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HYDROGEOCHEMISTRY OF SHALLOW GROUNDWATER IN KURGWI AND ENVIRONS, NORTH-CENTRAL NIGERIA

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ABSTRACT

A hydrogeochemical study of groundwater was carried out in Kurgwi and Environs. The aim of the study was to determine the chemical composition of the various water sources in the area and their suitability for domestic, industrial and agricultural purposes. Forty (40) water samples from shallow (hand-dug) wells were collected and analysed. Major cations and trace elements were analysed using the Inductively Coupled Plasma Optical Emission Spectrometer and the anions and bicarbonate were determined by double VV-visible spectrophotometer (Hitachi model 2000).and titration methods respectively. Results of laboratory analysis and plots on Piper Trillinear diagrams show the dominant water type in the area to be Ca-Na-HCO_3 water. Physico-chemical parameters of waters in the areas show most concentrations are within WHO permissible limits for drinking. However, calcium, potassium, TDS, total hardness and electrical conductivity are above the WHO upper limits in few locations and so are aluminium, iron, and manganese. Geogenic sources as well as minor anthropogenic activities have been observed to be the major control on the composition of groundwater in the area. Groundwater in the area is generally not very suitable for domestic purpose such as laundry, but is suitable for livestock and irrigation purposes.

KEYWORDS: Hydrogeochemical, Groundwater, Concentration, Total Hardness, Major Cations.

INTRODUCTION

The quality of groundwater is as important as it quantity (Fetter, 2007). Groundwater quality determines the usefulness to which the water can be put for the safety and well being of human lives (Schwartz and Zhang, 2002). Consumption of contaminated drinking water may be hazardous to human health and epidemiological studies have shown that many communities suffer from diseases linked to groundwater ingestion several decades ago (Jordan and Batista, 2004). Hence there is the need to routinely carryout analysis of groundwater to measure the concentration of constituents.

Kurgwi is located at the southern fringe of Plateau State (Fig 1). Southern Plateau is a lowland area composed of basement complex rocks overlain in some areas by sedimentary rocks of the Middle Benue Trough. The study area is characterized by pockets of the basement complex rocks occurring mostly as low relief outcrops. Within the crystalline environment (areas underlain by basement complex rocks) groundwater yield are relatively fair and hand dug wells are relatively shallow. Groundwater sources in the area are recharged mainly through precipitation during the rainy season and seepage within the water shed into adjoining surface sources (Dung, 2014).

Kurgwi town and environs like any other rural community in Nigeria depend on groundwater mainly from hand - dug wells and hand pumps for domestic uses. These shallow groundwater sources with depth of < 15m (hand dug well) and < 30m (hand pumps) are often located close to point sources of contamination such as waste disposal sites and pit- latrines. Individual houses in the communities own their own hand dug wells to meet domestic needs. Hand pumps, where available are provided by the government to meet the need of the community. These water sources have never been tested with regards to water quality parameters to determine their usefulness for drinking and other domestic uses. This work is aimed at assessing the hydrogeochemisty of the shallow groundwater in Kurgwi and environs with emphasis on their quality for domestic and irrigation uses.

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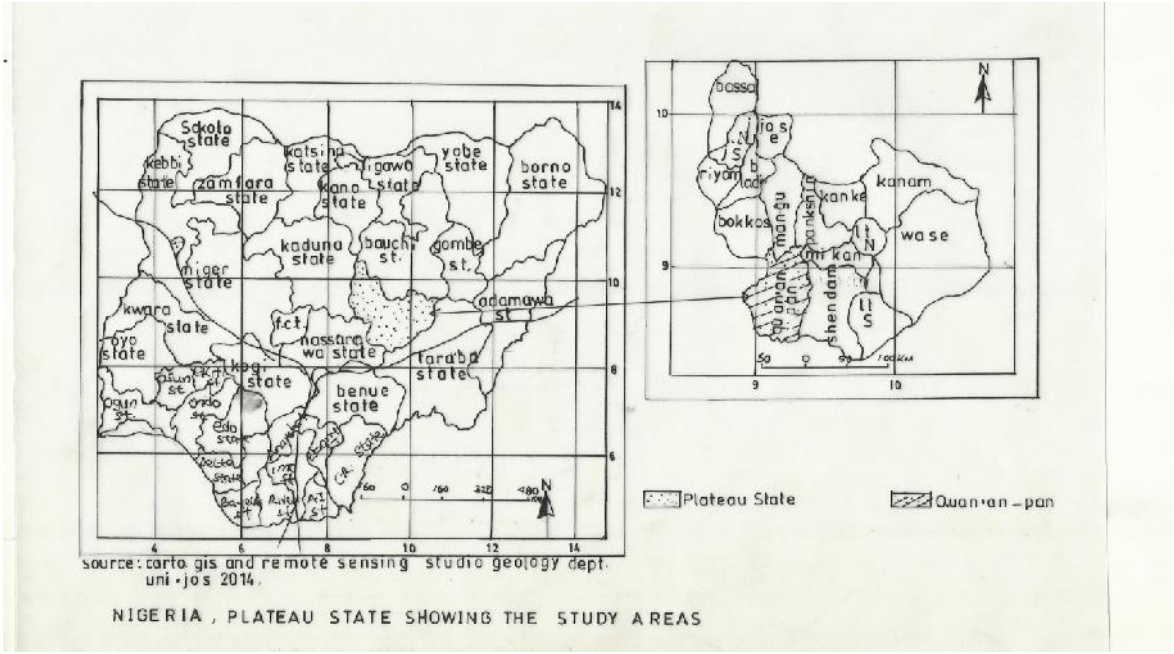

Figure 1: Map of Nigeria and Plateau State Showing the Study Area.

