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REVIEW ARTICLE

GROUNDWATER QUALITY ASSESSMENT OF KARSHI AND ITS ENVIRONS, PART OF MALUMFASHI SHEET (SHEET 79 S.E) KANO STATE, NORTHWESTERN NIGERIA

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ABSTRACT

This research is aimed at assessing the quality of groundwater for safe drinking in karshi and its environs, kano state. In achieving this aim, ten (10) samples were taken from both hand pump Boreholes and open wells that were selected at different settlements, taken into consideration the fact that the dwellers depend on this water for consumption and other commercial uses and that, understanding the water quality is of importance. Water from each of the selected hand pump boreholes and open wells were sampled in a sterilized 500ml plastic containers and taken to the laboratory for chemical analysis. Fifteen (15) relevant parameters on the test for water quality were taken into consideration. Analysis of physical parameters reveals that electrical conductivity is the only physical parameter with mean value of 1016.5 Mg/l that is neither within or below the permissible range of 300 - 400mg/l but rather it is higher. The mean value of chemical analysis reveals that Electrical Conductivity (Ec) and Iron (Fe) does not fall within or below the permissible ranges stipulated but rather are found to be higher, the mean concentration of Sulphate (SO_4), Total Dissolved Solid (TDS), Calcium (Ca), Magnesium (Mg), Sodium (Na) are below the permissible ranges, but concentration of Magnesium (Mg) in location (RT5) is within the permissible range stipulated by (WHO, 2022), while Sodium (Na) in (RT5) is higher than the permissible range stipulated. All other physicochemical parameters such as; pH, Temp., Hardness, Nitrate (NO_3^-) are within the standards set by the World Health Organization (WHO, 2022) as stipulated in the WHO Standards for drinking water. Furthermore, the analysis reveals that the water are moderately suitable for drinking and no contamination. The quality of the water was understood through geological, hydrogeological and Hydrogeochemical investigations. Geological investigations reveals that the targeted area is underlained majorly by both quartzites covering about approximately 60% of the area, medium-coarse grained granite and porphyritic granites covering the remaining 40% of this study area. Hydrogeological investigation reveals that aquifer type in the area is fractured basement with water flowing perpendicular to the water level contours and from areas of high to low topography. Hydrogeochemical investigations identified NaCl and CaCl water types as the two water types in the study area and that the chemistry of water is controlled by ion exchange and simple dissolution or mixing. Durov diagram provide information on the hydrochemical facies so as to identify the water types and display some possible geochemical processes that could help in understanding the quality of groundwater and its evaluation.

KEYWORDS

Physicochemical Parameters, Spatial Distribution, Groundwater Quality, Hydrogeology,

1. INTRODUCTION

Concealed beneath the vast and varied landscape of kano State is a treasured and important natural resources. It is neither petroleum nor gas, which are the natural resources that are certainly important and have brought wealth to many people. This concealed treasured is water, and to be precise, groundwater. Groundwater occurs everywhere but sometimes its availability in economic quantity depends solely on the distribution of the subsurface geological units that are referred to as the aquifers. This implies that where groundwater is not potentially endowed enough, there may be either complete lack or inadequacy due to increasing industrial and domestic needs (Akpan et al., 2013).

Groundwater is a vital resource, with a large fraction of the world's population relying on the resource directly or indirectly for livelihoods. Much of the groundwater can be said to be meteoric in origin, which is originating from the atmosphere. A small percentage is known to enter the hydrologic cycle from subterranean sources and is described as juvenile water. This water includes water of magmatic and volcanic sources, while connate water is entrapped between the interstices of sedimentary formations.

In this study the aim of evaluating ground water quality is to determine if it meets the requirements for its many different uses. Ground water quality can be affected or degraded as a result of 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. Recently, groundwater quality has become a matter of concern due to discharge of industrial and domestic effluents directly into both surface and underground, the use of agricultural chemicals, land use and cover changes. Thus water quality is influenced by many factors, including atmospheric chemistry, the underlying geology, climate change and anthropogenic activities. The quality of water should satisfy the requirements or standards set for specific uses, such as drinking, domestic, agricultural, industrial and recreational purposes (Sanjay, 2010).

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2. STRATIGRAPHIC LEVEL

2.1 Geological field mapping

Geological field mapping was carried out using ground traverses provided by major and minor roads, footpaths, as well as several farmlands. A topographic map on a scale of 1:50,000 was used as a base map, and a Global Positioning System (GPS) instrument (Plate 1) was used for traversing and recording of coordinates on the field notebook. Compass and clinometer (Plate 2) was used to measure dip angle, dip direction and strike of geological structures. Geological hammer (Plate 3) was used in collecting rock samples. Samsung mobile phone camera was used to take photographs of some distinguished features on the outcrop. The field mapping was done with the aim of producing a geological map and hydrogeological map of the study area. ArcGIS computer software was used to digitize the base map.

2.2 Hydrogeological mapping

The methodology followed is hydrogeological, i.e. measurement of hydraulic head in different hand-dug wells in the study area. The hydrogeological mapping involved measurement of depth to water table. The Measurement was done with the aid of measuring tape (Plate 4) at the end of which water table map was produced on a scale of 1: 50,000. Global Positioning System (GPS) was used in taking records of locations (coordinates) and exact elevations of wells meters above sea level. The field work was done in February 2023, data on depth to water table of 9 open wells/ hand dug wells were recorded. This was done simultaneously with identification of rocks, and analysis of water quality.

