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Full Length Research

Quality Status of Groundwater Resources in parts of Birnin-Gwari Schist Belt, North-Central Nigeria

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An assessment of groundwater quality around Zungeru and Minna, Niger State in the Birnin-Gwari Schist belt, North-Central Nigeria, was studied. The study was aimed at evaluating the suitability of the groundwater for use. The physico-chemical parameters measure include; Na^+ (mg/l), K^+ (mg/l), Ca^{2+} (mg/l), Mg^{2+} (mg/l), Fe^{2+} (mg/l), Cl^- (mg/l), SO_4^{2-} (mg/l), HCO_3^- (mg/l), pH, EC (µS/cm), PO_4^{3-}(mg/l), NO_3 (mg/l), F^- (mg/l), As (mg/l), Mn (mg/l) and Cu (mg/l). Result of the study showed that temperature ranged from 26.9 – 30.0°C, with an average of 28.33°C.The pH ranged from 6.4 – 8.31 (mean 7.48) while Conductivity ranged from 69 – 128µS/cm (mean 337uS/cm). Results also reveal a high concentration of Bicarbonates (250mg/l), Chlorides (78.9mg/l), Nitrates (44mg/l) and cations of Sodium (13.5mg/l), Potassium (29.5mg/l) and Magnesium (27.01mg/l). The concentrations of trace elements in the area are very low, with Arsenic (0.01mg/l), Manganese (1.002mg/l) and Copper (1.31mg/l). Piper trilinear plots indicate Chloride-Calcium-Sodium water. The results also show that the anions are more of the Bicarbonate type and there is no dominant cation. Generally, the study reveals that the chemical composition of the water in the area is a direct reflection of the mineralogy of the rock types. The study has shown that the water quality is within the WHO minimum permissible limit for drinking water, except for the increased concentration of Nitrate and Chloride which can be attributed to fertilizer application in farmlands and unplanned septic tanks, soakaways and pit latrines that characterizes the main sewage disposal system in the area. It is recommended that groundwater analysis be carried out frequently to monitor the rate and kind of contaminants that may affect groundwater quality in the area.

Key words: Groundwater Quality, Contamination, Physico-Chemical Properties, Schist Belt, Nigeria

Introduction

Of recent, there is a global recognition that groundwater quality is as important as its quantity. Current emphasis is not only on how abundant water is, but also on whether its quality status is good enough to sustain its various uses (Udom *et al.,* (1999). The quality of groundwater determines its usability for domestic, industrial and agricultural purposes. The chemical composition of groundwater and the water types found in an environment are determined greatly by local geology, types of minerals found in the environment through which the recharge and groundwater flows, anthropogenic activities such as mining and waste disposal as well as climate and topography (Akpah and Ezeigbo, 2010).

The quality status of water is a crucial factor in what the water is to be used for (Udom and Acra, 2006). For example, water meant for drinking and domestic purposes must meet laid down local and international standards, otherwise the consumer stands the risk of water-borne diseases such as typhoid fever, dysentery, diarrhea and hepatitis.

The chemical constituents of groundwater is known to cause some health risks, so supply cannot be said to be safe if specific information on water quality which is needed for sustainable resource development and management is lacking (Nwankwoala and Udom, 2011). This study is therefore intended to establish the status of groundwater and to determine whether pollution is occurring or likely to occur in the area. Groundwater quality monitoring is one of the important methods supporting policy of groundwater protection and quality conservation (Jaroslav, 1989).

Location and Geology of Study Area

The study area (Fig.1) is lies within latitude $9^0$30' to $10^0$00'N and longitude $6^0$00' to $6^0$58'E covering a total area of 3250km^2. It extends from Minna to Zungeru, all within Niger State, North-Central Nigeria.

