*UJMR, Vol. 8 No. 1, June, 2023, pp 161-170.* *E-ISSN: 2814 – 1822; P-ISSN: 2616 – 0668*

https://doi.org/10.47430/ujmr.2381.020

**Received:** 17 June 2023 **Accepted:** 27 June 2023

# A Comparative Seasonal Study on the Physicochemical Properties of Open Well Waters in Kura District, Kano State, Nigeria

**Mujahid Ajah Matazu[1], [2]Abdulhakim Hassan Wagini, [1] Iliya Garkuwa Muhammad, [1]Amina Shehu Hambali, [3]Usman Bello, [4]Binta Umar Mohammad, [1]Hadiza Zakari Mustapha and [5]Abdullahi Abubakar**

[1]Department of Environmental Management, Bayero University Kano
[2]College of Hydrology and Water Resources, Hohai University, Nanjing, Jiangsu, China
[3]Department of Biochemistry, Umaru Musa Yaradua University, Katsina
[4]Department of Chemistry, Kano State College of Art, Science and Remedial Studies
[5]Department of Physic, Federal College of Education, Gidan Mahadi, Sokoto
*Corresponding Author's Email Address: mujahidaudi2023@gmail.com

## *Abstract*

*Water is one of the most important compounds on earth and is vital to the survival of any organism. The aim of the study was to assess the seasonal variation of the physico-chemical properties of open well water in Kura District, Kano State, Nigeria. A total of ten (10) water samples were collected randomly from five locations in Kura district, namely Dan Hassan, Karfi, Dalili, Gundutse, and Kosawa. The samples were analysed for pH, turbidity, conductivity, nitrate, calcium, chloride, and total dissolved solids, following the standard of American Public Health Association. Average values of physicochemical properties during the dry season were as follows: pH was 5.5 to 9, electrical conductivity was 340 to 456 S/cm, turbidity was 4.6 to 7 NTU, total dissolved solids was 400 to 420 mg/l, nitrate was 0.6 to 2.15 mg/l, chloride was 259 to 590 mg/l, and calcium was 8 to 25 mg/l. The average values for various physicochemical properties in the dry season were recorded as follows: pH ranged from 5.8 to 6.4, electrical conductivity ranged from 89 to 420 S/cm, turbidity ranged from 3.4 to 6.4 NTU, total dissolved solids ranged from 380 to 720 mg/l, nitrate ranged from 0.5 to 1.8 mg/l, chloride ranged from 8 to 14 mg/l, and calcium ranged from 160 to 450 mg/l. The results of the paired sample t-test indicated that there was no significant difference in concentration between the wet and dry seasons for pH, conductivity, turbidity, and nitrate* ($p < 0.05$)*. However, concentrations of calcium, chloride, and TDS varied significantly between wet and dry seasons. Given that the dry season that was examined exceeded the WHO threshold limits for pH and turbidity, it is recommended to implement suitable water treatment techniques such as coagulation, sedimentation, and filtration in order to reduce turbidity and regulate pH levels in order to meet the required standards. Further research is necessary to investigate the presence of alternative contaminants in open well water, like heavy metals, microbial contaminants, or organic pollutants.*

**Keywords:** Seasonal Study, Open well waters, Physico-chemical, water quality and Kura district

## INTRODUCTION

Water plays a vital role in a number of industries, including industry, agriculture, and others, and is an essential requirement for human life. It is also a highly vulnerable component of the environment. Over the past few decades, rapid industrialization and population growth have substantially increased the demand for freshwater (Med Crave, 2017). Access to safe drinking water is not only a fundamental human right but also vital for maintaining good health. In order to achieve optimal health and development, a continuous supply of safe drinking water is imperative for any country's population (Miner *et al.*, 2016; Fatima *et al.*, 2020). Unfortunately, a large part of the world's population does not have adequate access to safe water, and approximately 884 million people are faced with this problem. Over one third of this population lives in Sub-Saharan Africa (Kassie and Hayelom, 2017; Fatima and Kollegen, 2020).

Physical, chemical, and biological parameters in the water and sediments typically determine surface and groundwater quality (Cherotich und Kollegen, 2023). These parameters show significant variation according to seasonal changes and the type of pollution (Kithiia, 2012;

UN/WWAP in Jahr 2019; Kerich und Fidelis in Jahr 2020; Cherotich and Kollegen, 2022). Physical and chemical pollutants change the quality of receiving water bodies, contributing to water quality deterioration (Bairu *et al.*, 2022).

Chemical contaminants in drinking water are a major concern worldwide, and they pose a risk to human health. They are frequently found in the vicinity of canyons, where waste products negatively affect the water quality (Meseret, 2012; Arasaretnam *et al.*, 2018).

According to the World Health Organization (WHO, 2003), poor sanitation, contaminated water, or a lack of water account for up to 80 per cent of all diseases worldwide. A review of 28 studies conducted by the World Bank revealed a correlation between the quality and quantity of available water and sanitation and the incidence of specific waterborne, washable, and sanitation-related diseases (Ramesh *et al.*, 2015; Arasaretnam *et al.*, 2018). Longe and Balogun (2010) reported that a significant number of Nigerians still rely on shallow wells, while the majority obtain their domestic and drinking water from ponds and streams. Approximately 40 million Nigerians are at risk of waterborne diseases like cholera, dysentery, diarrhea, and typhoid because they depend on alternative water sources (Adelegan, 2004; Orubu, 2006; WHO, 2017). The prevalence of these diseases further burdens Nigeria's inadequate healthcare services, leading to a severe economic downturn for both the struggling health system and the predominantly impoverished population (Okonkwo *et al.*, 2014).