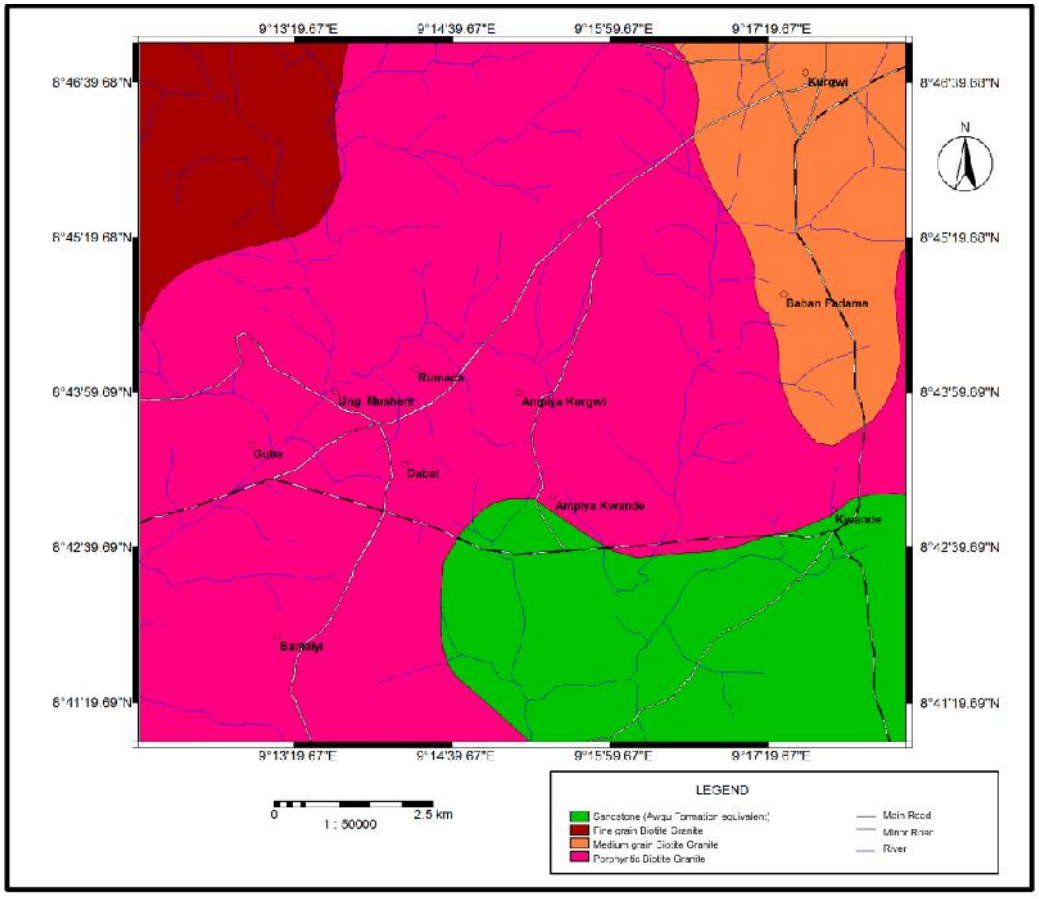

Figure 2: Geologic map of the study area (Dung, 2014)

METHODLOGY

Shallow groundwater samples were collected from forty (40) locations. Two water samples were collected in a 250ml polyethylene bottle capacity; one was acidified with nitric acid (HNO_3) to a pH of < 2 to avoid bacterial growth and to prevent ion adsorption and precipitation in solution. The water samples from hand-dug wells were collected using a plastic bucket tied to a rope (Davies, 1994). Determination of pH, temperature and conductivity were carried out using the pH/temperature/MV meter.

