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Assessment of Drinking Water Quality and Irrigation Indices in the Bajoga Community, Gombe State, Nigeria

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Abstract

Groundwater quality and soil characteristics are important considerations in evaluating drinking-water resources and agricultural suitability. This study assessed water from existing wells and boreholes and examined soil properties in the Bajoga community. A well inventory was conducted, and water samples were collected following American Public Health Association (APHA) procedures. Laboratory analyses examined physicochemical parameters and major and trace elemental composition. Irrigation suitability was evaluated using salinity hazard, soluble sodium percentage (SSP), sodium adsorption ratio (SAR), and Kelley's ratio, while soil analysis assessed fertility and water retention characteristics. Most measured cations and anions were within the drinking-water reference limits applied in the study, whereas nitrate concentrations slightly exceeded the adopted benchmark. Poor sanitary conditions around wells and fertilizer runoff were considered possible contributors to elevated nitrate concentrations. Salinity hazard, SSP, and SAR indicated suitability for irrigation. However, Kelley's ratio classified water from motorized wells BH1 and BH3 as good to permissible, while water from hand-dug wells BH4 and BH5 was unsuitable. These differences support preferential use of deeper groundwater sources for irrigation in the assessed locations. The soils exhibited low fertility but good water retention capacity,

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indicating potential for rain-fed and irrigated fruit and vegetable production with appropriate fertility management. Row intercropping and surface drip irrigation were proposed as management options to improve productivity. The findings provide a basis for selecting irrigation water sources and coordinating water use with soil fertility management in the Bajoga community.

Keywords: Groundwater Quality; Irrigation Suitability; Hydrochemistry; Soil Fertility; Bajoga

INTRODUCTION

With the African Union's initiative to combat the issue of desertification in the Sahara and Sahel regions, it is crucial to tackle the challenges posed by land degradation in Nigeria. This action aims to protect and restore ecosystems by providing vital ecosystem services that play a significant role in reducing poverty, improving food security, and enhancing overall living standards. Furthermore, economic development in both urban and rural areas is closely linked to effective planning and ongoing management strategies for sustainable water resources. The study entailed an assessment of existing water wells, carrying out well inventory studies in the community, Determination of physicochemical parameters of well water, and hydrochemical sampling of water wells using the AHPA sampling standard. Laboratory analysis of water samples to determine major and trace elemental composition of the wells and Assessment of the Irrigation indices and drinking water quality. This research will contribute to the existing knowledge by a comprehensive assessment of the present state of existing groundwater wells in Bajoga community.

Location and Geology of the Study Area

Bajoga, the headquarters of Funakaye Local Government Area in Gombe State, Nigeria, is located at approximately 10.85^{0} N and 11.31^{0} E, with an average elevation of about 438m above the mean sea level. The town is situated approximately 98 km by road northeast of gombe, the state capital.

A. Stratigraphic Setting

The project site is located in the Upper Benue Trough Basin which is one of the main sedimentary basins in Nigeria. The Benue Trough originated from the Early Cretaceous rifting of the Central West Africa basement uplift. It forms a regional structure

that is exposed starting from the northern frame of the Niger Delta and runs northeastwards for about 1000km to the Lake Chad, where it terminates. Regionally, the Benue Trough is an Early Cretaceous rift complex known as the West and Central African Rift System. The oldest sedimentary unit in the basin is the Bima Formation Albian in age, which was deposited under continental conditions. The formation lies unconformably on the Precambrian Basement Complex. The transitional Yolde Formation (Cenomanian) lies conformably on the Bima Sandstone and represents the beginning of marine incursion into the Upper Benue Trough [17]. The Gongila Formation which is overlain by the Fika Shale is a lateral equivalent of the Pindiga Formation and lie on the Yolde Formation. They represent marine incursion into the Upper Benue Trough during the Turonian-Santonian times. The Santonian period involves folding and deformation in the whole of the Benue Trough [8]. Post-folding sequences are represented by the continental Gombe Formation (Maastrichtian) and the Kerri-Kerri Formation (Tertiary). The Gombe and Kerri-Kerri Formations are mostly restricted to the western part of the basin [10]. As can be observed from Fig. 1, two geological formations underlie the studied area. The Limestone and Shale of the Pindiga Formation and Shale, limestone, and Sandstone of the Yolde Formation. The former is mainly found in Funakaye LGA (with little extension to Nafada LGA).

