Nigerian Journal of Water Resources
2024, 10(1): 147-159
Print ISSN: 115-9944
Online ISSN: 2795-3793

GROUNDWATER QUALITY ASSESSMENT IN PARTS OF NORTHERN BIDA BASIN, KWARA STATE NORTHWESTERN NIGERIA

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ABSTRACT
Groundwater assessment of parts of Northern Bida Basin is aimed at understanding the groundwater potential of the study area and assessing its suitability for irrigation and domestic usage. The physical and chemical properties of the water and also the chemical and biological oxygen demand were all carried out. Using a heavy, insoluble, non-corrosive object of known length attached to the zero end of a measuring tape, the overburden thickness of >20m was determined and suggest a low to moderate groundwater potential of the weathered and fractured aquifer. The average abundance of the anion and cation in the water sample are in the following order; $HCO_3^- > Cl^- > SO_4^{2-}$ *and* $Ca^{2+} > Na^+ > K^+ > Mg^{2+}$ *respectively. The Schoeller diagram reveal the cation order in Bokungi, Share, Zambufu, Tsaragi and Gada is of the order* $Na^+ + K^+ > Ca^{2+} > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$ *respectively. According to the water quality index, the bulk of the water sample showed that the water is threatened by anthropogenic activities thus not suitable for drinking. The evaluation of water for irrigation suitability using the sodium absorption ratio, soluble sodium percentage, percentage sodium, Kelly's ratio, magnesium ratio, permeability index and residual sodium carbonate it seen that most of the water in the study area is suitable for irrigation purpose.*

KEYWORDS: *Groundwater quality, Northern Bida Basin, Bivariate analysis, Ion exchange process, Hydrogeochemical types*

INTRODUCTION

Water is life; a prime natural resource and precious national asset, forms the most constituent of ecosystem. Besides the need of water for drinking, water resources play a vital role in various sectors of economy such as agriculture, livestock production, forestry, industrial activities, hydropower generation, fisheries and other creative activities. The availability and quality of water either surface or ground, have reduced due to some important factors like increasing population, industrialization, urbanization etc. Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits. (WHO, 2004).

In the developing world, groundwater is extensively used for drinking water supplies, especially in smaller towns and rural areas, where it is often the cheapest source. Groundwater schemes consist typically of large number of boreholes, often drilled on an uncontrolled basis, providing untreated, unmonitored and often unconnected supplies. (Naomi *et al*, 2019)

This research work is based on the evaluation of the properties of groundwater (Borehole and Hand dug wells) and surface water (streams), in part of Northern Bida Basin. Natural geochemical and biochemical, as well as anthropogenic impact on groundwater do not only threaten the quality of human health but also pose a threat to sustainable development and management of groundwater resources. The frequent use of fertilizers and pesticides to obtain high crop yield is also a source of groundwater contamination and some of the chemicals applied on farmland move down with the deep percolation of water. Zambufu and Wadata. The study area can be assessed by major and minor road.

This paper aims at understanding the lithological characteristics and ground water potential, characterization the aquifer parameters of the soil along Share Wodata road using grain size analysis. And more so, to effectively conclude on the quality of the water in the study area

1.1 Study area

The study area is located in the northern part of Kwara state, which falls within longitudes $4^{o}\ 46^{I}\ 00^{II}$ to $5^{O}\ 60^{I}\ 00^{II}$ and latitudes $8^{O}\ 45^{I}\ 00^{II}$ and $8^{O}\ 5^{0I}\ 00^{II}$ which covers over an area of about an area of about 800 km^{2}(Figure 1). Within this study area lies some settlements and Ifelodun Local Government Secretariat. The settlements found in the study area include, Share, Tsaragi, Bukungi, Yipata, Gidan- Sanni, Gada, Zambufu and Wadata. The study area can be accessed by major roads and minor roads.

