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Original Research Article

Water Quality Analysis of some Reservoirs in Kano State, Nigeria

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Abstract

Freshwater reservoirs are essential for agricultural production, fisheries, and domestic use in Nigeria, but increasing anthropogenic pressure poses significant threats to their ecological integrity and water quality. This study assessed the spatial and seasonal variability of selected physico-chemical parameters and heavy metal contaminants in Challawa Gorge, Thomas, Tiga, and Wasai reservoirs in Kano, Nigeria. Water samples were analyzed using multi parameter water quality meter and Atomic Absorption Spectrophotometry. Wasai recorded the highest electrical conductivity (713–738 μS/cm) and pH (8.82), indicating ionic enrichment. Water temperature was significantly higher during the rainy season compared to the dry season ($p < 0.05$), while pH was significantly higher during the dry season (8.46±0.26; $p < 0.01$) Salinity remained within the acceptable limits. Concentrations of cadmium (0.0083-0.1043 mg/L}) and lead (0.096-1.237mg/L) exceeded World Health Organization (WHO) safety thresholds across almost all sites and seasons. Chromium exhibited a significant rainy season peak ($p < 0.05$), whereas Zinc was significantly higher during the dry season ($p < 0.05$). The study concludes that heavy metal contamination in Kano's reservoirs exhibits strong seasonal and spatial variability. Continuous monitoring, runoff control, and stricter industrial discharge regulations are urgently recommended to protect aquatic ecosystems and public health.

Introduction

Freshwater reservoirs play a central role in supplying water for domestic utilization, agricultural irrigation, commercial fisheries, and hydropower generation across many parts of Nigeria. Assessing their water quality directly governs public health outcomes, agricultural yields, and aquatic biodiversity conservation (Mukaribu & Mu'azu, 2023). Seasonal changes principally characterized by the strict alternation between a prolonged dry season and an intense rainy season in Northern Nigeria exert a commanding influence over reservoir hydrology. These climatic transitions strongly regulate the ambient concentration and spatial distribution of water temperature, dissolved oxygen (DO), essential nutrients, turbidity, and electrical conductivity (EC) within reservoirs (Sani et al., 2025). Heavy rainfall and subsequent runoff during the wet season accelerate surface erosion, elevating the influx of suspended solids, turbidity levels, and nutrient loads into receiving reservoirs.

Conversely, the dry season often concentrates dissolved ions and ambient salts due to minimized freshwater inflows and elevated evaporation rates (Alkhader et al., 2025).

Heavy metal contamination within surface water systems has emerged as a paramount global environmental and public health crisis due to the persistent, non-biodegradable, and bioaccumulative nature of these toxic elements. Metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), zinc (Zn), and copper (Cu) cannot be broken down biochemically and tend to settle and accumulate within aquatic matrices, presenting long-term ecological risks and human health hazards (Ali et al., 2019; Kumar et al., 2019). Furthermore, rapid industrialization, accelerating urbanization, and intensive agricultural practices have dramatically increased the flux of these metallic contaminants into freshwater pathways (Zhou et al., 2020; Bawa-Allah et al., 2023).

Recent reservoir health assessments across Northern Nigeria demonstrate that while many physicochemical values align with broad World Health Organization (WHO) or national regulatory standards, episodic exceedances and seasonal peaks in nutrient loading or turbidity threaten ecosystem stability and downstream water uses if left unmanaged (Nasir et al., 2024; Isyaku et al., 2024). Studies within Kano State and surroundings indicate that upstream industrial effluents, municipal wastewater, and irrigation return flows induce measurable, seasonal spikes in pollutants and trace metals during specific months, emphasizing the critical importance of location-specific environmental monitoring (Abdullahi et al., 2025). Reservoirs featuring divergent catchment configurations, distinct operational regimes, and varying degrees of anthropogenic pressure display contrasting seasonal patterns that directly impact water usability for drinking, irrigation, and aquaculture (Abdul-Azeez et al., 2025).

Comparative seasonal investigation of physicochemical parameters and heavy metal analysis across reservoirs with water quality variations attributable to catchment land use, reservoir operations, and seasonal hydrology is critical, considering the information required to guide regional environmental management, pollution mitigation, and sustainable water allocation policies (Mukaribu & Mu’azu, 2023). This study therefore, examined the seasonal variation in physicochemical parameters and heavy metal concentrations of four prominent freshwater reservoirs in Kano state, Nigeria.

