 ± 0.23^{b}	6.09 ± 0.20^{a}	0.005*
Alkalinity (ppm)	25.26 ± 1.59^{a}	24.93 ± 1.35^{b}	25.12 ± 1.44^{ab}	0.073*
Ammonia (ppm)	1.56 ± 0.54^{a}	1.55 ± 0.51^{a}	1.56 ± 0.53^{a}	0.691
Hardness (ppm)	80.25 ± 11.26^{a}	78.56 ± 11.23^{b}	80.02 ± 11.25^{a}	0.001*

"Different superscript letters along the row indicate that the values differ statistically ($p < 0.05$). * Denotes the calculated p-value for the comparison.".

Table 2: Seasonal variations of physicochemical parameters of Kalgwai Reservoir from January 2022 to December 2023

Parameter	Season		T-test value	P-value
	Dry	Rainy		
Temperature (°C)	24.59 ± 3.05	26.67 ± 1.02	-5.506	0.001*
Transparency (m)	0.26 ± 0.03	0.27 ± 0.03	-1.909	0.058
pH	6.53 ± 0.60	6.61 ± 0.43	-0.875	0.383
DO (mg/l)	6.02 ± 0.25	6.11 ± 0.21	-2.338	0.021*
Alkalinity (ppm)	25.07 ± 1.83	25.13 ± 0.96	-0.278	0.781
Ammonia (ppm)	1.55 ± 0.65	1.56 ± 0.38	-0.180	0.858
Hardness (ppm)	84.91 ± 11.68	74.31 ± 7.68	6.437	0.001*

Note: * indicates significantly calculated P-value

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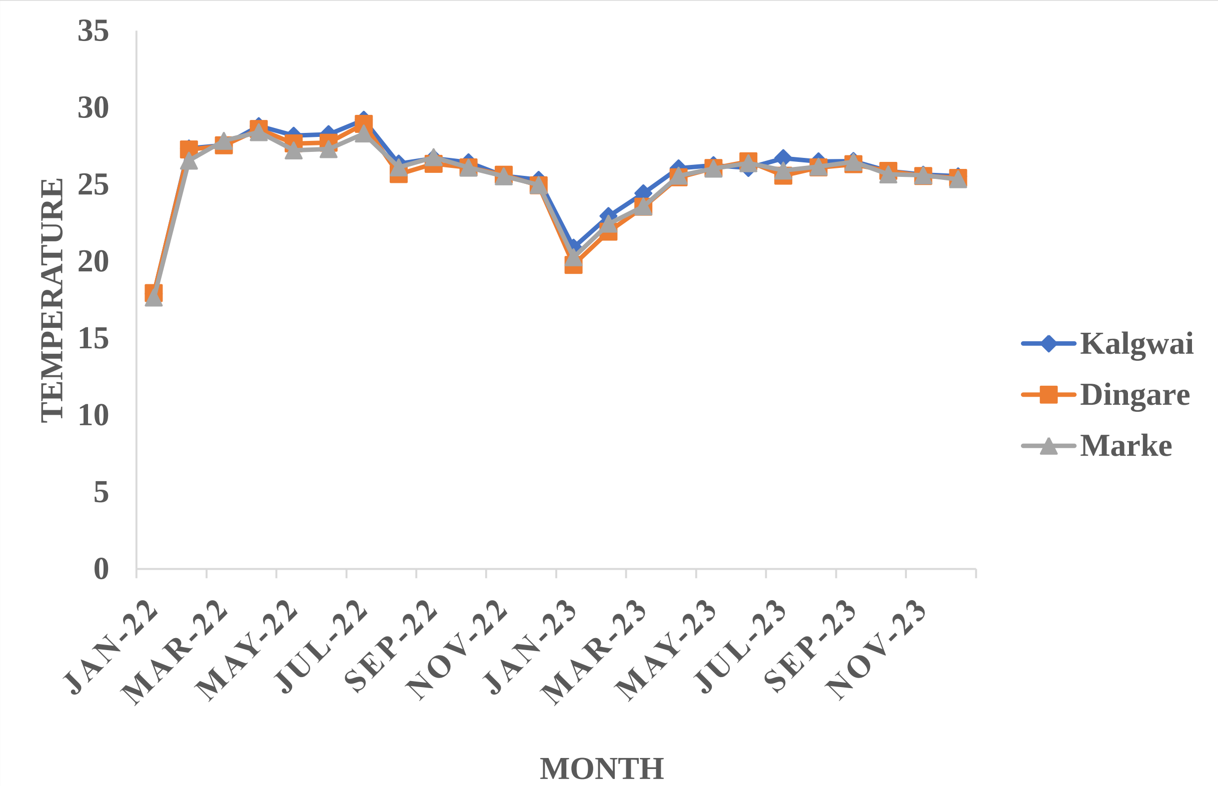

