

Hydrochemical Characteristics and Groundwater Quality Evaluation of Roni Area, Northwestern Nigeria

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ABSTRACT: Rapid population growth rate in the study area results to an increasing demand of water for various uses. It necessitated the geoscientists to evaluate the water quality of the area for potability. Twenty (20) water samples were collected using plastic bottles and properly labelled. Atomic Absorption Spectrometry (AAS) and X-Ray Fluorescence (XRF) were used to analyse the water quality. The in-situ measured parameters of water are mostly within limit of NIS, 2007 and WHO, 2011. Cations and anions analyses revealed, they were within the range of acceptable standard, except higher concentration of Fe^{2+} , Pb^{2+} and Mn^{2+} which might have resulted from acidic water of the area and weathering of silicate minerals. The cations preponderance is of the order $\text{Na}^+ > \text{K}^+ > \text{Mg}^{2+} > \text{Ca}^{2+}$ while for the anions dominance are $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$. The dominant water facies are $\text{Na}^+ - \text{HCO}_3^-$. These facies might have sources from rock-water interaction of silicate minerals. Wilcox plot of salinity hazard of the water samples indicated that, the water of the area is good for irrigation. It can be classified, the value of electrical conductivity of 0 – 250 excellent, 250 – 750 good, 750 – 2250 doubtful and $> 2250 \mu\text{S}/\text{cm}$ unsuitable. Field study and petrographic analysis revealed that, the area is underlain by three (3) major rocks units which are muscovite schist, porphyritic granite, sandstone (Chad Formation) with quartzite occurring as the minor lithology.

KEYWORDS: Hydrochemical characteristics, ground water, water quality, concentration, electrical conductivity

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I. INTRODUCTION

Water being an essential commodity for the survival of life on Earth and groundwater forms the primary source of water, there is the compelling need for geoscientists to evaluate the water potential of a region, to monitor its flow and control by geologic phenomena as well as assessing its quality for potability. The aim of assessing groundwater quality is to determine if the resource meets the requirements of being potable. Any water described as potable must comply with WHO Standards (WHO, 2011), and Nigerian Industrial Standard (NIS, 2007), for drinking, domestic and agricultural (irrigation) use.

Groundwater experiences various chemical processes or impacts during its migration from a recharge to a discharge area. The chemical composition of groundwater collected from wells or hand pumps is a summation of those processes and impacts. These processes and impacts include human activities that introduce contaminants into the environment. It can also be affected by natural processes that result in elevated concentrations of certain constituents in the groundwater. For example, despite the fact that soil horizons serve as a filter or barrier that attenuate the downward migration of

contaminants released on the land surface; elevated metal concentrations can result when metals are leached into the groundwater from minerals present in the earth crust.

A. Location of Study Area

The area is located in northwestern part of Kano State, about 65 km away from the Kano metropolitan. It also covers part of Jigawa and Katsina States. The whole area is part of Kazaure schist belt, northwestern Nigeria. It lies between latitude $12^\circ 30' 00'' \text{N}$ to $12^\circ 45' 00'' \text{N}$, and longitude $8^\circ 15' 00'' \text{E}$ to $8^\circ 30' 00'' \text{E}$, covering an area of about 770.063 km^2 as shown in Figure 1.

The study area is underlain by three major and one minor lithological unit. These are muscovite schist, porphyritic granite and sandstone (Chad Formation) with quartzite occurring as the minor lithology. The metasediments were intruded by Older Granitic rocks during the Pan Africa Orogeny; while the Plio-Pleistocene Chad Formation overlies these Precambrian rocks as illustrated in Figure 2.

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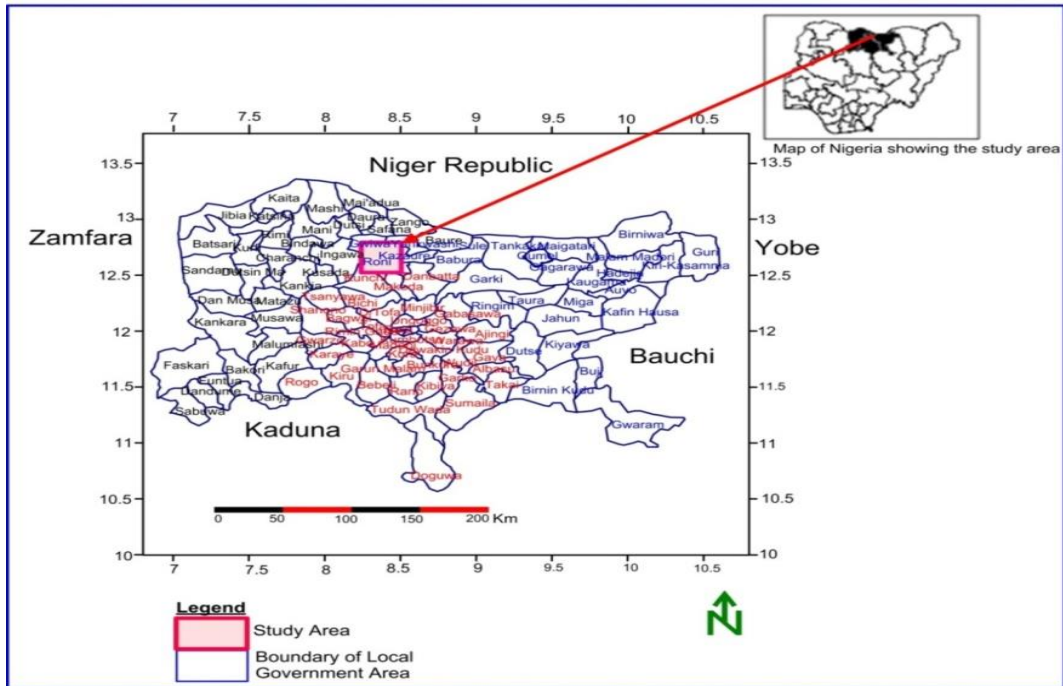


