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Water Quality Evaluation of Dadin Kowa Reservoir for Human Consumption, Gombe State, Northeastern Nigeria

by

[1]Emmanuel D. Dawha; [2]Jacob. K. Nyanganji; [3]Abdussalam Barkindo, [4]Kelechi Friday Nkwocha

[1,2,3]Department of Geography University of Maiduguri

[4]Department of Geography University of Maiduguri/Department of Geography, Islamic University in Uganda, Mbale.

Corresponding author: emmadawha@gmail.com

Abstract

The study investigated the water quality of Dadin Kowa Reservoir situated in Gombe State, Northeaster Nigeria. The study 1: Evaluated the physicochemical and bacteriological quality of the raw water 2. Identified potential sources of contamination affecting the water quality of the reservoir. And 3. Assessed the suitability of the untreated reservoir water for direct human consumption. Data were collected through systematic sampling that covered the depth, width and Length of the reservoir. The raw water was analyzed for key indicators including pH, turbidity, total dissolved solids, heavy metals, and microbial contaminants such as coliforms and E. coli. The results was then compared with the national (NAFDAC) and international (WHO) drinking water standards. Findings reveal varying degrees of contamination influenced by both natural and anthropogenic factors within the catchment. The rainy season water index gave a value of 339.18 while the dray season index gave a value of 298.87 which by far have exceeded the WHO standard for drinking water which stands as 0 -50 as good and drinkable water, 51 – 100 as bad water and any value above 100 as unfit for drinking. Thus the result shows that the raw reservoir water is not fit for human consumption. The study thus recommends treatment before consumption. The Catchment also need to be managed to minimize denudation processes through which much of the contaminants find their way into the dam. The result also underscores the need for integrated water quality monitoring to safeguard public health in the study area.

Keywords: Dadin Kowa Catchment, Reservoirs and Public health, Reservoir, Water Quality,

Introduction

Globally, Water resources development, through construction of dams, plays a very important role in supporting socioeconomic development. Dams are usually designed for either single or multipurpose uses and this may include water supply, recreation, irrigation, flood management or hydroelectric power generation. In Nigeria, multipurpose dams have become pivotal to local and regional developments especially in the Sahel and Sudan Savana regions where the Dadin Kowa Dam in Gombe State is located.

The Dadin Kowa Dam is located approximately 37 kilometers on the outskirts of Gombe town in Yamaltu-Deba Local Government area. It was constructed in the 1980s and was designed to serve as a multi-purpose Dam to provide water for Irrigation, hydroelectric power generation, potable water supply and also help in controlling flood in the downstream sector. The reservoir has an estimated storage capacity of 2.8 billion cubic Litters, and at full capacity, it is projected to generate up to 40 megawatts of electricity and also irrigate approximately 44,000 hectares of farmland. In addition, it also supplies up to 30,000 cubic meters (approximately 19 million gallons) of treated water daily to Gombe town and surrounding communities.

Despite its strategic importance, the full realization of the dam's multipurpose potentials has faced delays. As of 2022, only the water supply component was fully functional, while hydroelectric power generation and large scale irrigation activities remained partially developed. However, interventions, including a Build-Operate-Transfer (BOT) agreement with Mabong Nigeria Ltd., aim to reactivate the dormant components and optimize the dam’s multipurpose role.

A preliminary hydro-geomorphic evaluation of the Dadin Kowa Reservoir highlighted a significant knowledge gap which is the absence of comprehensive qualitative data on the raw reservoir water. No publicly available studies were identified that assess the quality of the impounded water for human consumption, despite observations that several riparian communities directly depend on the untreated reservoir water for drinking and domestic use. This situation raises public health concerns given the critical role of water quality in safeguarding human health. It is therefore imperative to systematically evaluate the suitability of the raw water from Dadin Kowa Reservoir for human consumption. Such an assessment is particularly crucial for an informed water treatment practices, guiding public health interventions, and raising awareness among dependent communities regarding the potential risks of consuming the untreated water. Furthermore, the study equally provides water treatment engineers with a clear profile of the contaminants present in the raw water enabling more informed and effective treatment strategies that will ensure the delivery of safe drinking water. Thus, this study seeks to evaluate the physicochemical and microbial quality of Dadin Kowa Reservoir water and establish its compliance with national and international drinking water standards.

Although conducted at a local scale, this study contributes to the global discourse on drinking water safety by providing evidence of water quality challenges that mirror those faced across many developing regions. The findings highlight persistent gaps in achieving SDG 6 targets related to safe water access and water quality improvement. Strengthening water treatment infrastructure, routine monitoring, and community engagement remains critical for advancing sustainable water management and safeguarding public health globally.

Statement of the Problem

Access to safe and clean drinking water remains a fundamental public health necessity and a critical target under the Sustainable Development Goals (SDG 6: Clean Water and Sanitation). While Dadin Kowa Dam was constructed to enhance water availability for Gombe State for irrigation, hydroelectric generation, and potable water supply, there is a noticeable gap in the evaluation of the raw water quality of the reservoir. Despite its strategic importance and the direct dependence of surrounding communities on the reservoir's untreated water, there is a lack of empirical data assessing its physicochemical and microbial characteristics.