Figure; 2 Patterns of Temperature at Kalgwai Reservoir across the study months

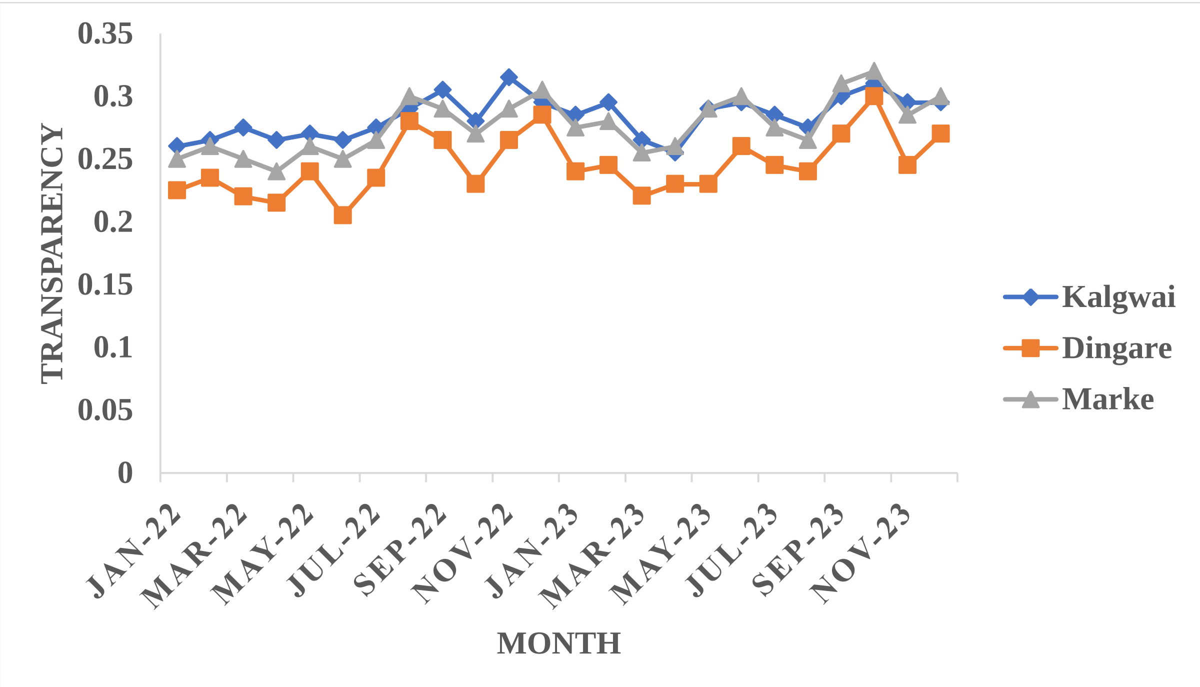

Figure 3: Patterns of Transparency at Kalgwai Reservoir across the study months

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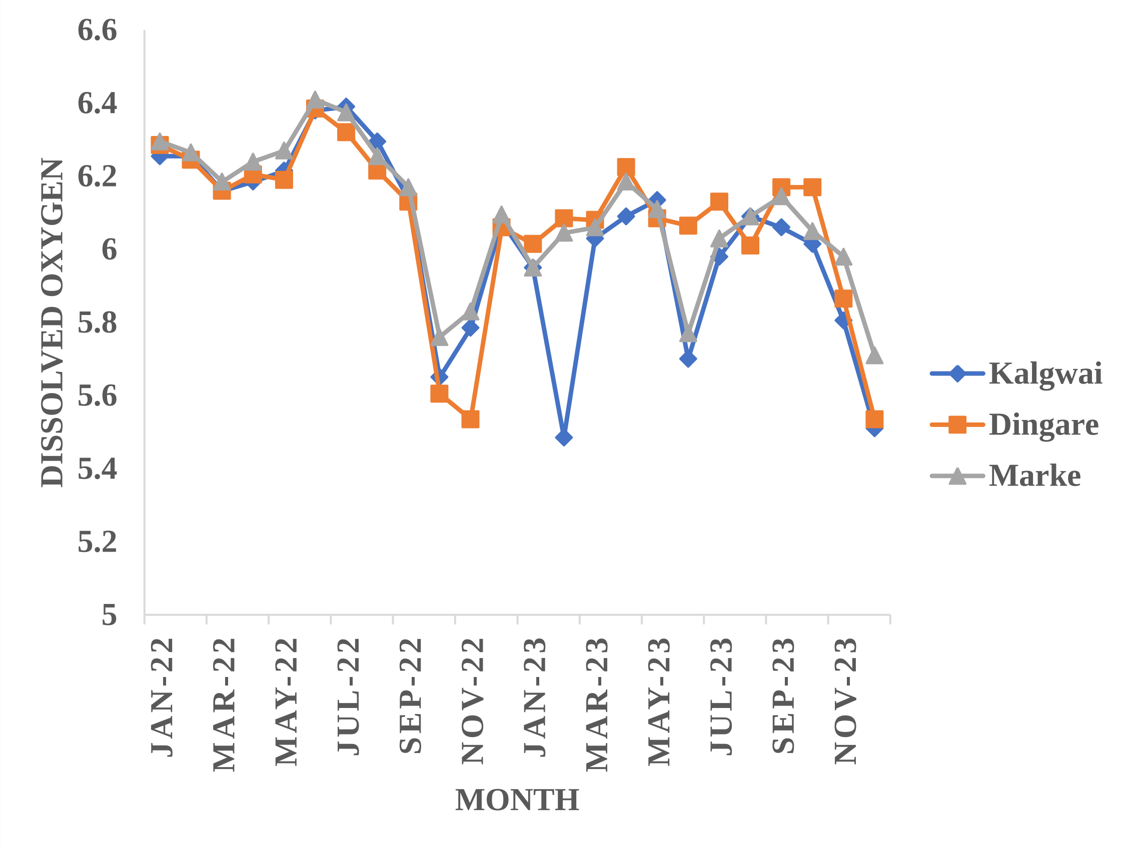