The climate of the area is similar to what is obtainable in the central Nigeria, with an annual average rainfall of 1250mm with seven months of rainy season and five months of dry season (Idris-Nda, 2005). The Birnin Gwari

Schist belt covers a much extensive area, extending from Katsina State through Kaduna State and terminating around Minna in Niger State. The principal rock type of the formation consists of phyllite, biotite-quartz-muscovite schist and amphibolite schist. The schist have a dominant strike of 020^0 (NNE-SSW) and a dip of 46^0E ($020^0/46^0$E). The rocks are not hard, but are impervious and highly resistant to weathering and erosion, resulting to the formation of moderate to strong relief features. The rocks have major fracturing in dip direction while the strike faults are similar and widely spaced. They have a characteristic low resistivity of between 10 – 100 ohm-meters and a corresponding high conductivity of 10 – 25mS/cm. Groundwater yield to wells placed in them is very low, ranging from completely dry to 0.3lt/s (<800m^3/day). Groundwater recharge is through the vertical strike fault, which transmits water from the surface. The water is stored in dip faults and schistocity planes. Groundwater Transmissivity is very low (<0.5m^2/day).

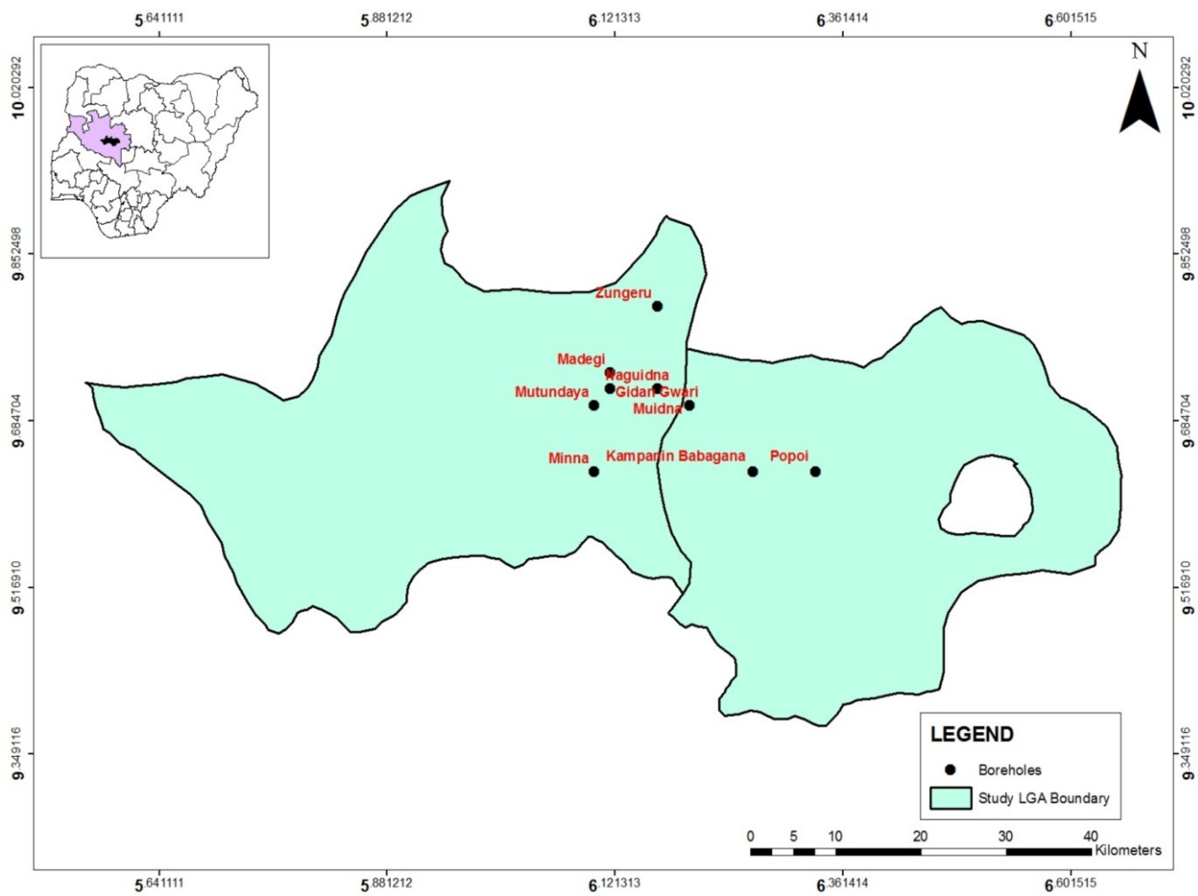

Figure 1: Map of the study area showing sampled locations

Generally, the study area is underlain by rocks of the Nigerian basement complex consisting of migmatite-gneiss complex, two low-grade Schist belts and older granite suite. The migmatite-gneiss complex includes migmatites, gneisses, mylonites and amphibolites. The mylonites are major shear zones which mark the stratigraphic breaks between the gneissic basement complex and the cover rocks of the Birnin-Gwari Schist formation (Ajibade *et al.,* 1976).

The Schist belts in this area occur as two elongated bodies separated by the older granite suite. The tips of the two Formations are separated by a 40km expanse of the older granite suite. However, this study indicates a much smaller separation of less than 10km. the Birnin-Gwari Formation lies to the West of the older granite (the Minna Batholith) while the Kushaka Formation lies to the East. A gravity survey model conducted over the area (Udensi *et al.,* 1986) showed that the two formations have a maximum thickness of 11 and 6km, respectively.