Materials and Methods

Study Area

Kano State is located in the semi-arid part of northwestern Nigeria (10°33' N and 12°23' N and longitudes 7°45' E and 9°29' E), featuring four reservoirs selected for study (Figure 1), it has a tropical savanna climate with a distinct dry and rainy season (Yusuf, 2025). Kano State has the largest number of reservoirs than any other state in Nigeria, 11 of which are owned and managed by the State Government, while four are owned and managed by the Federal Government (Shanono & Nasidi, 2026). Problems that have been affecting these dams include sedimentation, weed infestation, and degradation of embankments, crests, spillways, and other infrastructures (Umma et al., 2014).

Study Sites

Wasai Resevoir Minjibir Local Government Area (Latitude 12° 53' N, Longitude 8° 32' E) located in the Northern part of Kano State, Nigeria. The reservoir was constructed in 1976 for the purpose of irrigation, recreation and wildlife conservation (Magaji & Rabiu, 2020).

Thomas Reservoir Dambatta Local Government Area of Kano State (Latitude 12°16° N - 12° 18°N and Longitude 8° 30′E - 8° 31′E) serves primarily as an essential dry season irrigation source for agricultural cooperatives outside the capital city (Lawal, 2013).

Challawa Gorge Reservoir Karaye Local Government Area, Kano State (Latitude 11°44′34″ N, Longitude 8°1′2″ E) was initiated by the Kano State Government and later completed by the Federal Government of Nigeria via the Hadejia Jamaare River Basin Development Authority (HJRBDA) across the Challawa River southwest of Kano state (Awomeso, 2010).

Tiga Reservoir Bebeji Local Government Area of Kano State (Latitude 11°26′14″ N, Longitude 8°24′9″ E) was constructed between 1971 and 1974 (Ismail, 2025), a major tributary of the Hadejia River, and it serves as the cornerstone and primary water supplier for the famous Kano River Irrigation Scheme (KRIS) centered in Kadawa, irrigating tens of thousands of hectares of cash crops (Ismail, 2025; Muhammad, 2011).

Sample Collection

Water samples were collected at three different locations from each reservoir. The location of sample collection varied based on anthropogenic activities. An area with minimum to non-anthropogenic activity (A), then fishing and farming sites designated as B and C respectively. The water samples were placed in clean bottles and glass jars, labeled and transported to the laboratory where they were stored at 4°C till further analysis (Attah et al., 2023). Samples were collected monthly from July to December 2025 spanning both rainy and dry seasons.

Determination of Physico-chemical Parameters

The water samples were analyzed using the JQ-006 multiparameter water testing tool (Monira et al., 2024) to determine some physico-chemical parameters that include pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Salinity, while temperature was taken in-situ using a mercury thermometer (Piccolroaz, 2024).

Heavy Metal Analysis

Water samples were collected from each site in plastic bottles and preserved with nitric acid (HNO_3) to prevent adhesion of metals to the wall of the containers. The samples were digested on a hot plate using hydrochloric acid (HCl) and nitric acid (HNO_3) with a volume ratio of 1:0.5%. The beaker was washed down with deionized water after digestion, then filtered and poured in 100 ml volumetric flask and made up to 100 ml with deionized water (Magaji et al., 2023). The digested samples were taken to the Central Research Laboratory at Bayero University Kano State for determination of heavy metals using PerkinElmer PinAAcle™ 900H Atomic Absorption Spectrometer (PerkinElmer Inc., USA).