Figure 1: Location Map of the Roni Area.

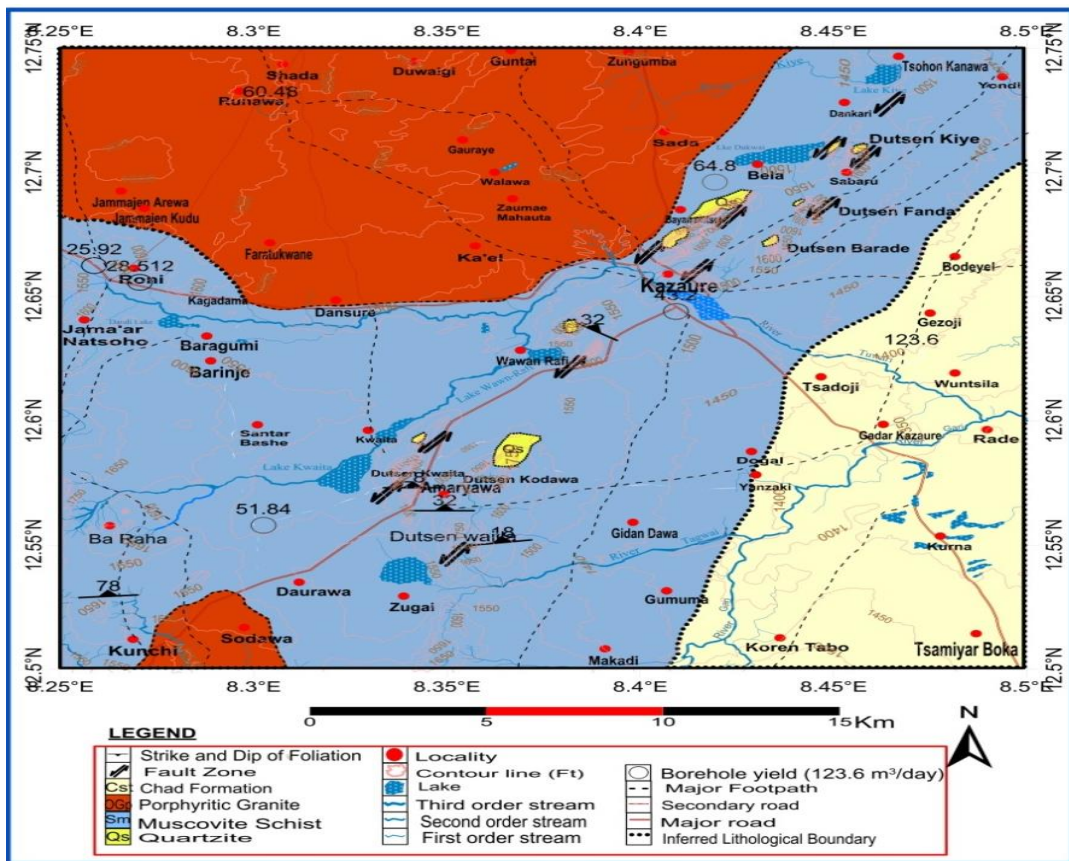


Figure 2: Geological Map of the Roni Area.

B. Geology of the Study Area

The study area is underlain by three major and one minor lithological unit. These are muscovite schist, porphyritic granite and sandstone (Chad Formation) with quartzite occurring as the minor lithology. The metasediments were intruded by Older Granitic rocks during the Pan Africa Orogeny; while the Plio-Pleistocene Chad Formation overlies these Precambrian rocks (see Figure 2).

II. METHODOLOGY

Forty water samples from twenty different wells locations were collected. Plastic bottles were used for collection of the water sample, and at each sampling point the bottle was rinsed with the water to be sampled before the water was collected. Two water samples from each of these twenty wells, one acidified and the other non-acidified were carefully collected and packaged, labeled and transported to the laboratory. The acidified water samples were used for the analysis of cations while the other non-acidified water samples for the anions. Few drops of concentrated solution of nitric acid were added to the samples at the sampling points for the purpose of keeping the ions in solution and also to minimize reaction with the container wall. Coordinates of each of the wells were taken during the field work. During the collection of these samples, physical parameters such as temperature, conductivity, pH and total dissolved solids were obtained with the help of four-in-one meters (brand of the measuring meter was Mi 806 combined meter).

