HYDROGEOLOGICAL AND HYDROGEOCHEMICAL EVALUATION OF THE GROUNDWATER POTENTIALS OF KADUNA AREA, CENTRAL NIGERIA

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Abstract

An assessment of the groundwater potentials of Kaduna area, Central Nigeria, has been carried out using hydrogeological and hydrogeochemical characteristics. The investigations had led to a fairly good appraisal of the hydrogeological characteristics of the area of the basement complex terrain in Nigeria. Groundwater contour map showed the flow direction to be southwards and southeastward in the northern part of the area while the flow direction in the southern part is northwards toward River Kaduna. Analysis of the relationship between static water levels and depth of dug wells in the area gave a correlation of 0.89 with a regression coefficient of 0.79. While a correlation coefficient calculated for the variation of static water level with elevation of wells was -0.0479. The mean depth to water table was 4.03m with a standard deviation of 1.49 and a coefficient of variability of 37. The mean elevation of wells is 603.75m with a standard deviation of 27.54 and a coefficient of variability of only 4.5. Borehole yields in the area range from 30.24 to 207.36m^3/day with an average of 90.65m^3/day, Transmissivity values range from 0.38 to 47.4m^2/d with an average of 6.96m^2/d and specific capacity values range from 0.43 to 31.85m^3/day with an average of 6.13m^3/day/m. The depth to water level range from 1.1 to 16.63m with an average 6.51m while the overburden thickness range from 8.5 to 42.0m with an average of 23.4m. Analysis of hydrogeological parameters from boreholes in the area revealed a correlation coefficient calculated for the variation of the overburden thickness with the transmissivity , specific capacity and yield as 0.083, -0.249, and -0.18 respectively with a regression coefficient of 0.0069, 0.062, and 0.032 respectively . The correlation coefficient calculated for the relationship between the transmissivity and the specific capacity was 0.78 and the regression coefficient 0.61. Chemical analysis of major ions for groundwater in the area indicates Sodium and Potassium ions and Bicarbonate ions were the dominant ions and hence the groundwater of the area is classified as Na-K and Bicarbonate water type.

Keywords: *Groundwater, Kaduna, Transmissivity, Hydrogeological and Hydrogeochemical parameters*

Introduction

Groundwater is a very important water resource as throughout history it has been a major source of drinking water and even today, more than half of the world's population depends on groundwater for survival (UNESCO, 1992). Groundwater forms more than 98% of the available freshwater in the world's water supply exceeding the volume of surface water (Fetter, 1980). However evaluation of groundwater quality and quantity is essential for development of civilization and to establish database for planning future water resources development strategies (Omar *et al.,* 2006). Access to clean freshwater will be one of the biggest global resource problem of the coming decades. One billion people had no access to clean drinking water from public supply in the year 2003. Probably, between 2 and 7 billion people will live in water scarce countries in the middle of this century. Recent estimates suggest that climate change will account for about 20 percent of the increase in global water scarcity (www.unesco.org).

The aim of this research work is to use major ions in the characterization of hydrogeochemical condition of groundwater and to ascertain the quality of groundwater in the study area using major ions. Also, to determine if the groundwater in the study area is potable for people living in the area.

The area of study is located in northern Nigeria and lies between latitudes 10^0 25'N and 10^0 40' and longitudes $7^0$15' and 7^0 30'E. It covers a total area of about 716 sq km in the Guinea savannah region with two seasons – Wet season from March/April to October and Dry season from November to March. Mean monthly temperature range from $15^{0\ to}$ 36^0, with average annual rainfall of 1270mm and mean annual relative humidity of 57%.

Geology and Hydrogeology

The area of study is essentially situated within the northern sector of the Nigerian basement complex and is characteristically underlain by the Granite-Gneisses, Porphyroblastic Gneisses, medium to coarse grained Granites, Porphyritic Granites and Quartzites (Eduvie 1991) (Fig. 1) Essentially, two aquiferous units are delineated in the study area- The weathered overburden and the fractured crystalline rocks which are generally interconnected. The weathered overburden is represented by a mantle of in situ weathering products of varying thicknesses. It is quite variable and highly weathered, degrading to a material containing high percentage of kaolinite. This stage of weathering is found in the topmost part of the zone, extensive and has significant storage potential. At greater depth beneath the kaolinite, the degradation has similar lithologic characteristics with clayey grit and the joints and fractures s in the layer tend to be open (Mogekwu, 1987).The intermediate zone is more productive at the base where the rock fragments are coarser in size and have not been subjected to extensive weathering processes. (Offodile,1983; Jones, 1985; Egboka, 1988)

The fractured basement represents the more prolific aquifer system in the area. Groundwater occurs in fissures, joints and fractures, which have been developed through the geologic processes of fracturing, faulting and weathering. It constitutes the most prolific aquifer system in the crystalline rocks the world over (Oteze, 1981). The capacity of this zone to hold and transmit water depends on the extent, pattern, size openness and continuity of the fractures and the degree to which the fractures are connected hydraulically (Stewart, 1964; Oteze, 1981)