Heavy Metal Pollution Load Index and Contamination Factor

Pollution load index (PLI) and contamination factors are standardized methods used in determining the level of contamination of an ecological system (Thomlinson et al., 1980). The contamination factors are classified into CF <1 for low contamination, CF2 1-3 for moderate contamination, CF3 3-6 for considerable contamination and CF4 >6 for extremely high contamination. The equations used in determining the CF and PLI are presented in equations 1 and 2.

$$Cf = \frac{Csample}{Cbackground} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \; 1$$

$$PLI_{zone} = (Cf_1 \times Cf_2 \times Cf_3 \ldots\ldots \; Cf_n)^{1/n} \quad \ldots\ldots\ldots.. \; 2$$

Where PLI < 1 represents baseline pollution/unpolluted, PLI < 2 moderate pollutions, PLI < 3 heavy pollutions and PLI > 3 extremely severe pollution

Statistical Analyses

Descriptive statistics (mean ± SD) were used to summarize the data obtained from the samples. Paired student t-tests was used to assess seasonal variations in physicochemical parameters and heavy metal concentrations. Data were analyzed using Microsoft Excel 2016 and R statistical software Version 4.6.0. All Statistical significance was set at $p < 0.05$.

Results

The physicochemical parameters of water samples across the sampled reservoirs during the rainy and dry season are given in Table 1. Temperature, pH, EC, TDS, and salinity were markedly higher at Wasai than other reservoirs. Furthermore, comparison of values for the physicochemical parameters between the two seasons showed that water temperature was significantly higher during the rainy than dry season, while pH was significantly higher during the dry season. Electrical conductivity, TDS, and salinity showed no statistically significant seasonal differences (Table 2).

Heavy Metal Concentrations of Water

Our findings showed that lead concentrations were very high in both seasons and all sites (most especially Thomas), while cadmium concentrations were highest in Tiga during the rainy season, and lowest in Thomas during the dry season (Table 3).

A widespread heavy metal contamination was detected across the reservoirs. This is significantly influenced by seasonal cycles and location of specific anthropogenic activities (Figure 2). The level of heavy metal contamination is also indicated by seasonal Contamination Factor (CF) and Pollution Load Index (PLI) (Table 4).