Part of the samples were analysed at Multi-User Research Laboratory in Chemistry Department in ABU Zaria while, some at the Federal Ministry of Water Resources, Department of Water Quality Control and Sanitation, Zonal Office, Kano. The techniques for the analysis were Atomic Absorption Spectrophotometric (AAS), Flame photometer and Water Kit technology. The result of the chemical analysis of water samples from the boreholes were plotted using AquaChem software developed specifically for graphical and numerical analysis and modeling of water quality data.

III. RESULT AND DISCUSSION

A. Physicochemical Parameters

Result of physical parameters which were measured in-situ during field work, and are presented in Table 1. These include pH, Total Dissolved Solid (TDS), Temperature and Electrical Conductivity. The **pH** values range of 4.74 to 6.59 with an average of 5.5365. The pH indicates acidic condition. It observed that, only water that is sampled from a well at Kurna (12.64827778° N, 8.30188889° E), that conform to the permissible limit set by both NIS, 2007 and WHO, 2011 which range 6.5 to 8.5 while, the rest falls below this range (Table 2). **TDS** ranges from 0.00 to 530 mg/l with an average of 120 mg/l. This is good value, far below the desirable level of 500 mg/l, and makes water excellent for drinking and domestic uses. (Schoeneich, 2001) reported that, concentration of TDS in basement complex of Nigeria is usually low when compared with the sedimentary Basins. **Temperature** varies from 28.8 to 33.9°C with an average of 30.59°C (Table 2). **EC** ranges

from 10-910 uS/cm, with an average value 208.5 uS/cm (Table 1). The values fall within the desirable limit set by (NIS, 2007). Wilcox (1995) stated that, conductivity can be used as an index of salinity hazard in assessment of water quality for irrigation. When conductivity is less than 250 uS/cm, the water is excellent for irrigation especially within the Crystalline Hydrological Province of Nigeria. Therefore, since most of the values measured in the area are < 250 uS/cm, and most of the area is Basement Complex, the groundwater will be excellent for irrigation.

B. Cations and Anions

Ca²⁺ ranges from the values of 4 to 27 mg/l with an average of 7.85 mg/l. The highest value observed, is also far below the recommended limits of 75 to 200 mg/l of (NIS, 2007) and 100 mg/l of (WHO, 2011) as in (Table 2). The major sources of this element are from rock-water interaction of silicate minerals in granitic rocks (Figure 3). Calcium is essential for the human body development, especially bone and teeth (Schoeneich, 2001). Accordingly, calcium-deficient children show rickets, the condition of undermineralized bone resulting in structural deformities of growing bones, while bone undermineralization in adults is involved in osteoporosis with associated increases in fracture risk (WHO, 2009).

Na⁺ concentration range from 0.00 to 120 mg/l with an average of 33 mg/l. **K⁺** also ranged from 5 to 165 mg/l with an average of 27.88 mg/l (Table: 2). Some of the samples are within the permissible limit set by (NIS, 2007) and (WHO, 2011). Areas with high concentration are Kwagga (12.61452778°N, 8.48388889°E), Yanzaki (12.5673333°N, 8.42988889°E), Jada (12.73116667°N, 8.40055556°E) and Karaftayi (12.62077778°N, 8.37575°E). **Mg²⁺** ranges from 0.00 to 22.1 mg/l with an average of 4.5375 mg/l. Sources of this ion in groundwater is similar to calcium ion. (Figure 3). Magnesium is very essential element needed to stimulate bone and teeth in human body (WHO, 2009).

Fe²⁺ varies from 0.02 mg/l to 4.13 mg/l with an average of 1.168 mg/l. These values when compared with standards shows that, most of the samples have high concentration of iron (Table 2). Locations with high level of iron concentration include, Kurna, (12.54419444°N, 8.48005556°E), Roni, (12.65580556°N, 8.27055556°E), Tsabawa (12.72197222°N, 8.29905556°E), Shada, (12.74208333°N, 8.3093333°E) and Ka'el, (12.65430556°N, 8.3375°E). High concentration mostly resulted from the leaching weathering of iron bearing minerals, like micas (biotite and muscovite), amphiboles and pyroxenes as well as acidic nature of the water. The acidity of the water may have causes high concentration of iron in groundwater, which make Fe²⁺ very soluble especially most of the aquifer in the area is very deep. The high level concentration of iron in drinking water for domestic use is objectionable because it impacts brownish colour on laundered cloth, leaves brown deposit in water, cause growth of iron bacteria, affects taste of drinking water as well as beverages such as tea and coffee

(WHO, 2011). Mn^{2+} range from 0.018 to 0.807 mg/l with an average of 5.62745 mg/l. source is also similar to that of iron.