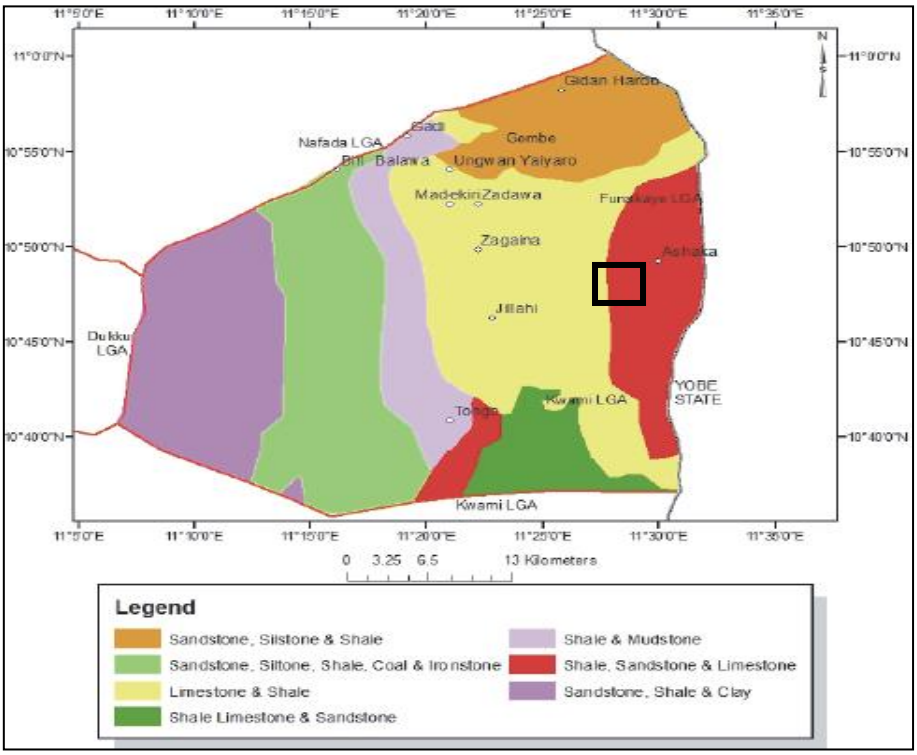


Fig. 1 Geological map of Funakaye LGA showing the study area After [13].

B. Hydrogeological Setting

Groundwater distribution in Nigeria is largely determined by the geological framework described in the previous section. Nigeria has a great potential for groundwater which far exceeds the surface water resources [3]. [16] Presented details of the different hydrogeological basins in Nigeria. Generally, aquifer distribution in Nigeria can be divided into 2 along geological lines; basement and sedimentary aquifers. The Bima Formation is thus the most extensive aquifer in the Gombe sub-catchment of the Upper Benue Trough [14]. The Bima and the Yolde Formation aquifers fall under the consolidated sedimentary rocks group, which account for almost 35% of the geology of Nigeria which encompasses most of the inland sedimentary basins and have aquifers with an average yield of 1.0-8.0l/s [22]. The depth to water table depth is usually between 60 and 165 m. Boreholes range in depth from 30 to 300 m with poor to moderate yields of about 1 to 5 l/s [14]. The Upper Benue Basin also has aquiferous units in the Gombe Sandstone and Kerri Kerri Formations. These aquifers mostly show coarse-grained and highly permeable materials. The Kerri Kerri aquifer has a yield of 1.25 to 9.5 L/s [4].

METHODS AND PROCEDURES

A. Field Investigation

A hydro-geological and hydrochemical survey was conducted to assess the present state of existing groundwater wells in the Bajoga community in Funakaye local Government area of Gombe State. The specific works undertaken in the course of the field studies are itemized below;

- A well inventory study in the community and determination of physicochemical parameters of well water
- Hydrochemical sampling of water wells using the AHPA sampling standard.
- Laboratory analysis of water samples to determine the major and trace elemental composition of the wells
- Assessment of the Irrigation indices and drinking water quality

B. Measurement of well inventory and Physico-chemical Parameters

Determination of good inventory including good topography (WT), well depth (WD), and groundwater table (GWT) was conducted on 10 representative wells that spread

through the area (Fig 2). The water table and depth of each borehole were measured in meters using water level indicators. A portable Etrex Garmin Global Positioning System (GPS) was used to measure the geographical coordinates of all boreholes/hand-dug wells locations across the area. Elevations were measured relative to the mean sea level. Parameters such as temperature, pH, conductivity, and total dissolved solids (TDS) were determined at the wellhead using a digital conductivity meter (Hanna HI9861-3).