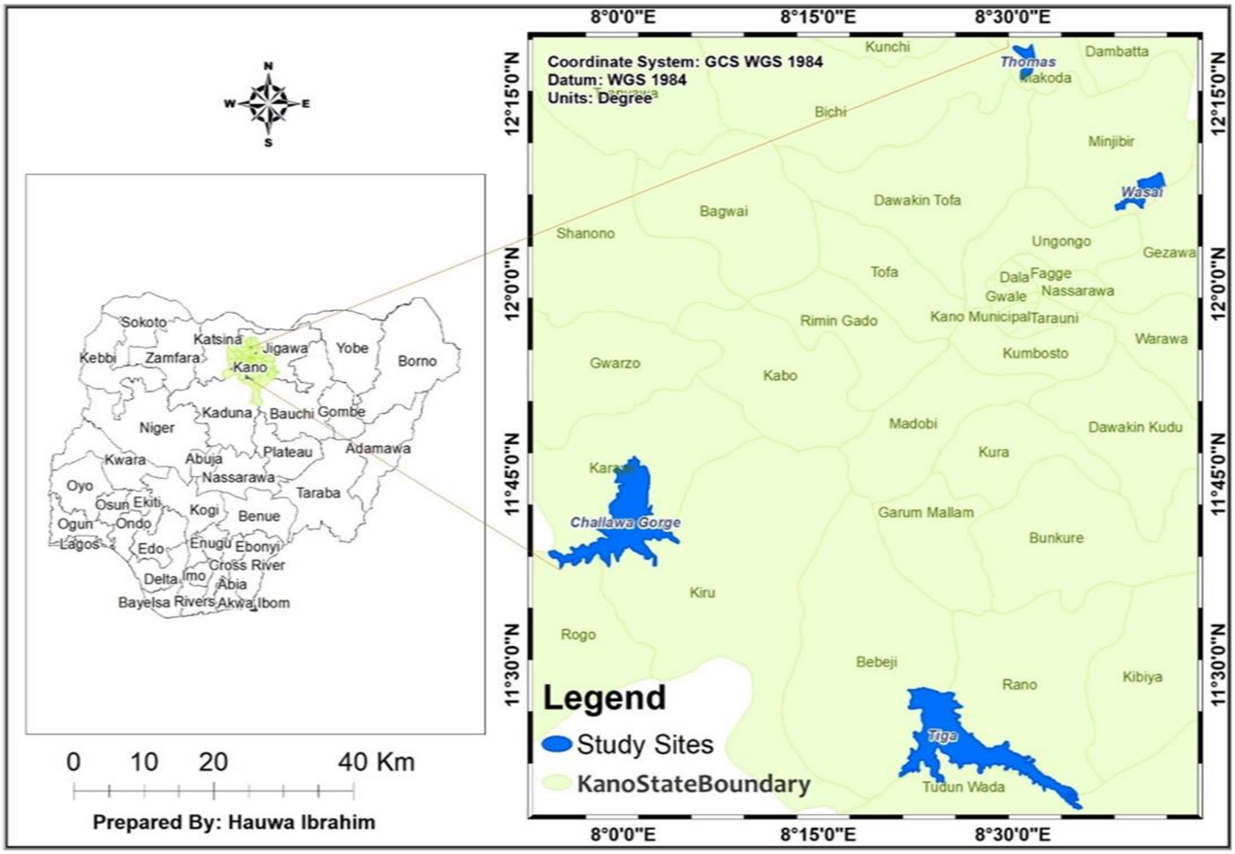

Figure 1: Map of Kano State Showing Location of Study Sites

Table 1: Mean Physicochemical Parameters of Water Samples measured during the Rainy and Dry Seasons

Reservoir	Temperature (°C)		pH		EC (µS/cm)		TDS (mg/L)		Salinity (ppt)	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Wasai	25.67± 2.65	21.33± 1.58	8.05± 1.09	8.82± 0.20	738.22± 63.93	716.11± 18.29	374.78± 31.43	356.22± 9.11	0.235± 0.152	0.246± 0.160
Thomas	26.00± 2.18	20.89± 1.54	7.93± 0.82	8.46± 0.18	155.44± 10.73	160.22± 6.30	79.33± 5.07	79.89± 3.10	0.076± 0.005	0.075± 0.005
Challawa	22.44± 1.51	20.33± 1.12	7.84± 0.66	8.29± 0.10	96.67± 18.24	95.67± 9.68	50.67± 9.81	47.11± 4.70	0.054± 0.008	0.047± 0.006
Tiga	22.44± 1.59	19.33± 1.32	7.75± 0.59	8.25± 0.10	86.89±9 .02	94.56± 7.92	45.67± 7.58	46.33± 4.36	0.044± 0.010	0.047± 0.006

Values are presented as mean ± standard deviation

Table 2: Seasonal Variation in Physicochemical Parameters

Parameter	Rainy Season (Mean ± SD)	Dry Season (Mean ± SD)	t (df)	p-value
Temperature (°C)	24.139 ± 1.961	20.472 ± 0.862	5.539 (3)	0.0116
pH	7.892 ± 0.125	8.455 ± 0.258	-7.909 (3)	0.0042
EC (μS/cm)	269.306 ± 314.074	266.639 ± 301.216	0.396 (3)	0.7183
TDS (mg/L)	137.611 ± 158.805	132.389 ± 150.039	1.147 (3)	0.3345
Salinity (ppt)	0.103 ± 0.090	0.104 ± 0.096	-0.444 (3)	0.6872

Table 3: Mean Heavy Metal Concentration during the Rainy and Dry Seasons

Reservoir	Cd (mg/L)		Cr (mg/L)		Pb (mg/L)		Zn (mg/L)	
	Season							
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Challawa	0.089± 0.0015	0.0117± 0.0015	0.068± 0.0166	0.056± 0.022	0.359± 0.291	0.097± 0.005	0.0710± 0.018	0.258± 0.093
Thomas	0.015± 0.0015	0.0083± 0.0006	0.035± 0.0091	0.024± 0.013	1.238± 1.788	0.122± 0.027	0.0700± 0.008	0.276± 0.081
Tiga	0.104± 0.0155	0.0160± 0.0010	0.055± 0.0321	0.039± 0.016	0.274± 0.029	0.096± 0.003	0.0783± 0.022	0.467± 0.134
Wasai	0.019± 0.0047	0.0113± 0.0006	0.036± 0.0274	0.012± 0.011	0.273± 0.060	0.158± 0.028	0.1490± 0.053	0.286± 0.090
WHO Limit	0.003		0.050		0.010		3.000	