Figure 4: Patterns of PH at Kalgwai Reservoir across the study months

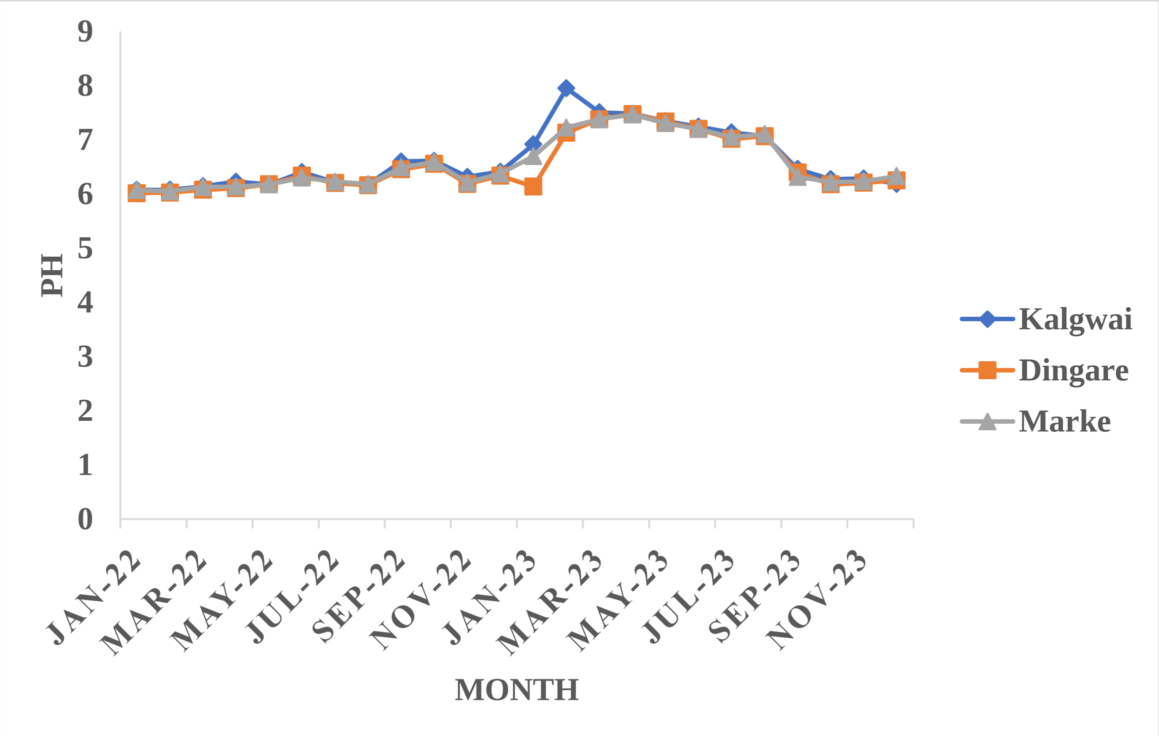

Figure 5: Patterns of DO