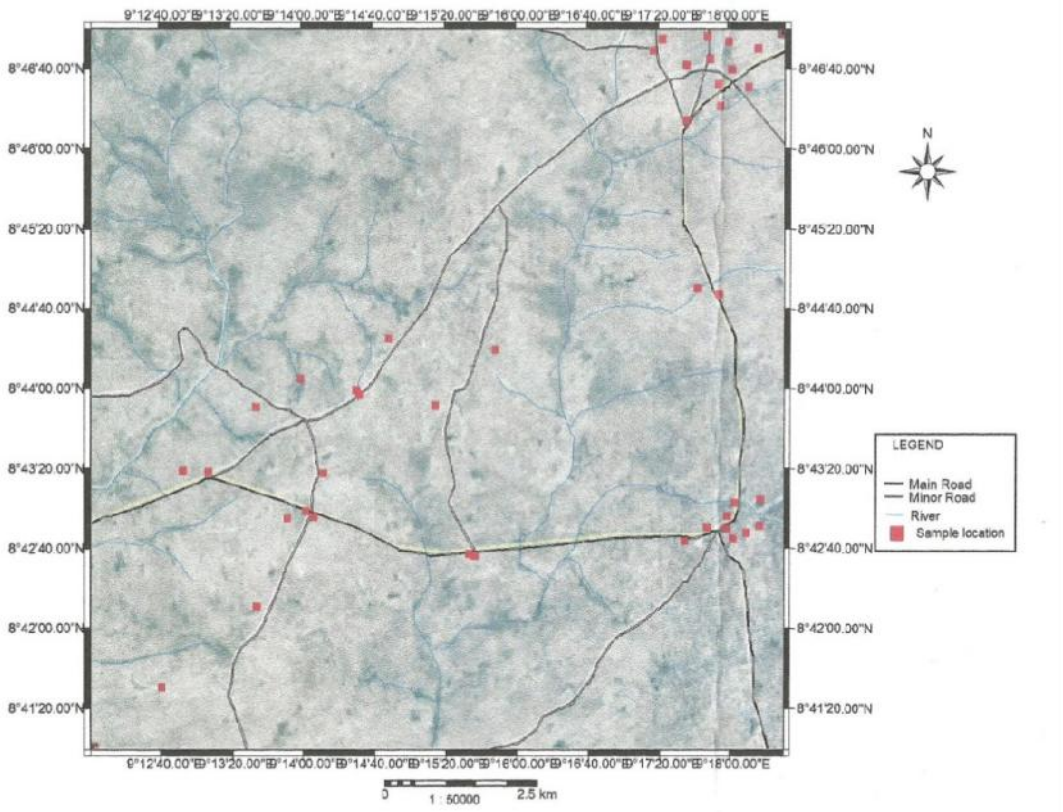

Fig. 3: Sample location map on the satellite image of the study area

Laboratory Analysis

Concentration of major cations and trace elements were analysed at the Acme Analytical Laboratories Vancouver, Canada. The Inductively Coupled Plasma Optical Emission Spectrometry was used to analyse for major cations and trace elements. The unacidified water samples were analysed at the University of Jos, Department of Geology and Mining for the anions. biicarbonate was determined titrametrically, sulphate and chloride were determined following turbidity method using double VV-visible spectrophotometer (Hitachi model 2000).

RESULTS AND DISCUSSION

Results

The summary of physico – chemical parameters of water samples collected from forty (40) hand – dug wells are presented in Table 1. Symbol map of pH and TDS for the study area are presented in Figure 2 and 3, the static water levels in the study area have depths ranging from 4.25 to 14.9m. The pH of water samples in the study area ranges from 6.9 – 9, with a mean of 8.2, indicating almost neutral to slightly alkaline condition. Nine (9) samples out of the forty (40) have pH higher than WHO recommended range of 6.5 – 8.5. The Electrical conductivity of water in the study area ranges from 4.7 – 1678 us/cm, with a mean value of 410.625 us/cm. In the study area 22 of the forty (40) locations have their electrical conductivities above WHO permissible limit of 300us/cm. The locations are Angwan Bori, Angwan Dem, AngwanGagar, AngwanWaje, AngwanAnkwai, all in Kurgwi, AngwanKasa, AngwanLiman, SabonPegi, all in Kwande, Ampiya - Kwande, Angwan, Gube (two locations), Ampiya – Kurgwi (two locations) Rumada (two locations), Agwankasuwa, Angwan Mushere and Shiptak (all in Dabat) (Fig 2).

The temperature of water in the area ranges from 28.5 - 31°c, with a mean of 29.8. This probably reflects the mean annual temperature of the area during this period. Total dissolved solids (TDS) in the area ranges form 21.95 – 842mg/l, with a mean TDS of 210.85mg/l, Angwan Dem, Kurgwi having the highest value. The TDS of samples of water in the area are almost all below WHO permissible limit of 500mg/l with the exception of Angwan Dem with a value of 842mg/l. This indicates that bulk waters in the area as fresh (Fig 3).

Calcium concentration in water samples of the area ranges between 6.09 and 202mg/l, with a mean value of 38.49mg/l. Angwan Dem, kurgwi has the highest calcium concentration of 202.9mg/l. Magnesium concentration ranges from 0.34 – 38.74 mgl/, with a

mean of 8.97mg/l. Rumada (Old Loko) has the highest magnesium concentration. Sodium concentration in the study area ranges between 3.3 and 94.7mg/l with a mean value of 34.46mg/l. Angwan Dem in Kurgwi has the highest concentration 88.43 mg/l. Potassium concentration ranges from 0.57.83 – 20.58mg/l, with a mean of 6.17. Bicarbonates in groundwater of the study area ranges from 14.14 – 311.1mg/l, with a mean of 128.28mg/l. Sulphate concentration in groundwater ranges from 7.5 – 30.2mg/l, with a mean value of 15.44mg/l. Rumada (Old Loko) has the highest sulphate concentration of 30.2mg/l. The relatively higher sulphate may probably be attributed to agricultural activities. Chloride concentration in water samples of the area ranges between 00 and 283.9mg/l, with Angwan Dam having the highest value 283.9mg/l. A minimum value of 00mg/l concentration of chloride in the area is obviously an analytical error, considering the conservative nature of chloride. Water sample from Angwan Dem (Kurgwi) has high chloride probably due to its proximity to septic system. Nitrate concentration in the study area varies between 4.5 and 7mg/l. The range of nitrate concentrations in the area suggests limited influence of anthropogenic activities on groundwater quality in the area.