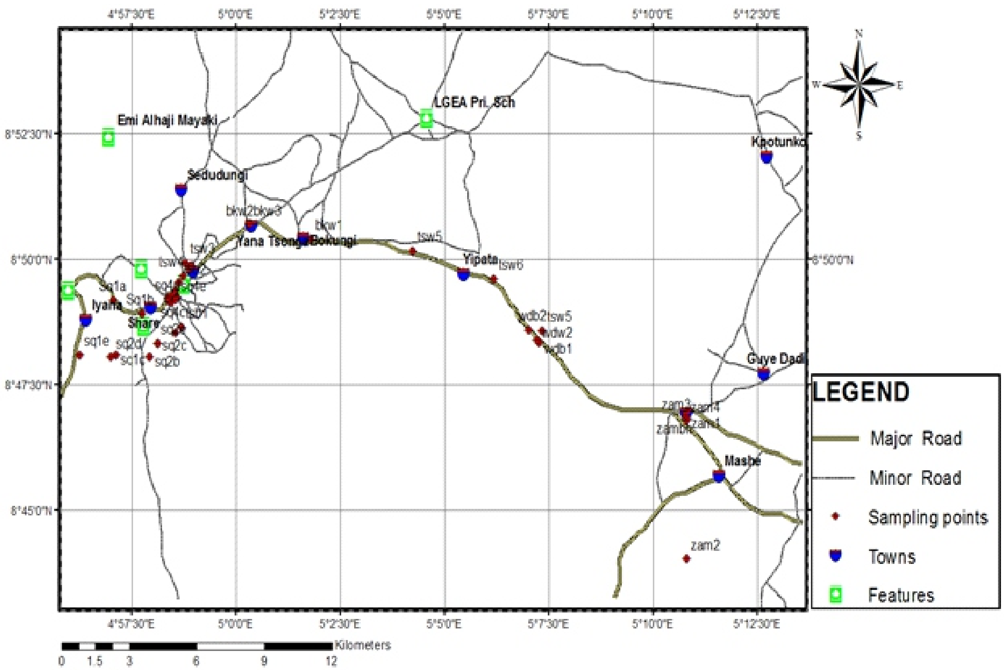

Figure 1: Topographic map of the study area showing water sample points

2.0: Methodology

2.1 Determination of Physical Parameters for Water Samples

Parameters such as temperature, static water level, hydrogen ion concentration were measured onsite. The temperature of each sample was taken using mercury thermometer, measured in degree Celsius(°C).

To determine the static water level, a heavy, insoluble, non-corrosive object of known length was attached to the zero end of a measuring tape of about 50meters. The object is measured from where it is attached to give the value for the length of depth indicator. The ground surface to the point where the well starts is measured to obtain the value of elevation. Then the tape is released into the well until the heavy object touches the water surface and the readings were taken at the upper surface of the well at the earth surface. The difference between the measured length and the elevation is the static water level. Total depth was determined by releasing the measuring tape more until the object touches the floor of the well and the reading was taken. The difference between the value attained and the elevation is the total depth

i.e. TD=SWL-E …………………1

Water column is the difference between the total depth and the static water level. This indicates the actual volume of water in the well

I.e. WCTD-SWL……………… 2

Where,
TD-Total depth of water
SWL-Static water level
E-Elevation of well
WC- Water column

The pH was determined using the portable pH meter. The tester head of the pH meter was rinsed with the water before it is placed in the bottle containing the water sample then allow for few seconds is have a more stable reading before the reading was taken. The standard measurement of pH of water is 6.5-8.5 (WHO 2012)

2.2 Determination of Chemical Parameters

2.2.1 Method of determination of total dissolved solids;

5-ml of each water sample is put inside a petri-dish, and then each petri-dish is placed on a burner for evaporation. After evaporation, each petri-dish containing the residue is allowed to cool. The weighing of the petri-dish therefore confirms the amount of the total dissolved solids.

2.2.2 Method of determination of Alkalinity;

The test vessel was rinsed with the sample water to be tested and filled to 5ml mark. Two drops of indicator p were added and shaken.

The titration pipette was loosely placed on the reagent bottle and filled with the titration solution by slowly drawing the plunger of the syringe upwards until lower rim of the black plunger seal till it is leveled with the zero (0) mark on the scale

The titration pipette was removed and briefly stroked off any liquid on the outside, then the titration solution was added drop wise to the prepared water sample, swirling the test vessel constantly until the color of the water changed from red to colorless

A. The alkalinity P (+) value in mol/l of the titration pipette was read
B. Positive m-value (indicator color changed at pH of 4.3)
C. The test vessel was rinsed with the sample water to be tested and filled to 5ml mark

Two drops of indicator solution M were added and shaken. The titration pipette was placed loosely on the reagent bottle and filled with the titration solution by slowly drawing the plunger of the syringe upwards until the lower rim of the black plunger seal was leveled with the zero (0) mark on the scale.