Nigeria also faces challenges in managing and developing groundwater resources, with resource management lagging behind the pace of development and exploitation often being poorly regulated. The current state of groundwater resources is unsatisfactory and requires significant changes (Nwankwoala, 2011). Groundwater withdrawals in arid regions of Nigeria account for 20% of the total water use, showing the importance of these resources. Researchers have directed their attention towards the pollution problem and the quality of these internationally valuable resources, making it a relevant topic in groundwater resource management (Pradhan, 2009; Shirazi *et al.*, 2012; Manap *et al.*, 2013; Saidu *et al.*, 2021). In Kano metropolis, several studies have assessed groundwater quality from boreholes (Bichi, 2000; Abdullah *et al.*, 2008; Akan *et al.*, 2009; Bolagun *et al.*, 2021; Saadu *et al.*, 2021), but little attention has been given to the water quality of open wells in rural areas of Kano State. Consequently, this study aims to comparatively analysed the physicochemical properties of selected open wells waters in selected towns of Kura District, Kano State, Nigeria.

## MATERIALS AND METHODS

### The Study Area

The study was conducted in selected towns of Kura districts, Kura Local Government, Kano State, Nigeria. Kura is located at 11°46'17" E and 8°25'49" N (Figure 1). With a population of about 14,601 in 2006 (NPC, 2006), Kura's growth rate in 2006 was an estimated 3.6% by 2021, with an estimated population of 21416.86. Kura is known for its edible and herbal production. The dry season usually starts from October to April, with an average annual rainfall of 134.4 mm (Osang et al., 2013). The main business of the inhabitants is agriculture, and the main crops are rice, wheat, corn, millet, beans, tomatoes, sugarcane, and cabbage. The inhabitants are also into the production, processing and trading of locally produced rice.

### Research Materials

Each water sampling site's geographical coordinates were recorded using the GPS German 76 model. At these sampling points, water samples were taken in plastic bottles with secure lids. When collecting water from open wells, a ladle or scoop was used to ensure that the scoop did not come into contact with the sides of the well or any other surface that could contaminate the sample.

### Sampling sites selection

For this study, well water samples were randomly collected from five different locations within and around the Kura district. These areas were labelled as A, B, C, D, and E, specifically Kosawa, Dalili, Karfi, Gundutse, and Dan Hassan. Consequently, five sampling sites were selected, as can be observed in Figure 1.