Table 1: Summary of Minimum, Maximum, Mean and Standard Deviation of Major Elements and Physical Parameters in the Study Area

Element	Minimum	Maximum	Mean	S.D. (Standard Deviation)
Temperature	28.5	31	29.8	0.66
pH	6.9	9	8.2	0.617
TDS	21.94	842	210.85	201.35
EC	47	1678	410.625	292.22
Ca	6.092	202.9	38.49	35.19
Mg	0.349	38.74	8.97	9.29
Na	3.3	94.7	34.46	24.09
K	0.5783	20.58	6.17	5.80
HCO_3	14.14	311.1	123.28	78.848
SO4	7.5	30.2	15.44	7.56
Cl	0.0	283.9	45.11	45.89
NO_3	4.5	7	5.89	0.60

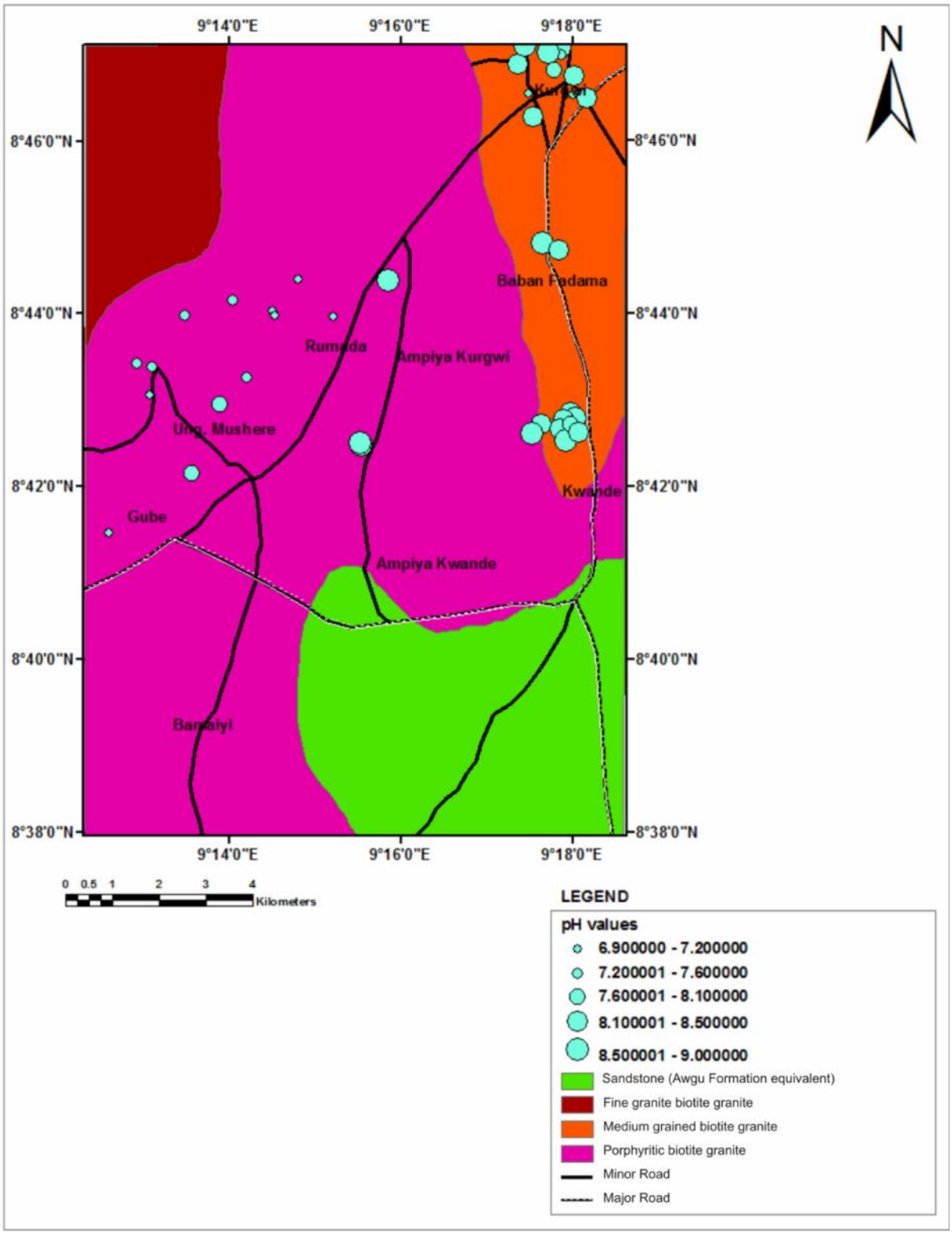