Values are presented in mean ± Standard deviation

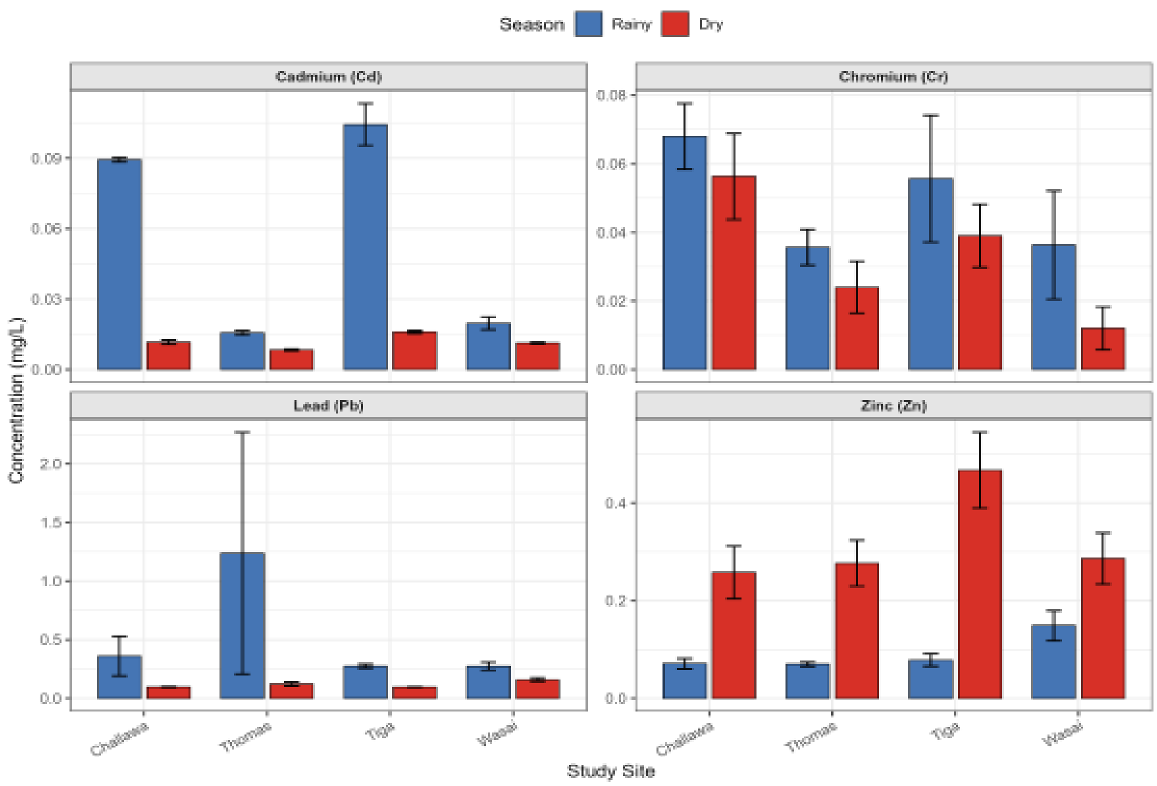

Figure 2: Seasonal Variations in Heavy Metal Concentrations by Season and Study Site

Table 4: Contamination Factor (CF) and Pollution Load Index (PLI) of Heavy Metals across Study Sites and Seasons

Season	Reservoir	CF_{cd}	CF_{cr}	CF_{pb}	CF_{zn}	PLI_{site}	Site classification
Rainy	Wasai	6.33	0.72	27.30	0.05	1.58	Polluted (PLI > 1)
	Thomas	5.00	0.70	123.70	0.02	2.32	Polluted (PLI > 1)
	Challawa	29.67	1.36	35.90	0.02	2.32	Polluted (PLI > 1)
	Tiga	34.67	1.10	27.40	0.03	2.36	Polluted (PLI > 1)
	Zone Mean	-	-	-	-	1.95	Polluted
Dry	Wasai	3.77	0.24	15.80	0.10	1.09	Polluted (PLI > 1)
	Thomas	2.77	0.48	12.20	0.09	1.10	Polluted (PLI > 1)
	Challawa	3.90	1.12	9.70	0.09	1.39	Polluted (PLI > 1)
	Tiga	5.33	0.78	9.60	0.16	1.59	Polluted (PLI > 1)
	Zone Mean	-	-	-	-	1.28	Polluted

Note: Baseline WHO (2026) concentrations used for calculations: Cd = 0.003mg/L, Cr = 0.050mg/L, Pb = 0.010mg/L, Zn = 3.000mg/L.