Despite the heavy reliance of semi-arid regions of Nigeria on surface water reservoirs, there is a notable lack of systematic and seasonal monitoring of reservoir water quality and hydrological dynamics. Most existing studies are limited to single-season assessments, failing to capture the strong wet–dry seasonal contrasts that influence pollutant concentrations, storage capacity, and treatment efficiency. This gap is increasingly problematic in the face of climate variability, which exacerbates water stress and contamination risks. Consequently, water resource management, public health protection, and progress toward Sustainable Development Goal 6 are constrained by insufficient seasonally resolved data.

This lack of baseline information poses serious concerns especially that the Gongola River, which feeds the reservoir, traverses extensive agricultural lands, human settlements, and diverse geological formations, exposing it to various potential contaminants. Without systematic assessment, the wholesomeness of the reservoir water for human consumption remains uncertain, exposing dependent communities to waterborne diseases and undermining public health efforts. Furthermore, water treatment processes currently in place operate without critical information on the nature and concentration of contaminants, limiting their effectiveness. Addressing this knowledge gap is essential not only for protecting human health but also for ensuring that the water treatment interventions are appropriate, efficient, and sustainable. Therefore, there is an urgent need to evaluate the water quality of Dadin Kowa Reservoir against established national and international drinking water standards to determine its fitness for human consumption and inform necessary mitigation and treatment strategies. The study therefore sets out to: 1. Evaluate the physicochemical and bacteriological quality of the raw water in Dadin Kowa Reservoir 2. Identify potential sources of contamination affecting the water quality of the reservoir and 3. Assess the suitability of the untreated reservoir water for direct human consumption.

Conceptual Framework and literature Review

Conceptual Framework

The study is based on the process response concept of analysis. The need to analyze the raw water of the reservoir is predicated on the acknowledgement of the overland flow processes and the possibility of contamination of the water as it flows downslope till it stagnates in the dam. As the water moves, it dissolves and as well carry tiny particles and microbials entrained in it and moves them downstream and into the dam. Thus, the process response concept is chosen for the analysis.

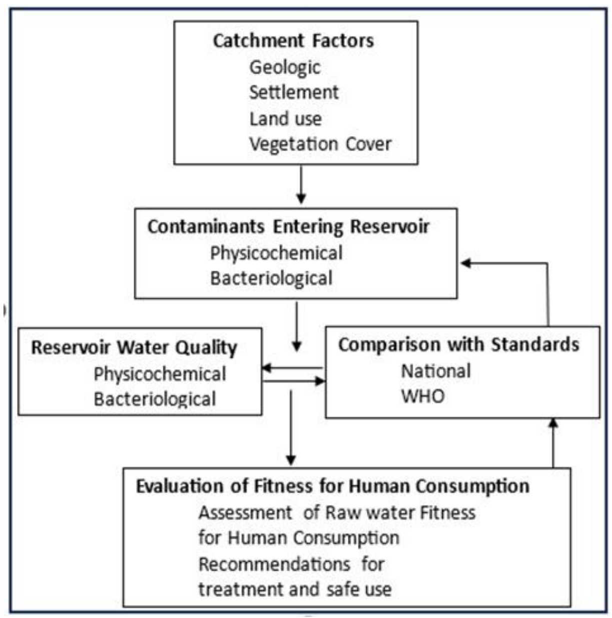

Figure 1 **Conceptual Flow Model for Evaluating Surface Water Quality in Human Impacted Catchments"**

The conceptual framework presents a systematic process of assessing the water quality of the reservoir and its fitness for human consumption. The research begins with an analysis of Catchment Factors such as geology, human settlements, and agricultural activities around the reservoir. These factors influence the type and amount of Contaminants Entering the Reservoir, including both physicochemical (e.g., salts, metals) and bacteriological contaminants like the coliforms and the E. coli pollutants. The Row Reservoir Water Quality is directly assessed by measuring these physicochemical and bacteriological parameters. This data is then subjected to a Comparison with the National Agency for Food and Drugs Administration and Control (NAFDAC) and the World Health Organization (WHO) drinking water guidelines, to evaluate compliance. Based on this comparison, an Evaluation of Fitness for Human Consumption is carried out. This step involves assessing whether the raw water is suitable for direct consumption or if treatment is necessary.

Literature Review

Water availability in any given area depends not only on quantity but significantly on the quality of the available water. Kwakaram, Salih, and Hama (2012) emphasized that large volumes of water may be present, but if the quality is poor and unsuitable for intended uses, true water availability cannot be claimed. The United Nations (2013) similarly noted that water quality is central to sustainable human and environmental development. Consequently, evaluating the quality of water bodies, particularly large reservoirs, both spatially and temporally, has become a critical research focus.

The Water Quality Index (WQI) approach is widely recognized as an effective method for assessing water quality, especially in large water bodies. Pathak and Limaye (2011) and Khanna, Bhutiani, Tyagi, Tyagi, and Rhuhela (2013) stated that the WQI reflects the composite influence of various physicochemical and bacteriological parameters, providing an integrated value describing the quality of the water in question. Although initially applied mainly to surface waters, WQI has increasingly been used in groundwater assessments as well (Atulegwu & Njoku, 2004).