Figure 4: Symbol Map of pH for the Study Area

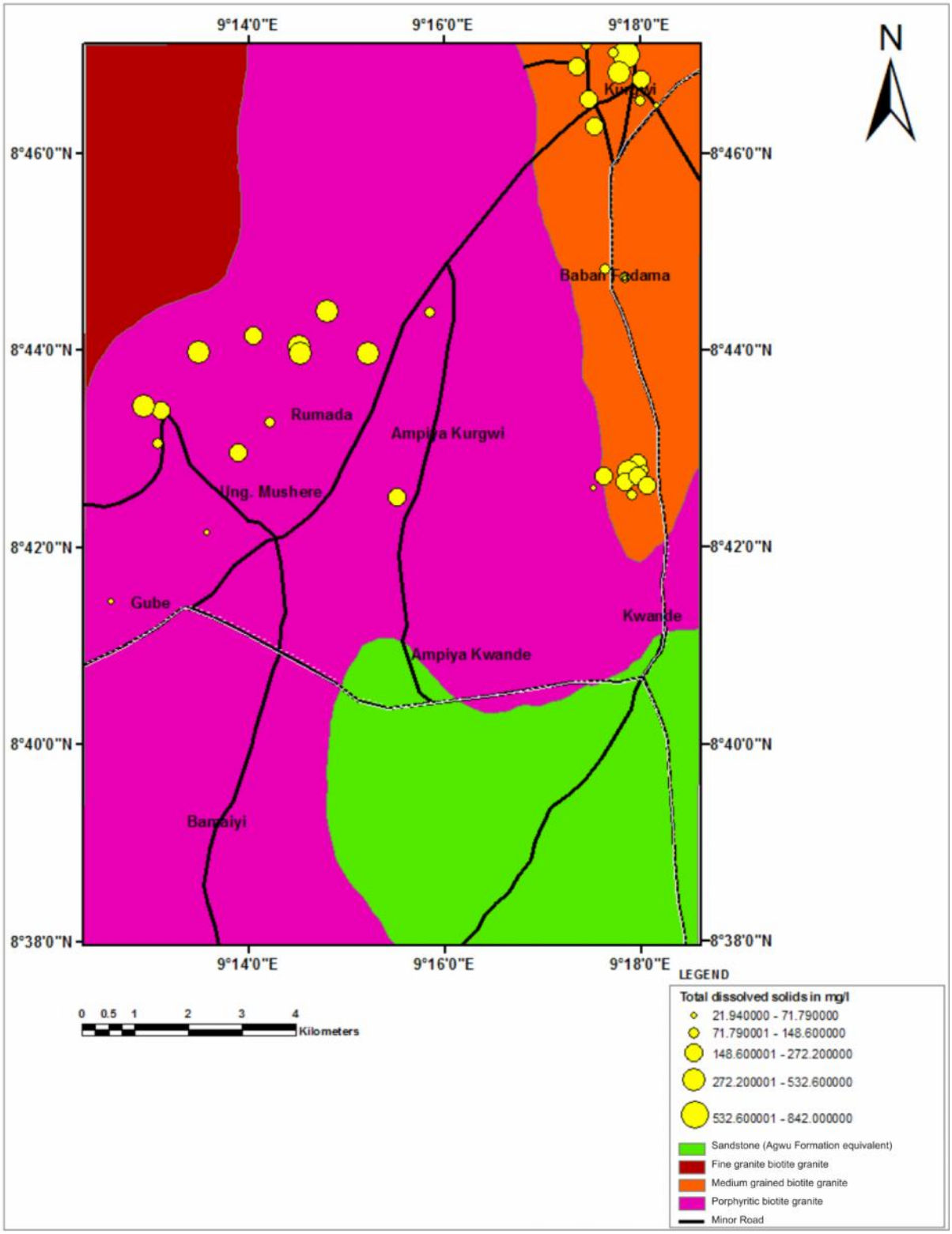

Figure 5: Symbol Map of TDS for the Study Area

More than fifty (50) trace and rare earth elements were analysed in the forty (40) water samples collected, but thirteen (13) are presented on the basis of their appreciable detectable concentrations in the samples (Table 2). All these elements occur in concentrations below WHO permissible limits except for Aluminium (Al) Iron (Fe), and Manganese (Mn) that are above the permissible limits in some locations.

