UMYU Scientifica, Vol. 3 NO. 2, June 2024, Pp 080 – 085
https://doi.org/10.56919/usci.2432.008
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Analysis of Geochemical Parameters for Surface and Groundwater in Zuru Local Government Area of Kebbi State, Nigeria

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ABSTRACT

As one of the fundamental elements of life, living nature could not survive without water. Contaminated water consumption can lead to water-borne diseases and can also cause gastrointestinal illnesses, nervous system illnesses, reproductive effects, and chronic diseases such as cancer. In this study, some geochemical parameters were analysed for surface and undergroundwater around Zuru in southern part of Kebbi state. The result was compared with WHO's prescribed standard for quality water consumption. Four samples of each surface and groundwater were collected from various geographical locations within Zuru for analyses to determine density, conductivity, total hardness, calcium (Ca^{2+}) hardness, magnesium (Mg^{2+}) hardness, pH, and total dissolved solids (TDS) by employing scientific and technological approaches. Surface water has higher values for mean total hardness (93.8 mg/L), the average value for calcium (62.0 mg/L), magnesium (Mg^{2+}) hardness (44.0 mg/L), and the mean value for total dissolved solids (TDS) (620 mg/L), while groundwater has lower values for mean total hardness (30.0 mg/L), the average value for calcium (26.0 mg/L), magnesium (Mg^{2+}) hardness (17.0 mg/L) and mean value for total dissolved solids (TDS) (564.5 mg/L). Groundwater has higher values of average density (0.92 g/cm^3), conductivity (114.3µS/cm), and average pH level (7.0), while surface water has lower values of average density for (0.90 g/cm^3), conductivity (76.1µS/cm), and average pH level (6.9). The research has shown that groundwater is favourably more recommended for drinking and other domestic usages.

ARTICLE HISTORY

Received August 23, 2023
Accepted December 01, 2023.
Published June 08, 2024.

KEYWORDS

Surface water, groundwater, Geochemical parameters, WHO, Contaminated, Consumption..

INTRODUCTION

Water is one of the fundamental elements of life; living nature could not survive without it. In nature, water is found everywhere. The majority of the Earth's water is in the oceans. Water with a low salt content is vital for humans and animals (WHO, 2005). Water is a chemical substance with the chemical formula H_2O; its molecule contains one oxygen and two hydrogen atoms connected by a covalent bond (APHA, 1992). Water is required for many needs, such as drinking, cooking, transportation, recreation, electrical power production, and support for aquatic life (CDPC, 2000). Water pollution occurs through industrial and municipal discharges or runoff from agricultural land or construction (CDPC, 2000). Surface water is located on top of the Earth's surface and may also be referred to as blue water. In common usage, it is usually used specifically for terrestrial (inland) water bodies, the vast majority of which is produced by precipitation and runoff from nearby higher areas. As the climate warms in the spring, snowmelt runs off toward nearby streams and rivers, contributing to a large portion of human drinking water. Alongside being used for drinking water, surface water is also used for irrigation, wastewater treatment, livestock, industrial uses, hydropower, and recreation (EPA, 2017). Groundwater is the *water* beneath the *Earth's* surface in rock and *soil pore spaces* and in the *fractures* of *rock formations*. About 30 percent of all readily available freshwater in the world is groundwater (IGRAC, 2022). Groundwater is also often withdrawn for *agricultural, municipal,* and *industrial* use by constructing and operating extraction *wells*. The study of the distribution and movement of groundwater is *hydrogeology*, also called groundwater *hydrology* (IGRAC, 2022).

The density of water is about 1 gram per cubic centimetre (62 lb/cu ft); this relationship was originally used to define the gram. The density varies with temperature, but not