Given that Dadin Kowa Dam spans over 47 kilometers and 9 communities along its banks rely on the reservoir for drinking, domestic, and livestock use, a thorough evaluation of its water quality is crucial. This study compared the reservoir's water quality parameters against the standards set by the World Health Organization (WHO) and Nigeria's National Agency for Food and Drug Administration and Control (NAFDAC), assessing its overall suitability for human consumption.

When considering water for animal use, physicochemical properties, nutrient excesses, toxic compounds, and microbial contaminants are critical indicators of suitability. According to Huggins, Agouridis, and Gumbert (2008), key parameters for assessing livestock water include Sodium (Na^{+}), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}), Nitrate (NO_3^{-}), Total Dissolved Solids (TDS), heavy metals like Manganese (Mn), Cadmium (Cd), Nickel (Ni), Zinc (Zn), Lead (Pb), and microbial agents. Faries, Sweeten, and Reagor (1998) emphasized that high concentrations of these constituents, particularly metals and bacteria, can pose severe health risks to animals. Fatoki, Lujizan, and Ogunfowokan (2002) further observed that while some minerals may have nutritional benefits in moderate amounts, excess levels become hazardous, corroborated by Curran and Robinson (2007).

In related studies, Sisodia and Moundiotiya conducted a detailed water quality study of Kolakho Lake, Rajasthan, India, monitoring seasonal variations between January 2002 and December 2003. By examining eight basic physicochemical parameters, they found that the WQI was poor across all three seasons: 414 in winter, 480 in summer, and 614 during the monsoon season. The elevated WQI values were attributed to the dumping of municipal waste and agrochemical runoff from nearby agricultural activities into the lake catchment, rendering the water unsuitable for drinking, bathing, or even swimming (Sisodia & Moundiotiya, 2006).

Similarly, Tandel, Macwan, and Soni (2012) evaluated the water quality of small lakes in South Gujarat, India, using ten physicochemical parameters. Unlike the findings from Kolakho Lake, this study reported good water quality for these smaller lakes. These comparative studies demonstrate that reservoirs must be monitored both over time and across different spatial zones. WQI remains the most suitable method for providing a comprehensive description of water status, classifying it into excellent, good, or poor categories. Thus, this research applied WQI methodology to Dadin Kowa Reservoir, providing a holistic and spatially detailed assessment covering the upper, middle, and lower stretches and comparing them against WHO and NAFDAC standards.

Local assessments of reservoir water quality across Nigeria also reveal both common trends and regional differences that help contextualize the patterns observed in Dadin Kowa (Adano et,al 2022; and Koloanda, & Oladimeji, 2004). The physicochemical analysis of Dadin Kowa Reservoir showed significant monthly and seasonal variations in parameters such as temperature, pH, transparency, nutrients, and biochemical oxygen demand, with overall values largely within WHO safe limits but influenced locally by anthropogenic activities such as washing and agricultural inputs (Muhammad et al., 2018). In contrast, studies on the Kainji Lake system and its major rivers reported pronounced seasonal influences on water quality parameters, including dissolved oxygen, turbidity, and nutrient concentrations over extended monitoring periods, suggesting that hydrological and climatological cycles drive temporal dynamics in these larger northern reservoirs as well (Ajibade et al., 2019; Omonona et al., 2019). Results from Shiroro Lake also indicate seasonal differences in surface water chemistry, with wet season temperature and turbidity values significantly higher than dry season values, although trends in pH and nutrient levels vary by season and reservoir morphology (Shiroro Lake study, 1999–2000), underscoring the influence of catchment inputs and hydrological regime on water quality patterns. Together, these studies illustrate that while many Nigerian reservoirs experience seasonal variability in physical and chemical water quality parameters, the magnitude and specific parameter responses differ with reservoir size, hydrology, and watershed characteristics. This variability highlights the need for systematic, seasonally resolved monitoring strategies to inform sustainable water management and public health protection across diverse semi-arid and tropical settings.

Study Area

Dadin-Kowa Reservoir is located in Gombe State, northeastern Nigeria, lying between latitudes 10°18' N to 10°45' N and longitudes 11°20' E to 11°40' E (Figure 1). The reservoir is positioned about 35 kilometers east of Gombe town and was created through the damming of the Gongola River (the major tributary of the Benue River). The river originates from the eastern escarpments of the Jos Plateau which is characterized by rugged highlands that gradually transition into the undulating plains of Gombe State.

Commissioned in 1984 by the Federal Government of Nigeria, the Dadin-Kowa Dam was primarily designed as a multipurpose Dam to enhance urban water supply, facilitate irrigation farming, control flooding and promote regional development. At full capacity, the reservoir holds approximately 800 million cubic Liters (MCL) of water, covering an expanse of roughly 300 square kilometers (Infrastructure Concession Regulatory Commission [ICRC], 2018).