Sampling and Analytical Techniques

Field sampling was carried out in the month of October, 2010 and water samples were collected with a new plastic bucket and poured into l litre polythene bottles after measuring physical parameters such as temperature, pH and Electrical Conductivity (EC) (that change rapidly with time). The parameters were measured in the field using 09 Kion pH, temperature and conductivity meter. After sampling, the bottle was capped immediately to minimize oxygen contamination and the escape of dissolved gases. A global positioning system (GPS) was used at each sample station to measure coordinates of the station and heights above sea level. Table 1 shows borehole locations, heights above sea level, depths and yields in the study area.

The hydrochemical analysis was carried out at the National Metallurgical Development Centre Laboratory, Jos, Nigeria. The cations (Na^+, K^+, Ca^+, Mg^{2+}, Fe^{2+} and Mn^{2+}) were determined using Atomic Absorption Spectrophotometer (UNICAM 969AAS) while the anions (Cl^- and SO_4^{2-}) were analysed using DR 2000 Spectrophotometer at wavelength 455nm and 450nm. Carbonates and bicarbonates (CO_3^{2-} and HCO_3^-) were determined titrimetrically using phenolphthalein and methyl orange indicator method (Ademoroti, 1996). Samples meant for anion determination were acidified and the choice of acid depended on the anion. For example, sample meant for iron determination was primed with 0.5M solution of nitric acid to keep the iron in solution.

Table 1: Borehole locations, Depths, heights and yields in the study area.

S.No.	Location	Coordinates	Heights (m) >msl	BH Depth (m)
1	Naguidna	$9^0$43’, $6^0$10’	129	54
2	Popoi	$9^0$38’, $6^0$20’	135	68
3	Zungeru	$9^0$48’, $6^0$10’	142	60
4	Muidna	$9^0$42’, $6^0$12’	147	53
5	Mutundaya	$9^0$42’, $6^0$06’	164	55
6	Minna	$9^0$38, $6^0$06’	151	67
7	Kampanin Babagana	$9^0$38, $6^0$16’	218	62
8	Gidan Gwari	$9^0$43’, $6^0$07’	150	61
9	Madegi	$9^0$44, $6^0$07’	124	59

Results and Discussion

The results of the physical and chemical properties of the groundwater samples measured from the study area are shown in Table 2. The parameters include; Na^+ (mg/l), K^+ (mg/l), Ca^{2+} (mg/l), Mg^{2+} (mg/l), Fe^{2+} (mg/l), Cl^- (mg/l), SO_4^{2-} (mg/l), HCO_3^- (mg/l), pH, EC (µS/cm), PO_4^{3-}(mg/l), NO_3 (mg/l), F^- (mg/l), As (mg/l), Mn (mg/l) and Cu (mg/l).