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How to cite: Namadi, A. Z., Anaegbu, J. O., & Yahaya, A. A. (2024). Analysis of Geochemical Parameters for Surface and Groundwater in Zuru Local Government Area of Kebbi State, Nigeria. *UMYU Scientifica*, 3(2), 80 – 85. https://doi.org/10.56919/usci.2432.008

linearly: as the temperature increases, the density peaks at 3.98 °C (39.16 °F) and then decreases (Greenwood *et al.*, 1997). The conductivity (or specific conductance) of an electrolyte solution is a measure of its ability to conduct electricity. The SI unit of conductivity is Siemens per meter (S/m). Conductivity measurements are used routinely in many industrial and environmental applications as a fast, inexpensive, and reliable way of measuring the ionic content in a solution(James, 2004). Hard water has a high mineral content (in contrast with "soft water") and is formed when water percolates through deposits of limestone, chalk, or gypsum. (WHO, 2003). Calcium reacts exothermically with water and acids, and calcium metal coming into contact with bodily moisture results in severe corrosive irritation (Hluchan and Pomerantz 2006). Magnesium is capable of reducing *water* and releasing highly flammable *hydrogen* gas. The potential of *hydrogen* (or "power of hydrogen" (pH)) is a scale used to specify the *acidity* or *basicity* of an *aqueous solution*. Acidic solutions (solutions with higher concentrations of H^+ ions) are measured to have lower pH values than basic or *alkaline* solutions (Jensen, 2004). Total dissolved solids (TDS) measure the dissolved combined content of all *inorganic* and *organic* substances in a liquid in *molecular*, *ionized*, or micro-granular (*colloidal sol*) suspended form. TDS concentrations are often reported in parts per million (ppm). A digital meter can determine Water TDS concentrations (The Berkey Report, 2020).

Ehizemhen *et al.* 2020 carry out a study on hydrogeochemical features and groundwater attribute evaluation in Northcentral Abuja Nigeria. The outcomes of their analysis exhibited extensive spatial variations, where temperature and pH inclosing with the slightest variability of 4.5 and 5.9 respectively. Most of the borehole water samplings, especially 64.0%, are within the faintly acidic portentous suspension of composite crypt rocks. According to (Nwankwoala *et al.*, 2018), Water is essential for life and one of the most significant factors in determining the quality of life of humans. Groundwater is one of the most refined forms of water available in nature. It is a valuable natural resource and an important water source for agriculture and domestic use. Groundwater is a preferred source of drinking water in most developing countries, including Nigeria because of its higher quality, and unlike surface water, it is less vulnerable to contamination.

Consumption of contaminated water can lead to water-borne diseases such as Cholera, Dysentery, and Hepatitis C' which cause loss of lives. Contaminated water consumption can also cause gastrointestinal illnesses, nervous system illnesses, reproductive effects, and chronic diseases such as cancer. The findings of this research allow the relevant bodies to establish baseline values, ultimately increasing the knowledge and understanding surrounding the specific issues of the water body. This research aims to determine the water quality by determining the geochemical properties of the water. Also, to investigate if water used for domestic purposes meets WHO's prescribed standard. The article is organized as follows: section 1 contains the introduction, materials, and methods in Section 2, results and discussion in Section 3, and Section 4 contains the conclusion, followed by acknowledgment and references at the end.

MATERIALS AND METHODS

Study Area

Kebbi State is located in the North-Western part of Nigeria, with its capital at Birnin Kebbi. It is bordered by Sokoto State, Niger State, Zamfara State, Dosso Region in the Republic of Niger and the nation of Benin. It has a total area of 37.418km² and a population of 3,256,541 at the 2006 census. The study area lies in north-western Nigeria between latitude 100 23'28" and 120 26'24"N and longitude 03° 53'08" and 060 38'18"E (Fig. 1) (Sani *et al.*, 2019). It is located in the Fakai local government area of Kebbi state and is accessible through Abuja, the Federal Capital Territory, via Minna – Kontagora – Zuru – Mahuta – Garin Awwal (Sani *et al.*, 2019).

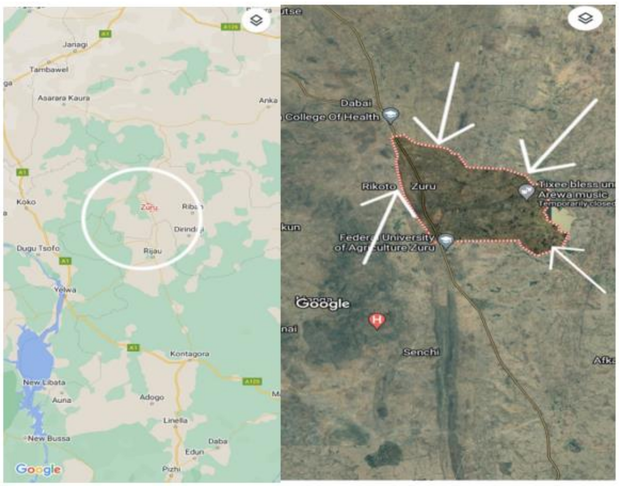

Figure 1: Google Map of Zuru town showing the sample collection areas.