C. Sampling and analytical procedures

Five representative groundwater samples were collected from hand-dug and motorized wells for hydrochemical analysis. The groundwater samples were collected in pre-cleaned, 120-mL HDPE plastic bottles that were rinsed with sample water three times before use in line with the methods described by APHA (1995), precise location of the sample points was determined in the field using global positioning system (GPS). At each location, two samples were collected; one for cations and the second for anions analysis. The samples for cations were acidified to a pH of < 2.0 with concentrated nitric acid to maintain the stability of the oxidation state of the various elements present in the solution so as to prevent precipitation.

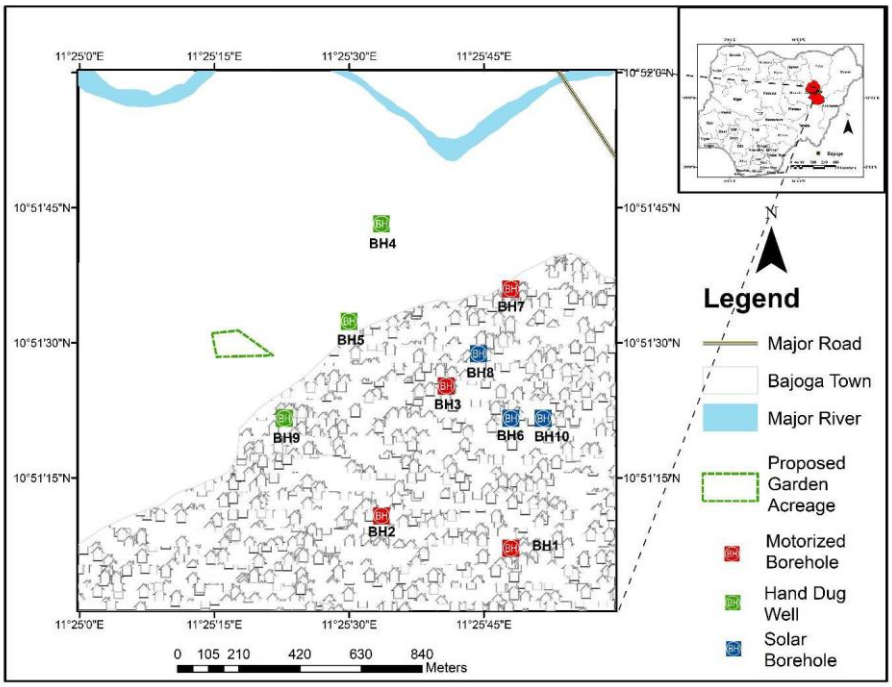


Figure 2 Map of the studied area Showing the Well and Borehole Distribution.

D. Laboratory analysis of water samples to determine major and trace elemental composition of the wells

The hydrochemical analysis for major cations, anions, and trace metals was undertaken at the Public Health Engineering Laboratory, ATBU, Bauchi. The concentration of major cations (Ca^{2+}, Mg^{2+}, $Na^{+,}$ and K^{+}) and the trace metals were analyzed through atomic absorption spectrophotometry (AAS), while that of major anions (NO_3^{-}, SO_4^{2-} and Cl^{-}) were determined by ion chromatography (IC). The purpose of the hydrochemical assessment is to determine the chemical composition of groundwater in the area which will give insight on its irrigation quality parameters.

E. Assessment of the Irrigation indices and drinking water quality

Sodium adsorption ratio (SAR), sodium percentage (% Na), and salinity (conductivity) were employed for the evaluation of groundwater quality for irrigation purposes. SAR can show the degree to which irrigation water tends to participate in cation-exchange reactions in the soil [15]. When sodium replaces adsorbed calcium and magnesium, it can potentially damage the soil structure by enhancing compaction, thereby decreasing the soil permeability. A high %Na in irrigation water concerning Ca^{2+}, $Mg^{2+,}$ and K^{+} causes deflocculation and impairment of soil permeability which could be detrimental to the crops [11].