The landscape surrounding the reservoir is dominated by open savanna vegetation, interspersed with farmlands and riparian zones. The soils are mainly sandy-loam, moderately fertile, and prone to erosion, especially under intensive agricultural activities. The area experiences a tropical wet and dry climate, with distinct wet (May - October) and dry (November - April) seasons which influences both the inflow and quality of water entering the reservoir.

Dadin-Kowa Reservoir serves as the principal source of potable water for Gombe town, supplying approximately 30,000 cubic meters of treated water daily through a treatment plant located three kilometers from the reservoir. It also supports rural communities along the supply routes. The Dadin Kowa Reservoir is surrounded by 9 settlements (Difa, Ruhu, Lubo, Hurfure, urara, Tungo, Jillehu, Gongola and Bajoga) all the villages depend on the raw water from the reservoir for either their drinking and/or domestic needs. Given its multipurpose importance, understanding the physical characteristics, catchment processes, and potential contamination pathways is critical for sustainable reservoir management and the preservation of water quality standards.

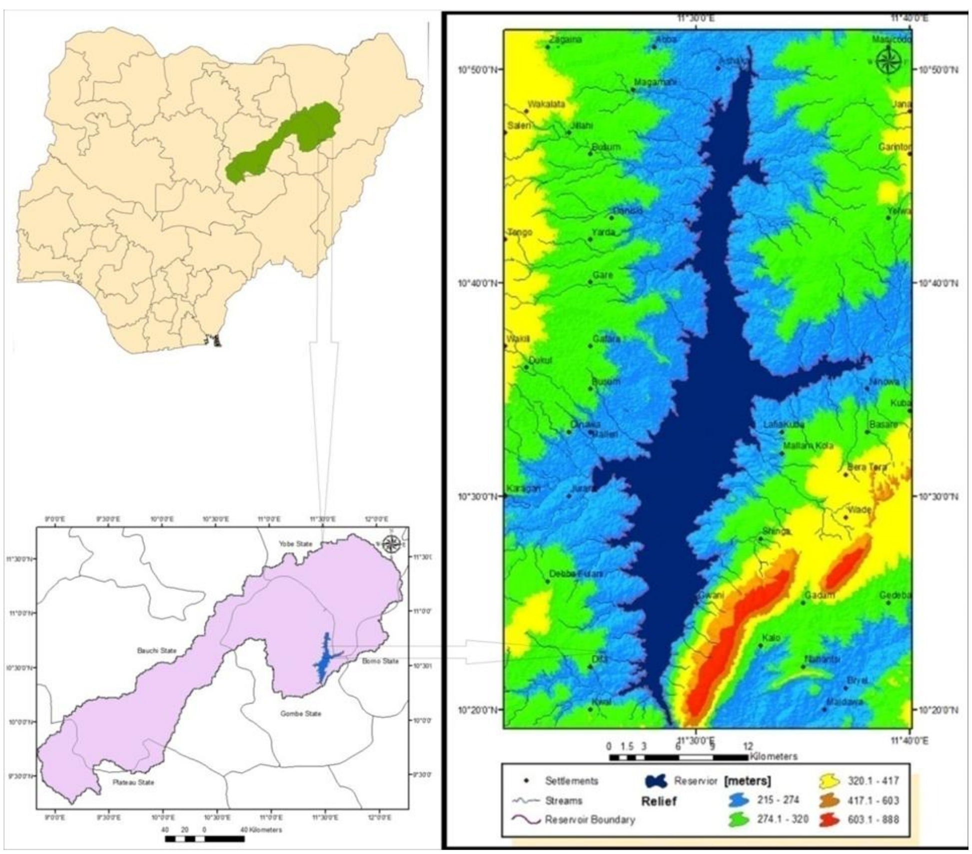

Figure 1: the study area

Methodology

Study Design and Sampling Strategy

A comprehensive water quality assessment of the Dadin Kowa Dam was conducted using a structured approach that integrated field sampling and laboratory analysis. To ensure representative and reliable results across the extensive length of the reservoir (over 47 km), the dam was systematically divided into three longitudinal segments: the upper course, middle course, and lower course. Within each segment, water samples were collected at approximately 5-kilometer intervals and also across the breadth of the reservoir, covering the left bank, central axis, and right bank. At each sampling point the breadth of the dam was divided into two halves, and water samples were collected from the midpoint of each half and from the central axis, yielding three sampling points per 5-kilometer interval. Three samples were collected across each segment and mixed to form a composite sample representing the segment's average water quality. In total, nine composite samples (three per segment) were collected for laboratory analysis.

Sample Collection Procedure

To accurately represent the water column from surface to bottom an improvised water column sampler (validated by supervisory and water engineering staff) was used at each point. At every sampling location, the sampler was deployed three times to collect vertically integrated samples. The collected samples were mixed thoroughly in a 20-liter sterilized container to produce a composite water sample. From each composite, a final one-liter aliquot was drawn for laboratory testing.

Strict quality control measures were adopted to prevent contamination. All sampling containers were chemically cleansed and double-rinsed with ambient reservoir water before use. Sterilized commercial water bottles (i.e Swan Water bottles) were purchased, emptied on-site, and used for final sample storage. Samples were labeled, stored in coolers with ice packs, and promptly transported to the laboratory. To stabilize biological parameters during transportation, 10 mL of concentrated HNO_3 was added to each one-liter sample, following procedures outlined by Mendham et al. (2002).

