Water Quality Assessment in Relation to Water Depth in Dan-Zaria Dam North Central Nigeria

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Abstract- This study assesses the influence of water depth on the physicochemical properties of Dan Zaria Dam and its suitability for agricultural and domestic use. Statistical analysis revealed significant variations with depth in parameters like pH, electrical conductivity, total dissolved solids (TDS), and dissolved oxygen (DO). pH decreased with depth ($p < 0.05$), indicating more acidic conditions, while conductivity and TDS increased ($p < 0.05$), reflecting higher mineral concentrations. DO levels also declined at greater depths, likely due to reduced oxygen diffusion. Other parameters, including calcium hardness, alkalinity, and nitrate, showed no significant depth-related changes and remained within safe limits. The findings emphasize the need for depth-sensitive water quality management, focusing on potential issues like DO depletion and mineral accumulation in deeper water layers.

Indexed Terms- Agricultural, Depth, Parameters, Layers.

I. INTRODUCTION

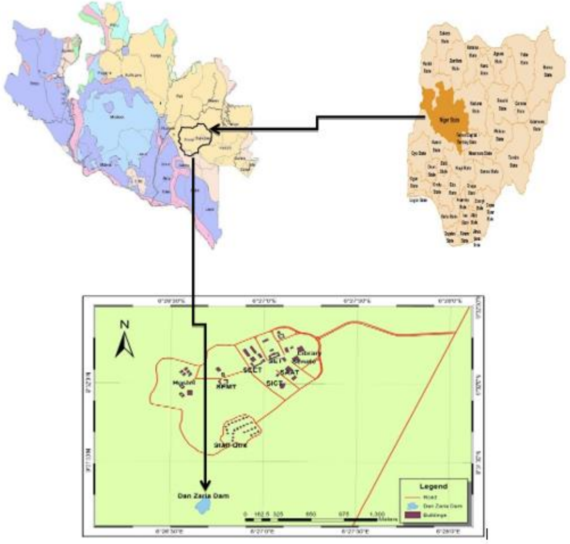
Water is an essential resource for human survival and development, playing a crucial role across domestic, agricultural, and industrial sectors. With increasing global populations and heightened demand for water, the need for sustainable water quality management has become more pronounced (Mazzoni et al., 2023). This is particularly critical in regions where water resources are limited or vulnerable to environmental and anthropogenic pressures. In semi-arid areas like Northern Nigeria, dams are vital in securing water supplies for irrigation and domestic consumption (Umukiza et al., 2023). Dan Zaria Dam, located at the Federal University of Technology Minna in Niger State, Nigeria, is one such key resource. However, rising utilization calls for consistent water quality monitoring, particularly about variations in water depth.

Water quality can vary significantly in depth, affecting its suitability for various uses. The stratification of water bodies due to thermal gradients, nutrient cycling, and dissolved oxygen (DO) levels often leads to changes in physical and chemical properties at different depths (Syeed et al., 2023). Deeper water layers may accumulate nutrients and pollutants, while surface water is more exposed to atmospheric oxygenation and solar radiation, impacting parameters such as pH, electrical conductivity (EC), and DO. Understanding these depth-related variations is crucial for managing water for irrigation and domestic purposes.

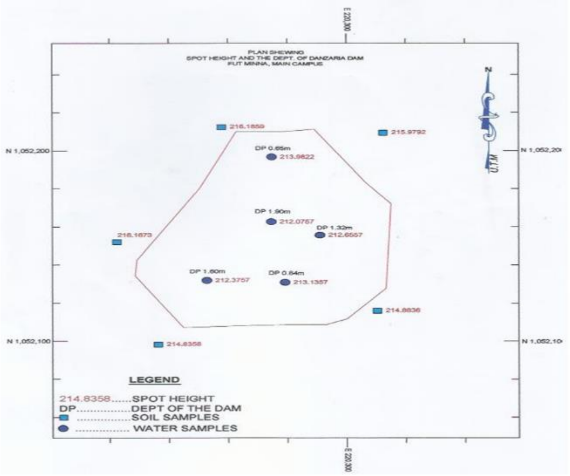
In the case of Dan Zaria Dam, where water is used for both irrigation and domestic supply, assessing depth-related water quality variations is essential. Parameters such as pH, EC, total dissolved solids (TDS), and DO are known to fluctuate with depth, affecting both crop health and human consumption. For instance, water at greater depths often exhibits lower DO and higher concentrations of dissolved minerals, which can influence soil salinity and crop productivity if used for irrigation. Additionally, deeper water layers may exhibit lower pH levels, which could impact on its palatability and suitability for household use, as well as its potential to cause pipe corrosion.