The titration pipette was removed and briefly stroked off any liquid on the outside, then the titration solution was added drop wise to the prepared water sample, swirling the test vessel constantly until the color of the water changed from blue to colorless

2.2.3 Calcium and Magnesium Ions

A) Calcium

This cation was determined through edta titrimetric analysis. The following procedures were observed in the laboratory;

1. The test vessel was rinsed with the sample water.
2. 50 mL sample was taken and boiled for 1 min and cooled before titration. Samples which contain alkalinity greater than 300 mg/L were be neutralised with acid.
3. 2 mL of NaOH solution was added. Titration was started immediately after addition of the alkali. 0.1 to 0.2 g indicator mixture was added and titrated with EDTA solution, with continuous mixing, till the colour changed from pink to purple. End point was checked by adding 1 to 2 drops of excess titrant to make certain that no further colour change occured.

B) Magnesium

This was derived from calculation from total hardness and calcium. The values for Total Hardness and Ca Hardness were determined by EDTA and Mg was calculated as follows;

Mg mg/L = (TH as mg CaCOL - Ca Hardness as mg CaCO/L) x 0.243

Where;

TH=Total Hardness, mg CaCO/L.

2.2.4 Sodium and Potassium Ions

A) Sodium Ion

This cation was analyzed using the flame emission photometric method.

Calculation;

mgNa/LmgNa/Lfrom the calibration curve *Dilution

Where Dilution = (mL sample mL distilled water) /ml. sample

B) Potassium Ion

This cation was analyzed following instructions of flame photometer manufacturer for selecting proper photocell, wavelength, slit width adjustments, fuel gas and air pressure, steps for warm up, correcting for interference and flame background, rinsing of burner sample ignition and emission intensity measurements.

1. Blank and potassium calibration standard were prepared in any of the applicable ranges, 0-100, 0-10, or 0-1 mg Na/L. Instrument was set to zero standard containing no potassium. Emission was measured at 766.5nm and calibration curve was prepared. Potassium concentration of the sample was determined from the curve.

Calculation;

mgK/L=mgK/Lom the calibration curve *Dilution

where Dilution = (ml sample mL distilled water) /mL sample

2.2.5 Chloride Ions

Chloride ion concentrations were determined through argentometric titration.

N-0.0141 (mL standard NaCl + [V-BJ)

Where:

N=normality of $AgNO_3$,
V mL $AgNO_3$, titrant
BmL. titration for blank
Procedure;

1. About 100 mL sample or a suitable portion was diluted to 100 mL
2. 1 mL K_2CrO4, indicator solution was added and, titrated with $AgNO_3$, titrant to a pinkish yellow end point.
3. The titration was repeated with distilled water blank. A blank of 0.2 to 0.3 mL is usual.

Calculation;

mg CI /L= [(A-B) *N*35450] /mL sample

2.2.6: Sulphate Ions

They are determined using nephelometry method.
Normality of sulphuric acid was calculated:
Normality N (A B) +(53.00*C)

Where

Ag NagCO, weighed into the 1-L flask for Na CO, standard 8 ml. Na CO, solution taken for standardization titration Cml acid used in standardization titration.

2.3: Chemical Oxygen Demand

Chemical oxygen demand (COD) is used to determine the quantity of pollution in water after wastewater treatment (Tomsic *et al*;2023). The higher value of chemical oxygen demand indicates the higher organic pollution in the water sample. Only chemically digestible matter can be determined by the COD test.

Calculation of chemical oxygen demand:

$$COD = \frac{8 \times 1000 \times df \times M \times (VB - VS)}{Volume\ of\ samples\ (ml)}$$

Where,

DF – Dilution Factor (if applicable)

M – Molarity of standardized Ferrous Ammonium Sulfate solution
VB – Volume consumed in titration with blank preparation
VS – Volume consumed in titration with sample preparation

2.4: Biological Oxygen Demand (BOD)

The amount of oxygen, taken up by the microorganisms that decompose the organic waste matter in wastewater is known as biological oxygen demand or biochemical oxygen demand. Therefore, it is used to measure the amount of certain type of organic water pollution BOD is calculated by keeping a sample of water containing a known amount of oxygen for five days at 20 °C. The oxygen content is measured again and BOD is calculated. A high BOD indicates the presence of a large number of microorganisms which indicates a high level of pollution in wastewater.