The sampling materials included:

- Improvised water column sampler
- Swan water bottles (sterilized)
- Funnels
- 20-liter sterilized containers
- GPS receiver
- Motorized boat

Laboratory Analysis

The laboratory analysis was conducted at the NAFDAC Laboratory in accordance to standard procedures. Both field-based and laboratory-based analyses were carried out across dry and wet seasons to capture seasonal variability in water quality.

Parameters Tested

Water quality assessment was guided by WHO standards, covering the physical, chemical, and microbiological characteristics of the water. Radiological testing was excluded due to the absence of known radioactive contamination in the region. The Physical Parameters include: pH (Color Match Method); Turbidity (Colorimetric Method); Total Dissolved Solids (TDS) (Gravimetric Method) and Hardness (Titrimetric Method). The Chemical Parameters included: Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, SO_4^{2-}, CO_3^{2-}, PO_4^{3-}. Heavy metals including Cd, Co, Cr, Ni, Pb, Zn were also tested (by Atomic Absorption Spectrophotometry, AAS). Dissolved Oxygen (DO) (Oxygen Meter) Biochemical Oxygen Demand (BOD) (Winkler's Method following Ezekiel, 2017). The Biological Parameters tested are: Fecal coliform count (Eijkman test) Fecal streptococci count. Observation of miscellaneous organisms

Water Quality Index (WQI) Computation

To simplify the interpretation of complex water quality data, a Water Quality Index (WQI) was computed based on the weighted arithmetic mean method recommended by WHO and following the procedures of Thakor et al. The water quality rating for each parameter was calculated using the equation:

$Q_n = V_n - V_{io} / V_S - V_{io} * 100$………………………………………………………… equation 1

Where

Q_n = water quality rating of each parameter

V_n = Observed value of water quality parameter obtained from laboratory analysis

V_{io} = Ideal value of water quality parameter as obtained from standard tables (i.e., zero (0)

for all other parameters with the exception of pH and dissolved Oxygen (DO) having

7.0 and 14.6mg/l respectively)

V_S = Standard permissible value of water quality parameter as recommended by SON/WHO.

The relative weight of each of the parameters was calculated thus:

$Wn = k/V_s$……………………………………………………………………….equation 2

which gives a value inversely proportional to recommended standard value (V_s) of the parameter.

Where

Wn =unit weight for water quality parameter

K = constant of proportionality expressed as:

$k = 1/(1/V_{s1} + 1/V_{s2} + 1/V_{s3} + 1/V_{sn})$……………………………………………..equation 3

The overall water quality Index WQI was then calculated by aggregating the water quality rating with unit weight linearly, using the following weighted arithmetic index equation.

$WQI = \sum Q_n W_n / \sum W_n$……………………………………………………….…. equation 4

Water quality was classified according to the scale adapted from **Mishra and Patel (2001)** (Table1)

Table 1: Water quality classification

WQI Range	Water Quality Status
0–25	Excellent
26–50	Good
51–75	Poor (bad)
76–100	Very Poor (bad)
>100	Unfit for drinking

In writing the report, essential parts were fed into artificial intelligence (Chatgpt) for enhancement of readability and coherence

Results and Discussion

Seasonal Variations in Water Quality Parameters

The Dadin Kowa Reservoir, situated within the Sudano-Sahelian ecological zone of northeastern Nigeria, experiences distinct wet (rainy) and dry seasons, which influences its water quality. During the rainy season, high precipitation leads to high runoff draining into the reservoir while the dry season is marked by low inflow and high evaporation. Paired t-tests conducted on 21 water quality parameters (Table 2) revealed that 10 parameters exhibited statistically significant seasonal differences ($p < 0.05$), while 11 parameters did not show significant variation. Dissolved Oxygen (DO) and microbial parameters including Unspecified Rod Bacteria (URB) and Microbial Colony Assay (MCA) recorded higher concentrations during the rainy season, likely due to runoff carrying organic and microbial loads. Conversely, parameters such as Sodium (Na) and Total Dissolved Solids (TDS) showed elevated levels during the dry season, attributable to concentration effects from evaporation and reduced dilution.

The seasonal variations observed in the water quality of Dadin Kowa Reservoir reflect the combined influence of climatic and anthropogenic factors. Elevated microbial and organic contamination during the rainy season can be attributed to rainfall-induced runoff from surrounding agricultural fields, grazing areas, and nearby settlements, which transport fertilizers, animal waste, and improperly disposed domestic wastes into the reservoir. Similar patterns have been reported for Goronyo Dam and tributaries of the Lake Chad Basin (Olayemi, 2015; Bako et al., 2019). In contrast, the dry season is characterized by increased concentrations of dissolved solids and selected physicochemical parameters due to reduced inflow, higher evaporation rates, and longer water residence time. When compared with World Health Organization (WHO, 2022) guidelines and NAFDAC drinking water standards, some parameters, particularly microbial indicators during the rainy season exceeded permissible limits, indicating potential public health risks if the water is consumed without adequate treatment. These findings highlight the need for season-specific monitoring, improved catchment management, and stricter regulation of land-use activities around the reservoir to ensure safe and sustainable water supply.