The concentration of Fe is above WHO permissible limit of 0.3 mg/l in Angwan Muskwani, Kurgwi, Child friendly Primary School (Kwande), Angwan Kasuwa (Dabat) Bamaiyi (Old Jondshakal), and AngwanKwanka (Kurgwi). Manganese is above the limit of 0.05mg/l in Angwan Muryen (Kurgwi), Angwan Dem (Kurgwi). Angwan kwanka (Kurgwi), Angwan mission (Kurgwi), Baban Fadama, Child Friendly School

(Kwande), AngwanSarki (Dabat), AngwanKasuwa (Dabat), Ampiya - Kwande, and Bamaiyi (Old Jonshakal) (Fig 3). Aluminium (Al) in groundwater of the area has concentration in most locations below the permissible limit, but present in high concentration (above limit of 0.2mg/l) in AngwanMuskwani (Kurgwi), AngwanKwanka (Kurgwi), AngwanKassa (Kwande), and Angwanampiya –Kwa

Table 2: Summary of some trace elements in waters of the study area

Element	Minimum	Maximum
Fe	< 0.009	0.841
Mn	0.002	0.084
Zn	0.001	0.151
Sr	0.027	1.071
Co	<0.001	0.005
Cr	<0.004	0.005
Li	0.001	0.157
As	<0.004	0.500
Al	0.001	3.031
B	<0.004	0.299
Mo	<0.1	8.7

DISCUSSION

Composition of Groundwater in the Study Area

The composition of groundwater is determined by a variety of factors such as natural and anthropogenic (Nelson, 2002). Major natural factors that control groundwater composition include rock type, residence time, and the chemical state of groundwater (Schwartz and Zhang, 2002).

Considering the rock types in relation to water composition in the study area, the water is predominantly calcium – sodium- bicarbonate (Ca – Na - HCO_3) type (Fig 6). Kurgwi and Environs is underlain predominantly by granitic rocks of the basement complex (Dung, 2014). These crystalline rocks are all Pan – African Granites that differ only in texture. The vast nature of these granites may be responsible for the predominant calcium -sodium bicarbonate water type in the study area. In south – eastern part of the study area where sedimentary formation pinched into basement rocks, the water type is predominantly sodium bicarbonate (Na – $HCO_{3)}$, as evident in samples 15 – 23 (Kwande town). This may probably be attributed to ion exchange. The slightly higher calcium and potassium concentration at Angwan Dem and Angwan Ankwai (both in Kurgwi), and Rumada .may be attributed to anthropogenic activities as the locations are underlain by the same granitic rocks like most other locations. Nitrate concentration in groundwater which is dependent on anthropogenic activities is generally low (that is, below 10mg/l) in the area. This suggests that human activities have had less effect on groundwater quality in the area.

Trace elements in the study area generally occur in concentration in low concentration, this is expected considering the low solubility of their minerals. The mobility of most trace elements such as Iron (Fe), manganese (Mn), and aluminium (Al), and so on, is enhanced by low pH and depth (Fetter, 2007). The slightly alkaline nature of water in the area is probably responsible for low concentration of trace elements in groundwater samples of the area. The presence of Fe, Mn and Al in appreciable concentration in some locations may probably be due to circulation of water through soils and rocks thus dissolving iron and manganese bearing minerals.