Calculation:

Blank correction = B.R. for blank at D0 – B.R. for blank at D5
BOD mg/l = [(B.R. for sample at D0 –D5) – blank correction] x dilution factor

$$Dilution\ factor = \frac{Bottle\ volume\ (300ml)}{Sample\ volume}$$

Where:
B.R. = burette reading
D0 = Initial
D5 = Day five after incubation

2.5 Determination of Hydrogeochemical types

For the determination of the Hydrogeochemical types, the Piper tri-linear diagram (Figure 2), and Schoeller semi-logarithmic diagrams (Figure 3) were used

3.0 Results and Discussions

Table 1: Summary statistics of the water samples, and WHO standards for drinking

Parameter	Unit	Min	Max	Average	Std	WHO
Ph		6.1	9.5	7.56	0.94	6.5-8.5
EC	µS/cm	10.5	211.0	70.04	42.93	
TDS	mg/L	14.0	645.0	231.55	206.53	500
Temp	mg/L	26.0	27.6	26.86	0.33	40
DO	mg/L	30.4	60.8	42.28	8.20	
COD	mg/L	1.6	7.2	4.29	1.44	150
BOD	mg/L	4.8	49.6	22.05	10.43	80
Turb	NTU	0.1	2.1	1.05	0.42	10
TA	mg/L	0.4	4.1	1.14	0.98	
HCO_3	mg/L	36.0	408.0	113.65	97.68	
Cl	mg/L	1.0	11.5	4.42	2.36	250
SO4	mg/L	1.2	11.5	2.58	2.03	400
Ca	mg/L	1.6	68.1	23.78	19.66	200
Mg	mg/L	0.3	12.1	4.28	3.45	150
Na	mg/L	2.5	21.6	12.52	5.40	-
K	mg/L	0.3	52.0	9.19	11.27	-
Fe	mg/L	0.0	5.7	0.19	0.79	3

3.1: Hydrogeochemical types

3.1.1: Piper tri-linear diagrams

Piper tri-linear diagrams have been widely used to increase the understanding of hydrogeochemical regimes and to classify and compare hydrogeochemical facies types (Wu *et al*. 2018). On the cation ternary of the Piper diagram (Figure 2), Share, and Tsaragi water samples are either Ca^{2+} dominated, Na^{+} dominated, or mixed Ca^{2+} and Na^{+} dominated. The cation ternary also shows that all of Bokungi water samples are $Na^{+}+K^{+}$ dominated, Gida Sanni is mixed with no dominate cation, Gada is Ca^{2+} dominated, Wodata samples are Ca dominated or mixed cations, and Kokouna shows dominance between Mg^{2+} and $Na^{+}+K^{+}$, All the water samples in the study locations are of HCO_3^- dominance. The Piper diamond shows that weak acid radicals (HCO_3^-) dominate the strong acid radicals (SO_4^{2-} and Cl^-). Majority of the water samples are of Alkaline earth exceeding alkalies ($Ca^{2+} + Mg^{2+} > Na^{+}+K^{+}$). The facies type of the water samples is of the order HCO-Ca type>>HCO-Na type>mixed type.

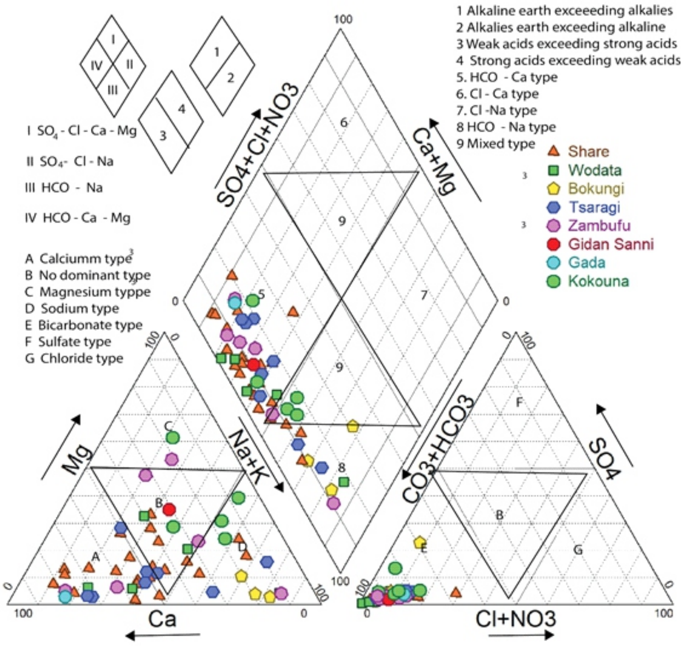

Figure 2: Piper Diagram of the Study Locations

3.1.2: Schoeller diagram

Schoeller diagram (Figure 3) is a semi-logarithmic diagram of the concentration of the main ionic constituents in water (SO_4^{2-}, HCO_3^-, Cl^-, Mg^{2+}, Ca^{2+}, $Na^+ + K^+$) in milliequivalent per liter of solution (meq/L). The concentrations of ions in each sample are represented by points on six equally spaced lines and points are connected by a line. The diagram gives absolute concentration but the line also gives the ratio between two ions in the same sample. Shoeller diagram (Figure 3) of the water samples reveals that HCO_3^- is the dominant anion species in all the locations and Cl^- is generally the less dominating anion. Shoeller diagram also reveal the cation order in Bokungi, Share, Zambufu, Tsaragi and Gada is of the order $Na^+ + K^+ > Ca^{2+} > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$, $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$ respectively.