Table 2: Seasonal Variation in Water Quality Parameters at Dadin Kowa Reservoir

S/No	Parameter	Mean Value Mg/L		Std Deviation		T Value	P Value
		Wet Season	Dry Season	Wet Season	Dry Season		
1.	Na	163.222	253.432	19.47	35.34	-6.707	0.000
2.	Ca	1.333	1.647	.500	.384	-1.491	0.155

3.	Mg	0.778	0.557	.441	.119	1.452	0.166
4.	Cl	9.670	8.000	3.87	1.23	1.231	0.236
5.	SO_4	30.000	21.890	10.31	11.52	1.574	0.135
6.	PO_4	1.778	1.523	.666	.378	0.996	0.334
7.	NO_4	1.444	1.608	.527	.405	-0.737	0.472
8.	DO	9.000	3.778	2.291	1.829	5.344	0.000
9.	TDS	317.780	213.330	150.819	62.850	1.920	0.073
10.	TH	181.890	189.780	24.579	52.792	-0.406	0.690
11.	pH	8.889	8.630	.333	.520	1.257	0.227
12.	Turbidity FTU	9.220	97.560	3.420	52.759	-5.012	0.000
13.	Mn	0.000	0.492	0.E-7	.646	-2.287	0.036
14.	Cd	0.000	0.289	0.E-7	.178	-4.866	0.000
15.	Cr	0.000	0.073	.000	.037	-5.880	0.000
16.	Ni	4.111	2.692	.928	.729	3.607	0.002
17.	Zn	1.333	0.460	.500	.198	4.871	0.000
18.	Pb	0.667	0.991	1.581	1.701	-0.419	0.681
19.	URB	37.444	2.074	27.226	.324	3.897	0.001
20.	MCA	26.222	1.444	19.123	.471	3.886	0.001
21.0	CA	15.222	0.852	8.318	.603	5.169	0.000

(Source: Researcher's analysis)

Longitudinal (Upper, Middle and Lower Course) Variations

Given the reservoir’s elongated morphology (approximately 47 km), longitudinal spatial differences were assessed across the lower, middle, and upper reaches using ANOVA.

During the rainy season, only Calcium (Ca) exhibited significant variation along the reservoir ($p = 0.005$). However, in the dry season, Sodium (Na), Total Dissolved Solids (TDS), and Lead (Pb) showed significant differences ($p < 0.05$) across the reservoir's longitudinal sections.

These spatial patterns reflect the influence of hydrological inputs. Tributary inflows during the rainy season introduce localized variability, while evaporative concentration during the dry season leads to increasing downstream concentrations. Similar longitudinal gradients were reported by Ogbeibu et al. (2014) in Nigeria's Ikpoba River and by Mbuh et al. (2022) in Cameroon's Lagdo Reservoir.

Lateral (Cross-Sectional) Variations

Lateral variations in water quality across the reservoir width (left, middle, and right banks) were generally minimal, indicating effective lateral mixing under most hydrological conditions. This relative uniformity suggests that wind-driven circulation and reservoir-wide water movement limit the persistence of bank-specific contamination. However, statistically significant lateral differences were observed in the middle course during the rainy season for sodium (Na), chloride (Cl), sulfate (SO_4), and total dissolved solids (TDS) ($p < 0.05$). These localized variations are likely associated with rainfall-induced runoff and inflow dynamics, which temporarily introduce dissolved ions and suspended materials from adjacent agricultural lands and human activities before full mixing occurs as documented in other large reservoirs such as Kainji and Shiroro dams (Akan et al., 2013). The absence of persistent lateral gradients during the dry season further supports the role of seasonal hydrology in controlling spatial heterogeneity. From a management perspective, these findings suggest that routine monitoring may rely on representative mid-channel sampling during stable periods, while intensified spatial sampling is warranted during peak rainfall to capture short-lived but environmentally significant lateral variability. These findings highlight the complex and dynamic hydrochemical processes governing Dadin Kowa Reservoir's water quality and the need for seasonally adaptive and spatially targeted management interventions.

Concentration of Ionic, Physical, Metallic, and Biological Contaminants Against WHO

Comparison of observed parameter concentrations against WHO standards (Table 3) revealed that several parameters exceeded permissible levels, notably: Sodium (Na) which exceeded the WHO maximum limit (253.4 mg/L dry season vs. 200 mg/L permissible limit).Magnesium (Mg): Exceeded consumer acceptability thresholds. Heavy Metals (Mn, Cd, Cr, Ni, Pb): Surpassed WHO permissible concentrations, particularly during the dry season. Microbial Contaminants (URB, MCA, CA): Significantly higher during the rainy season, indicating faecal pollution and heightened risk of waterborne diseases.

These findings align with results from similar studies in semi-arid reservoirs, such as in Lake Geriyo (Waziri, 2017) and Hadejia Basin systems (Ismaila & Adebayo, 2021), where heavy metals and microbial contamination spike seasonally due to agricultural runoff, sediment resuspension, and anthropogenic activities.