Seasonal fluctuations in water levels due to rainfall and evapotranspiration further complicate water quality management, with lower water levels in the dry season concentrating pollutants and increasing salinity (Naeem et al., 2023). Moreover, human activities around the dam, such as farming, livestock grazing, and waste disposal, introduce contaminants that may settle in deeper water layers, compounding water quality challenges (Bangira et al., 2023). Regular, depth-specific monitoring of water quality in Dan Zaria Dam is, therefore, critical to ensure the resource remains suitable for its intended uses.

II. METHODOLOGY



Map of Niger state showing the study area.



Plan showing spot height and depth with water sample points in Dan-Zaria Dam.

2.1 Study Area

The Dan Zaria Dam, located within the university school farm at the Gidan Kwanu Campus of the Federal University of Technology, Minna, is positioned between latitudes 4ºN and 14ºN. The dam's precise Universal Transverse Mercator (UTM) coordinates are N1,052,200 and E220,300. It features an average spot height of 212.845 meters and an average depth of 1.262 meters. The dam, constructed in 2005, serves multiple purposes, including irrigation and various domestic uses. Additionally, water samples were collected from designated points within the dam to assess its water quality. The strategic location of the dam within the university premises provides a valuable opportunity to study its impact on local water resources and its role in supporting agricultural activities and daily water needs of the campus community below show the Dan Zaria Dam.

Dan-Zaria Dam at Gidan-Kwano Campus. Federal University of Technology, Minna, Niger state, Nigeria

2.2 Water Sampling

To ensure the accuracy of the water sample analysis, each container was rinsed three times with the water sample to remove any impurities and prevent contamination. This step is crucial to avoid any alteration in the results due to residual water in the container (Chidiac et al., 2023). Four samples were collected from different points at the center of the reservoir, with each sample taken at 20-meter intervals. This systematic sampling method ensures a representative analysis of the water quality across the reservoir (Muniz & Oliveira-Filho, 2023).

2.3 Sample Identification

Each sample was identified by attaching a masking tape to the side of the bottle. The tape was labeled with essential information, including a code name, location, and date, to prevent any mix-up or misplacement of samples. Proper labeling is critical for maintaining the integrity of the samples and ensuring accurate tracking throughout the analysis process (Chidiac et al., 2023).

2.4 Physical and Chemical Analysis

The following procedures were used for the physical and chemical analysis of the water samples:

Determination of pH Value

The pH was measured using a standardized pH meter before analysis (Zheng et al., 2022; APHA, 2020).

Conductivity

Conductivity was measured using a conductivity meter to determine the concentration of mobile ions in the sample (Ellis et al., 2024).

Dissolved Oxygen (DO)

Dissolved oxygen was determined using the Winkler method, involving sequential reagent additions and titration (Zhu et al., 2022).

Calcium Hardness

Calcium hardness was determined by titrating with EDTA in the presence of sodium hydroxide and murexide indicator (Krishnamoorthy et al., 2023).

and calculating

Calcium (mg/l) $= \frac{T \times 400.5 \times 1.05}{V}$

where T= volume of titrant (ml) and V= volume of sample an

Calcium hardness (mg/l, *as* $CaCO_3$) $= \frac{T \times 1000 \times 1.05}{V}$

where (T) is the volume of titrant (ml) and (V) is the volume of the sample.

Total Dissolved Solids (TDS)

TDS was determined by evaporating the filtered sample and calculating the residue weight (Dewangan et al., 2023).

calculating TDS (mg/l) $= \frac{(A-B)}{V} \times 100$,

where (A) is the final weight of the evaporating dish, (B) is the initial weight of the evaporating dish, and (V) is the volume of the sample taken.