at Kalgwai Reservoir across the study months

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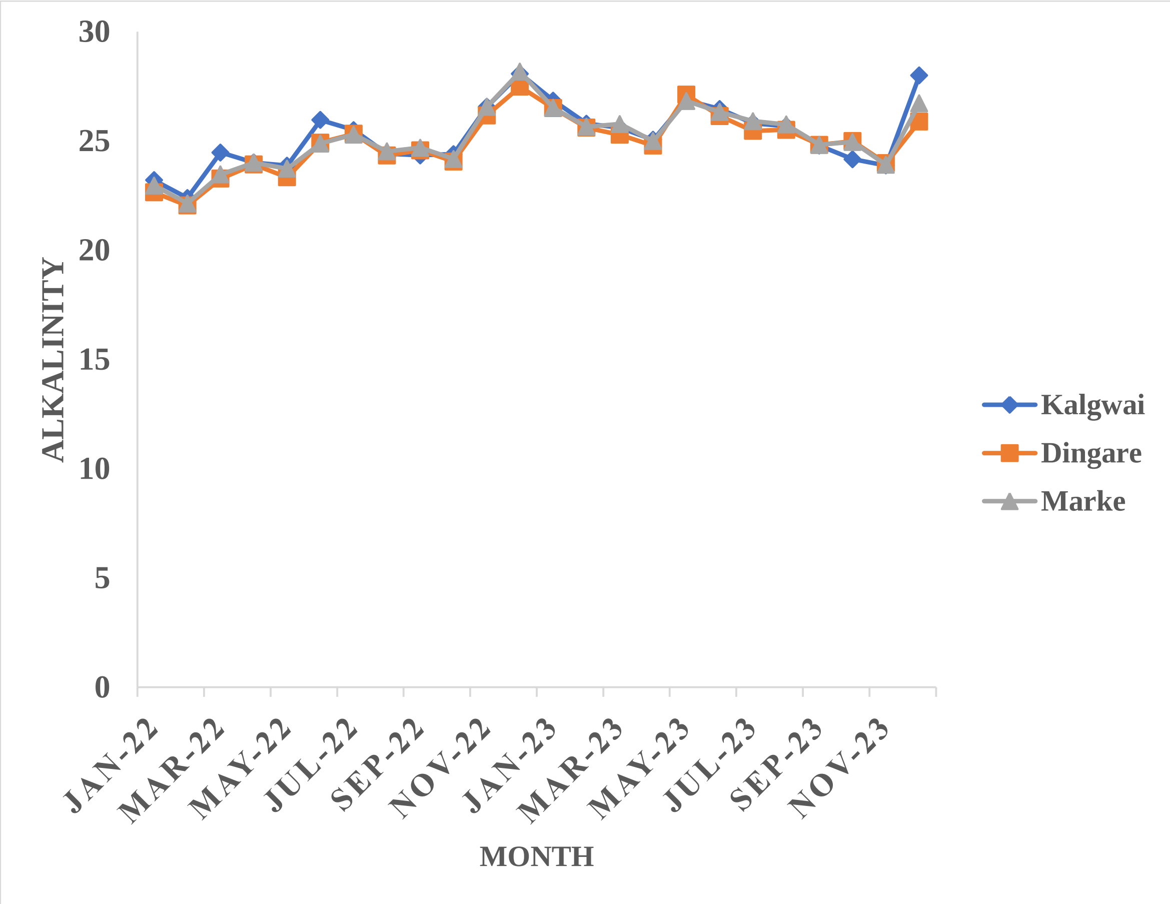