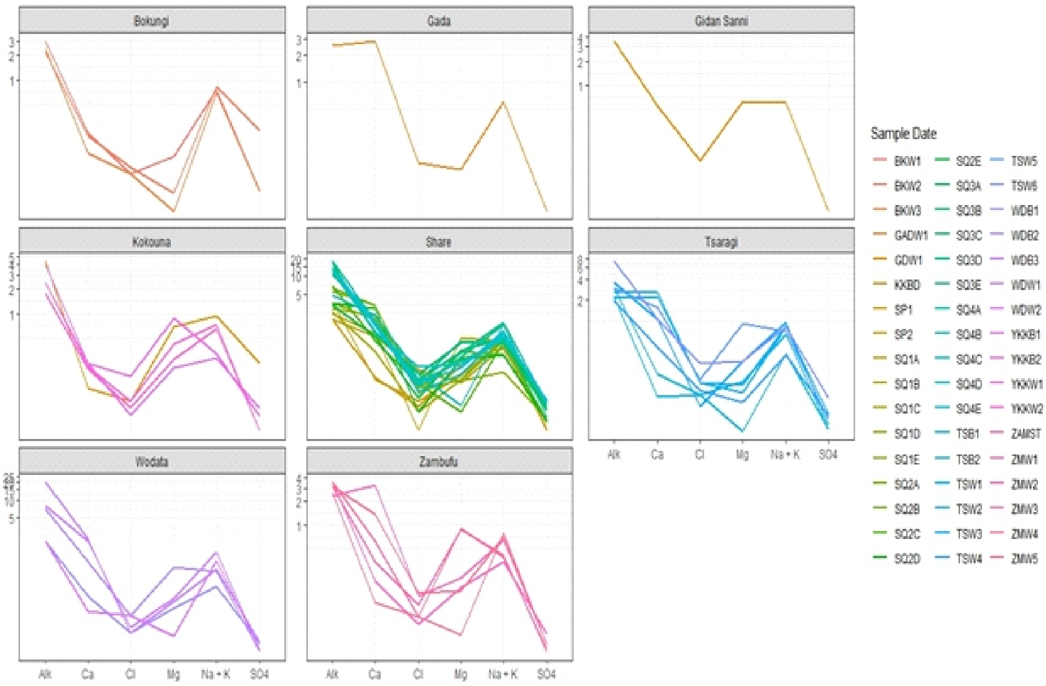

Figure 3: Shoeller Diagram of the water samples in all the locations

3.2 Ion Exchange Processes

To understand the chemical interchange of ions between water and its surrounding aquifer material, Schoeller (1977), suggested the chloro-alkaline indices, CAI-1 and CAI-2 which are computed using equations 1 and 2 and values of the parameters must be in meq/L. The value of these indices can be positive or negative. When the value of CAI-1 and CAI-2 are positive it signifies an exchange of Na^+ and K^+ from the groundwater with Mg^{2+} and Ca^{2+} in the rocks (reverse cation exchange reaction) and negative values of CAI-1 and CAI-2 signifies an exchange of Mg^{2+} and Ca^{2+} from the groundwater with Na^+ and K^+ in the rocks - normal cation exchange reaction (Al-Ahmadi, 2013).

3.3 Water Quality Evaluation Drinking and Irrigation Purposes

3.3.1 Drinking water quality evaluation (Water Quality Index)

The overall water quality is sometimes difficult to evaluate from a large number of samples and parameters (Chapman 1992). Analysis of any monitored parameter, either in alone or group according to a common feature, provides partial information on the overall water quality (Pesce and Wunderlin 2000). Water quality index is a vital approach to assess the overall water quality status and its suitability for drinking uses (Tiwari *et al*, 2013; Abbasnia *et al*, 2018; Ezugwu *et al*., 2019). The general WQI was developed by Brown *et al* (1970). WQI transform large quantities of water quality data into a single number (Stambuk-Giljanovic 1999) which provides a simple and understandable tool for managers and decision makers on the quality and possible uses of a given water body (Bordalo *et al*. 2001). Goher *et al* (2014) suggests a classification of WQI into 5 classes, with water quality rated excellent, good, poor, very poor and unfit when the value of the index lies between 0–25, 26–50, 51–75, 76–100 and >100, respectively