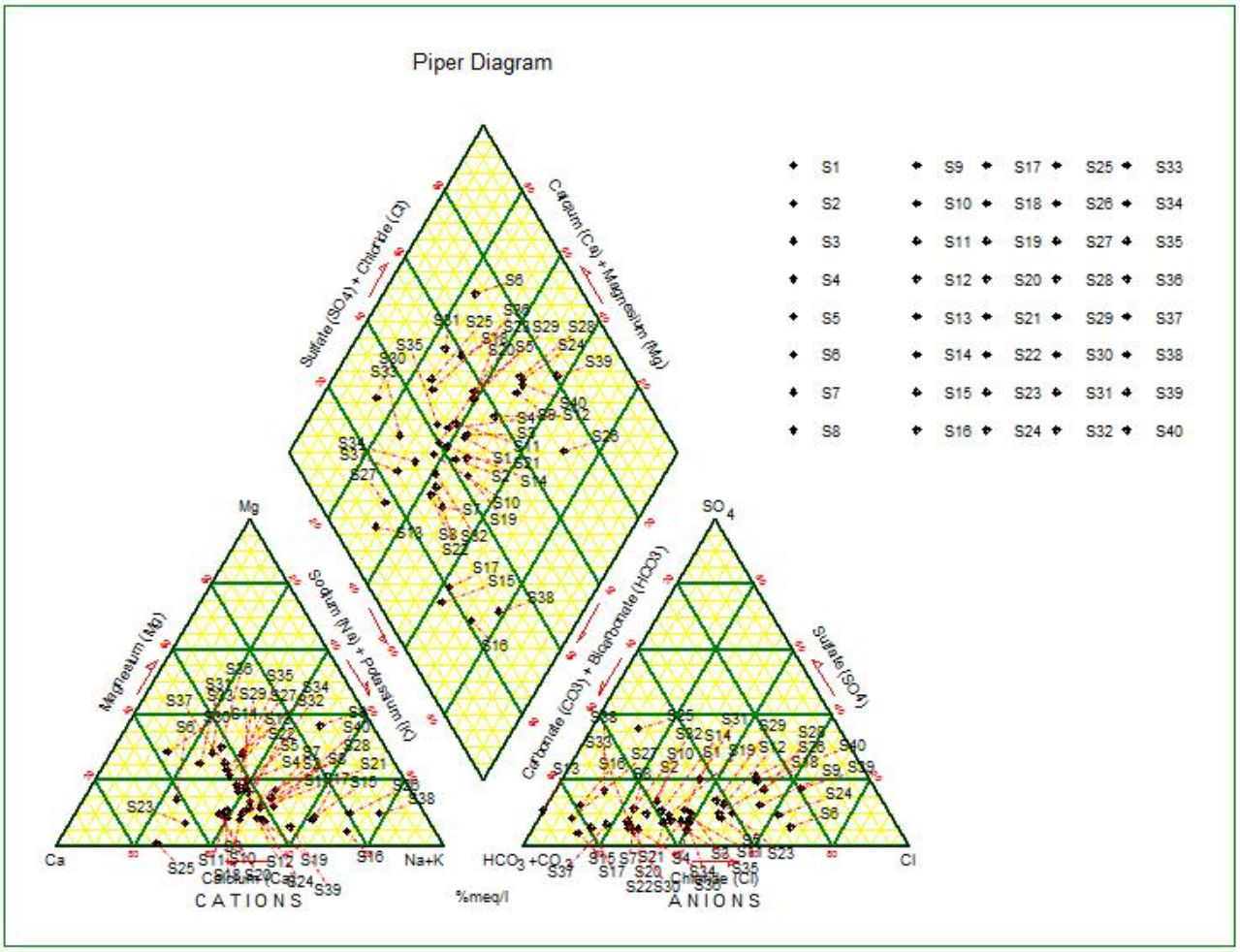

Figure 6: Piper Diagram of the Entire Study Area.

Domestic Water Quality

Drinking and domestic water quality criteria are based on World Health Organization (WHO, 2011) Guidelines for drinking water. For drinking purpose, all the both the major cations and anions are within the WHO recommended limits for drinking. The hardness values of groundwater in the area are not generally safe for domestic use.