RESULTS AND DISCUSSION

A. Well Inventory

From the result of the well inventory measurement (Table. 1) conducted for the wells in the Bajoga community it was observed that the majority of the wells are productive. The motorized boreholes revealed a depth range of between 45- 66m and 9.7-10m for the hand-dug wells. The altitude/ elevation of the well's ranges between 285 and 296m above sea level. It is important to note that while the motorized wells in the Bajoga community are generally productive and functioning well, most of the hand pump boreholes are bad and this could be attributed to the depth of the wells which is generally higher than the hand pump assemblage can carry. This is because hand pump boreholes should generally not be installed in wells with depths greater than 60m. Another issue affecting the motorized wells in the area is that of power (electricity) which is quite erratic in the area. This is evident from the fact that all of the commercial motorized wells in the

community rely on generating sets owing to the inadequate power supply in the area. Consequently, for this project, solar-powered wells would be highly recommended.

Table 1: Well inventory data of wells in the Bajoga area

Name	Type	Latitude	Longitude	Depth	DWT
BH1(Danjago)	Motorized	10° 51' 125"	11° 25' 772"	N.D	N.D
BH2 (Maiduguri)	Motorized	10° 51' 206"	11° 25' 539"	N.D	N.D
BH3 (Ung. Madaki)	Motorised	10° 51' 445"	11° 25' 705"	45m	N.D
BH4 (Issa Farm) 01	Hand dug	10° 51' 41.7"	11° 25' 33.5"	10m	5m
BH5 (Issa Farm) 02	Hand dug	10° 51' 33.6"	11° 25' 30.5"	9.7m	5.5m
BH6 (Madaki) 01	Solar	10° 51' 386"	11° 25' 816"	N.D	N.D
BH7 (Madaki)02	Motorised	10° 51' 570"	11° 25' 808"	N.D	N.D
BH8 (Madaki GDSS)	Solar	10° 51' 471"	11° 25' 728"	N.D	N.D
BH9 (Issa quarters)	Hand-dug	10° 51' 20.9"	11° 25' 24.3"	66m	N.D
BH10 (cent. mosque)	Solar	10° 51' 20.5"	11° 25' 52.8"	N.D	N.D

B. Physio-chemical and chemical composition of the groundwater samples

The physicochemical parameters of the groundwater samples shown in Table 2 revealed that the pH measured varied from 7.2 to 7.6 (basic). The EC ranged from 310 to 510 µS/cm with an average of 391 µS/cm. TDS varied between 215 and 378 mg/L with an average of 284 mg/L. All the samples were classified as fresh (TDS < 1000 mg/L) [12]. The relatively low TDS in the study area indicates a lowly mineralized groundwater system with limited migratory history and rock–water interaction [20]. The total hardness (as CaCO3) of ground-water samples varied from 110 to 128 mg/L with an average of 118 mg/L indicating hard water. The hardness of the groundwater is attributable to the dissolution of carbonate minerals from the limestone of the Pindiga and Yolde formations which underlie the Bagoja area.

Using the hydrochemistry of the analyzed groundwater in the Bajoga area, all the anions and cations in the samples were generally within the acceptable limits of the WHO and the NSDWQ, except for the nitrates levels which are slightly higher than the WHO threshold of 45 mg/L and this could be linked to either poor sanitary condition around the wells or deposition of fertilizers by runoff water.