The WQI for part of Northern Bida water samples were calculated by using pH, EC, alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), and SO_4^{2-}. The WQI computation involved obtain measurements on individual water quality indicators, transform measurements into "subindex" (Equation 5) values to represent them on a common scale using relative weight (Equation 3) and a quality rating (Equation 4), and finally aggregate the individual subindex values into an overall WQI value.

$$Wi = wi / \sum_{i=1}^{n} wi \quad (3)$$

$$qi = \frac{Ci - Co}{Si - Co} x\ 100 \quad (4)$$

$$SIi = Wi * q \quad (5)$$

$$WQI = \Sigma\ SIi \quad (6)$$

Where, *Wi* = relative weight, *wi* = weight of each parameter and *n* = number of parameters, *qi*= quality rating, *Ci* = concentration (mg/l) of each chemical parameter in each water sample and *Si* = standard (mg/l) for each chemical parameter, Co = ideal value of ith parameter in pure water, Co = zero for all parameters except for pH = 7.0 (Tripaty and Sahu, 2005). *SIi* = sub-index of *i*th parameter, *qi* = rating based on concentration of *i*th parameter.

Table 4 shows the summary statistics and classification of the water samples based on WQI values. The water quality indexes computed for the water samples varies between 27.35 and 75.07 (average= 45.26). The rating percentages for good, poor, and very poor for the water samples are 74.5, 23.5, and 2.0% respectively. Bulk of the water samples that rated poorly are within Share community and show that the water in this region is threatened by anthropogenic activities.

Table 2: Drinking water Standards and proposing agency

Parameter	**Standards**	**Agency**	**Relative Weight (Wi)**	**Quality rating (qi)**	**Sub Index SIi (SQ1A)**
Ph	6.5-8.5	BIS	0.0302	21.4286	0.68571
EC	300	BIS	0.0009	6.8	0.2176
Alkalinity	120	BIS	0.0021	40	1.28
DO	5	BIS	0.0514	800	25.6
BOD	5	BIS	0.0514	512	16.384
SO42-	150	BIS	0.0017	1.33333	0.04267
				WQI	44.21

Table 3: Statistical Classification and Summary of drinking water and irrigation water quality indices

Parameter	Boundary	Min	Max	Mean	Median	Number	Percent (%)
EC	<250	10.50	211.00	70.04	63.00	51	100.0
	250–750					0	0.0
	750–2250					0	0.0
	>2250					0	0.0
SAR	<10	0.09	3.08	0.85	0.63	51	100.0
	10–18					0	0.0
	18–26					0	0.0
	>26					0	0.0
SSP	<60	10.89	84.89	40.17	40.17	42	82.3
	>60					11	17.7
%Na	<20	3.51	84.13	33.42	25.64	17	33.3
	20-40					19	37.3
	40-60					7	13.7
	60-80					5	9.8
	>80					3	5.9
KR	< 1	0.04	5.30	0.87	0.34	39	76.5
	1 – 2					5	9.8
	>2					7	13.7
MR	<50	3.12	85.08	29.57	23.03	41	80.4
	>50					10	19.6
PI	<25	33.29	268.71	107.77	106.52	0	0.0
	25-75					12	23.5
	>75					39	76.5
RSC	<1.25	-2.67	4.35	0.32	0.27	40	78.4
	>1.25					11	21.6
WQI	0-25	27.35	75.07	45.26	43.37	0	0
	26-50					38	74.5
	51-75					12	23.5
	76-100					1	2.0
	>100					0	0.0