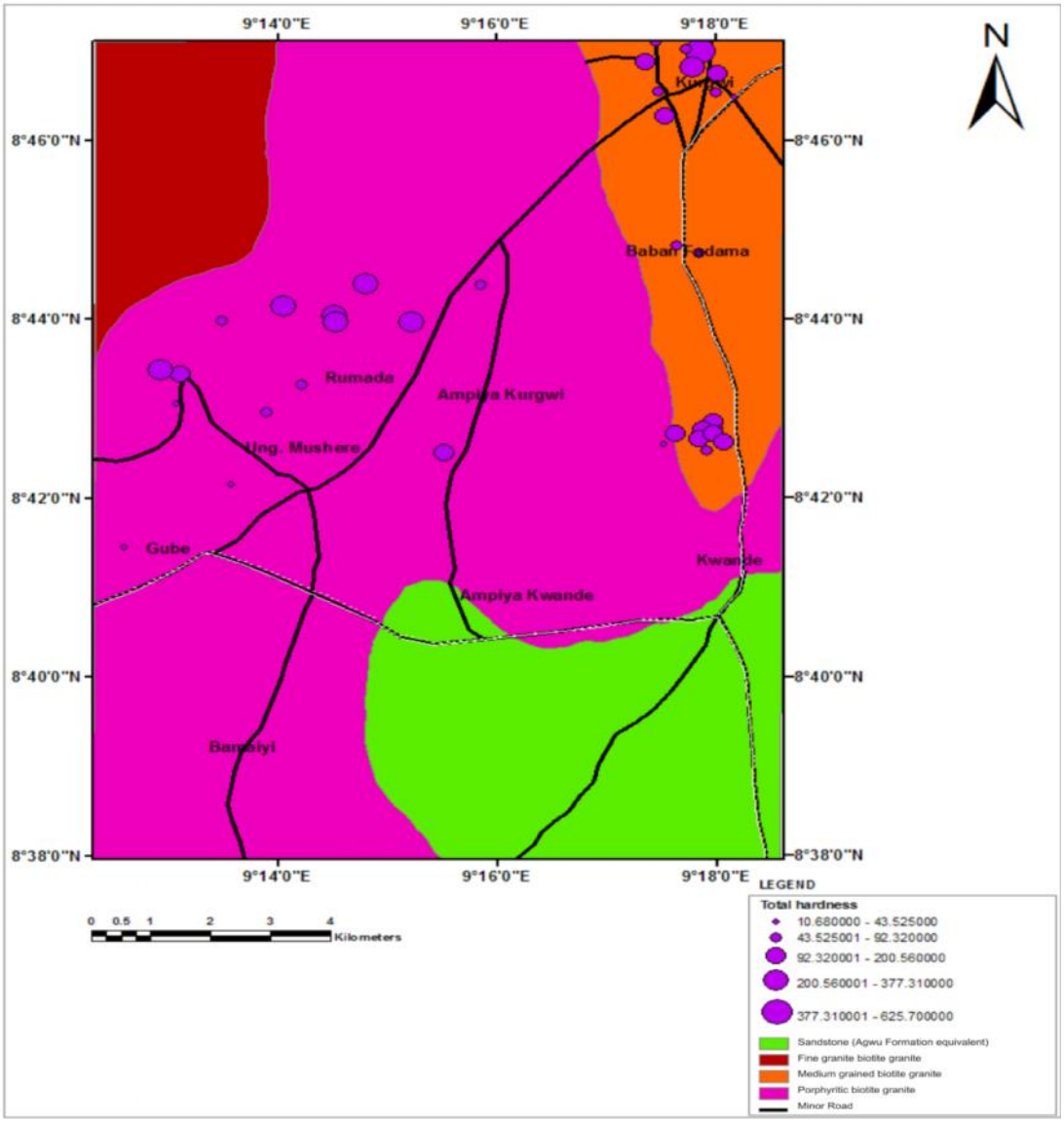

Figure 7: Symbol map of Total Hardness in groundwater of the study area

such as bathing and laundry work. The Mn and Fe concentrations being high in some locations make the water not so suitable for laundry purposes since they can cause reddish – brown or black stains on laundry and household fixtures (Schwartz and Zhang, 2002).

Livestock Water Quality

Total Dissolved Solids is critical in considering waters to be administered to livestock (Anudu, et. al, 2011). With respect to the Australian and UNESCO standards (Hamil and Bell, 1986) show that values below 2100 mg/l are suitable for all animals). In view of this standard, groundwater in the study area is suitable for livestock consumption.

Irrigation Water Quality

The demand for good quality surface and groundwater for irrigation is on the increase in different parts of the world, and as a result it is important to consider its requirements with regards to water quality (Anudu et al, 2011). Some of the important requirements in relation to plant include Sodium Absorption Ratio (SAR) and Salinity Hazard. Salinity Hazard relates to accumulation of excessive soluble salts. Such salts restrict plant roots from absorbing water even in the midst of plenty water thus resulting in physiological drought conditions (Hiscock, 2005). Sodium Absorption Ratio relates to the proportion of Na^+ to Ca^{2+} and Mg^{2+} in the water as follows.

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}}$$

with atomic concentration expressed in $meqL^{-1}$ (Hamil and Bell, 1986). In the study area, SAR ranges from 299 x 10^{-3} to 3.43. Based on classification of irrigation water quality by Wilcox, 1995, the sodium hazard of the water to crops is low thus the water quality is suitable for irrigation (Fetter, 2007).

CONCLUSION

Hydrogeochemistry of groundwater in Kurgwi and environs revealed physical parameters as well as major elements compositions in groundwater are within WHO permissible limits. High concentration of some

cations (above WHO permissible limits) in the study area is attributed to geogenic sources. Groundwater in the area is generally slightly alkaline with mean pH of 8.2. Trace elements concentrations in groundwater of the area are generally low possibly due to the slightly alkaline nature of water which does not favour or enhance the mobility of these elements. Concentrations of Mn, Fe, and Al are above the permissible limits in a number of locations. Groundwater in the study area is predominantly Ca –Na- HCO_3 type.

Groundwater in the area is not very suitable for drinking and domestic purposes owing to its general hardness but is good for irrigation and livestock uses. Due to the low level or concentration of nitrate, chloride and sulphate in the area, it is evident that human or anthropogenic activities have not seriously affected groundwater quality in the area.

REFERENCES

Anudu, G. K., Obrike, S. E., Onugba, L. N and Ikporkonte, A. E., 2011. Hydrochemical Analysis and Evaluation of Water in Angwan Jeba and Environs, Nassarawa State, North central Nigeria. Research Journal of Applied Sciences.p 128-132.

Davies, T. C., 1994. Water quality characteristics associated with fluorite mining in the Kerio Valley area of Western Kenya. International Journal of Environmental Health Research 4, pp 165 - 175.

Dung, S. G., 2014. Hydrogeochemistry of Shallow Groundwater in Kurgwi and Environs, Northcentral Nigeria. Unpublished M.Sc Thesis, University of Jos, Department of Geology and Mining.

Fetter, C. W., 2007. Applied Hydrogeology. 2nd Edition. CBS Publishers, New Delhi, Bengalore. Pune Kochi Chennai.592p

Hamill, L and Bell, F. G., Groundwater Resource Development. Buttersworth Publishers, Stoneham Massachussets ISBN – 13:9780 408014090, 344 p.

Hiscock, K. M., 2005. Hydrogeology: Principles and Practice. John Wiley and Sons, New York ISBN – 1B: 978019857634, 389 p.

Jordana, S and Batista, E., 2004. Natural groundwater quality and health. Geologica Acta, 2, (2): 175 – 188.

Nelson, D., 2002. Natural Variation in the composition of groundwater. Drinking Water Program, Oregon Department of Human Services, Springfield, Oregon. Pp 1 – 8.

Schwartz, F. N and Zang, H., 2002. Fundamentals of Groundwater. John Wiley and Sons.Inc.583P.

WHO., 1984. World Health Organization Guidelines for drinking water quality. Vol.2, Health criteria and other supporting information, Geneva,pp335.

WHO (World Health Organization)., 2011. Guidelines for drinking water quality (4th edition,pp.186), available at (http://www.who.int).

Wilcox. L. V., 1995. classification and use of irrigation water.US Department of Agriculture, Washington Dc. P.19P.