Materials

The materials employed in this research include a pH meter used for measuring the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity. Conductivity meter: which measures electrical conductivity in a solution. Beam balance: which measures the mass of an object. Measuring cylinder: used for measuring the volume of a liquid. 1L plastic bottles: used for collecting water samples. Buffer (pH10): is an acid or base aqueous solution consisting of a weak acid and its conjugate base, or vice versa. Eriochrome black T indicator: used for complexometric titrations in the water hardness determination process. 2M NaOH and 0.01m ETA solution are compounds used in the analysis (Gordon, 2022).

Data Collection

Eight (8) water samples were collected for both surface and ground from four (4) locations in Zuru. The locations are Dambu Gomo, Manga, Rafin Zuru, and Rikoto. Surface water samples were collected from the Dambu Gomo River at Dambu Gomo near Gadar Zango, Manga River in Manga, Unguwan Zuru River, and Rafin Mosey River in Rikoto ward. Samples for groundwater were also collected from locations closest to that of surface water. One liter of surface and groundwater samples were collected from four different locations, making a total of eight (8) water samples.

Data Analysis

The geochemical parameters analysed in this study include; Density, Conductivity, Total hardness, Calcium C^{2+} hardness, Magnesium Mg^{2+} hardness, pH, and Total dissolved solids (TDS).

Density Analysis:

Water sample, beam balance, and measuring cylinder. It was used in the density analysis of the sample. The mass of the clean, dry, empty cylinder (M_0) was measured using beam balance, then the cylinder was filled with water, and 30 ml of water sample was measured and recorded as the mass of the filled cylinder (M_1) using beam balance. Mass of 30ml of water (M_2) was computed using:

$$M_2 = M_1 - M_0 \quad 1$$

Density was calculated using $\rho = \frac{M2}{Volume}$ 2

Conductivity

The conductivity meter and Electrode are the apparatus used in measuring the conductivity of the water samples. Method: The meter was switched on and about to warm for about 5 minutes. It was then standardized with 0.01 $moldm^{-3}$ KCI solutions and obtained a conductivity reading of 1413 micro-Siemen per centimetre. The Electrode was then immersed into the water sample, and the conductivity readings were recorded for each water sample.

Total Hardness

The reagents used to measure water hardness are Buffer (pH10), Eriochrome black T indicator, 2M NaOH, and 0.01 m EDTA solution. Method: A pipette of 50.00 mL of the sample was poured into a 250.00 mL flask. 1 mL of pH10 buffer and 1 drop of Eriochrome black T indicator was added. It was titrated with EDTA from a 50.00 mL burette and noted when the colour changed from wine-red to blue. The procedure was repeated to ensure accurate results. The result was computed using the equation below.

$$\text{Total} = Ca^{2+}Mg^{2+} \text{ Concentrations} \quad 3$$

$$\text{Hardness} \left(\frac{mg}{L}\right) = \text{volume of EDTA used x 0.01 m x} \frac{1000}{CM^3} \text{of the sample taken} \quad 4$$

Calcium (C^{2+}) Hardness

A pipette of 50.00 mL of the water sample was poured into a 250.00 mL flask. Then, 2 mL of 2M NaOH was added and swirled for 2 minutes to precipitate magnesium as Mg $(OH)_2$(which may not be visible). A small amount of measurable indicator was added. The colour then changed from pink to purple. The two separate titrations were carried out, each with 50.00 mL of the same sample, to ensure an accurate value for the Ca^{2+}.

$$Ca^{2+} \text{ hardness mg/L} = \frac{\text{volume of EDTA x 0.01m x 1000}}{CM^3 \text{ of sample taken}} \quad 5$$

Magnesium Mg^{2+} Hardness

$$Mg^{2+} \text{ hardness} = \text{Total Hardness} - Ca^{2+} \text{ hardness} \quad 6$$

pH: The apparatus employed to measure pH are pH meter and Electrode. Method: The pH meter is switched on for about 5 minutes to warm up. The Electrode is fixed and immersed into the water and the reading is taken for each water sample.