Alkalinity

Alkalinity was determined by titration with sulfuric acid using phenolphthalein and methyl orange as indicators (Khanjani et al., 2024).

Chloride Ion (Cl^-)

Chloride concentration was determined by titration with silver nitrate, using potassium chromate as an indicator (Xue et al., 2023). calculated using the formula: Chloride (mg/l) was calculated using the formula.

Chloride (mg/l) $= \frac{V \times N \times 35.457}{Vs} \times 1000$, Where V=titre value; N=normality of $AgNO_3$ (0.02) and VS=volume of sample used.

Nitrate (NO_3^-)

Nitrate concentration was measured using a spectrophotometer after adding nitrate reagents to the sample (Zazouli et al., 2024).

Magnesium (Mg^{2+})

Magnesium concentration was determined using EDTA titration after neutralizing the sample with NH_3 and HCl solutions (Jamroen et al., 2023; WHO, 2021).

Manganese (Mn^{2+})

The manganese color close was inserted into a Hellinge comparator, and the reading was taken in mg/l (Jamroen et al., 2023; WHO, 2021).

Zinc (Zn^{2+})

concentration in water was determined by filtering samples, acidifying with HNO_3, and using an atomic absorption spectrophotometer at 213.9 nm, with concentrations calculated from a calibration curve (APHA, 2020; Sahreen *et al.*, 2022; Altahaan *et al.*, 2024).

Iron (Fe^{2+})

Iron concentration was measured using thiocyanate to develop color, compared with a standard disc (Biswas et al., 2023; EPA, 2022).

III. RESULTS AND DISCUSSION

3.1 Discussion of the Result

The Nigerian Standard for Drinking Water Quality (NSDWQ) specifies the minimum criteria for water quality in public water supplies across the country. These standards are designed to protect public health and promote community well-being (Standards Organisation of Nigeria, 2015). Given the continuous development of new chemicals and the evolving understanding of the relationship between water quality and health, these standards are subject to regular review and updates (Standards Organisation of Nigeria, 2015).

According to the NSDWQ, potable water should be free from organisms of fecal origin, coliform bacteria, and harmful chemicals or substances that cause unpleasant taste, odor, or color (Standards Organisation of Nigeria, 2015). The results from the laboratory were statistically analysed using descriptive analysis for the physiochemical parameters such as mean, standard deviation, standard error, Lower bound, Upper bound, minimum, maximum, and post hoc test on Homogeneous Subsets were measured in comparison with the standards of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) and depth of each point in Dan Zaria Dam

Water depth (m)	Ph	Conductivity (μΩ/cm)	Dissolved Oxygen (DO) (mg/l)	Total Dissolved Solid (TDS) (mg/l)	Calcium Hardness (mg/l)	Alkalinity (mg/l)	Chloride (Cl^-) (mg/l)	Nitrate (NO_3^-) (mg/l)	Magnesium (Mg^{2+}) (mg/l)	Manganese (Mn^{2+}) (mg/l)	Zinc (Zn^{2+}) (mg/l)	Iron (Fe^{2+}) (mg/l)
0.65	7.15 ± 0.2^{c}	104.4 ± 0.81^{b}	5.67 ± 0.57^{a}	64.5 ± 0.91^{a}	48.0 ± 1.00^{b}	49.03 ± 0.15^{b}	21.85 ± 0.67^{d}	1.55 ± 0.09^{b}	16.72 ± 0.15^{c}	0.013 ± 0.002^{a}	0.29 ± 0.004^{c}	0.84 ± 0.04^{d}
0.84	6.47 ± 0.3^{b}	108.23 ± 0.63^{c}	5.33 ± 1.15^{a}	66.67 ± 1.46^{b}	48.73 ± 0.85^{bc}	50.80 ± 0.75^{c}	17.98 ± 0.19^{b}	2.38 ± 0.04^{c}	17.32 ± 0.64^{d}	0.083 ± 0.007^{b}	0.10 ± 0.003^{a}	0.61 ± 0.009^{b}
1.60	5.66 ± 0.09^{a}	126.0 ± 1.4^{e}	7.3 ± 1.15^{b}	73.69 ± 0.38^{c}	31.26 ± 0.50^{a}	50.33 ± 0.75^{c}	21.05 ± 0.48^{c}	1.58 ± 0.03^{b}	12.69 ± 0.18^{b}	0.094 ± 0.003^{c}	0.12 ± 0.002^{b}	0.67 ± 0.05^{c}
1.90	5.69 ± 0.19^{a}	120.27 ± 0.72^{d}	5.33 ± 0.57^{a}	73.48 ± 0.32^{c}	49.43 ± 0.50^{c}	46.70 ± 0.65^{a}	16.65 ± 0.40^{a}	1.26 ± 0.06^{a}	17.60 ± 0.18^{d}	0.095 ± 0.001^{c}	0.10 ± 0.002^{a}	0.92 ± 0.01^{e}
FAO	8.5 ± 0.00^{d}	20.0 ± 0.00^{a}	7.50 ± 0.00^{a}	2000 ± 0.00^{e}	80.00 ± 0.00^{e}	150.00 ± 0.00^{d}	150.00 ± 0.00^{e}	100.00 ± 0.00^{e}	120.00 ± 0.00^{a}	0.2 ± 0.00^{d}	2.00 ± 0.00^{d}	0.3 ± 0.00^{a}
WHO	9.2 ± 0.00^{e}	20.0 ± 0.00^{a}	7.50 ± 0.00^{a}	1000 ± 0.00^{d}	75.00 ± 0.00^{d}	500.00 ± 0.00^{e}	250.00 ± 0.00^{f}	10.00 ± 0.00^{d}	150.00 ± 0.00^{e}	0.05 ± 0.00^{e}	5.00 ± 0.00^{e}	0.3 ± 0.00^{a}