Plate 1: GPS -Global Positioning System

Plate 2: Compass and Clinometer

Plate 3: Geological Hammer

Plate 4: Measuring Tape

2.3 Groundwater Quality Assessment

To assess the level of groundwater contamination, sampling of groundwater was done from open wells and handpump well located in the study area. Good quality narrow mouth screw-capped polypropylene bottles of 100ml capacity were used to collect the samples. Before sample collection, bottles were rinsed twice with the in-situ water to be sampled and then samples were collected.

2.3.1 Labelling of the samples

Every sample was coded adequately and marked by a code on sampling bottles using permanent marker and masking tape, all the information regarding name of the sampling location, source and date of collection were recorded in the field notebook to avoid any confusion and error.

Figure 1: showing a labelled sample from the study area.

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2.3.2 Collection of samples

The following were carried out before and when collecting the samples,

- The pipeline of boreholes /hand pumps were flushed for a sufficient period of time, so that sample can be collected which represents the actual groundwater.
- Sample bottles were rinsed twice with the water to be collected and then filled completely to avoid encroachment of air bubble.
- Sample bottles screw-caped tightly and brought to the laboratory.
- The samples were preserved in refrigerator at 25°C. A total of ten (10) samples were collected and 9 open well sample was presented.
- The analysis of physical parameters; Temperature, pH, Total Dissolved Solid (TDS) and Electrical Conductivity were made in field with WAGTECH pH/COND/EC/Temp. meter (Plate 5). Chemical parameters were analysed in the laboratory using different analysis techniques (Plate 6)

2.3.3 Examination of samples

Groundwater samples of various locations were analysed for determination of degree of contamination with respect to the following physico-chemical parameters and heavy metals opted for investigation in the study locations.

- pH
- EC (Electrical Conductivity)
- T.D.S (Total Dissolved solids)
- T.H (Total Hardness)
- Calcium (Ca^{2+})
- Magnesium (Mg^{2+})
- Sodium (Na^{2+})
- Iron (Fe^{2+})
- Lead (Pb^{2+})
- Bicarbonate (HCO_3)
- Chloride (Cl^-)
- Sulphate (SO^{2-})
- Nitrate (NO^{3-})

2.3.4 Standard methods adopted for analysis

The ground water samples collected from various selected locations were analyzed for physicochemical parameters in order to determine degree of pollution. Standard methods given in "Standard methods for the examination of water and wastewater, 17th edition, 1989, prepared and published jointly by American public health Association, American water works association (AWWA) and water pollution control federation (WPCF), were used for determination of various physicochemical parameters (APHA, 1998).

2.3.4.1 Methods for physical analysis

The physical parameters analyzed were; temperature, pH, conductivity and total dissolved solids. The result was presented in table 4.

- pH is the measure of acidity and basicity of water samples. WAGTECH portable pH/COND/EC/Temp. meter was used in determining the pH of the samples in the field. Each sample was taken in a sample bottle that was rinsed with the in-situ location's water and WAGTECH portable pH meter wires connected to a probe which was immersed into the sampling bottle then the corresponding values of the pH displayed on the screen were then recorded. The pipe that was inserted was washed thoroughly and carefully with distilled water before analysis of next sample.
- Temperature was determined using the direct reading of WAGTECH portable pH/COND/EC/Temp. meter. The probe of this instrument was immersed into the sample and its temperature was displayed on the screen.
- Electrical Conductivity is the measure of the amount of ions in the water sample. The instrument used was the same WAGTECH portable pH/COND/EC/Temp. meter and no reagent was used. The probe was inserted into the sample bottle and the conductivity result read's on the screen. Its units is µs/cm.
- Total Dissolved Solids (TDS), the WAGTECH portable pH/COND/EC/Temp. meter was also used. 100ml of each sample was taken and poured into a tiny container attached to the WAGTECH portable meter and it was inserts back into the Meter and the result was displayed on the instruments screen. Its unit is mg/L.

Plate 5: Analysis of physical parameters in the study area.

2.3.4.2 Methods for chemical analysis

Groundwater samples collected were analyzed for major and minor chemical constituent which includes dissolved ions of Na^{2+}, Mg^{2+}, Ca^{2+}, Pb^{2+}, Fe^{2+}, $S0_4^{2-}$, Cl^- NO_3^-, HCO_3^- and Total Hardness. The chemical analysis was categorized into two phases; the analysis of $S0_4^{2-}$, Cl^- NO_3^-, Na^{2+}, HCO_3^- and Total Hardness, which was carried out at Soil, Plant and Water Laboratory, Old Agric Department, Bayero University Kano. And the analysis of some heavy metals Mg^2+, Ca^{2+}, Pb^{2+}, and Fe^{2+}, which required digestion of the samples prior to analysis was carried out at , Old Agric Department, Bayero University Kano. The anions are:

- Chloride (Cl^-): Chloride in the water samples was determined using the Argentometric method as described in American Public Health Association in 1992. 20ml of the water sample was titrated against 3 drops of silver nitrate solution using potassium chromate solution as indicator until a pinkish yellow end point was achieved. The initial and final titer values was used to calculate the actual titer value which was later used to determine the concentration of Chlorine in each groundwater sample using the relation:

$$Cl^- \text{ (Mg/L)} = \frac{\text{T.V x N x 35.5 x 1000}}{\text{V}}$$

Where

T.V is the sample actual Titre Value

N is the concentration of AgNO3 (0.01ml)

V is the volume of sample used (20ml)

35.5 and 1000 are constants.