The analysis of the result of the study shows that temperature ranged from 26.9 – 30.0^{o}C. The average temperature of the water sample is 28.33^{o}C. The temperature values were found to remain approximately constant throughout the duration of the field work; an advantage groundwater has over surface water. pH ranges from 6.4 – 8.31 (mean 7.48), Conductivity 69 – 128µS/cm (mean 337uS/cm), Na^+ 4.5 – 13.5mg/l (mean 15.38mg/l), K^+ 0.1 – 29.5mg/l (mean 8.36mg/l), Ca^{2+} 0.09 – 15.40mg/l (mean 5.10mg/l), Mg^{2+} BDL – 27.01mg/l (mean 9.88mg/l), Fe^{2+} BDL – 0.17mg/l (mean 0.07mg/l), SO_4^{2-} 1.0 – 11.9mg/l (mean 4.39mg/l), Cl^- 22.10 – 78.9mg/l (mean 38.96mg/l), PO_4^{2-} 0.05 – 2.22mg/l (mean 0.94mg/l), CO_3^{2-} Below Detection Limit (BDL), HCO_3 80 – 250mg/l (mean 173.78mg/l), NO_3 1.91 – 44mg/l (mean 16.62mg/l), F^- 0.25 – 0.73mg/l (mean 0.52mg/l), Mn 0.002 – 1.002mg/l (mean 0.114mg/l), As 0.01 – 0.01mg/l (mean 0.01mg/l) and Cu BDL – 1.31mg/l (mean 0.37mg/l).

The results also recorded a high concentration of bicarbonates (250mg/l), Chlorides (78.9mg/l), Nitrates (44mg/l) and cations of Sodium (13.5mg/l), potassium (29.5mg/l) and Magnesium (27.01mg/l). The concentrations of trace elements in the area are very low, with Arsenic (0.01mg/l), Manganese (1.002mg/l) and Copper (1.31mg/l). The mean concentrations of constituents in the groundwater in the area are shown in Figure 2. Generally, the chemical composition of the water in the area is below the World Health Organization (WHO) minimum permissible limits for drinking water (WHO, 2006) except for Nitrate and Chloride that shows a significant concentration. The high concentration of Chlorides and Nitrate in the area may be indicative of an extensive use of organic and inorganic fertilizer for farming. It may also be indicative of a gradual pollution of the groundwater (Idris-Nda, 2005).

Table 2: Physico-chemical composition of groundwater samples in the area
Note: BDL =Below Detection Limit; NS = Not Stated