Table 2: Results of Physico-chemical analysis of groundwater in Bajoga

S/N	Parameters	BH2	BH3	BH4	BH5	BH1
1	Temperature ^{O}C	27.9	27.8	28.9	27.8	26.8
2	Color (pt.-co)	40	21	41	40	25
3	Odor	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
4	pH	7.3	7.3	7.5	7.6	7.2
5	E/Conductivity (µs/cm)	310	510	312	314	510
6	Total Dissolved Solid (mg/l)	225	371	235	215	378
7	Total Suspended Solid (mg/l)	80	100	88	81	105
8	DO (mg/l)	5.44	5.09	5.43	5.44	5.29
9	Turbidity (NTU)	4	5	3	4	5
10	Total hardness as (CaCO3) (mg/l)	111	128	113	110	128
11	Carbonate (mg/l)	0.8	0.2	0.6	0.8	0.5
12	Phosphate PO4 (mg/l)	4.58	5.08	4.55	4.57	5.08
13	Phosphorus P (mg/l)	1.50	1.65	1.54	1.57	1.65
14	Nitrate NO3 (mg/l)	49.8	47.9	47.8	51.8	47.8
15	Nitrogen N (mg/l)	11.2	10.8	13.2	10.2	11.8
16	Calcium Ca^{2+} (mg/l)	0.418	0.703	0.419	0.416	0.703
17	Lead Pb^{2+} (mg/l)	0.000	0.000	0.000	0.000	0.000
18	Chromium Cr^{6} (mg/l)	0.000	0.000	0.000	0.000	0.000
19	Cadmium Cd^{2+} (mg/l)	0.009	0.019	0.009	0.009	0.019
20	Iron Fe^{2+} (mg/l)	0.003	0.024	0.013	0.003	0.014
21	Zinc Zn^{2+}(mg/l)	0.000	0.001	0.000	0.000	0.001
22	Magnesium(mg/l)	0.17	1.94	1.17	0.17	1.04
23	BOD5 (mg/l)	4.27	3.02	4.28	4.25	3.32
24	Chlorine(mg/l)	0.32	1.06	0.41	0.24	0.26
25	Total Bacterial Count (cfu/100ml)	2/100	0/100	2/100	0/100	0/100
26	Sodium	2.0	1.2	3.3	2.6	1.1

C. Results of Soil Analysis

Results of the soil's physical and chemical properties revealed that the soil is clay loam in texture. It also indicated that the soil pH is slightly acidic, low in organic carbon, available phosphorous (mg/kg), and total nitrogen (g/kg). While the exchangeable cations (mol/kg) are medium, following the ESU rating. Based on the result below Table 3, the soil of the selected site even though low in fertility, has a good water retention capacity and can be used for rain-fed and irrigated farming. The site is therefore recommended for the cultivation of fruit and leafy vegetables such as tomato, onion, carrot, lettuce, cabbage,

green beans, cucumber, watermelon, sweet melon, and peppers with good soil fertility management.

Table 3: Physical and chemical properties of soil of Bajoga

S/N	Parameters	Sample Name; - Bajoga
1	Color	Brown
2	pH	6.87
3	E/Conductivity (µs/cm)	116
4	Phosphate (mg/l)	3.717
5	Phosphorus (mg/l)	1.212
6	Nitrate (mg/l)	2.8
7	Nitrogen (mg/l)	0.6
8	Texture	Clay loam
9	Sand (%)	35.64
10	Silt (%)	13.28
11	Clay (%)	51.08
12	Bulk density (g/dm^3)	1.462
13	Moisture Content (%)	4.35
14	Organic carbon g/kg	7.81
15	Available P(mg/kg)	6.52
16	Fe^{2+} (mg/l)	10.679
17	Pb^{2+} (mg/l)	0.000
18	Cu^{2+} (mg/l)	0.2072
19	Porosity(g/cm^3)	0.792
20	Calcium	2.68
21	Magnesium	0.87
22	Sodium	011

D. Irrigation Indices

The quality of water utilized for irrigation/agricultural purposes is consequential as it has a detrimental effect on the overall crop yield and soil productivity (Ali and Ali, 2018). The efficacy of water for irrigation is mainly governed by the TDS (salinity) and the ratio of sodium to calcium and magnesium in the water [5].

Salinity hazard is a measure of the electrical conductivity (EC) of the water. Physiological drought is the main impact of elevated concentrations of salts in water on plants [6]. In the Bajoga area, salinity values ranged from 310 to 510 µS/cm and averaged 391 µS/cm. [18] classified water with EC of < 250 µs/cm as good and those with EC > 750 µs/cm as unsuitable for irrigation. Therefore, based on salinity hazard the groundwater

in the study area is adjudged to be good for irrigation purposes. Other irrigation indices employed are as follows:

$$SSP = \frac{(Na^{+} + Ca^{2+})}{(Ca^{2+} Mg^{2+} + Na^{+} + K^{+})} \times 100 \quad (1)$$