- Sulphate (SO_4^-): 1ml of barium chloride was added to each 20ml of the water sample in the presence of sulphur. The sample was then cooled for 30mins and the result was read using clorimeter at 430nm with -0.02 as blank value. The actual concentration of sulfur was then calculated using the formular:

SO_4^{2-} = read value - blank value

- Total Hardness: Hardness results from the presence of divalent metallic cations of which calcium and magnesium are the most abundant in groundwater. It was determined using titrimetric method and it is carried out as follows: 14 drops of sodium hydrochloric acid ($NHCl_2$) indicator were added to the sample. This was titrated against 0.01ml EDTA until change of colour from purple to blue occurred, the titre value was recorded and total hardness is calculated using the formular

below:

$$Ca^{2+} + Mg^{2+} (Mg/L) = \frac{T.V \times N \times 100}{V} \times 390$$

Where

T.V is the sample actual titre value

N is the concentration of EDTA (0.01ml)

V is the volume of sample used (20ml)

100, 390 are constants. in the formular

- Nitrate (NO_3^-): Concentration of nitrate-nitrogen was determined by distillation-titration. Before the titration, 10ml of each sample was poured in a 100ml beaker, mixed with 10ml of boric acid, 10ml of Devard's alloy (mixture of 50% Cu, 45% Fe, and 5% Zn) and 3 drops of methyl indicator until the samples changed to green. The greenish samples were then titrated, initial, final and actual titration value were determined. The NO_3- was then calculated using the relation:

Where

$$NO3 (mg/l) = \frac{T.V \times N \times 14.01 \times 100}{V}$$

T.V is the actual titre value

N is the concentration of EDTA (0.01ml)

V is the volume of sample used (10ml), 14.01 and 100 are constants.

Plate 6: Analysis of chemical parameters

2.3.4.3 Sample digestion and analysis of heavy metals

Before the analysis of heavy metals using Atomic Absorption Spectrophotometry (AAS) analytical method, the water samples were digested at the Soil and Water Laboratory (Plate 7) and the analysis/reading was carried out. The digestion was done by washing the sample bottles, labelling accordingly and rinsing with the corresponding samples. The 100ml sample bottle was separated into two of which one of the sample bottle is concentrated with 30% HNO_3 acid. The sample was then boiled gently over a water bath as 95°C for 40mins until the sample is completely dissolved to 70ml

Plate 7: Digested Samples

They noted that the determination of heavy metals concentrations in water sample can be accomplished by various methods i.e. titrametric, gravimetric, colorimetric, flame photometric method, ion chromatographic, atomic absorption spectrophotometer (AAS) etc (Steve and Andy, 2017). Atomic absorption spectrophotometric method is widely used for determination of heavy metals present, even at very low concentrations in water samples because the technique is relatively simple, versatile, accurate and free from major interferences. Sixty-eight elements can be determined directly from atomic absorption spectrophotometer over a wide range of concentrations from ppm to ppb levels with good precision. The instrument is first calibrated with the standard solutions of metal to be analyzed using corresponding hollow cathode lamp of that metal.

The samples drawn in 500ml capacity sample bottles were transferred into a clean glass beaker and acidify with concentrated nitric acid. Some more quantity sample was cooled at room temperature, filtered through Millipore filter of 0.45µm pore size and collected into 50 ml glass volumetric flask. Further this was make up to mark with DM water. Now the sample is ready for analysis. For analysis of the heavy metals i.e Mg^{2+}, Ca^{2+}, Pb^{2+}, and Fe^{2+} by atomic absorption spectrophotometer, the hollow cathode lamps for Ca, Mg, Pb and Fe were used as radiation source and fuel as acetylene. All the samples and standards were run in duplicate. The results for each sample and the corresponding parameter were then read on the detector or data processor and the result was presented in (Table 4). Hydrogeochemical facies were worked out by developing Piper and Durov diagrams with the aid of "Geochemist's Workbench" computer software. Stiff diagram was also plotted using same software. Gibbs diagram was plotted with Microsoft excel and corel draw x3 to establish the relationship of water composition and aquifer lithological characteristics.

3. DISCUSSION AND RESULT

3.1 Geology of the study area

The study area is primarily composed of quartzite, medium to coarse grained granite and porphyritic granites. The quartzite covers about approximately 60 %, while the Porphyritic granite and the medium to coarse grained biotite granite occupies the remaining 40 % of the study area. Figure 12 is the geological map of the study area.