Discussion

Physicochemical parameters evaluated in surface waters of the four reservoirs displayed distinct temporal shifts driven by seasonal hydrologic dynamics. Water temperature was significantly higher during the rainy than the dry season ($t = 5.539$, $p = 0.0116$). The slightly lower temperature may be attributed to shift in climate towards cooler months. Similar patterns have been reported in freshwater reservoirs where shallow or stagnant water bodies tend to absorb more solar heat. For example, Sadauki et al. (2022) reported lower temperatures during cooler months while higher temperatures during warmer periods in Daberam Reservoir, Nigeria. pH values ranged from (8.05±1.09 to 7.75±0.59) during the rainy season to (8.82 ± 0.18 8.25±0.10) during the dry season remaining within the WHO-acceptable range (6.5-8.5) at most sites, with a marginal rise above this range at Wasai during the dry season. The alkaline pH values observed across the reservoirs during the dry season, particularly the high value recorded at Wasai, indicate that the reservoirs are probably influenced by carbonate-bicarbonate buffering systems typical of freshwater environments as suggested by Shangguan et al. (2025). Similarly, elevated pH values during dry seasons are commonly linked to reduced dilution and higher concentration of dissolved minerals due to evaporation and limited inflow as reported in a study conducted in Gubi Reservoir, Bauchi State (Muhammad et al., 2025).

Electrical conductivity (EC) and total dissolved solids (TDS) were highest at Wasai Reservoir during the dry season, indicating increased ionic concentration in the water. High EC and TDS values are often associated with the accumulation of dissolved salts from geological sources, evaporation, and anthropogenic inputs such as agricultural runoff. Similar observations were reported by Nasir et al. (2024) in Sabke Reservoir, Katsina State, where increased TDS and conductivity were strongly correlated with ionic concentration and seasonal changes in water chemistry. Despite variations in ionic content, salinity values in all reservoirs remained very low, confirming that the water bodies are freshwater systems. This observation agrees with findings from several freshwater reservoir studies in Nigeria where salinity levels remained within freshwater limits despite seasonal changes in other physicochemical parameters (Muhammad et al., 2025).

The statistically significant differences in physicochemical parameters observed among the reservoirs indicate spatial heterogeneity in water quality parameters. These differences may arise from variations in catchment land use, hydrological inputs, sediment transport, and anthropogenic activities within the watershed. Previous studies on tropical reservoirs have also reported significant spatial variations in physicochemical properties due to environmental and human influences (Odewade et al., 2021).

With regards to heavy metals, cadmium concentrations were substantially higher in the rainy season (0.0893-0.1043 mg/L) compared to the dry season (0.0083-0.0160 mg/L) displaying severe seasonal enrichment, with CF_Cd values up to six to tenfold higher in the rainy season compared to the dry season. The higher rainy season cadmium levels at Tiga (CF = 34.67) and Challawa (CF = 29.67). This pattern aligns with findings from the Kubanni Reservoir in northern Nigeria, where Okon et al. (2022) reported higher Cadmium concentrations during the rainy season due to increased surface runoff from agricultural lands. Similarly, Ayodeji et al. (2026) found that heavy metal concentrations in Esa Edo Reservoir were higher in the rainy season than in the dry season, with highly significant seasonal differences for Cadmium ($p < 0.001$). The elevated rainy season Cadmium concentrations likely results from dissolution and transport of Cadmium bearing fertilizers and agrochemicals from catchment areas. At Kiri Dam, Gambo et al. (2025) observed that lead and cadmium exceeded permissible limits, coinciding with cadmium (0.018 mg/L) and lead (0.11 mg/L) surpassing WHO standards.