Figure 6: Patterns of Alkalinity at Kalgwai Reservoir across the study months

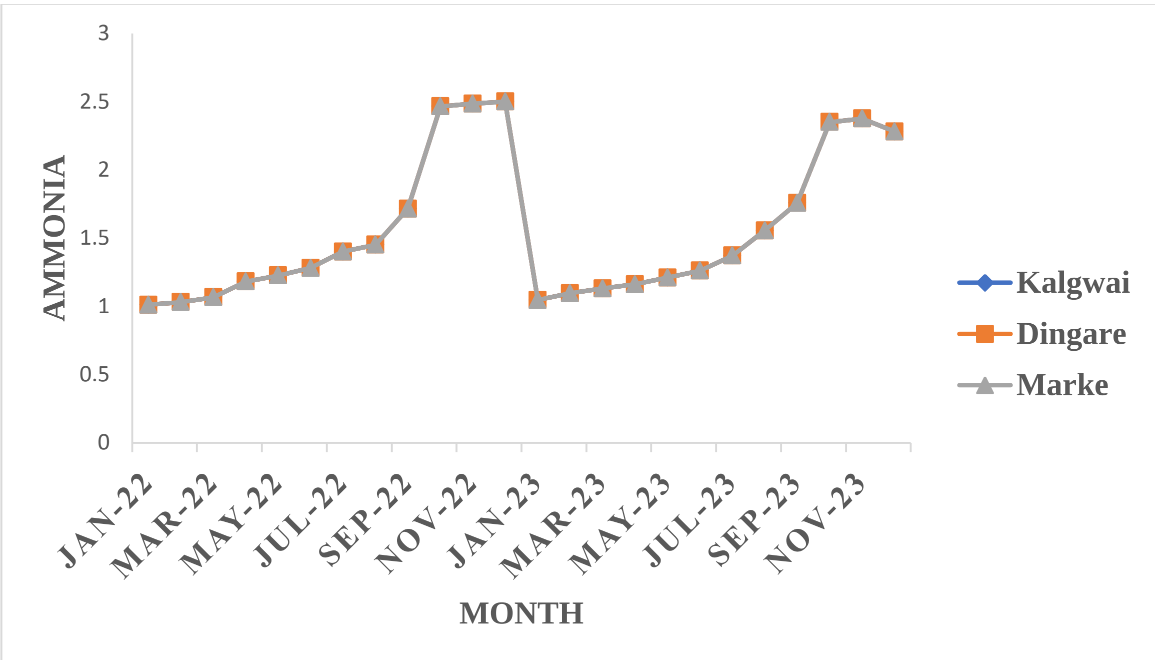

Figure 7: Patterns of Ammonia at Kalgwai Reservoir across the study months

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Figure 8: Patterns of Hardness at Kalgwai Reservoir across the study months

Discussion

Temperature

The annual surface water temperatures recorded in Kalgwai Reservoir ranged from 25.51 °C to 25.87 °C. This differs from Oniye et al. (2002), who reported a mean annual temperature of 26.56 °C in Zaria Dam, with the highest values in April, May, June, and October, and the lowest in December. The results, however, align with Lawal and Ahmed (2014), who noted that fish in tropical regions are adapted to a temperature range of 8 °C to 30 °C, representing the critical thermal minimum and maximum, respectively. Temperatures during the dry season were lower compared to the rainy season, consistent with observations by Ibrahim et al. (2009) and Andem et al. (2012).