Total Dissolve Solid (TDS)

Into an evaporating dish weighed after heating at 180^0C, $50cm^3$ filtrate of the water sample was added and heated to dryness on a water bath. The dish was weighed, and the total dissolved solid was calculated using the equation.

$$\text{TDS mg/L} = \frac{1000 \text{ x } (Mb - Ma)}{V} \quad 7$$

Where Mb = weight of the dish + dried residue (mg)

Ma = weight of the dish (mg)

V = volume of water sample filtrate (cm^3)

RESULTS

Table 1: Results for Geochemical parameters of Surface Water samples

Parameter/ Location	Density (g/cm^3)	Conductivity (µS/cm)	Total Hardness(mg/L)	Ca2+ Hardness (mg/L)	Mg2+ hardness (mg/L)	Ph	TDS (mg/L)
D-GOMO	0.91	128.6	87	51	43	6.9	582
MANGA	0.90	89.2	101	69	43	6.6	718
R-ZURU	0.92	86.7	97	41	53	7.1	630
RIKOTO	0.90	87.1	90	87	37	6.8	550
AVERAGE	0.90	76.1	93.8	62	44	6.9	620
MINIMUM	0.90	86.7	87	41	37	6.6	550
MAXIMUM	0.92	128.6	101	87	53	7.1	718
S. DEV.	0.00296	23.01	5.91	18.83	7.96	0.15	178.28

Table 2: Results for Geochemical parameters of Groundwater samples

Parameter/ Location	Density (g/cm^3)	Conductivity (µS/cm)	Total Hardness (mg/L)	Ca2+ Hardness (mg/L)	Mg2+ hardness (mg/L)	pH	TDS (mg/L)
D-GOMO	0.90	87.9	31	22	17	7.2	602
MANGA	0.92	123.1	30	28	25	7.0	462
R-ZURU	0.92	59.9	26	25	9	7.4	482
RIKOTO	0.92	186.4	33	29	17	6.2	712
AVERAGE	0.92	114.3	30	26	17	7.0	564.5
MINIMUM	0.90	59.9	26	22	9	6.2	462
MAXIMUM	0.92	186.4	33	29	25	7.4	712
S. DEV.	0.0129	50.20	2.89	2.31	5.71	0.79	179.41

Table 3: Comparison of results for Geochemical parameters between surface and groundwater.

Parameter/ Location	Density (g/cm^3)		Conductivity (µS/cm)		Total Hardness (mg/L)		Ca2+ Hardness (mg/L)		Mg2+ hardness (mg/L)		pH		TDS (mg/L)	
	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
D-GOMO	0.91	0.90	128.6	87.9	87	31	51	22	43	17	6.9	7.2	582	602
MANGA	0.90	0.92	89.2	123.1	101	30	69	28	43	25	6.6	7.0	718	462
R-ZURU	0.92	0.92	86.7	59.9	97	26	41	25	53	9	7.1	7.4	630	482
RIKOTO	0.90	0.92	87.1	186.4	90	33	87	29	37	17	6.8	6.2	550	712
AVERAGE	0.90	0.92	76.1	114.3	93.8	30	62	26	44	17	6.9	7.0	620	564.5

Key: SW= Surface Water, GW = Groundwater

Table 4: Results of calculated geochemical parameters compared with WHO Maximum permissible level.

Parameter	Maximum Level	Surface Water	Groundwater
Density (g/cm^3)	1	0.90	0.92
Conductivity (µS/cm)	2500	76.1	114.3
Total Hardness (mg/L)	500	93.8	30.0
Ca^{2+} Hardness (mg/L)	200	62.0	26.0
Mg^{2+} Hardness (mg/L)	150	44.0	17.0
Ph	8.5	6.9	7.0
TDS (mg/L)	1500	620	564.5

DISCUSSIONS

Analysis and comparison of various geochemical parameters between surface water and groundwater samples collected in Zuru town, Kebbi state, Nigeria, was carried out in this research. The study examined parameters including density, conductivity, total hardness, calcium (Ca2+) hardness, magnesium (Mg^{2+}) hardness, pH, and total dissolved solids (TDS) in these water samples. Table 1 shows the result of surface water samples, Table 2 shows the result of groundwater samples, and Table 3 shows the comparison between results from Table 1 and Table 2. Also, the comparison of the surface and groundwater results with the WHO maximum permissible level is shown in Table 4.