The table above contains water quality parameters for different water depths in the Dan Zaria Dam, along with reference values from FAO and WHO guidelines. The superscript letters (e.g., aaa, bbb, ccc) indicate homogeneous subsets, which are typically used in posthoc statistical analysis to group means that are not significantly different from each other which is interpreted as follows:

pH:

The pH at a water depth of 0.65 m is significantly higher than at depths of 0.84 m, 1.60 m, and 1.90 m. However, the pH values at depths of 1.60 m and 1.90 m are not significantly different from each other. This suggests that pH decreases with depth. All measured pH values are below the FAO and WHO guidelines. The drop in pH may indicate changes in water chemistry at different depths, possibly due to decomposition processes or lower oxygen levels in deeper water (Saalidong., *et al* 2022; Ogarekpe., *et al* 2023; Gemeda., *et al* 2024).

Conductivity (μΩ/cm):
Conductivity increases with depth, with the highest value observed at 1.60 m, which is significantly different from other depths such as 0.65 m, 0.84 m, 1.90 m respectively. However, the conductivity values at all depths are far above the FAO and WHO recommended values, indicating higher levels of dissolved ions. This suggests possible pollution or mineralization in the water. (Cong-Thi., *at al* 2024; Gemeda., *et al* 2024).

Dissolved Oxygen (DO) (mg/l):
The dissolved oxygen (DO) level at a water depth of 1.60 m is significantly higher (7.3 ± 1.15 mg/L) than at depths of 0.65 m (5.67 ± 0.57 mg/L). However, the DO levels at depths of 1.60 m and 1.90 m are not significantly different from each other. This suggests that DO decreases with depth. All measured DO values at shallower depths are below the FAO and WHO guidelines of 7.5 mg/L. The drop in DO may indicate oxygen depletion due to the decomposition of organic matter in the shallower layers (Jaeger, 2022; Fardowsa., 2024).

Total Dissolved Solids (TDS) (mg/l):
The Total Dissolved Solids (TDS) values at a water depth of 1.60 m and 1.90 m are significantly higher than at depths of 0.65 m and 0.84 m. However, statistically TDS values at depths of 1.60 m and 1.90 m are not significantly different from each other. This suggests that TDS increases with depth. All measured TDS values are far below the FAO and WHO maximum limits. The upward trend in TDS with depth may reflect higher concentrations of dissolved minerals and salts at deeper levels. (Adjovu., *et al* 2023; Doumtoudjinodji., *et al* 2024).