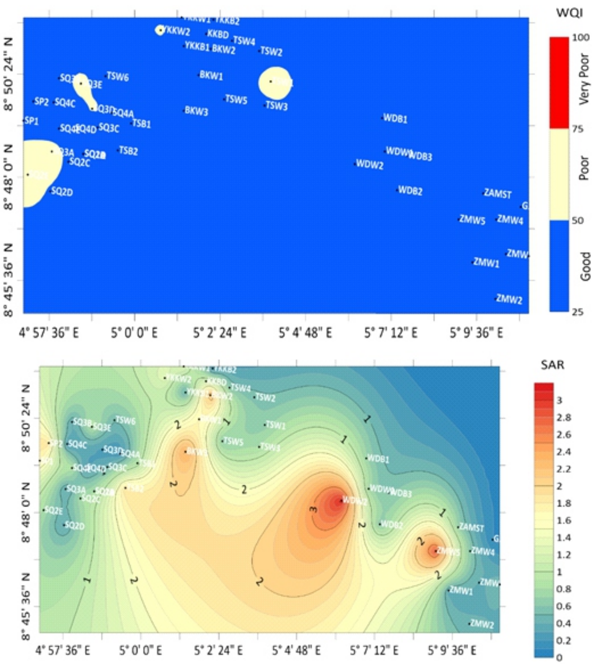

Figure 6: Spatial distribution of WQI (top) and SAR within the study area

3.3.2 Irrigation water quality evaluation

Irrigation water quality evaluation of water samples from part of Northern Bida basin was done using electrical conductivity (EC), sodium adsorption ratio (SAR), soluble sodium percentages (SSP), percentage sodium (%Na), Kelly's ration (KR), magnesium ratio (MR), permeability index (PI), and residual sodium carbonate. Multiple irrigation quality indices were used to increase the confidence of the result.

SAR, SSP, %Na, KR, and MAR (managed aquifer recharge) were computed based on the proposition of Richards (1954), Wilcox (1955), Todd (1980), Kelly (1963), Ayers and Westcot (1985) and Raghunath (1987). On the basis of SAR range, irrigation water can be classified into four classes as SAR < 10 (ideal or excellent), 10–18 (good), 18–26 (doubtful) and > 26 (unsuitable) Based on SSP values less than 60 is good for irrigation, while those greater than 60 are poor. The classification of water is based on %Na as excellent (< 20%), good (20–40%), permissible (40–60%), doubtful (60–80%) and unsuitable (> 80%). KR(Kelly's Ratio) of water that is suitable for irrigation must be must be less than 1 (Kelly, 1963). MAR causes a harmful effect to soil when it exceeds 50 (Raihan and Alam, 2008). According to Doneen (1964), PI(permeability index) can be categorized in three classes: class I (> 75%, suitable), class II (25–75%, good) and class III (< 25%, unsuitable). Water under class I and class II are recommended for irrigation on the basis of RSC range. Sodium hazard has been classified into three classes as follows: RSC < 1.25 (low), 1.25–2.5 (medium) and > 2.5 (high).

3.4 Multivariate Analysis

3.4.1 Correlation Analysis

The threshold defined being strong for Pearson correlation coefficient values in this study is 0.6. Correlation analysis (Table 4) reveals that pH has strong relation with TDS, HO_3 and K; likewise, TDS has a strong correlation with Turbidity, Cl, Ca and K; Turbidity has a strong correlation with HO_3, Cl and SO_4; HO_3 has a strong correlation with K; Cl has a strong correlation with K.

Table 4: Pearson correlation coefficient Matrix of the Analyzed water parameters

	Ph	Ec	TDS	DO	COD	BOD	Turb	HCO_3	Cl	SO_4	Ca	Mg	Na	K
Ph	1													
Ec	0.2	1												
TDS	**0.6**	0.5	1											
DO	-0.4	-0.3	-0.3	1										
COD	-0.5	-0.3	-0.4	0.1	1									
BOD	0.1	0.2	0.3	0.4	-0.5	1								
Turb	0.4	0.4	**0.7**	-0.3	-0.1	0	1							
HCO_3	**0.8**	0.3	0.6	-0.4	-0.4	0.1	**0.6**	1						
Cl	0.2	0.4	**0.7**	-0.2	-0.2	0.1	**0.6**	0.4	1					
SO4	0.4	0.4	0.5	-0.3	-0.4	0.3	**0.6**	0.4	0.4	1				
Ca	0.4	0.2	**0.8**	-0.1	-0.2	0.3	0.4	0.4	0.4	0.2	1			
Mg	0.3	-0.2	0.2	0.1	0	0	0.2	0.4	0.1	0	0.2	1		
Na	-0.1	-0.1	-0.3	0	-0.1	0.2	-0.4	-0.2	-0.3	-0.1	-0.1	-0.1	1	
K	**0.6**	0.4	**0.8**	-0.3	-0.2	0	**0.7**	**0.6**	**0.6**	0.5	0.5	0.1	-0.3	1

3.4.2 Cluster Analysis

Cluster analysis dendrogram (Figure 11) of the water samples identified three major groups; Samples SQ1A, TSB2, SP1, SP2, SQ1C, SQ1D, SQ2B, TSW1, and SQ2E belong to Group 1. Group 2 samples include samples WDB1, WDW2, BKW1, BKW3, ZMW5, TSW4, TSB1, ZAMST, TSW3, TSW2, TSW5, GDW1, YKKB2, YKKW1, YKKW2, ZMW1, ZMW4, GADW1, ZMW2, ZMW3, YKKB1, BKW2; Group 3 samples include SQ1B, SQ1E, SQ2C, TSW6, SQ4B, SQ2A, WDW1, SQ2D, WDB2, SQ3E, SQ4E, WDB3, SQ3A, SQ4A, SQ3B, SQ3C, SQ4C, SQ3D, and SQ4D. Sample KKBD is an outlier, and may be removed from subsequent interpretation. It may also be concluded that water quality decreases from left to right of the dendrogram, as it was observed that most of the samples that have poor WQI rating belongs to Group 3.