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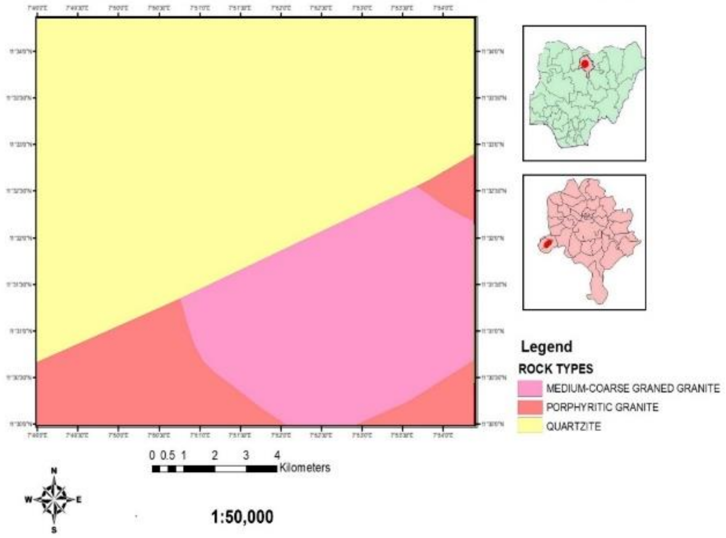

Figure 2 : Digitalised geological map of the study area using ArcGis Software

3.2 Quartzite

Quartzite is a metamorphic rock that forms when sandstone undergoes intense heat and pressure. It is primarily composed of quartz, which is a mineral made up of silicon dioxide (SiO2). Quartzite is known for its hardness and durability, making it a popular choice for various applications. The formation of quartzite begins with the deposition of sand grains in a marine or continental environment. Over time, these sand grains are buried and subjected to high temperatures and pressures caused by tectonic forces within the Earth's crust. The heat and pressure cause the sand grains to recrystallize and fuse together, resulting in the formation of quartzite.

3.3 Porphyritic granite

Igneous rock with crystals of distinctly different size is said to have a porphyritic texture, or might be referred to as porphyry. The larger crystals are called phenocrysts, and the smaller ones are referred to as the ground mass. Porphyritic granite on an estimate constitute about 15 % of the study area and outcrop as well as exposed ridges and inselbergs,

Plate 8: Porphyritic Granite, Dan Mamulo (N 11^0 33’ 11.9’’ E 7^0 50’ 31.5’’)

3.4 Medium-coarse grained granite

The medium -coarse grained granite constitute about 35 % of the study area it is exposed as inselberg, in this area rocks outcrops are few dipping at an angle of 20^0, dip direction 314^0 NW Strike 120SW-34^0 NE

Plate 9: Medium grained granites, (N 11^0 33’ 30’’, E 7^0 52’ 30’’)

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3.5 Geological Structures

(i) Veinlets were abundant structural features observed in the rock exposure at dan Mamulo in the study area. The rock displayed series of veinlets.

Plate 10: Feldspathic veinlets (N 11^0 33’ 15.5, E 7^0 51’ 11.0)

Xenolith, a rock fragment within an intrusive igneous body that is unrelated to the igneous body, it is also referred to as foreign material different in composition with the igneous body which it intruded. Xenolith of the study area represent pieces of older rock incorporated into the magma while it was still fluid, they are located near their original positions of detachment while others settled deep into the intrusion, because their density is greater.

Plate 11: Xenoliths within a medium grained granite (N 11^0 33’ 35’’, E 7^0 52’ 39’’)

3.6 Hydrogeology of The Study Area

The study area occurs within the crystalline Basement of Nigeria. The fractures in the rocks determine their hydrogeological properties and this depends on texture and mineralogy. The type of aquifer in the study area is a fractured basement. The decomposed materials overlie crystalline rocks and are largely covered by a thin layer of superficial material consisting mainly of gravels and silty materials. The fracturing in the study area is mainly due to faulting and shearing probably associated with the Pan African orogeny. The granitic basement aquifer with deeply weathered rocks beneath and fractured rocks with hydraulic conductivity yielded appreciable amount of water in the study area. The depth to water table in the study area ranges from 1.0m to the maximum of 9.0m depth. The mean average depth to water table of open wells in the study area was put at 4.6m. (Table 1) sampling location and sample code, (Table 2) Measured open wells for groundwater configuration map. The groundwater flow system of the study area is presented in (Figure 3).

Table 1: sampling location and sample code.

S/N	Location	Sample Code	Latitude (N)	Longitude (E)	Well Type
1.	KARSHI UNGWAR SARKI 2	RT1	11^0 32’ 53.7”	7^0 52’ 23.6”	Open well
2.	OLD G.R.A 2	RT2	11^0 32’ 56.0’’	7^0 49’ 51.6’’	Hand pump well
3.	DAN MAMULO 2	RT3	11^0 33’ 12.9”	7^0 50’ 41.5”	Open well
4.	KARSHI CIKIN GARI 2	RT4	11^0 33’ 30.4’	7^0 52’ 19.3”	Open well
5.	KARSHI CIKIN GARI 1	RT5	11^0 33 ‘27.3”	7^0 52’ 29.5”	Open well
6.	OLD G.R.A	RT6	11^0 32’ 57.2”	7^0 49’ 56.4”	Open well
7.	KARSHI UNGWAR SARKI 1	RT7	11^0 32’ 54.7	7^0 52’ 21.1”	Open well
8.	GIDAN WAKAYI	RT8	11^0 33’ 05.7”	7^0 50’ 05.0”	Open well
9.	DAN MAMULO	RT9	11^0 33’ 18.4”	7^0 51’ 23.7”	Open well
10.	HAYIN GAGARAU	RT10	11^0 33’ 02.6”	7^0 50’ 05.7”	Open well

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Table 2: Measured open wells for groundwater configuration map