Pb^{2+} ranges from 0.035 to 0.128 mg/l with an average of 0.0832 mg/l (Table 2). All the samples analysed are above the maximum permissible limit of 0.01 mg/l (Table: 2). High concentration is favoured by anthropogenic activities, like wet season farming, irrigation, through the application of herbicides and pesticides. Since, almost all the water sample analyzed has shown a low pH value i.e. acidic. The water which is acidic condition also increased the rate of solubility of lead compound as it leaching into the soil and rocks. Lead is also known to cause injury to the central and peripheral nervous systems, which results in headache, dizziness, memory deficits and decreased nerve conduction velocity and severe Kidney damage. Cd^{2+} concentration ranges from 0.0012 to 0.019 mg/l with an average of 0.01525 mg/l. Application of fertilizers produced from phosphate ores constitute a major source of diffuse cadmium pollution. The solubility of cadmium in water is influenced to a large degree by the water acidity; suspended or sediment-bound cadmium may dissolve when there is an increase in acidity (Ros and Slooff, 1987). High concentration of cadmium causes cancer, kidney damage as well as reproductive system toxicity.

Zn^{2+} ranges from 0.00 to 0.9472 mg/l with an average of 0.130055 mg/l. Concentration is within the acceptable limit set

by NIS, 2007 and WHO, 2011. Cr^{2+} Concentration varies from 0.00 to 0.442 mg/l with an average of 0.1694 mg/l. HCO_3^- the concentration of bicarbonate varies from 24.4 to 213.5 mg/l, on average 93.025 mg/l. Bicarbonate ion in groundwater is derived from the weathering of plagioclase feldspar.

Cl^- Concentrations in excess of 250 mg/l are increasingly likely to be detected by salty taste. The source of chloride is from minerals which contain chlorine as essential constituents as well as dissolution of the readily soluble salts of chloride ions precipitated in the soil zone due to high rate of evapotranspiration and minimal recharge. Concentration ranges from 28.4 to 85.2 mg/l with an average of 51.15 mg/l. The concentration is far below the NIS, 2007, and WHO, 2011, recommended limits of 250 mg/l. This indicates that, water from the area is suitable for drinking and other domestic uses. The chloride content shows that, the water samples analyzed are of meteoric in origin.

SO_4^{2-} Concentration ranges from 1.42 to 14.2 mg/l with an average of 4.7205 mg/l. Sulphate, SO_4^{2-} , enters water by oxidation of sulphides. NO_3^- Concentration ranges from 10 to 21.4 mg/l with an average of 14.765 mg/l. High concentration may causes (methaemoglobbinaemia) blue baby disease especially for infants younger than 6 month old.

Table 1: Physicochemical parameters measured in the hand pumps and hand dug wells.

Sample ID	Locations	Well/BH	Northing Decimal Degrees	Easting Decimal Degrees	pH	TDS(mg/l)	Temp.(°C)	EC(μS/cm)
L 1	Kwagga,	BH	12.61452778	8.48388889	4.94	220	31.5	390
L 2	Yammawa,	W	12.50886111	8.48591667	5	20	33.9	50
L 3	Kurna Danjibga,	BH	12.54419444	8.48005556	4.9	0	33.4	10
L 4	Gadar Kazaure Pri. .	BH	12.59447222	8.45569444	5.12	100	31.5	170
L 5	Yanzaki,	W	12.56733333	8.42988889	6.08	230	31.2	220
L 6	Layin Yarabaw,	W	12.64408333	8.40919444	5.71	110	31.6	210
L 7	U/Malam Adamu,	W	12.73436111	8.43305556	5.46	60	29.9	120
L 8	Jada	BH	12.73116667	8.40055556	5.72	90	29.3	170
L 9	Riniyal	BH	12.69616667	8.41927778	5.53	60	29.5	110
L 10	Sabuwar Jawo	BH	12.66988889	8.39661111	5.59	130	30.6	220
L 11	Karaftayi	W	12.62077778	8.37575	5.38	110	29.6	210
L 12	Elde,	W	12.58327778	8.34519444	5.59	80	29.7	160
L 13	Tsaka,	BH	12.56261111	8.32008333	5.95	190	29.9	350
L 14	Nawala	W	12.504	8.28883333	5.89	80	28.8	150
L 15	Mahuta	W	12.60761111	8.26169444	5.82	30	29.8	60
L 16	Roni Town	BH	12.65580556	8.27055556	5.42	280	31.1	490
L 17	Tsabawa,	W	12.72197222	8.29905556	5.87	0	30	20
L 18	Shada	BH	12.74208333	8.30933333	4.74	30	31	60
L 19	Kurna	W	12.64827778	8.30188889	6.59	530	29.7	910
L 20	Kael	W	12.65430556	8.3375	5.43	50	29.8	90

Table 2: Comparison of field data (author's result) with NIS (2007) and WHO (2011) recommended values for physical and chemical parameters of water for drinking and domestic uses.