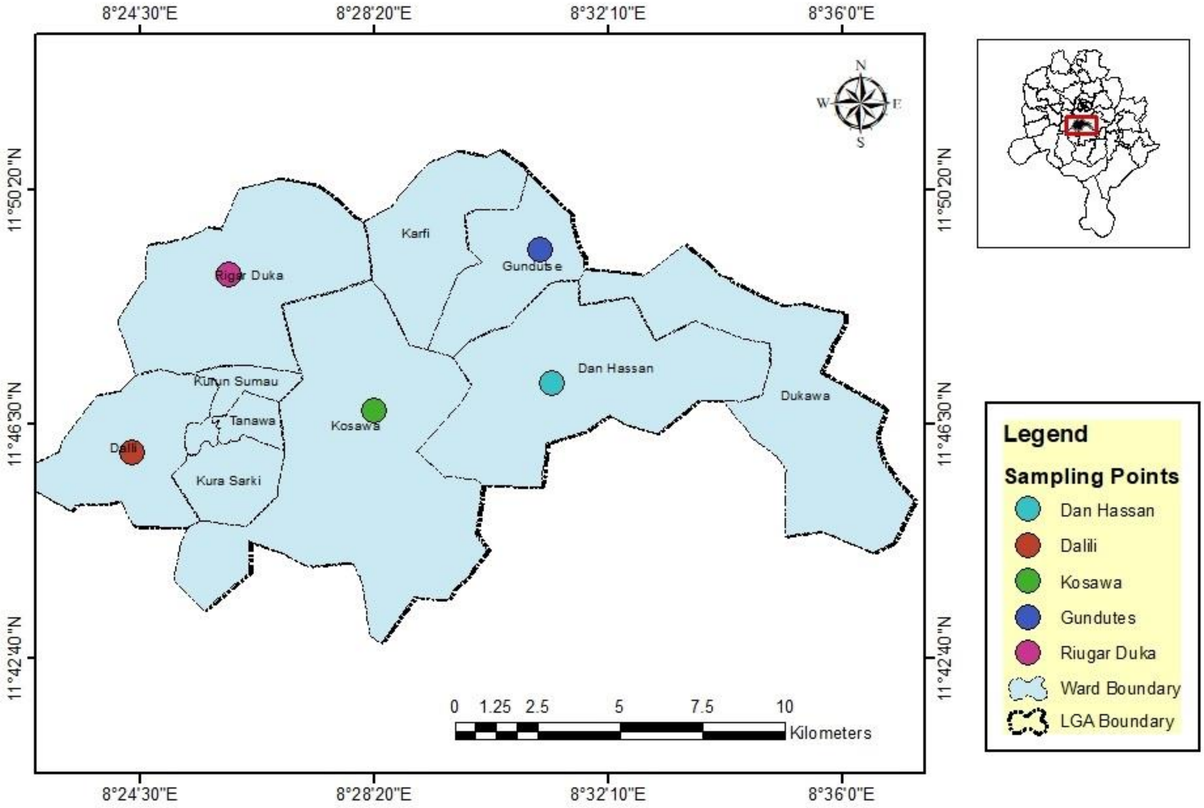

**Figure 1 Map showing the Sampling Sites**

**Sample Collection**

Ten (10) water samples were taken from five selected wells located in different towns in Kura district (Figure 1). The wells were categorized as A, B, C, D, and E. Samples were collected in August and November 2022, which represent the wet and dry seasons respectively. Plastic sample bottles were rinsed with distilled water and then filled with a small amount of the corresponding water sample to ensure proper collection. These bottles were placed in a cooler with an ice pack for transportation to the laboratory and sealed tightly to prevent air from entering.

**Physicochemical Analyses**

In the laboratory, the water samples were analysed for various physico-chemical parameters, including pH, turbidity (NTU), total dissolved solids (TDS), electrical conductivity (EC), nitrate ($NO_3$), chloride ($Cl^-$), and calcium ions concentration. The pH level was measured using a HANNA pH meter (Model HI 28129). Turbidity was determined through the nephelometric method employing a HACH 2100AN turbid meter (APHA, 2005). Total dissolved solids were assessed using the gravimetric method described by Kazi *et al.* (2009). The electrical conductivity was measured using a Jenway 4510 conductivity meter (Jenway, 2017). Until a stable reading was obtained and recorded, the meter probe was immersed into the water sample container. Spectroscopic analysis using the HACH DR/2010 was performed to determine the concentrations of major ions, such as nitrates ($NO_3$-) and chlorides ($Cl^-$) (APHA, 2017). After the digital Jenway 3505 pH meter was calibrated using standard solutions of pH 4 and 10.0, the concentrations of calcium ions were determined using a flame spectrometer (APHA, 2017).

**Statistical Analyses**

Average wet and dry season concentrations were calculated using IBM SPSS version 20, a statistical program for social scientists. In addition, the paired t-test was used to investigate the significant differences in physicochemical parameter concentrations during the dry and wet seasons.

## RESULTS AND DISCUSSION

Figure 2-5 presents the results for all the physico-chemical parameters (pH, EC, turbidity, chloride, calcium ions, TDS, and nitrate) for both dry and wet seasons in the studied locations.

**pH**

The pH values across all sampling points ranged from strongly acidic to alkaline. Specifically, Rugar Duka exhibited a higher pH of 9.0 during the dry season, while Gundutse recorded the lowest pH of 6.0, also during the dry season.

Except for the sample from Rugar Duka, the average concentration in five wells fell within the WHO-recommended range of 6.5-8.5 for drinking water in 2021. This finding contradicts reports by others in similar studies (Adebayo *et al.*, 2022). It is important to note that variations in the optimal pH range can influence the toxicity of toxins in aquatic environments. Previous studies by Okonnkwo *et al.* in 2008, Chikezie *et al.* in 2018, and Adebayo *et al.* in 2022 have highlighted this potential impact

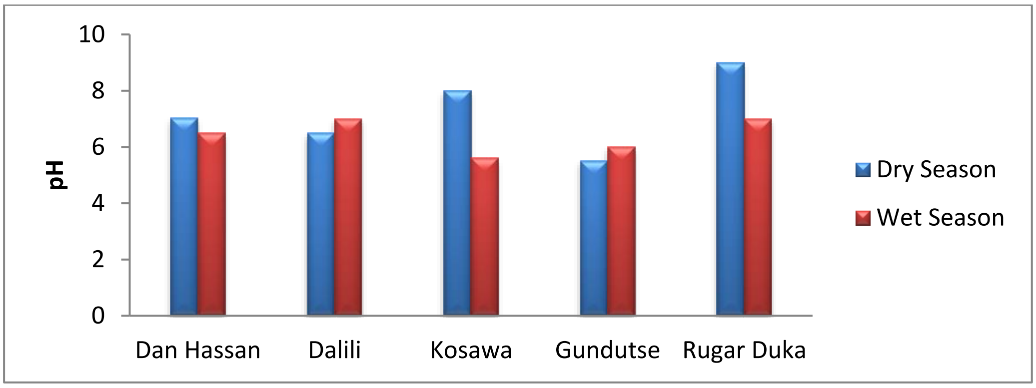

**Figure 2: pH values across the study locations**

### Turbidity

Turbidity values in the study area varied between 4.0 and 7.03 NTU (Figure 3). The highest average turbidity value (7.03 NTU) was recorded at Dan Hassan site during the dry season and the lowest average turbidity value (5.0 NTU) was recorded at Gundutse during the dry season. This contradicts the results of Nura *et al.* (2020) who reported that turbidity values for water samples taken at Metropolis Kano ranged from 1.05 NTU to 2.87 NTU. In another study done in Ghana, Schafer *et al.*,(2010) found that the turbidity of most well waters across Ghana ranged from 2 to 266 NTU.