S/N	Location	Latitude (N)	Longitude (E)	Depth to water table (m)	Well Elevation (m) ABS
1.	Karshi cikin gari	11^0 33 ‘27.3”	7^0 52’ 29.5”	9.0	561.8
2.	Karshi ungwar sarki	11^0 32’ 54.7	7^0 52’ 21.1”	6.0	569.4
3.	Karshi ungwar sarki 2	11^0 32’ 53.7”	7^0 52’ 23.6”	5.0	569.1
4.	Karshi cikin gari 2	11^0 33’ 30.4’	7^0 52’ 19.3”	1.80	557.1
5.	Dan Mamulo	11^0 33’ 18.4”	7^0 51’ 23.7”	3.20	570.5
6.	Dan Mamulo 2	11^0 33’ 12.9”	7^0 50’ 41.5”	3.85	591.9
7.	Gidan wakayi	11^0 33’ 05.7”	7^0 50’ 05.0”	5.0	625.2
8.	Hayin gagarau	11^0 33’ 02.6”	7^0 50’ 05.7”	4.60	612.3
9.	Old G.R.A	11^0 32’ 57.2”	7^0 49’ 56.4”	3.0	600.5
			Mean	**4.6**	**521.8**

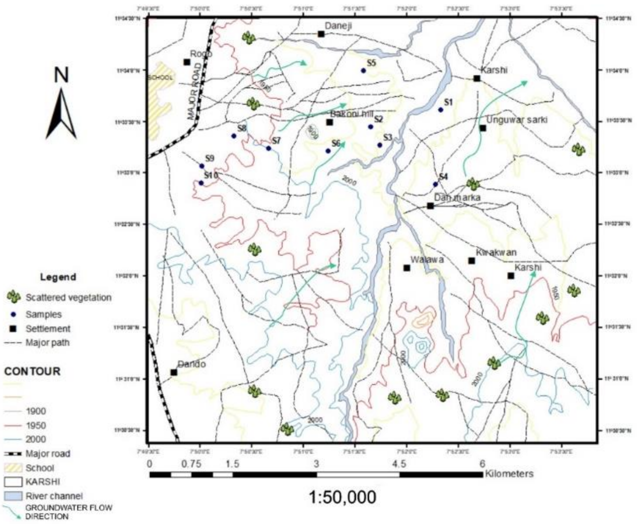


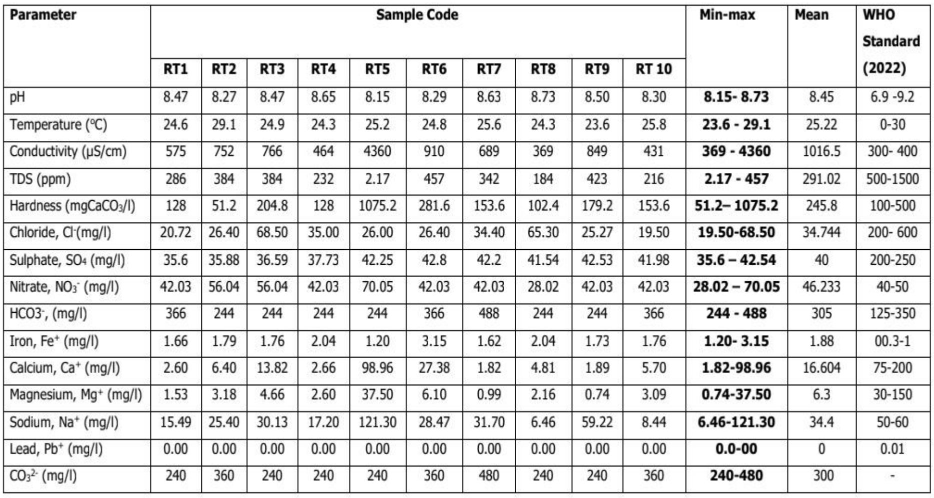
Figure 3: Groundwater configuration map showing groundwater flow direction of karshi and its environs (ArcGis Software).

Groundwater in the study area flow perpendicular to the water level contours (Figure. 13) and from higher topography to the low laying areas south-east trend. This corresponds to the eastern and other parts (recharge areas) towards the south east part (discharge area). At the recharge areas, the static water levels are deeper from the ground surface compared to the static water levels at the discharge area.

3.7 Groundwater Quality of the Study Area

The result of physicochemical analysis of groundwater is presented in table 6, highlighting the different physical and chemical parameters of groundwater analysed.

Table 3: Physico-chemical parameters results of samples collected, Mean and WHO standard for drinking (Water, 2022).