S/N	Locations	Temp ^0C	pH	Cond. μS/cm)	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Fe^{3+} (mg/L)	SO_4^{2-} (mg)	Cl^- (mg/L)	PO_4^{3-} (mg/L)	CO_3^{2-} (mg/L)	HCO_3 (mg/L)	NO_3 (mg/L)	F^- (mg/L)	M_n (mg/L)	As (mg/L)	Cu (mg/L)
BH1	Naguidna	29.0	7.53	128	5.8	2.00	15.40	BDL	0.05	1.0	22.10	0.81	BDL	230	21	0.734	0.005	0.01	1.22
BH2	Popoi	28.4	8.05	150	9.7	0.1	0.17	3.15	0.15	1.0	30.97	1.042	BDL	80	44	0.61	0.003	0.01	BDL
BH3	Zungeru	30.0	6.5	209	12.5	1.5	16.00	3.90	0.17	1.0	40.11	0.06	BDL	250	15	0.25	0.002	0.01	1.31
BH4	Muidna	29.2	8.66	74	4.5	0.15	0.09	1.62	0.05	11.5	31.50	0.45	BDL	213	2.31	0.51	0.003	0.01	0.08
BH5	Mutundaya	27.8	8.01	918	7.2	29.5	0.14	20.14	0.14	3.1	78.19	2.22	BDL	152	1.91	0.55	0.004	0.01	0.10
BH6	Minna (By FUT)	28.3	7.2	107	5.4	1.40	0.12	1.53	0.05	6.7	29.32	0.05	BDL	206	2.82	0.52	0.006	0.01	0.10
BH7	Kampanin Babangida	26.9	6.7	1281	5.9	21.3	1.56	2.27	BDL	11.9	36.15	1.53	BDL	153	25.3	0.49	0.002	0.01	0.12
BH8	Gidan Guari	27.1	8.31	97	12.3	0.1	12.30	2.31	0.07	2.3	51.3	1.11	BDL	80	34.5	0.278	1.002	0.01	0.24
BH9	Madegi	28.25	6.4	69	9.3	19.2	0.14	27.01	0.05	1.0	30.99	1.18	BDL	200	2.76	0.74	0.002	0.01	0.11
	Maximum	30.0	8.31	1281	13.5	29.5	15.40	27.01	0.17	11.9	78.19	2.22	BDL	250	44	0.734	1.002	0.01	1.31
	Minimum	26.9	6.4	69	4.5	0.1	0.09	BDL	BDL	1.0	22.10	0.05	BDL	80	1.91	0.25	0.002	0.01	BDL
	Range	26.9-30.0	6.4-8.31	69-1281	4.5-13.5	0.1-29.5	0.09-15.40	BDL-27.01	BDL-0.17	1.0-11.9	22.10-78.9	0.05-2.22	BDL	80-250	1.91-44	0.25-0.734	0.002-1.002	0.01-0.01	BDL-1.31
	Mean	28.33	7.48	337	15.38	8.36	5.10	9.88	0.07	4.39	38.96	0.94	BDL	173.78	16.62	0.52	0.114	0.01	0.37
	WHO (2006) Standard	NS	6.5-7.5	NS	200	2.0	250	1.00	1.00	40	200	NS	NS	NS	44	0.01	0.01	0.01	0.01

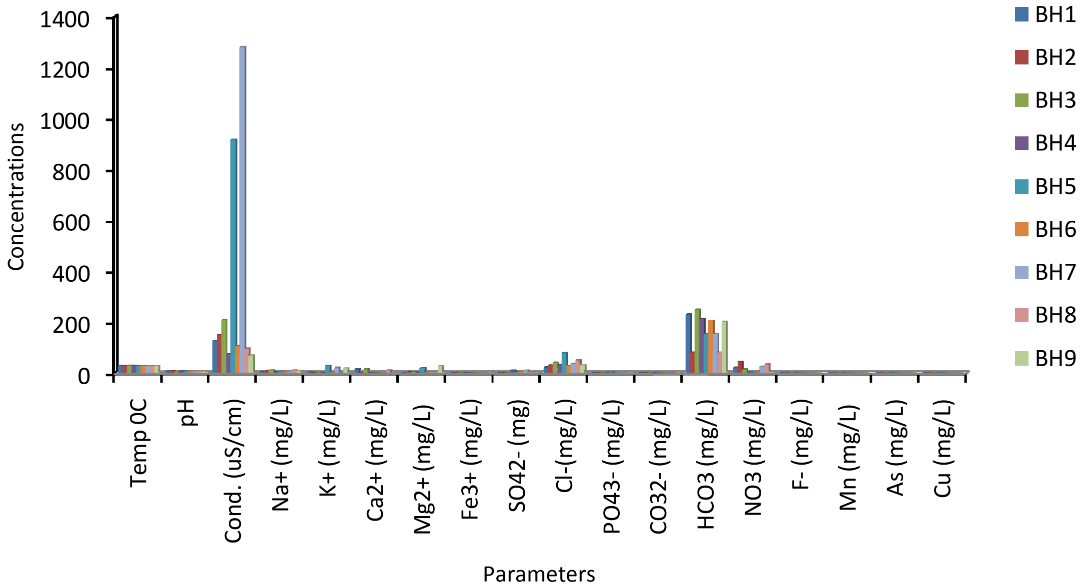

Fig. 2: Mean Concentrations of constituents in the groundwater of the study area

Classification of Water Types

The concept of hydrochemical facies was developed in order to understand and identify the water composition in different classes. Facies are recognizable parts of different characters belonging to any genetically related system. Hydrochemical facies are distinct zones that possess cation and anion concentration categories. To define a composition class (Back, 1960) suggested subdivisions of the tri-linear diagram. Piper (1944) trilinear diagram (Fig.2) was used to classify groundwater types in the area. It permits the cation and anion compositions of many samples to be presented on a single graph in which major groupings or trends in the data can be discerned visually (Freeze and Cherry, 1979). The plots indicate Chloride-Calcium-Sodium water. Analysis also shows that the anions are more of the Bicarbonate type and there is no dominant cation. Generally, the study reveals that the chemical composition of the water in the area is a direct reflection of the mineralogy of the rock types.