Calcium Hardness (mg/l):
At a depth of 1.60 m, the calcium hardness is notably lower compared to other depths. However, at a depth of 0.84 m, there is no significant difference between a depth of 0.65 m and 1.90 m, where the values are relatively consistent. All measurements fall below the FAO and WHO guidelines, indicating that the water is generally soft in calcium content across all depths. (Andaryani., *et al* 2023; Eid., *et al* 2024).

Alkalinity (mg/l):
At a depth of 1.90 m, the alkalinity is significantly lower compared to other depths. The homogeneous subset shows that the depths of 0.84 m and 1.60 m have no significant difference from each other. The alkalinity is well below the FAO and WHO standards, indicating low buffering capacity and potential vulnerability to acidification (Changsheng., *et al* 2022; Guo., *et al* 2024).

Chloride (Cl-) (mg/l):
At a depth of 0.65 m, chloride levels are the highest, followed closely by those at 1.60 m. Statistically, the superscript indicates significant differences across depths. All measured chloride levels are well within the FAO and WHO guidelines, indicating no significant chloride contamination. (Semar., *et al* 2024; Zhang., *et al* 2024).

Nitrate (NO3-) (mg/l):
The highest nitrate concentration was observed at a depth of 0.84 m, showing a significant difference compared to other depths. However, the nitrate levels at depths of 0.65 m and 1.60 m did not show significant differences from each other. Overall, the nitrate levels are well below the FAO and WHO recommended limits, indicating minimal nitrate pollution (Choudhary., *et al* 2022; Odone., *et al* 2024).

Magnesium (Mg2+) (mg/l):
Magnesium levels decrease significantly with depth, with the highest concentration observed at 0.65 m and the lowest at 1.60 m. However, the magnesium levels at depths of 0.84 m and 1.90 m do not show significant differences from each other. All values are within the acceptable limits set by FAO and WHO standards (Peng., *et al* 2023; Tauseef Azam., *et al* 2024).

Manganese (Mn2+) (mg/l):
Manganese levels increase significantly with depth, with the highest concentration observed at 1.60 m. There are no significant statistical differences between the depths of 1.60 m and 1.90 m. Although all values are within the acceptable limits set by FAO and WHO standards, the increase at depth might indicate

mobilization of manganese from sediments. (Friedman., et al 2024; Ravindiran., *et al* 2024).

Zinc (Zn2+) (mg/l):
Zinc concentrations are highest at a depth of 0.65 m and decrease with increasing depth. However, at the subset depths of 0.84 meters and 1.90 m, there are no significant statistical differences between them. All values are below the FAO and WHO standards, and the grouping shows that surface water 0.65 m has significantly higher zinc concentrations than deeper water (Price., *et al* 2023; Sugino., *et al* 2023).

Iron (Fe2+) (mg/l):
Iron concentrations are highest at a depth of 1.90 m, exceeding WHO limits. Elevated iron levels at deeper depths may indicate mineral leaching from the dam's bed. However, the homogeneous subsets show significant differences across the depths, with higher iron levels in the deepest water compared to the shallow water. (Christenson, 2024; Tammeorg., *et al* 2024).

CONCLUSION

The water quality assessment of Dan Zaria Dam reveals significant depth-dependent variations, impacting both irrigation and domestic use. Key findings include increased conductivity, TDS, and iron concentrations with depth, indicating higher mineral content in deeper layers, which poses challenges for drinking and irrigation. Iron levels at 1.90 meters exceed WHO limits, necessitating treatment or selective extraction. Manganese levels also surpass recommended guidelines at certain depths, requiring continuous monitoring. Shallower depths are more suitable for domestic and agricultural use, with lower conductivity, TDS, and acceptable nutrient levels. Surface water pH aligns with FAO and WHO standards, though zinc and chloride levels, while permissible, need monitoring. For irrigation, water quality is generally acceptable across all depths, but increasing salinity at greater depths could affect soil and crop yields if unmanaged. Recommendations include prioritizing shallower water for domestic use due to lower iron content, monitoring deeper water for salinity and iron to prevent long-term agricultural impacts, and regular water quality monitoring along with integrated water resource management (IWRM) strategies to address emerging challenges from mineralization at greater depths. This study highlights the need for adaptive water management strategies to ensure sustainable water resources for communities relying on the dam.

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