Parameter	Sample Code										Min-max	Mean	WHO Standard (2022)
	RT1	RT2	RT3	RT4	RT5	RT6	RT7	RT8	RT9	RT 10			
pH	8.47	8.27	8.47	8.65	8.15	8.29	8.63	8.73	8.50	8.30	**8.15- 8.73**	8.45	6.9 -9.2
Temperature (℃)	24.6	29.1	24.9	24.3	25.2	24.8	25.6	24.3	23.6	25.8	**23.6 - 29.1**	25.22	0-30
Conductivity (µS/cm)	575	752	766	464	4360	910	689	369	849	431	**369 - 4360**	1016.5	300- 400
TDS (ppm)	286	384	384	232	2.17	457	342	184	423	216	**2.17 - 457**	291.02	500-1500
Hardness (mgCaCO$_3$/l)	128	51.2	204.8	128	1075.2	281.6	153.6	102.4	179.2	153.6	**51.2– 1075.2**	245.8	100-500
Chloride, Cl$^-$(mg/l)	20.72	26.40	68.50	35.00	26.00	26.40	34.40	65.30	25.27	19.50	**19.50-68.50**	34.744	200- 600
Sulphate, SO$_4$ (mg/l)	35.6	35.88	36.59	37.73	42.25	42.8	42.2	41.54	42.53	41.98	**35.6 – 42.54**	40	200-250
Nitrate, NO$_3^-$ (mg/l)	42.03	56.04	56.04	42.03	70.05	42.03	42.03	28.02	42.03	42.03	**28.02 – 70.05**	46.233	40-50
HCO3$^-$, (mg/l)	366	244	244	244	244	366	488	244	244	366	**244 - 488**	305	125-350
Iron, Fe$^+$ (mg/l)	1.66	1.79	1.76	2.04	1.20	3.15	1.62	2.04	1.73	1.76	**1.20- 3.15**	1.88	00.3-1
Calcium, Ca$^+$ (mg/l)	2.60	6.40	13.82	2.66	98.96	27.38	1.82	4.81	1.89	5.70	**1.82-98.96**	16.604	75-200
Magnesium, Mg$^+$ (mg/l)	1.53	3.18	4.66	2.60	37.50	6.10	0.99	2.16	0.74	3.09	**0.74-37.50**	6.3	30-150
Sodium, Na$^+$ (mg/l)	15.49	25.40	30.13	17.20	121.30	28.47	31.70	6.46	59.22	8.44	**6.46-121.30**	34.4	50-60
Lead, Pb$^+$ (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0-00**	0	0.01
CO$_3^{2-}$ (mg/l)	240	360	240	240	240	360	480	240	240	360	**240-480**	300	-

3.8 Graphical Presentation of Hydrogeochemical Data

As water circulate in the subsurface it comes in contact with rocks and soils, ions are leached out and dissolved in the groundwater. The geological formations, water-rock interaction and relative mobility of ions are the prime factors influencing the geochemistry of the groundwater (Yousef et. al., 2009). Because of chemical analysis results of water in form of tables may be difficult to interpret. The graphic representations are used to discuss the water-rock interaction in the study area. Hydrogeochemical facies were worked out by developing Piper (Figure. 4) and Durov (Figure. 5) diagrams for the study area.

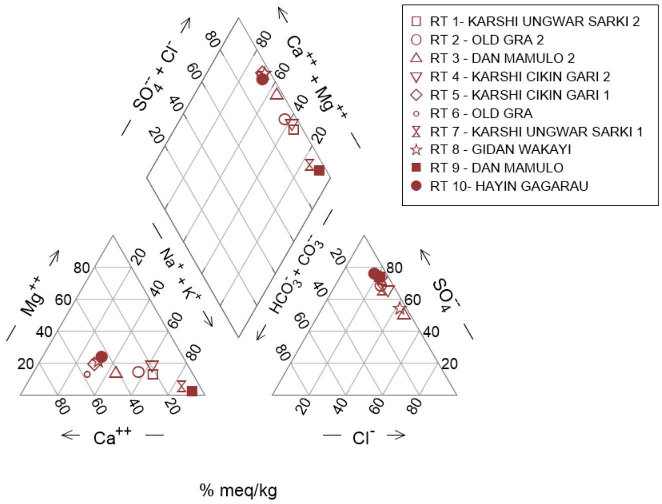


Figure 4: Graph of Chemical classification of water from wells in the study area (modified after Piper, 1944).

Researcher introduced another diagram which provides more information on the hydrochemical facies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding quality of groundwater and its evaluation (Durov, 1948). The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest; sides form a binary plot of total cation vs. total anion concentrations; expanded version includes electrical conductivity (μS/cm) and pH data added to the sides of the binary plot to allow further comparisons.

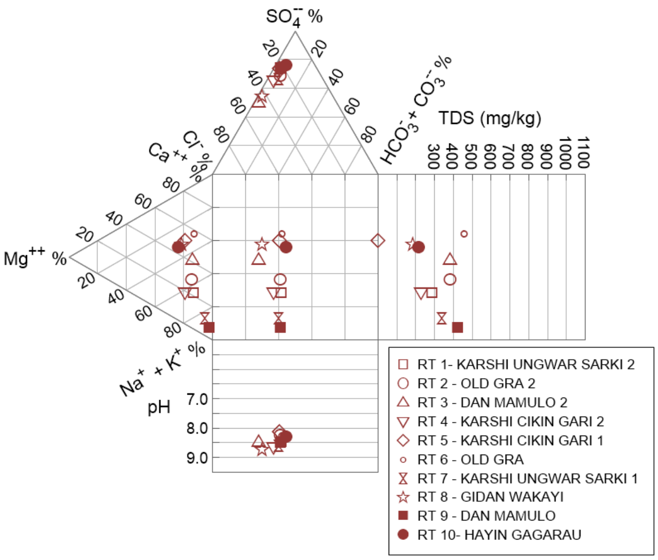


Figure 5: Graphical presentation of water of the study area showing mechanisms controlling the geochemistry of water types and TDS level based on the major ions measured (after Durov, 1949).