Transparency

Water clarity, or turbidity, reflects the presence of suspended particles, sediments, and other materials. Higher sediment levels increase turbidity, reducing light penetration and raising water temperature as suspended particles retain heat (Omondi et al., 2011). Transparency in Kalgwai Reservoir ranged from 0.25 m to 0.28 m, which agrees with Tegu and Ekemube (2023), who reported higher turbidity during the rainy season (28.50) compared to the dry season (11.64). This was attributed to particulate matter and biofilm sloughing (Smith & Davies-Colley, 2001).

PH

PH values of Kalgwai Reservoir ranged from 6.56 to 6.64, remaining within the acceptable limits of 6.5–8.5 for freshwater bodies as set by the National Standard for Drinking Water Quality (2007). These findings are consistent with Teame and Abergelle (2016), who reported seasonal variations with lower pH in the dry season (7.80 ± 0.58) compared to the wet season (8.30 ± 0.34). The hydrogen ion concentrations recorded in this study comply with FEPA guidelines (6.5–8.5 for drinking water; 6.0–9.0 for aquatic life) and are suitable for culturing tropical fish species (WHO, 2000).

Dissolved Oxygen (DO)

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DO concentrations ranged from 6.03 mg/L to 6.09 mg/L. These results support Chindah and Braide (2003), who noted that DO fluctuates depending on temperature, depth, and biological activity. Hanna (2003) reported that DO levels of 5 mg/L or higher support healthy fish growth, which aligns with the current findings.

Alkalinity

Alkalinity values ranged from 24.93 ppm to 25.26 ppm across sampling stations. Observed concentrations fell within the recommended range of 5–500 mg/L (Lawson, 1995). While S. Idris et al. (2025) reported slightly lower alkalinity values (24.65–24.67 ppm) in Kitiri Reservoir, the results are consistent with USEPA (1976), which emphasized alkalinity's role in buffering pH fluctuations from photosynthesis. Natural freshwater systems typically maintain alkalinity above 20 ppm (USEPA, 1976), and values of 30–50 mg/L as $CaCO_3$ are suitable for fish and shrimp production (Lawson, 2011).

Ammonia

Annual ammonia concentrations ranged from 1.55 ppm to 1.56 ppm. High ammonia levels may inhibit oxidation, but concentrations between 10–150 mg/L are typically required to observe these effects (Kim et al., 2008; Hira et al., 2018). Ammonia is toxic to freshwater organisms at 0.53–22.8 mg/L, with toxicity influenced by pH and temperature.

Hardness

Total hardness ranged from 78.56 ppm to 80.25 ppm. This aligns with Mustapha (2009), who noted that water with less than 5 ppm $CaCO_3$ can adversely affect fish growth and survival. Hardness was higher in the dry season compared to the wet season, similar to findings by Kolo and Oladimeji (2004), attributed to reduced water levels and ion concentration. Wetzel (2001) also emphasized that productive waters typically have hardness below 500 ppm, supporting these results.

Conclusion

The study highlighted notable variations in the physicochemical properties of Kalgwai Reservoir across locations and over time during the two-year monitoring period. Parameters including temperature, pH, dissolved oxygen, alkalinity, and hardness displayed clear differences between sampling stations and months, reflecting the combined effects of natural conditions and environmental influences on water quality. Seasonal comparisons showed that temperature, dissolved oxygen, and hardness experienced more pronounced shifts between the dry and rainy seasons, whereas other parameters remained relatively stable. These findings provide valuable baseline information for future water quality evaluations and emphasize the importance of continuous monitoring to support the sustainable management and conservation of the reservoir ecosystem**.**

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