Parameters	Unit	WHO 2011	NIS 2007	Author's Result 2015 Range	Average	Remark
Water Temp.	C°	-	-	28.8 – 33.9	30.59	Good
Conductivity	µS/cm	-	1000	10 – 910	208.5	Excellent
Ph	-	6.5 – 8.5	6.5 – 8.5	4.74 – 6.59	5.5365	Low
TDS	mg/l	1000	500 – 1500	0.00 – 530	120	Excellent
Ca ²⁺	mg/l	100	75 – 200	004 – 027	7.85	Low
Na ⁺	mg/l	200	200	0.00 – 120	33	Low
K ⁺	mg/l	10 – 15	-	005 – 165	27.885	High
Mg ²⁺	mg/l	50	0.2	0.00 – 22.1	4.5375	Low
Fe ²⁺	mg/l	0.3	0.3	0.02 – 4.13	1.168	High
Mn ²⁺	mg/l	0.1	0.2	0.018 – 0.807	5.62745	High
HCO ₃ ⁻	mg/l	500 – 1000	-	24.4 – 213.5	93.025	Low
Cl ⁻	mg/l	250	250	28.4 – 85.2	51.15	Good
SO ₄ ²⁻	mg/l	250	100	1.42 – 14.2	4.7205	Low
NO ₃ ⁻	mg/l	50 – 100	50	10.0 – 21.4	14.765	Excellent
F ⁻	mg/l	1.5	1.5	0.46 – 0.60	0.5295	Excellent
Cd ²⁺	mg/l	0.003	0.003	0.012 – 0.019	0.01525	High
Pb ²⁺	mg/l	0.01	0.01	0.035 – 0.128	0.0832	High
Zn ²⁺	mg/l	0.1	3	0.00 – 0.9472	0.130055	Good
Cr ²⁺	mg/l	0.05	0.05	0 – 0.442	0.1694	Good

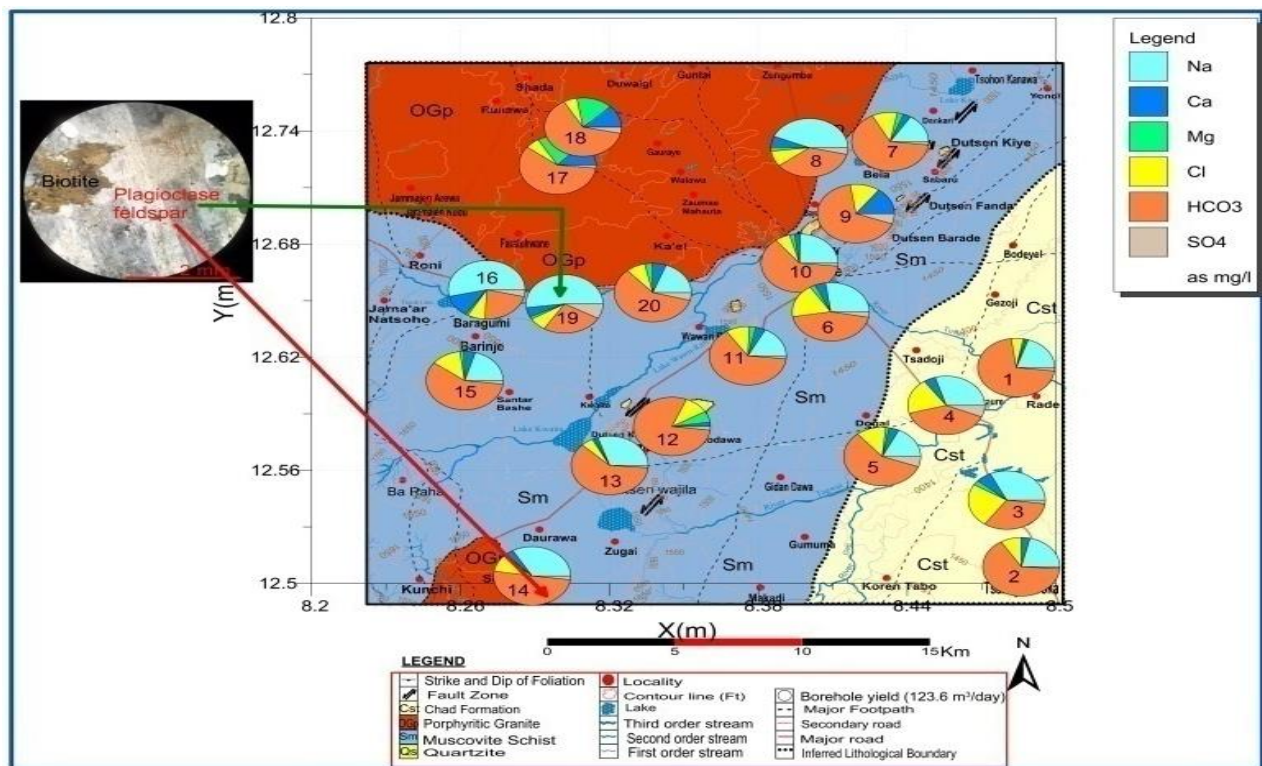


Figure 3: Groundwater type of the Roni area, superimposed on the geological map.

F⁻ the source of fluoride in water are believed to be fluorine bearing minerals such as micas (muscovite and biotite). The concentration of fluoride range from 0.46 to 0.60 mg/l with an average of 0.5295 mg/l. Fluoride stimulates bone formation and small concentrations have beneficial effects on the teeth by hardening the enamel and reducing the incidence of dental caries especially in children below 7 years. (McDonagh *et al.*, 2000). Since all samples within the study, shows low concentration of fluoride which make the water to be excellent for drinking. Concentration beyond the NIS, 2007 and WHO, 2011 of 1.5 mg/l causes dental and skeletal fluorosis, and lesions of the endocrine glands, thyroid and liver.