$$SAR = \sqrt{Na\,(Ca + Mg)/2} \quad (2)$$

$$\%Na = (Na + K)\,100 / Ca + Mg + Na + K \quad (3)$$

$$\text{Kelly ratio} = (Na^{+} + Ca^{2+}) / Mg^{2+} \quad (4)$$

$$\text{Magnesium Hazard} = (Mg^{2+} / Ca^{2+} Mg^{2+}) \times 100 \quad (5)$$

Table 4 Irrigation indices of groundwater in Bajoga

BH No.	Salinity hazard (EC)	SSP	SAR	%Na	KR	Mg hazard
BH1	510	28.37	0.19	39.61	0.40	70.89
BH2	310	71.36	0.66	249.22	2.49	40.10
BH3	510	21.12	0.17	26.78	0.27	81.96
BH4	312	55.03	0.59	122.37	1.22	82.13
BH5	314	76.47	0.86	324.91	3.25	40.22

As shown in Table 4, the soluble sodium percent (SSP) ranges between 21-76% and averages 50.5 in the Bajoga area. The soluble sodium percentage (SSP) also known as % Na is a measure of the dissolved sodium content of the water and an indication of Na hazard in water in base-exchange processes, calcium ions are substituted by sodium ions which reacts with the soil to lower its permeability (Wilcox 1955). SSP values of <50 is best for irrigation according to Wilcox. By implication, the SSP values are slightly higher than the desired threshold. Based on the sodium absorption ratio, however, all the samples a good for irrigation purposes as the required value for SAR is <1. In terms of sodium percent and Kelly ratio the values obtained in the motorized wells (BH1 and BH3) were good to permissible for irrigation purposes while those in the hand-dug wells (BH4 and BH5) were generally unsuitable. It can therefore be concluded based on salinity hazard and SAR, that the groundwater is good for irrigation purposes, however, in terms of SSP, %Na, and K.R. the deeper wells (motorized boreholes) are generally better for agricultural purposes.

CONCLUSION

An inventory of existing boreholes and wells in Bajoga was done to determine their status and good for drinking and irrigation. Both water and soil samples were taken to determine the quality of the water for drinking/irrigation. Based on the water geochemistry, the anions and cations in the samples were generally within the acceptable limits of the WHO and the NSDWQ, except for the nitrates levels which are slightly higher than the WHO threshold of 45 mg/L and this could be linked to either poor sanitary condition around the wells or deposition of fertilizers by runoff water. The salinity hazard, soluble sodium percent (SSP), and Sodium Absorption ratio (SAR) were well within the limits suitable for irrigation purposes. Also, the Kelly ratio was good to permissible for Motorized wells (BH1 and BH3) but unsuitable for hand-dug wells BH4 and BH5. This generally supports the use of deeper sourced water (motorized wells or solar wells) for irrigation. The results of the soil analysis showed a low soil fertility but good water retention capacity which makes it appropriate for both rain-fed and irrigated farming. The soil is generally good for the cultivation of fruits and leafy vegetables such as tomato, onion, carrot, lettuce, cabbage, green beans, cucumber, watermelon, sweet melon, and peppers with good soil fertility management. Maximum productivity can be achieved by adopting a row intercropping pattern and surface drip irrigation method.

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REFERENCES

[1] Abubakar, B. Y. (2013). *North-east economic summit: Upscaling agricultural business in the northeast through innovative value and agricultural clusters.*

[3] Adelana, S. M. A., Olasehinde, P. I., Bale, R. B., Vrbka, P., Edet, A. E., & Goni, I. B. (2008). An overview of geology and hydrogeology of Nigeria. In S. Adelana & A. MacDonald (Eds.), *Applied groundwater studies in Africa* (pp. 171–198).

[4] Akujieze, C. N., Coker, S. J. L., & Oteze, G. E. (2003). Groundwater in Nigeria – A millennium experience – Distribution, practice, problems and solutions. *Hydrogeology Journal, 11*(2), 259–274. https://doi.org/10.1007/s10040-002-0227-3

[5] Alagbe, S. A. (2006). Preliminary evaluation of hydrochemistry of the Kalambaina Formation, Sokoto Basin, Nigeria. *Environmental Geology, 51*(1), 39–45. https://doi.org/10.1007/s00254-006-0302-5

[6] Ali, S. A., & Ali, U. (2018). Hydrochemical characteristics and spatial analysis of groundwater quality in parts of Bundelkhand Massif, India. *Applied Water Science, 8*(1), Article 39. https://doi.org/10.1007/s13201-018-0678-x

[7] American Public Health Association. (1995). *Standard methods for the examination of water and wastewater* (19th ed.). American Water Works Association; Water Environment Federation.