The Gibbs' diagram method was used to determine the major natural mechanisms controlling water chemistry. It is represented by the weight ratio $Na^+/Na^+ + Ca^{2+}$ in the x-axis and the total dissolved solid on the y-axis (Figure. 6)

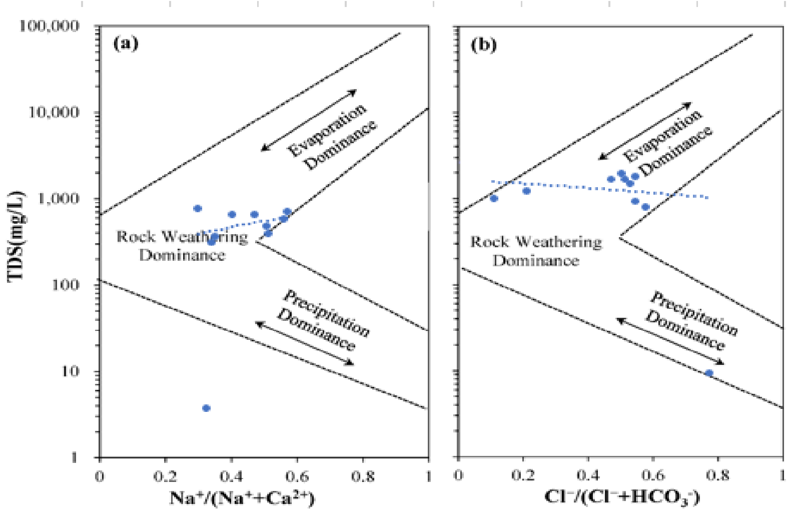


Figure 6: Gibbs plot showing (a) Total Dissolved Solids (TDS) Vs Na^+ /Na^+ + Ca^{2+} and (b) TDS vs $Cl^-/(Cl^- + HCO_3^-$ to illustrate the dominant groundwater chemistry in the study area.

4. SUMMARY

Based on the physico-chemical parameters analysed, the graphical analysis and the calculated mean, the water samples collected from the study area is found to be moderately suitable for drinking and has no contamination as some falls within the WHO guidelines for suitable drinking water, some other samples falls below the permissible range. And that Durov plot reveal that the water quality falls under a no contamination and moderate quality zone as this depends on the projected field on the plot. In the study area the result of total hardness indicates dissolution of Iron (Fe^{2+}) in high concentration which falls above the WHO permissible standards for drinking water. And as such required treatment for drinking purposes.

The geology of the study area is primarily composed of quartzite, medium to coarse grained granite and porphyritic granites. The quartzite covers about approximately 60 %, while the Porphyritic granite and the medium to coarse grained biotite granite occupies the remaining 40 % of the study area. Joints were present in some of the rock exposures with a dominant SE -NW trend, following the general North - South trend. Other structural features observed include veinlets and xenoliths. Aquifer type in the area is a fractured- rock aquifer with water flowing perpendicular to the water level contours and from higher topography to the low laying areas, the fracturing in the study area is mainly due to jointing and shearing probably associated with the Pan African orogeny.

Piper plot identified two water types from the study area and they are; sodium chloride (NaCl) and calcium chloride (CaCl) types. Durov plot of the water from the study area reveals that the chemistry of the water is controlled by ion exchange and simple dissolution or mixing and it also reveals that the water quality falls under a non-contamination and moderate quality as this depend on the projected field in the plot.

High levels of chloride in drinking water can have some effects, particularly in terms of taste and potential health concerns in certain circumstances, Elevated levels of chloride in water can give it a salty or brackish taste just as it was observed in the study area, this taste may not be desirable to some individuals, and it can affect the palatability of the water, Chloride is often found in combination with sodium, and high levels of chloride in water can contribute to increased sodium intake. Chloride can also have environmental implications when it comes to water bodies and aquatic life. Elevated chloride levels in freshwater sources can harm aquatic ecosystems and impact the survival and reproduction of certain species.

High concentrations of iron (Fe^{2+}) can have both beneficial and detrimental effects, depending on the context and the specific system in which it occurs the Beneficial effects are:

- Nutrient for organisms: Iron is an essential micronutrient for many organisms, including plants, animals, and microorganisms. It plays a vital role in various biological processes, such as oxygen transport, DNA synthesis, and electron transfer reactions.
- Plant growth: Iron is a crucial component of chlorophyll, the pigment responsible for photosynthesis in plants. Adequate iron concentrations promote healthy plant growth and development.

While the detrimental effects are:

- Toxicity to organisms: High concentrations of iron can be toxic to certain organisms.
- Environmental impacts: Excess iron concentrations in water bodies can lead to environmental problems. Iron-rich runoff from mining sites or industrial processes can result in the deposition of iron precipitates, which may alter the pH levels and oxygen availability in aquatic ecosystems, potentially harming aquatic life.
- Rust and corrosion: High iron concentrations in certain environments can accelerate the corrosion of metals, leading to the degradation of infrastructure, equipment, and pipelines. Rust formation is a common example of this effect

5. CONCLUSION

The results from this research showed that the water samples were odourless and some varies in taste and color. pH range of the samples (8.15mg/l -8.73mg/l) was within the world health organization recommended limits of 6.9mg/l - 9.2mg/l WHO (2022). The values for the temperatures range from 23.6 °C to 29.1°C are fair enough for drinking water. Hardness range from 51.2mg/l -1075 mg/l with sample from RT5 being harder than other samples with highest value of 1075.2 mg/l. Values for Ca analyzed from all samples sources range from 1.82mg/l - 98.96 mg/l which did not comply with WHO (2022) standard of 75 - 200 mg/l. There are minimal health risks that can be associated with the samples. This is true as the presence of Iron(Fe) are high. There were significant differences in water quality from open well water and hand pump well in Old G.R.A 2.