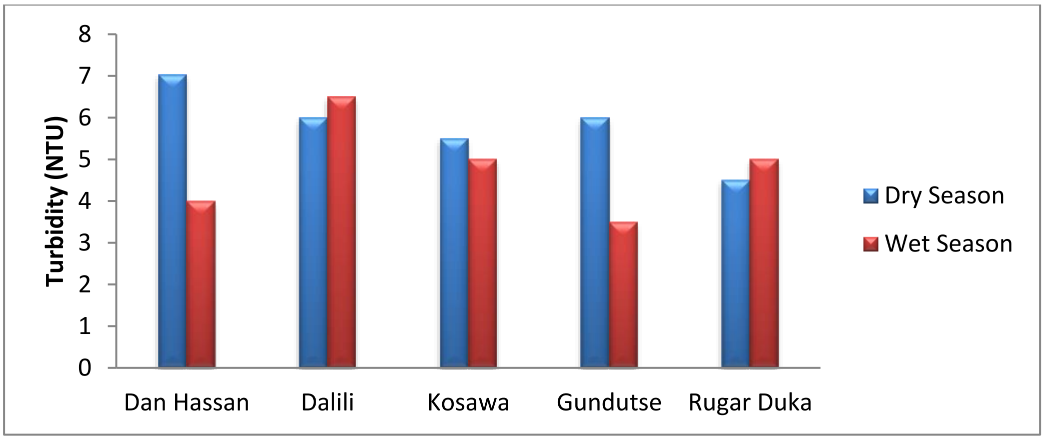

**Figure 2: Turbidity Values of Well Water sample across Sample Site**

### Conductivity

The conductivity values of well water samples obtained from the study area are shown in Figure 4. During the wet season Rugar Duka showed the highest mean EC value (457.02), while Dalili showed the lowest mean concentration (89) during the same period. The average EC value measured for the water samples conformed to the WHO standard (2021) of 1000 µS/cm. The reduced conductivity recorded in this investigation may be attributed to either the inherent salinity of the water in the study area or the leaching of rocky reservoirs where water accumulates (Nouayti *et al.*, 2015; Malek *et al.*, 2016).

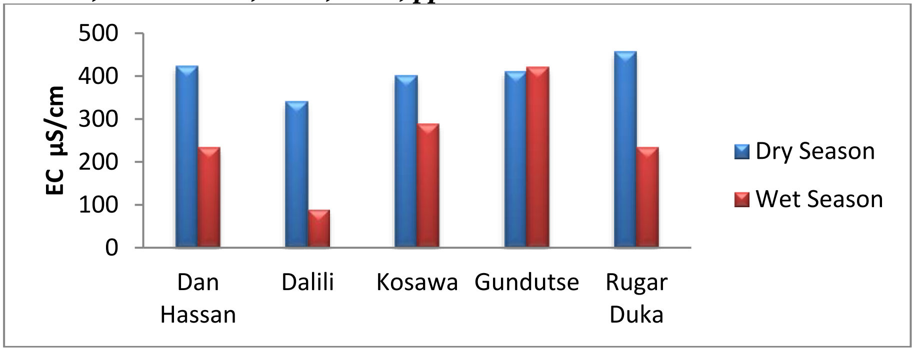

**Figure 4: EC Values of Well Water samples across sampling Sites**

### Chloride ions

In both wet and dry seasons, chloride ion levels fluctuate from 7.0 to 25.35 mg/L, as shown in Figure 5. These concentrations are significantly below the safety limit of 250 mg/L set by the World Health Organization. Among the samples collected, Kosawa exhibited the highest chloride ion concentration (25.35 mg/L), while Gundutse displayed the lowest levels. This research contradicts the findings of Addo *et al.* (2014) in Ghana, who reported chloride concentrations ranging from 155.95 to 165.95 mg/L in groundwater near cement plants. Chloride ions, an important inorganic anion present in natural waters, serve as an indicator of pollution (Makhoukh *et al.,* 2011; Malek *et al.,* 2016). Their presence in groundwater may suggest anthropogenic contamination, as they can be traced back to urine and personal care products (Malek *et al.,* 2016).