In contrast, Zinc exhibited higher concentrations during the dry season (0.2580–0.4673 mg/L) than the rainy season (0.0700–0.1490 mg/L), supported by a significant t-value of 4.18 ($p = 0.024$). This observation is consistent with Okon et al. (2022), who reported higher As, Cr, Cd, Pb and Zn higher than WHO permissible limits at Kubanni Reservoir. The reduction in Zn during the rainy season can be explained by dilution effects from increased water volume and adsorption onto suspended particulates. Malami et al. (2014) found similar patterns at Challawa Gorge Reservoir, with metal contents generally higher in the dry season. The seasonal variation for Lead suggests a weak but emerging seasonal signal. The extreme CF-Pb values recorded during the rainy season peaking at 123.70 in Thomas Reservoir point to acute, episodic influxes of runoff containing lead from vehicular emissions, agricultural chemicals, and urban waste deposits. The notable reduction in CF-Pb during the dry season (down to 9.60-15.80) further confirms that storm driven runoff serves as the predominant transport mechanism for lead into these aquatic systems. While Ogungbile et al. (2019) found Lead below detection limits in Agodi Reservoir, Olowojuni et al. (2025) found downstream areas exhibited highest concentrations of metals, and Ayodeji et al. (2026) found significant higher concentrations of lead in the wet season. The present study's rainy season Lead at Thomas Reservoir (1.238 ± 1.788 mg/L) shows extreme variability, reflecting significant spatial heterogeneity across the reservoir ranging from 0.203-3.302 with a median of 0.208, driven primarily by localized heavy metal accumulation at sampling site A, indicating episodic contamination from storm-driven runoff of industrial or traffic sources.

Challawa Gorge Reservoir showed low Cadmium and Zinc concentrations in the dry season but moderate levels in the rainy season, while Thomas Reservoir exhibited a dramatic Lead increase. Ayodeji et al. (2026) similarly reported notable seasonal variations in Esa-Odo Reservoir, linking heavy metal concentrations to agricultural runoff and artisanal mining. Jolaosho et al. (2025) found strong location-season interactions in Lekki and Lagos Lagoons, where Cd, Pb and As peaked at stations influenced by agriculture, tourism and dredging, while industrial areas showed elevated Cadmium, Chromium and Lead.

While Cadmium shows relative stability, Chromium and Zinc exhibit strong seasonal signals, and Lead shows location dependent variability. Cadmium and Lead consistently exceeded WHO permissible guidelines across almost all sites and seasons. Ameh et al. (2025) found that Cadmium in Omi Dam presented moderate to considerable ecological risk. Olabamiji et al. (2025) revealed that Cd, As and Hg in Ikere Gorge Dam have hazard quotient values > 1, indicating high non-carcinogenic health risks. Continuous monitoring and remediation strategies (e.g., buffer zones, runoff control, industrial discharge regulation) are essential. The Pollution Load Index (PLI > 1) across all reservoirs demonstrates that despite individual spatial variations, none of the studied water bodies represent pristine baseline conditions. The higher overall regional pollution load in the rainy season (PLI_zone = 1.95) compared to the dry season (PLI_zone = 1.28) underscores the dominant role of non-point source catchment inputs in driving reservoir contamination. This finding aligns with Ayodeji et al. (2026) who reported that the heavy metal pollution index in Esa-Odo Reservoir exceeded the critical threshold of 100, with higher values in the wet season than the dry season.

The Physicochemical and Heavy Metal characteristics of Wasai, Thomas, Challawa, and Tiga Reservoirs exhibit noticeable spatial and seasonal variations. These findings carry major ecological and public health implications. High CF-Cd and CF-Pb levels pose substantial bioaccumulation risks to benthic biota and commercial fish populations. Similar heavy metal risk evaluations in Nigerian surface waters were reported by previous researches (Ameh et al. 2025; Olabamiji et al. 2025).

Conclusion

This study indicates the physicochemical dynamics and heavy metal contamination across multi-purpose reservoirs in Kano State. The findings reveal distinct seasonal shifts in water quality, with widespread heavy metal contamination exceeding health guidelines underlining significant water quality degradation driven by discharge and surface runoff. Continuous monitoring, agricultural runoff management, and targeted effluent treatment are urgently needed to protect aquatic ecosystems and downstream consumers.

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Conflict of Interest

All authors declare no conflict of interest.

Author Contribution

HIU Conceptualized the work, collected and analyzed the data, drafted the manuscript. ASM: Supervised the work, reviewed the manuscript. BUG: Supervised the work, reviewed the manuscript.

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