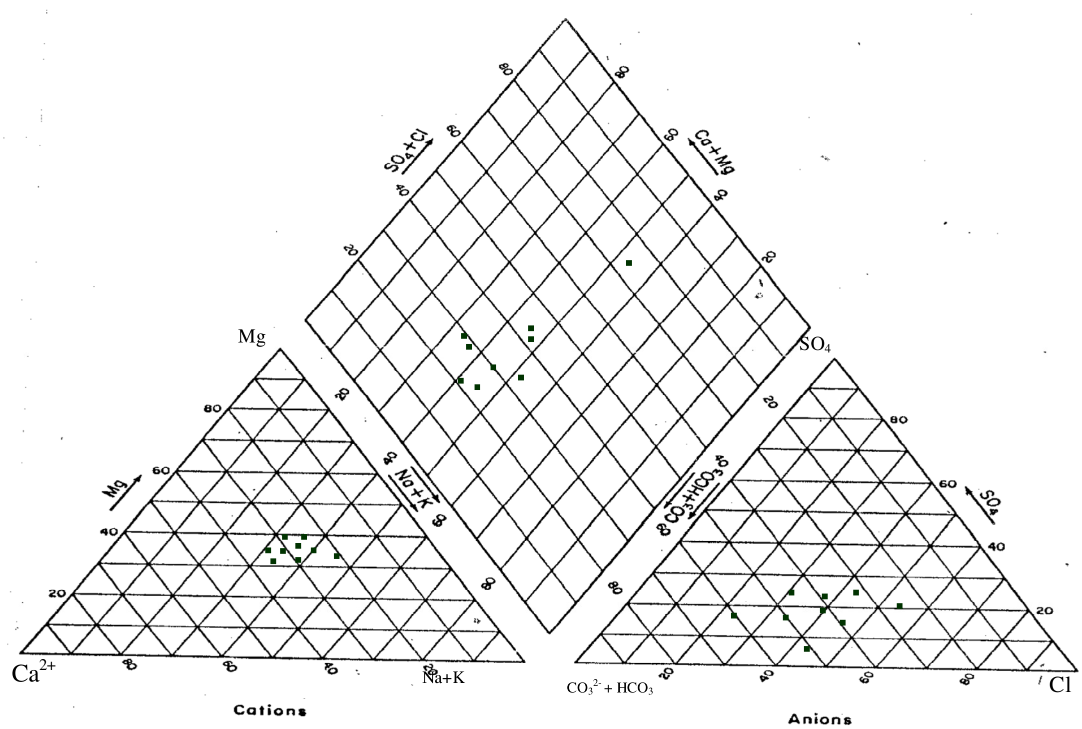

Fig. 3: Piper Trilinear diagram showing classification of water types in the area.

Conclusion

Results of this study shows that groundwater quality in the area is within the WHO minimum permissible limit for drinking water, except for the increased concentration of Nitrate and Chloride which can be attributed to fertilizer application in farmlands and unplanned septic tanks, soakaways and pit latrines that characterizes the main sewage disposal system in the area. Results also show Chloride-Calcium-Sodium water type and that the anions are more of the Bicarbonate type while there is no dominant cation. The concentrations of trace elements in the area are very low, with Arsenic (0.01mg/l), Manganese (1.002mg/l) and Copper (1.31mg/l). Since this is a baseline study, it is recommended that groundwater analysis be carried out frequently to monitor the rate and kind of contaminants that may affect groundwater quality in the area.

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