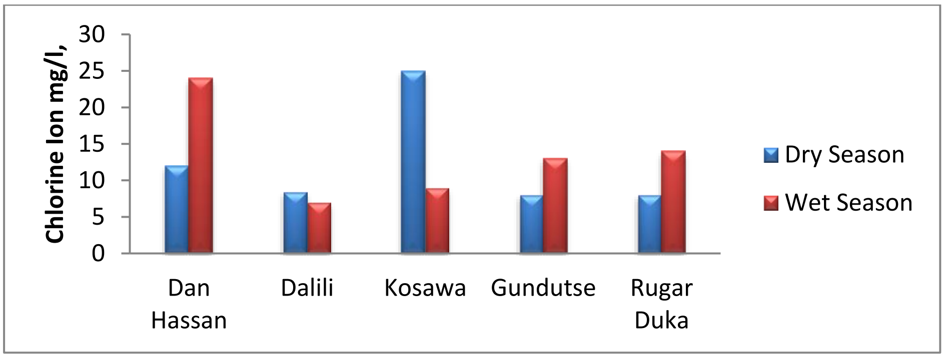

**Figure 5: Chloride ions concentration at Sample Sites**

### Total Dissolve Solid (TDS)

The TDS levels measured at the current sampling point range from 374.03 mg/l to 717.3 mg/l. Dan Hassan had the lowest TDS concentration of 374.03 mg/l, while Dalili had the highest TDS concentration of 717.3 mg/l in a well water sample (Figure 6). These results show higher TDS values than those reported by Baraka *et al.*,(2022), who recorded TDS values between 18 and 55 for certain boreholes at the Balaton Centre, Kenya. As noted by Ketata *et al.* (2011) and Baraka *et al.* (2022), significant variations in TDS concentrations across regions are caused by geological variations in mineral solubility.

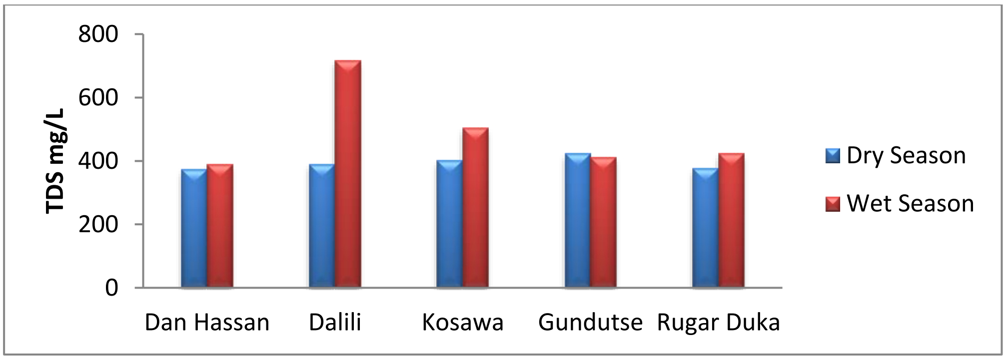

**Figure 6: TDS Concentration for Different Sampling Sites**

**Nitrate**

According to Figure 7, the Gundutse sampling site recorded the highest nitrate value (2.15 mg/kg) during the dry season, while the Kosawa sampling site recorded the lowest nitrate value during the wet season (0.79 mg/kg). The results of this study indicate significantly lower nitrate levels compared to the findings reported by Saidu *et al.,*(2021), who reported nitrate levels ranging from 1 to 12 mg/kg. The World Health Organization has set a maximum contamination level (MCL) of 1 mg/l for nitrite and nitrogen in water. According to Addo *et al.,*(2011) high nitrite levels in water are an important indicator of biological contamination due to the presence of nitrogen compounds.

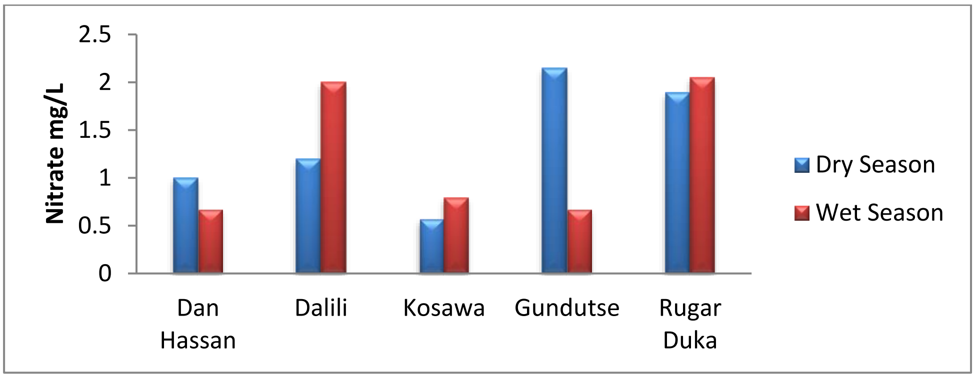

**Figure 7: Nitrate ($NO_3$-) concentrations for Different Sampling Sites**

**Calcium ions Concentrations**

Figure 8 displays the calcium concentration span ranging from 374.03 mg/L to 717.3 mg/L. During the rainy season, Kosawa documented the highest calcium concentration at 456 mg/L, while water samples collected on the outskirts of Gundutse recorded the highest calcium concentration at 717.3 mg/L. In comparison to Yani *et al.'s* (2019) findings, which reported an average groundwater calcium content of 126.75 mg/liter (classified as high), the results of this study demonstrate relatively higher calcium levels.