[8] Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough (Nigeria). *Journal of African Earth Sciences (and the Middle East), 8*(2–4), 251–282. https://doi.org/10.1016/S0899-5362(89)80028-4

[9] Carter, J. D., Barber, W. N., & Tait, E. A. (1963). *The geology of part of Adamawa, Bauchi, and Borno Provinces in northeastern Nigeria* (Bulletin No. 30). Geological Survey of Nigeria.

[10] Dike, E. F. C. (1993). Stratigraphy and structures of Kerri-Kerri Basin, northeastern Nigeria. *Journal of Mining and Geology, 29*, 77–93.

[11] Glover, C. R. (1996). *Irrigation water classification systems* (Guide A-116). Cooperative Extension Service, College of Agriculture and Home Economics, New Mexico State University.

[12] Hem, J. D. (1985). *Study and interpretation of the chemical characteristics of natural water* (3rd ed., Water-Supply Paper 2254). U.S. Geological Survey. https://doi.org/10.3133/wsp2254

[13] Mayomi, I., Gideon, D., & Abashiya, M. (2018). Analysis of the spatial distribution of geology and pedologic formations in Gombe State, North Eastern Nigeria. *Journal of Geography and Geology, 10*(1), 83–108. https://doi.org/10.5539/jgg.v10n1p83

[14] Iyioriobhe, S. E., & Ako, B. D. (1986). The hydrogeology of the Gombe subcatchment, Benue Valley, Nigeria. *Journal of African Earth Sciences, 5*(5), 509–518. https://doi.org/10.1016/0899-5362(86)90060-6

[15] Jafar Ahamed, A., Loganathan, K., & Ananthakrishnan, S. (2013). A comparative evaluation of groundwater suitability for drinking and irrigation purposes in Pugalur area, Karur district, Tamilnadu, India. *Archives of Applied Science Research, 5*(1), 213–223. https://www.scholarsresearchlibrary.com/abstract/a-comparative-evaluation-of-groundwater-suitability-for-drinking-and-irrigation-purposes-in-pugalur-area-karur-district--765.html

[16] Offodile, M. E. (2002). *Groundwater study and development in Nigeria*. Mecon Services Ltd.

[17] Popoff, M., Wiedmann, J., & de Klasz, I. (1986). The Upper Cretaceous Gongila and Pindiga Formations, northern Nigeria: Subdivisions, age, stratigraphic correlations and paleogeographic implications. *Eclogae Geologicae Helvetiae, 79*(2), 343–363.

[18] Richards, L. A. (Ed.). (1954). *Diagnosis and improvement of saline and alkali soils* (Agriculture Handbook No. 60). U.S. Department of Agriculture. https://www.ars.usda.gov/pacific-west-area/riverside-ca/agricultural-water-efficiency-and-salinity-research-unit/docs/publications/handbook-no-60/

[19] Schwankl, L. J., & Hanson, B. R. (2007). Surface drip irrigation. In F. R. Lamm, J. E. Ayars, & F. S. Nakayama (Eds.), *Microirrigation for crop production: Design, operation, and management* (Vol. 13, pp. 431–472). Elsevier. https://doi.org/10.1016/S0167-4137(07)80015-1

[20] Talabi, A. O., & Tijani, M. N. (2013). Hydrochemical and stable isotopic characterization of shallow groundwater system in the crystalline basement terrain of Ekiti area, southwestern Nigeria. *Applied Water Science, 3*(1), 229–245. https://doi.org/10.1007/s13201-013-0076-3

[21] Tijani, M. N. (2004). Evolution of saline waters and brines in the Benue-Trough, Nigeria. *Applied Geochemistry, 19*(9), 1355–1365. https://doi.org/10.1016/j.apgeochem.2004.01.020

[22] Tijani, M. N., Crane, E., Upton, K., & O Dochartaigh, B. E. (2016). *Africa groundwater atlas: Hydrogeology of Nigeria*. British Geological Survey. Retrieved March 2016, from https://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_Nigeria

[23] Wilcox, L. V. (1955). *Classification and use of irrigation waters* (Circular No. 969). U.S. Department of Agriculture.