Table 3: WHO Standards vs Observed Means for Water Quality Parameters

S/No	Parameter	Unit	WHO Desirable	WHO Maximum Permissible	Seasons Dry Season Mean	 Wet Season Mean	Standard	Health Implication
1	Sodium (Na)	Mg/l	0	200	253.4	163.4	WHO	None
2	Calcium (Ca)	Mg/l	0	100	1.7	1.5	WHO	
3	Magnesium(Mg)	Mg/l	0	0.2	0.6	0.6	WHO	Consumer acceptability
4	Chloride (Cl)	Mg/l	0	250	8.0	9.7	WHO	None

5	Sulphate (SO_4)	Mg/l	0	100	21.9	30.0	WHO	None
6	Phosphate (PO_4)	Mg/l	0	0.40	1.5	1.9	WHO	
7	Nitrate (NO_3)	Mg/l	0	50	1.6	1.5	WHO	Cyanosis, and asphyxia („blue-baby syndrome") in infants under 3 months
8	Dissolved Oxygen(DO)	Mg/l	14	1.0	3.8	9.0	WHO	None
9	TDS	Mg/l	0	500	213.3	317.8	WHO	None
10	Hardness	Mg/l	0	150	189.8	181.9	WHO	None
11	pH	Mg/l	7	6.5 – 8.5	8.6	8.7	WHO	None
12	Turbidity	NTU	0	5	97.6	9.2	WHO	None
	Heavy Metals							
13	Manganese (Mn)	Mg/l	0	0.2	0.5	0.3	WHO	Neurological disorder
14	Cadmium (Cd)	Mg/l	0	0.003	0.3	0.2	WHO	Toxic to the kidney
15	Chromium (Cr)	Mg/l	0	0.05	0.1	0.1	WHO	Cancer
16	Nickel (Ni)	Mg/l	0	0.02	2.7	4.1	WHO	Possible carcinogenic
17	Zinc (Zn)	Mg/l	0	3	0.5	1.3	WHO	None
18	Lead (Pb)	Mg/l	0	0.01	1.0	0.6	WHO	Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems
1	coliform	cfu/	00	01	2.1	37.	WH	Indication of faecal

9	count (URB)	mL				4	O	contamination
20	E. Coli count (MCA)	cfu/ mL	00	00	1.4	26.2	WHO	Urinary track infections, bacteria anemia, meningitis, diarrhea, (one of the main cause of morbidity and mortality among children), acute renal failure and hemolyticanemia
21	*Aeroginosa* (CA)	cfu/ mL	00	00	0.9	15.2	WHO	Bacterial ?

(Source: Researcher's Comparative analysis with WHO standard)

Water Quality Index (WQI) Assessment

The WQI for Dadin Kowa Reservoir was calculated using WHO guidelines. The result shows WQI of 339.18 in Rainy Season and WQI of 298.87 in Dry Season. According to WHO classification, WQI of values > 300 are classified as unsuitable for drinking. WQI between 200 and 300 indicates poor water quality and requires treatment before human can consume it. Thus, the Dadin Kowa Reservoir water quality during both seasons falls into the poor to unsuitable category for direct use without treatment. Elements that contributed to the high WQI values included: Magnesium, Phosphate, and heavy metals (e.g., Cd, Ni, Pb), the high turbidity value during rainy season and high microbial loads during the rainy season. (Table 4, 5 & 6)

These findings reinforce concerns reported in northern Nigeria's water bodies (Ishaku et al., 2011; Mustapha, 2008), emphasizing the urgent need for watershed management, pollution control, and regular water treatment efforts in semi-arid reservoirs. The results reveals significant seasonal and spatial variability in the Reservoir’s water quality. High concentrations of metals and microbial indicators, particularly during the rainy season, pose serious public health risks. Management strategies must therefore incorporate seasonal monitoring, catchment protection measures, point-source pollution control, and water treatment enhancement to safeguard water security in the region.

Table 4 Determination of Rainy Season Water Quality Index for Dadin Kowa Reservoir

	Calculations of Water Quality Index of Rainy Season of the Dam										
	Parameters	WHO Desirable (Sn)	1/Sn	∑1/Sn	K=1/(∑1/Sn)	Wn=K/Sn	Ideal Value (Vo)	Mean Con.(Vn)	Vn/Sn	Qn=Vn/Sn*100	WnQn
1	Na (mg/l)	200	0.005	8.67531	0.11527	0.00058	0	163.37	0.81685	81.685	0.047079
2	Ca (mg/l)	100	0.01	8.67531	0.11527	0.00115	0	1.49	0.0149	1.49	0.001718
3	Mg (mg/l)	0.2	5	8.67531	0.11527	0.57635	0	0.65	3.25	325	187.3131
4	Cl (mg/l)	250	0.004	8.67531	0.11527	0.00046	0	9.67	0.03868	3.868	0.001783
5	SO4 (mg/l)	100	0.01	8.67531	0.11527	0.00115	0	30	0.3	30	0.034581
6	PO4 (mg/l)	0.4	2.5	8.67531	0.11527	0.28817	0	1.91	4.775	477.5	137.6031
7	NO3 (mg/l)	50	0.02	8.67531	0.11527	0.00231	0	1.5	0.03	3	0.006916
8	DO	1	1	8.67531	0.11527	0.11527	14	8.98	0.39	39	4.495515
9	TDS (mg/l)	500	0.002	8.67531	0.11527	0.00023	0	317.78	317.78	31778	7.326075
10	TH (mg/l)	150	0.00667	8.67531	0.11527	0.00077	0	181.89	0.36378	36.378	0.027955
11	PH	8.5	0.11765	8.67531	0.11527	0.01356	7	8.71	1.71	171	2.318953
			8.67531			1					339.1768