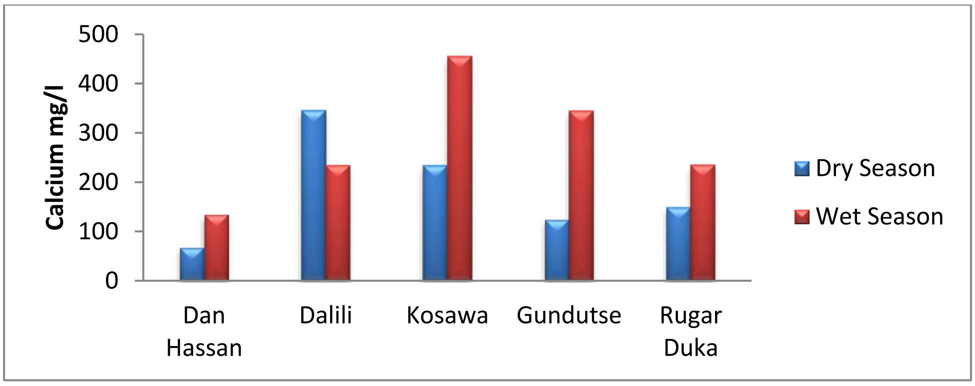

**Figure 8 Calcium Concentrations at the Sample Sites**

According to the World Health Organization (WHO) Guidelines for Drinking Water Quality (WHO 2011), the average calcium content in drinking water is 75 mg/L, with a maximum permissible limit of 200 mg/L. Water containing calcium levels above the upper limit can cause digestive disorders, kidney disease, bladder stones, and urinary tract obstruction in humans.

**Paired T-test**

A paired-sample t-test was used to show the seasonal differences in concentrations between wet and dry seasons in five groups of open-well water samples (A, B, C, D, and E), as shown in Table 3.

**Table 3: Paired Sample t-test for Difference in Physico-chemical Concentration between Wet and Dry Seasons**

| Parameters | Season | Mean | N | SD | t- cal. | P<_0.05 | Remark |
|---|---|---|---|---|---|---|---|
| pH | Dry Season | 7.00 | 5 | 1.32 | 3.24 | 1.41 | NS |
| | Wet Season | 6.42 | 5 | 1.27 | 1.27 | | |
| Turbidity | Dry Season | 5.90 | 5 | 1.18 | 4.400 | 1.41 | NS |
| | Wet Season | 4.64 | 5 | 1.07 | | | |
| Conductivity | Dry Season | 400 | 5 | 10.00 | 6.87 | 1.41 | NS |
| | Wet Season | 246 | 5 | 7.84 | | | |
| Nitrate | Dry Season | 1.33 | 5 | 0.57 | 3.451 | 1.41 | NS |
| | Wet Season | 1.08 | 5 | 0.43 | | | |
| Calcium | Dry Season | 180.0 | 5 | 6.70 | 1.48 | 1.41 | Sig |
| | Wet Season | 246.0 | 5 | 7.84 | | | |
| Chloride | Dry Season | 12.2 | 5 | 1.74 | 1.57 | 1.41 | Sig |
| | Wet Season | 14.0 | 5 | 1.80 | | | |
| TDS | Dry Season | 388.0 | 5 | 9.84 | 1.43 | 1.41 | Sig |
| | Wet Season | 484.0 | 5 | 11.0 | | | |

**Sources: SPSS Analysis (2023)**

The finding reveals that most parameters, including pH, turbidity, conductivity, and nitrate, have higher mean values during the dry season (Table 3). On the other hand, parameters such as chloride, total dissolved solids (TDS), and calcium have higher mean values during the wet season. These findings contradict a previous study by Cherotich *et al*., (2023) in Kenya, which reported higher TDS levels in the wet season compared to the dry season and an increasing trend from upstream to downstream during the wet season. In addition, the paired student t-test shows that parameters such as pH, conductivity, nitrate, and turbidity have calculated values (t calculated) lower than the table values at p less than 0.05, indicating that there is no significant concentration difference between the wet and dry seasons. But parameters like TDS, calcium, and chloride have calculated t values higher than table values, indicating a big difference in concentration between wet and dry seasons. Furthermore, the paired student t-test shows that parameters such as pH, conductivity, nitrate, and turbidity have calculated values (t) lower than the table values at p less than 0.05, indicating that there is no significant concentration difference between the wet and dry seasons.

## CONCLUSION AND RECOMMENDATION

The finding of the study revealed that average values for the physicochemical properties in the dry season were as follows: pH ranged from 5.5 to 9, electrical conductivity ranged from 340 to 456 S/cm, turbidity ranged from 4.6 to 7 NTU, total dissolved solids ranged from 400 to 420 mg/l, nitrate ranged from 0.6 to 2.15 mg/l, chloride ranged from 259 to 590 mg/l, and calcium ranged from 8 to 25 mg/l. The average values during the rainy season were as follows. pH 5.8 to 6.4, conductivity 89 to 420 S/cm, turbidity 3.4 to 6.4 NTU, total dissolved solids 380 to 720 mg/l, nitrates 0.5 to 1.8 mg/l, chlorides 3.4 to 6.4 NTU 8-14 mg/l, calcium content 160-450 mg/l. Paired-sample t-tests revealed that pH, conductivity, turbidity, and nitrate concentrations were not significantly different between wet and dry seasons ($p<0.05$). However, calcium, chloride, and TDS showed large differences in concentrations between the wet and dry seasons. Given that the dry season exceeds WHO limits for pH and turbidity, appropriate water treatment techniques such as flocculation, sedimentation and filtration should be introduced to reduce turbidity and adjust pH to levels that meet the required standards.