The results showed that surface water's average density (0.90 g/cm3) was slightly lower than groundwater's (0.92 g/cm3). This difference could be due to variations in mineral content, temperature, and other factors affecting water density. Conductivity measures the water's ability to conduct electricity and is influenced by dissolved ions and minerals present in the water. Surface water had an average conductivity of 76.1 µS/cm, which was lower than the average conductivity of groundwater (114.3 µS/cm).

Total hardness reflects the concentration of dissolved minerals, primarily calcium and magnesium, in the water (Ameloko *et al.*, 2018). Surface water exhibited an average total hardness of 93.8 mg/L, approximately three times greater than the total hardness of groundwater (30.0 mg/L). Calcium hardness indicates the presence of calcium ions dissolved in the water, which can influence its quality and suitability for various purposes. The average calcium hardness in surface water was 62 mg/L, more than twice that found in groundwater (26 mg/L). Magnesium hardness signifies the concentration of magnesium ions dissolved in the water, impacting its characteristics (Ameloko *et al.*, 2018). Surface water showed an average magnesium hardness of 44 mg/L, higher than groundwater (17 mg/L). pH measures the water's acidity or alkalinity, affecting its suitability for consumption and aquatic life. The average pH for surface water was 6.9, slightly lower than the pH of groundwater, which was recorded at 7.0. WHO recommends a pH between 6.5 and 8.5 for drinking water, indicating that surface and groundwater samples fall within the acceptable range.

TDS measures the total concentration of dissolved substances in the water, including minerals, salts, and other solids (Ameloko *et al.*, 2018). Surface water exhibited a higher average TDS value of 620 mg/L compared to groundwater, with an average TDS of 564.5 mg/L.

These findings suggest variations in mineral content, conductivity, hardness, and other characteristics between surface water and groundwater in the studied area. Such differences can influence the water's quality and suitability for different purposes, including drinking, agricultural use, and industrial applications. It's essential to note that prolonged water consumption with high mineral content (hardness) might pose potential health concerns, and continuous monitoring of water quality is crucial for ensuring its suitability for consumption and other uses.

Compeering our results with the WHO maximum permissible level as shown in Table 4, none of the findings of this research has exceeded the WHO permissible level prescribed for standard quality water for consumption.

CONCLUSION

This study analysed some geochemical parameters for surface and undergroundwater around Zuru in southern part of Kebbi state. The result was compared with WHO's prescribed standard for quality water consumption. Four samples of each surface and groundwater were collected from various geographical locations within Zuru for analyses to determine density, conductivity, total hardness, calcium (Ca^{2+}) hardness, magnesium (Mg^{2+}) hardness, pH, and TDS by employing scientific and technological approaches.

Groundwater has higher values of average density (0.92 g/cm^3), conductivity (114.3μS/cm), and average pH level (7.0), while surface water has lower values of average density for (0.90 g/cm^3), conductivity (76.1μS/cm), and average pH level (6.9). The result also indicates that surface water have higher values for mean total hardness (93.8 mg/L), average value for calcium (62.0 mg/L), magnesium (Mg^{2+}) hardness (44.0 mg/L) and the mean value for TDS (620 mg/L), while groundwater have lower values for mean total hardness (30.0 mg/L), average value for calcium (26.0 mg/L), magnesium (Mg^{2+}) hardness (17.0 mg/L) and mean value for TDS (564.5 mg/L). None of the findings of this research has exceeded the WHO permissible level prescribed for standard quality water for consumption. Although some of the findings are higher than others. The research has shown that groundwater is favourably more recommended for drinking and other domestic usages.

ACKNOWLEDGEMENTS

We appreciate Dr. Danladi Senchi Bonde (Department of Physics) and Dr. Haruna Yusuf (Department of Chemistry), Kebbi State University of Science and Technology Aliero, for providing guidance and advice during the course of this research. The authors also appreciate the reviewer's comment which has helped to improve the manuscript.

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