Source: Researcher's Adapted WHO Formula for Determination of Water Quality Index

Table 5 Determination of Dry Season Water Quality Index for Dadin Kowa Reservoir

	Calculations of Water Quality Index of Dry Season of the Dam										
	Parameters	WHO Desirable (Sn)	1/Sn	∑1/Sn	K=1/(∑1/Sn)	Wn=K/Sn	Ideal Value (Vo)	Mean Con. (Vn)	Vn/Sn	Qn=Vn/Sn*100	WnQn
1	Na (mg/l)	200	0.005	8.67531	0.11527	0.00058	0	253.43	1.26715	126.715	0.073032
2	Ca (mg/l)	100	0.01	8.67531	0.11527	0.00115	0	1.65	0.0165	1.65	0.001902
3	Mg (mg/l)	0.2	5	8.67531	0.11527	0.57635	0	0.56	2.8	280	161.3774
4	Cl (mg/l)	250	0.004	8.67531	0.11527	0.00046	0	8	0.032	3.2	0.001475
5	SO4 (mg/l)	100	0.01	8.67531	0.11527	0.00115	0	21.89	0.2189	21.89	0.025233
6	PO4 (mg/l)	0.4	2.5	8.67531	0.11527	0.28817	0	1.52	3.8	380	109.5061
7	NO3 (mg/l)	50	0.02	8.67531	0.11527	0.00231	0	1.61	0.0322	3.22	0.007423
8	DO	1	1	8.67531	0.11527	0.11527	14	3.78	1.86	186	21.44015
9	TDS (mg/l)	500	0.002	8.67531	0.11527	0.00023	0	213.33	213.33	21333	4.918093
10	TH (mg/l)	150	0.00667	8.67531	0.11527	0.00077	0	189.78	0.37956	37.956	0.029168
11	PH	8.5	0.11765	8.67531	0.11527	0.01356	7	8.63	1.1	110	1.491724
			8.67531			1					298.8718

Source: Researcher's Adapted WHO Formula for Determination of Water Quality Index

Table 6 WHO Water Quality Classification and Statuses

WHO Water Quality Index Classification	Water Quality Status (WHO)	Dadin Kowa Water Quality Index		Dadin Kowa Water Quality Status (WHO)
0 – 25	Excellent Water	Rainy Season	339.18	Unfit for Drinking
26 – 50	Good Water	Dry Season	298.87	Unfit for Drinking
51 – 75	Poor Water	Mean	319.02	Unfit for Drinking
76 – 100	Very Poor Water			
> 100	Unfit for Drinking			

Conclusion

This study evaluated the seasonal, longitudinal, and lateral variations in water quality parameters of the Dadin Kowa Reservoir in northeastern Nigeria. The study used rigorous statistical methods and the Water Quality Indexing (WQI) approach to categorize the reservoir water. Findings reveal significant seasonal variation in several parameters and also higher microbial and organic loading during the rainy season. There is an elevated ionic and metallic concentrations in the dry season which may be attributed to reduced dilution in the dry season. Spatial analyses also shows marked differences along the reservoir's length, particularly again during the dry season, while localized lateral variations at the middle course was indicated during the rainy season. The WQI values for both rainy (339.18) and dry (298.87) seasons exceeded WHO's thresholds for acceptable drinking water quality, categorizing the reservoir water as very poor. Critical exceedances were observed for sodium, magnesium, phosphate, and heavy metals such as cadmium, chromium, nickel, and lead which are associated with significant human health risks including kidney toxicity, neurological disorders, and carcinogenic effects. The detection of high microbial counts during the rainy season also indicates a pronounced vulnerability to faecal contamination and waterborne diseases.

Based on the observed seasonal variability and contamination patterns, it is recommended that local authorities establish a routine wet- and dry-season water quality monitoring programme aligned with WHO and NAFDAC standards. Catchment protection measures, including regulation of agricultural runoff, controlled waste disposal, and enforcement of buffer zones around the reservoir, should be strengthened to reduce pollutant inflow. In addition, community-based awareness campaigns should be implemented to educate surrounding populations on safe water use, sanitation practices, and the environmental consequences of indiscriminate waste disposal. These measures are critical for safeguarding public health and ensuring sustainable reservoir management.

Overall, the results underscore the dynamic and complex nature of water quality in the Dadin Kowa Reservoir, shaped by both seasonal hydrology and anthropogenic influences, and highlight an urgent need for integrated water resource management and pollution control strategies.

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