## REFERENCES

Abdullahi, B.A., Kawo, A.H. and Na"aliya, J. (2008). Observations on the Seasonal and Spatial Variations in Water Quality and Ecological Implications of Challawa River, Nigeria. Basic. Res. Commun., 20(3):121-126.

Adebayo K. R., Adesina I. K. and Adeniji F. A. (2022). Investigation of water qualities of open wells located at fuel stations within Ilorin metropolitan communities, Nigeria Journal of Research in Forestry, Wildlife & Environment, 14(2): 31 - 38

Addo, M & Darko, Emmanuel & Gordon, Christopher & Nyarko, B.J.B.. (2013). Water quality analysis and human health risk assessment of groundwater from open-wells in the vicinity of a cement factory at Akporkloe, South eastern Ghana. E-Journal of Science and Technology. Volume, 4 pp 15-30.

Akan, J. C., Ogugbuaja, V. O., Abdulrahman, F. I. and Ayodele, J. T. (2009). Pollutant Levels in Effluent Samples from Tanneries and Textiles of Kano Industrial Areas, Nigeria. Global Journal of Pure and Applied Sciences, 15, pp. 3-4.[Crossref]

Arasaretnam, S. Prasadini, H.R.P. and Venujah, K.(2018): Assessment of Open well Water Quality around Puttalam District, Sri Lanka, International Journal of Advances in Scientific Research and Engineering (ijasre), Volume 4, Issue 12, pp. 225-232. [Crossref]

American Public Health Association (APHA), (2005): Standard Methods for Examination of 560 Water American Public Health Association (APHA), Standard Methods for Examination of Water, Washington, D.C.

American Public Health Association (APHA): 2017: Standard Methods for the Examination of Water and Wastewater, 23rd Edition.

Bairu, M.W. Aremu, A.O. and Van Staden, A.O. (2011): "Soma clonal variation in plants: causes and detection methods," Plant Growth Regulation, 63(2), pp.147-173. [Crossref]

Balogun, David & Okewu, Augustine & Maikano, A & Ibrahim, A & Abdullahi, Muhammed. (2021). Groundwater Quality Assessment of Kano Metropolis using Water Quality Index and Geospatial Techniques. Volume 10. Page 19-27.

Baraka, A , Ogweyo, G. Njung'e , I and Abuto, E (2022): An Assessment on Water Quality (TDS, EC, ORP, and PH) of Selected Boreholes in Baraton Centre, Qual Healthcare Eco 5(1): pp 243-259. [Crossref]

Bichi, M. H. (2000). Surface Water Quality in the Kano industrial Environment. Issues in Land Administration and Development in Northern Nigeria, Proceedings of the National Workshop on Land Administration and Development in Northern Nigeria, Department of Geography Bayero University, Kano, pp. 305-313.

Cherotich S., Abong'o D. A., and Onyatta J. O. (2023): Assessing the seasonal changes on physicochemical parameters and major nutrient levels in water and sediments from Sulal River, Bureti Sub County, Kericho County, Kenya

Chikezie, A.O., Adedeji, M.A. and Isikwue,M.O.(2018). Prediction of soil wettingpattern for three soil types under dripirrigation. EPH - International Journal ofAgriculture and Environmental Research, 4(10):1-18. ISSN: 2208-2158.

Ezeribe, A. I., Oshieke, K. C., & Jauro, A. (2012). Physico-chemical properties of well water samples from some villages in Nigeria with cases of stained and mottled teeth. Science World Journal, 7(1), 1-8.

Fatima, G., Umar,S., Buhari, Y., Abdulazeez, A., Dabai, S.M. (2020): Bacteriological Quality Assessment of Water Sold in Plastic Jerry cans within Katsina Metropolis, Katsina State, Nigeria. UMYU Journal of Microbiology Research Volume 6 Number 2, December, 2021, pp 96 - 103[Crossref]

Galadima, A., Garba, Z. N., Leke, L., Almustapha, M. N. and Adam, I. K. (2011). Domestic water pollution among Local Communities in Nigeria-causes and consequences. European Journal of Scientific Research, 52(4), pp. 592-603. [Crossref]

Jenway. (2017). Jenway 4510 conductivity meter instruction manual. Jenway Scientific Instruments.

Kassie GG, Hayelom DH.(2017): Bacteriological quality of drinking water from source to point of use among rural communities of Fanta Woreda in North West, Ethiopia. African journal of microbiology research. 2017;11(26):1069-74. [Crossref]

Karthikeyan N, Saranya A, Shashikumar M.C (2013) Spatial Analysis of Groundwater Quality for Visudhunagar District, Tamil Nadu Using GIS. International Journal of Remote Sensing of Geoscience (IJRSG) 2(4): 23-30.

Ketata Rokbani M, Gueddari M, Bouhlila R (2011) Use of Geographic Information System and Index to Assess Groundwater Quality in El Khairat Deep AQUIFER. Iranica Journal of Energy of Environment 2(2): 133-144.

Kithiia, S. M. (2012). Water quality degradation trends in Kenya over the last decade. In: Voudouris K. and Voutsa D. Water

Quality Monitoring and Assessment, InTech, Rijeka, Croatia, pp. 509-560.