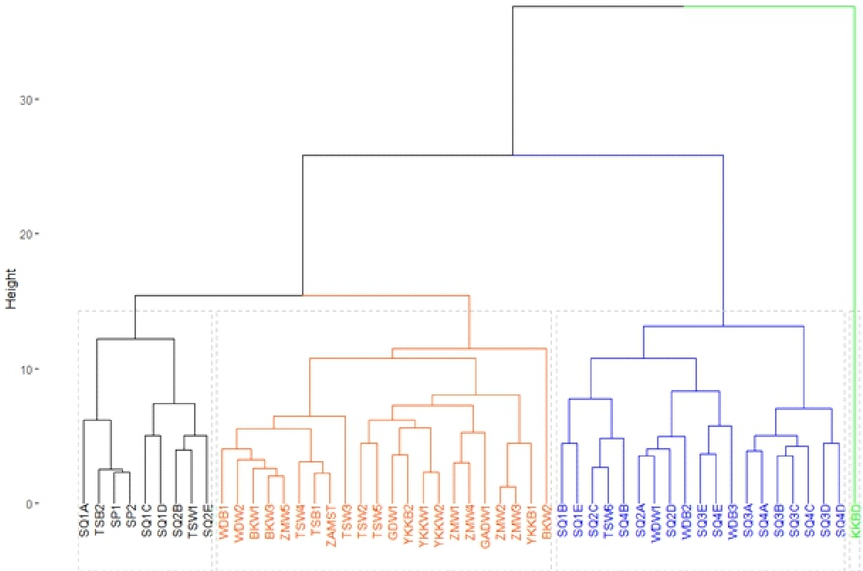

Figure 9: Dendrogram plot of water samples defining their groups

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

pH values vary between 6.1 - 9.5, with an average value of 7.56 indicating the water samples are slightly alkaline. COD, BOD, Turbidity of the water samples are all below maximum permissible limits. This also applies to the major ions. The order of anions and cations according average abundances in the water samples is HCO_3–> Cl–> SO_4^{2-} and Ca^{2+}>Na+ >K+ > Mg^{2+} respectively. Majority of the water samples are of Alkaline earth exceeding alkalies (Ca^{2+} + Mg^{2+} > Na^++K^+), and weak acid radicals (HCO_3-) dominate the strong acid radicals. The facies type of the water samples is of the order HCO-Ca type>>HCO-Na type>mixed type. rock water interaction dominating factor in which ions from the rocks are leached/dissolved into the aquifer.

End member diagram of the water samples shows that silicate weathering is the major hydrogeochemical process controlling the groundwater chemical composition, these shows that most of the wells are located within the weathered basement. The water quality indexes computed for the water samples varies between 27.35 and 75.07 (average= 45.26). The rating percentages for good, poor, and very poor for the water samples are 74.5, 23.5, and 2.0%

respectively. Bulk of the water samples that rated poorly are within Share and shows that the water in this region is threatened by anthropogenic activities. All the irrigation quality parameters; electrical conductivity (EC), sodium adsorption ratio (SAR), soluble sodium percentages (SSP), percentage sodium (%Na), Kelly's ration (KR), magnesium ratio (MR), permeability index (PI), computed shows that the water sample are mostly suitable for irrigation.

Correlation analysis reveals that pH has strong relation with TDS, HO_3 and K; likewise, TDS has a strong correlation with Turbidity, Cl, Ca and K; Turbidity has a strong correlation with HO_3, Cl and SO_4; HO_3 has a strong correlation with K; Cl has a strong correlation with K.

The hydraulic conductivity of the sample is 1.69 and 0.544m/days, this shows a high conductivity and the porosity values show that the sandstone will allow high flow of water through its unit. The plasticity chart shows the Atterberg limits plots above the A-line and within the zone of inorganic clays with low plasticity.

4.2 Recommendations

I. It is recommended that regular assessment should be carried out on the quality of groundwater in the area because the chemistry of the water is not constant.

ii. It is recommended that the water, mostly around Share should be well treated before domestic use.

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