C. General Discussion of Hydrochemical Analysis Result

Hydrochemical study usually reveals quality of water that is intended for various uses. Groundwater often consists of nine (9) major chemical elements- Ca²⁺, Mg²⁺, Si⁺, CO₃⁻, Na⁺, K⁺, HCO₃⁻, Cl⁻, SO₄²⁻ (Sadashivaiah *et al.*, 2008). The result of the study has indicated that among the major cations in the water samples concentration of the alkali Na⁺ and K⁺ exceed those of the alkaline earth Ca²⁺ and Mg²⁺. Similarly, concentration of the HCO₃⁻ ion exceeds those of Cl⁻ and SO₄²⁻ ions. The cations preponderance is of the order Na⁺ > K⁺ > Mg²⁺ > Ca²⁺ while for the anions dominance are HCO₃⁻ > Cl⁻ > SO₄²⁻ (Figure 4). (Schoeneich, 2014 in verbal discussion with post graduate students) pointed out that meteoric, sea, connate and juvenile waters are characterized by preponderance of Ca²⁺ and HCO₃⁻, Mg²⁺ and Cl⁻, Na⁺ and Cl⁻, and Na⁺ and HCO₃⁻ respectively.

Inferences from this, the dominant ions of groundwater in the study area are Na⁺ and HCO₃⁻ indicating a largely meteoric water origin not juvenile as the trend above shows. Consequently, the sources of both sodium and bicarbonate ions in the Roni area are from the rock-groundwater interaction (particularly weathering of silicate minerals present in the porphyritic granite) of feldspar (plagioclase) and weathering of bicarbonate (Figure 3). Bicarbonate (HCO₃⁻) might have also source as a result of natural rainwater interacts with carbon dioxide (CO₂) in the atmosphere, forming carbonic acid (H₂CO₃).

D. Hydrogeochemical Facies of Groundwater

The hydrogeochemical assessment of groundwater in the study area was determined by classifying the water into the different hydrochemical facies or water types. This classification is based on the TDS and the preponderance ions in each sample. Schoeneich (2001) stated that, water can be classified chemically based on mineralization; dominance ions; and some trace elements or some dissolved gases. Based on mineralization (TDS), all the waters samples analyzed are oligomineral waters or simply put as fresh waters because they have mineralization < 1 g/l (1000 mg/l) (Table 3). Chilton and Smith- Carington (1984) shows that high mineralization (TDS) is due to high leaching of soluble minerals from the weathered zone. Plots of the hydrochemical parameters of the water

samples on the Piper (1944) diagram shown in Figure 4, classified the groundwater system in the study area into different lithology as presented in Table 3.

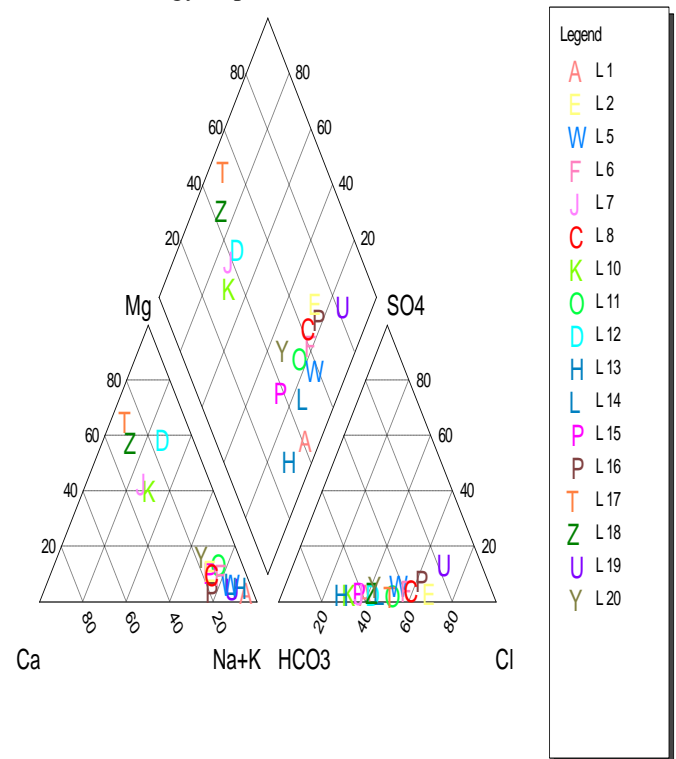


Figure 4: Piper trilinear diagram of the relative cation and anion composition of groundwater samples of the Roni area.

The term hydrochemical facies are used to describe the bodies of groundwater in an aquifer, that differ in their chemical composition. The facies are a function of the lithology, solution kinetics and flow patterns of the aquifer (Table 4).

The classification for cation and anion facies, in terms of major ion percentages and water type, is according to the domain in which they occur on the diagram segments (Figure 3). It is observed that Na⁺-HCO₃⁻ water type occupied 75 %, while the rest are mostly mixed water type (Table 5).