Longe, E.O. & Balogun M.R. 2010: Groundwater Quality Assessment nears a Municipal Landfill, Lagos, Nigeria. Research Journal of Applied Sciences, Engineering and Technology. 2(1), pp. 39-44.

Malek A., Kaholu M., Bouguerra H. 2019. Groundwater's physicochemical and bacteriological assessment: Case study of well water in the region of Sedrata, North-East of Algeria. Journal of Water and Land Development. No. 41 (IV-VI) p. 91-100.. **[**Crossref**]**

Manap, M. A., Sulaiman, W. N. A., Ramli, M. F., Pradhan, B. and Surip, N. (2013). AKnowledge-Driven GIS Modeling Technique for Groundwater Potential Mapping at theUpper Langat Basin, Malaysia. Arabian Journal of Geosciences, 6(5), pp. 1621-1637. **[**Crossref**]**

Makhoukh, M., Sbaa M., Berrahou A., Clooster M.V. (2011). Contribution à l'étude physico-chimique des eaux superficielles de l'oued Moulouya (Maroc oriental). [Contribution to the physico-chemical study of the surface water of oued Moulouya (oriental Morocco]. Larhyss Journal. Vol. 09 p. 149-169.

Meseret, B.A. (2012) "Assessment of Drinking Water Quality and Determinants of Household Portable Water Consumption in Simada District, Ethiopia," Cornell University, New York, USA.

Med Crave online: (2017). The importance of water and conscious use of water. International Journal of Humanities and Health, 5(1), 1-9. https://medcraveonline.com/IJH/the-importance-of-water-and-conscious-use-of-water.html

Miner CA, Dakhin AP, Al Z, Zaman M, Bimba J. Physical and Microbiological Quality of Drinking Water Sources in Gwafan Community, Plateau State,Nigeria. Pyrex Journal of Research in Environmental Studies. 2016;3(1):001-6.

Nwankwoala, H. O. (2011) An integrated approach to sustainable groundwater development and management in Nigeria, Journal of Geology and Mining Research Vol. 3(5), pp. 123-130.

Nura T, Datti Y, Dikko M. A., Imrana B. Suraj, A, Mudassir. Y.1 , Usman D.D. (2020): Analysis of some Physical and ChemicalParameters of Domestic Water (Borehole) I Kano Metropolis using Argentometric andSpectrophotometric Techniques, International Journal of Scientific & Engineering Research Volume 11, Issue 8, page 1546- 1558

Okonkwo, C. C., Ugwu, A. E., & Igwe, C. C. (2008). Assessment of physicochemical and bacteriological quality of water from selected boreholes in Nsukka metropolis, south eastern Nigeria. African Journal of Environmental Science and Technology, 2(10), 553-558.

Orubu, C.O. 2006: Water Resources, Environment and Sustainable Development in Nigeria. Journal of Human Ecology. 19(3), pp. 169-181. **[**Crossref**]**

Osang, J.E. Ewona, I.O. Obi, E.O. Udoimuk, A. B. & Kamgba, F.A. (2013). Analyses of radiation and rainfall pattern in Kano State-northern Nigeria (1978-2007). International Journal of Scientific and Engineering Research, 4(9), 971-984

Pradhan, B. (2009). Groundwater Potential Zonation for Basaltic Watersheds using Satelliteremote sensing data and GIS techniques. Open Geosciences, 1(1), pp. 120-129. **[**Crossref**]**

Ramesh, A., Blanchet, K., Ensink, J.H and Roberts, B (2015) " Evidence on the effectiveness of water, sanitation, and hygiene (WASH) interventions on health outcomes in humanitarian crises: a systematic review," PLoS One, , 10(9), e0124688. **[**Crossref**]**

Saidu A. A., Danazumi S. and Hamza S. M.(2021): Assessment of Groundwater Quality Using Water Quality Indexand Geographic Information System in Kumbotso LocalGovernment Area, Kano State, Nigeria, Nigerian Journal of Environmental Sciences and Technology, Vol 5, No. 2, pp 569 - 581. **[**Crossref**]**

Shirazi, S. M., Imran, H. M. and Akib, S. (2012). GIS-Based DRASTIC method forGroundwater Vulnerability Assessment: A review. Journal of Risk Research, 15(8), pp. 991-1011. **[**Crossref**]**

Tadesse D, Desta A, Geyid A, Girma W, Fisseha S, Schmoll O. Rapid assessment of drinking-water quality in the Federal Democratic Republic of Ethiopia: country report of the pilot project implementation in 2004-2005. Geneva: WHO/UNICEF; 2010.

United Nations/World Water Assessment Program. 2019. UN World Water Development Report: Water for People, Water for Life. UNESCO, Paris. Retrieved from https://www.

unwater.org/publications/world-water-development-report-2019/Link valid on 23rd May 2019.

World Health Organization (2003). Water-related diseases responsible for 80 per cent of all illnesses, deaths in developing world. Retrieved July 19, 2023, from https://press.un.org/en/2003/sgsm8707.doc.htm

World Health Organization. (2011). Guidelines for drinking-water quality, 4th ed. Geneva: WHO.

WHO. 2017: Yellow Fever. http://www.who.int/mediacentre/factsheets/fs100/en/ Accessed 10 June 2017.