Based on the results obtained from the analysis carried out in the study area the quality of karshi and its environs belongs to the NaCl and CaCl type of water, while the factors controlling the formation of ions are rock weathering and precipitation. Hydrochemical facies and controlling factor for ion formations in half of the study area are NaCl facies, precipitation and rock weathering. Aquifers in northeastern part of the study area are influenced by the NaCl facies and precipitation factor while those in the northern part are CaCl facies. The existence of the hydrochemical facies (NaCl) is accredited to river water intrusion while the factor controlling ion formations (precipitation) is attributed to precipitation of ions from host lithology.

RECOMMENDATIONS

- The quality of the water in the study area is moderately suitable for drinking as they fall within the WHO guidelines for suitable drinking water, yet it requires treatment because of the high concentration of iron (Fe^{2+}) and electrical conductivity of which these are risky to the health and it is still consumed by the inhabitants.
- Periodic chlorination of groundwater as treatment against high concentration of chlorine should be instituted.
- Guidelines and laws should be passed on locating wells in pollution vulnerable area to avoid drilling wells near contamination sources such as septic tanks.
- This study focuses on groundwater quality assessment which requires analysing the physico-chemical parameter of the groundwater, therefore I recommend that detailed and comprehensive geological mapping should be carried out to identify the types of the lithologies in the study area and their respective boundaries as they affect the chemistry of the water.
- Governmental agencies should conduct a periodic groundwater quality assessment so as to ensure that the ground water is safe for drinking and for other purposes by the poor inhabitants in the study area.

REFERENCES

C. R. Jassby., 2003. Salinity in rivers of the Southwestern United States. Environmental Science and Technology, 37(5), Pp. 914-920.

Drever, J., 1982. The Geochemistry of Natural Waters. Prentice-Hall, Inc., Englewood.

Dupreez, J. W and Brber, W., 1965. Distribution and chemical quality of groundwater in northern Nigeria. Geological survey, bulletin 36.

Durov, S. A., 1948. Natural Waters and Graphic Representation of their Composition. Doklady Akademii Nauk SSSR, 59, Pp. 87-90.

E. M. Goddek., 2016. A review of the possible effects of chloride from wastewater on drinking water sources in arid environments. Science of the Total Environment, 541, Pp. 1120-1134

Efe, S. I., 2005. Quality of water from hand dug wells in Onitcha metropolitan areas of Nigeria. Journal of Environmentalist, Vol. 25.

Egboka, B. C., 1983. Analysis of groundwater resources of Nsukka area and environs, Anambra State, Nigeria. Journal of mining and geology.

Kitchen N. R., 2015. Impact of chloride-enriched irrigation water on plant yield, chloride concentration, and soil salinity. Agronomy Journal, 107(2), Pp. 664-672

McCurry, P., 1976. The Geology of the Precambrian to Lower Paleozoic rocks of Northern Nigeria, a review in Geology of Nigeria. 1nd Revised Edition. C.A. Kogbe, Elizabethan Publication. Lagos. Pp. 15-39.

Mohammed, I., 1984. Hydraulic properties of the Basement Complex and Chad Formation aquifers of Kano State based on test-pumping of selected boreholes. M.Sc. Thesis, Dept. Geol., Ahmadu Bello University, Nigeria.

Morris, B. L., Lawrence, A. R., Chilton, P. J., Adams, B., Caylow, R. C. and Klinck, B. A., 2003. Groundwater and its susceptibility to degradation: a global assessment of the problems and options for management. UNEP Early Warning and Assessment Report Series RS. 03-3, Nairobi, Kenya.

Muslim, I., 1984. Report on geological cross sections in Kano State, volume 1.. A report of the Water Resources and Engineering Construction Agency (WRECA), Kano.

NGWA, T. G., 1999. Groundwater Hydrology for Water Well Contractors. NGWA Press Publication.

Ogunkoye, O. O., 1986. Quality of Flows as an Index of Aquifer Yield in the Basement Complex Area South Western Nigeria. Journal of Environment Management pp. 291-300. Academic Press London Limited.

Olofin, E. A., 1987. Some Aspect of Physical Geography of Kano State Region and its Related Human Responses. Department of Geography, BUK.

Oseiji, J. O., and Askhia, M. B., 2006. Determination of groundwater potential in obiaruku and environs using surface geoelectric sounding. Environmentalist, 26, Pp. 301-308.

Panteswaran L. H., 2018. Impact of water hardness and chloride content on corrosion scale of iron pipes in drinking water distribution systems. Environmental Science and Pollution Research, 25(6), Pp. 5599-5609.

Parker, B.L., Chapman, S.W., Guilbeault, M.A., 2008. Plume persistence caused by back diffusion from thin clay layers in a sand aquifer following TCE source zone hydraulic isolation. Journal of Contaminant Hydrology. 102 (1-2), Pp. 86-104.

Piper, A. M., 1994. A graphic procedure in the geochemical interpretation of water samples. American Geophysical Union Trans., V.25, pp. 914-923.

WHO - World Health Organization., 2023. Guidelines for drinking-water quality. 4th ed. Geneva: WHO.