In addition, presence of high percentage Na⁺-HCO₃⁻ waters type in the area, can be inferred due to higher concentration of sodium and bicarbonate from the silicate weathering, particularly plagioclase feldspar granitic rock of the area (Figure 2). Plagioclase and pyroxenes are the chief sources which supply the major cations (Ca²⁺, Mg²⁺ and Na⁺) and anions (HCO₃⁻) in groundwater from crystalline basement aquifer (Naik *et al.*, 2008). There is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate (Sadashivaiah *et al.*, 2008).

Table 3: Distribution of hydrochemical facies of groundwater from the different water bearing formations of the Roni area.

Sample ID	Location	Geology	Hydrochemical facies
L 1	Kwagga, Kazaure	Chad Formation	$K^+ - Na^+ - HCO_3^-$
L 2	Yammawa	Chad Formation	$Na^+ - HCO_3^-$
L 3	Kurna Danjibga	Chad Formation	$Na^+ - HCO_3^- - Cl^-$
L 4	Gadar Kazaure	Chad Formation	$Na^+ - K^+ - HCO_3^- - Cl^-$
L 5	Yanzaki, Kazaure	Chad Formation	$K^+ - Na^+ - HCO_3^- - Cl^-$
L 8	Jada, K/dankari	Porphyritic Granite	$K^- Na^+ - HCO_3^-$
L 9	Riniyal, Kazaure	Porphyritic Granite	$K^+ - Ca^{2+} - HCO_3^-$
L 10	Sabuwar Jawo Kzr	Porphyritic Granite	$Na^+ - HCO_3^-$
L 14	Nawala	Porphyritic Granite	$Na^+ - HCO_3^-$
L 17	Tsabawa	Porphyritic Granite	$Mg^{2+} - Ca^{2+} - HCO_3^-$
L 18	Shada	Porphyritic Granite	$Mg^{2+} - Ca^{2+} - HCO_3^-$
L 20	Ka'el	Porphyritic Granite	$Na^+ - HCO_3^-$
L 6	Kazaure, L/yaruba	Muscovite Schist	$Na^+ - K^- - HCO_3^-$
L 7	U/Mallam Adamu	Muscovite Schist	$Na^+ - HCO_3^-$
L 11	Karaftayi, Kazaure	Muscovite Schist	$Na^+ - K^+ - HCO_3^-$
L 12	Elde, Amaryawa	Muscovite Schist	$Mg^+ - HCO_3^- - Cl^-$
L 13	Tsaka	Muscovite Schist	$Na^+ - HCO_3^-$
L 15	Mahuta	Muscovite Schist	$Na^+ - HCO_3^-$
L 16	Roni Town	Muscovite Schist	$Ca^{2+} - Na^+ - HCO_3^-$
L 19	Kurna	Muscovite Schist	$Na^+ - HCO_3^-$

Schoeller (1965) diagram is also used to present average chemical composition of groundwater within the Roni area. From the diagram, Na^+ is the dominant cation, while Ca^{2+} is the least. In the case, of anion HCO_3^- is the dominant and SO_4^{2-} is the least. The cations preponderance are of the order $Na^+ > K^+ > Mg^{2+} > Ca^{2+}$ while for the anions dominance are $HCO_3^- > Cl^- > SO_4^{2-}$ (Figure 5). Dominance of the Na^+ and Mg^{2+} hints to the cation exchange processes through the rock water interactions.

Table 4: Summary of hydrogeochemical facies as worked out from piper diagram of the Roni area.

Facies/water type	Sampling stations	No of samples	Percentage (%)
$Na^+ - HCO_3^-$	Kwagga, Yammawa, Tsaka, Nawala, Mahuta, Ka'el, Sabuwar Jawo, Kurna, Kurna Danjibga, Gadar Kazaure, Yanzaki, Kazaure, L/yaruba, Jada, Karaftayi, and U/Mallam Adamu	15	75
Mixed $Mg^{2+} - Ca^{2+} - HCO_3^-$	Tsabawa, Shada	2	10
Mixed $Ca^{2+} - Na^+ - HCO_3^-$	Roni town	1	5
Mixed $K^+ - Ca^{2+} - HCO_3^- - Mg^{2+} - HCO_3^-$	Riniyal	1	5
	Elde, Amaryawa	1	5
Total		20	100

E. Suitability of Groundwater for Irrigation

Total salt concentration as measured by electrical conductivity (EC), relative proportion of sodium to other principal cation as expressed by Sodium Adsorption Ratio (SAR), are some of the techniques adopted by (Wilcox, 1995) in evaluating the suitability of water for irrigation purposes. It is a plot of Sodium Hazard (SAR) on the Y-axis versus Salinity Hazard (conductivity) on the X-axis in Figure 4.

Table 5: Measured of salinity hazard of groundwater samples of the Roni area.

Class	EC ($\mu\text{moh/cm}$)	Remark on Quality	Boreholes samples number	Hand dug wells sample number
C1	0 -250	Excellent	6	10
C2	250 – 750	Good	3	0
C3	750 – 2250	Doubtful	0	1
C4	> 2250	Unsuitable	0	0
Study sample average	208.5	Excellent		

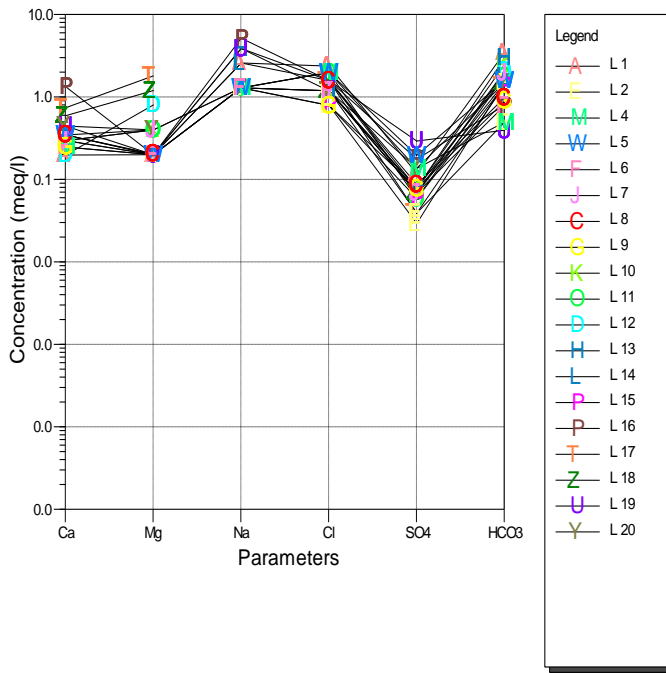


Figure 5: Schoeller diagram of the average composition of major cations/anions in meq/l of the groundwater of Roni area.

The total concentration of soluble salts in irrigation water in all the samples expressed in terms of specific conductance according to salinity hazard classes in Table 5 were mostly found to be excellent and hence suitable for irrigation purposes.

Table 6: Sodium hazard classification based on sodium absorption ratio after Wilcox (1995) of the Roni area.

Sodium Hazard Class	SAR	Remark on Quality	Number of samples
S1	10	Excellent	19
S2	10 - 18	Good	1
S3	18 – 26	Doubtful	0
S4	> 26	Unsuitable	0

F. Sodium Adsorption Ratio (SAR)

The exchange process of sodium in water for magnesium and calcium in soil reduces permeability and eventually results in soil with poor drainage. Hence, air and water circulation is restricted during wet conditions and such soils are usually hard when dry (Collins and Jenkins, 1996; Saleh *et al.*, 1999).

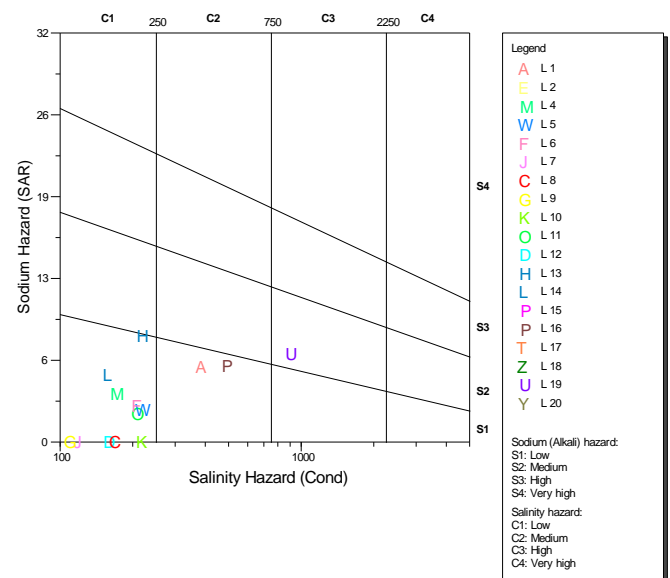


Figure 6: Wilcox plot for classification of irrigation water around Roni area.

It is defined by (Richards, 1954):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \tag{1}$$

Ca²⁺, Na⁺ and Mg²⁺ have been used to calculate SAR for the water samples. This ratio is commonly used to assess the suitability of water for irrigation.

The classification of the groundwater samples from the study, with respect to SAR as presented in (Table 6) indicate that the SAR values of all the samples were found to be in S1 and S2 of sodium hazard classes, making the water to be excellent, good for irrigation water.

IV. CONCLUSION

The observed physical parameters of pH, TDS, Temperature and Conductivity are within the WHO (2011) permissible limits for drinking water, except pH that falls below the standard level. High concentration of iron, cadmium and lead in groundwater of the area might be a result of acidic nature of the water analysed. Lead ions also might have resulted from the application of pesticides chemicals, during wet season and irrigation farming.

From the water quality analysis it was observed the major cations are sodium and calcium while the anions are bicarbonate and chloride. The dominant water facie in the study is Na⁺-HCO₃⁻. This might have been as a result of rock-water interaction of plagioclase feldspar of porphyritic granite. Result from salinity hazard of the water samples has indicated that, water of the area is good for irrigation. Generally, the result shows that the water of the Kazoure area is safe for drinking and domestic uses, based on the comparison with both NIS (2007) and WHO (2011).

The area is underlined by rock units, such as muscovite schist, porphyritic granite and Chad Formation. Quartzite also occurs as minor rock in the area. The major structural features mapped in the area include joints, fractures and foliations with most trending in the NE-SW direction.

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