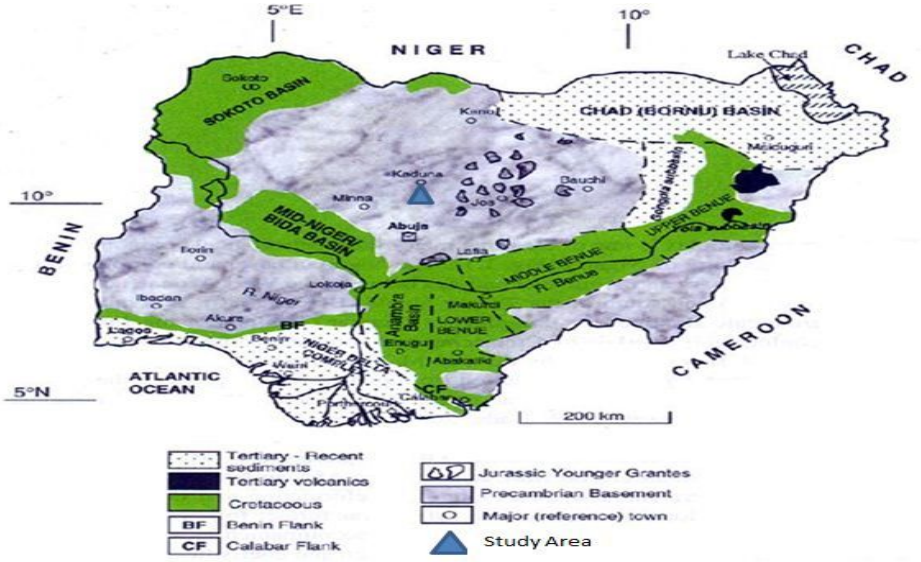

Fig 1: Geological Map of Nigeria (After Obaje and Abaa, 1996)

Materials and Methods

Water samples were obtained from thirty hand dug wells and water depth measurements from eighty wells. Grid method of sampling was used and water samples were collected from wells in each of the sampled points. The longitude, latitude and elevation of each location were recorded using a Global Positioning Systems (GPS). The static water level, total depth and water column of each hand dug wells were measured using meter tape along with their topographic elevation. The procedure in sampling for groundwater involves three basic steps; these are information on physical, chemical and biological properties. Based on the guidelines by WHO (1996), the physical properties examined include: the physical parameters (pH and Electrical Conductivity,) were determined on the field using a calibrated pH meter and Conductivity meter. Chemical ions determined were chloride, nitrate, carbonate, bicarbonate, calcium, sodium magnesium, and potassium. The samples were collected using 2 litres containers and were all taken to laboratory immediately.

Water level contour map (Fig 2) was produced from water level measurements which was statistically analysed together with hydraulic parameters from available data. Hydrogeochemical study of the area was investigated using analysis of major anions and cations carried out on thirty selected water samples from dug wells by Atomic Absorption Spectroscopy and Volumetric analysis.

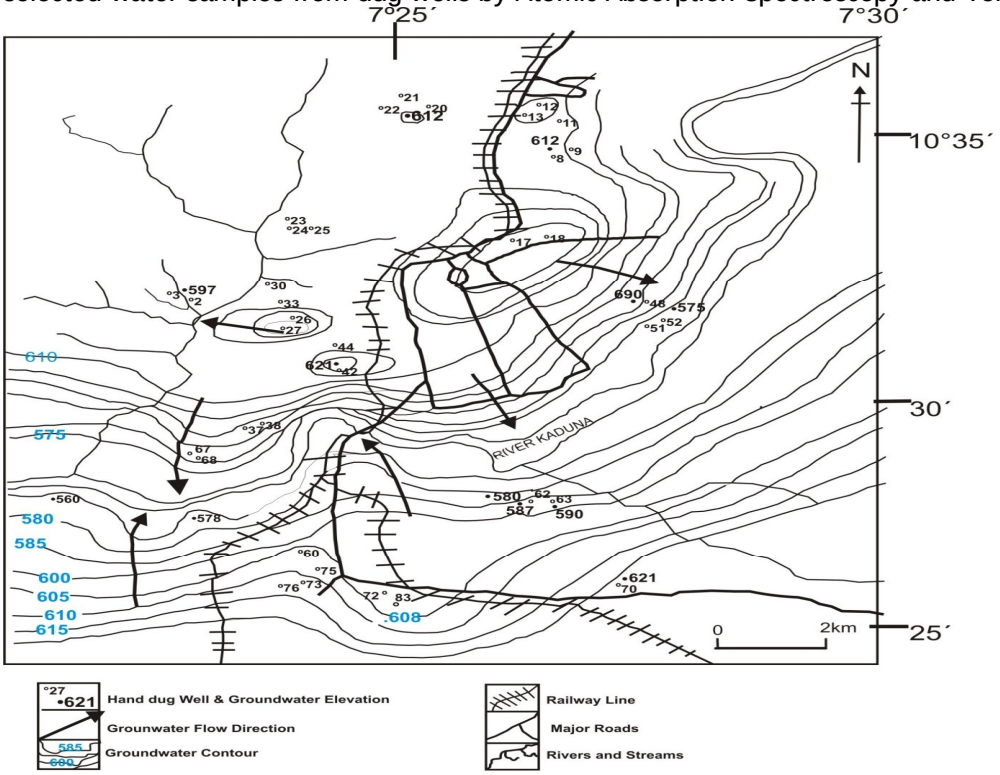

Fig.2: Groundwater Contour Map of the study Area

Results

A total of thirty hand dug wells were sampled for chemical analysis of the ions using Atomic Absorption Spectroscopy and Volumetric analysis. The characterization of the water shows that sodium ion concentration in the water samples range from 1.6 to 18 mg/l; potassium ions 1.8 to 19mg/l; calcium ion 0.57 to 18mg/l and magnesium ions 0.1 to 9.4mg/l. for the anions , the following concentrations were obtained: chloride ion range from 1.2 to 24 mg/l; sulphate ions 2.5 to

16mg/l and bicarbonate ions 15 to 112mg/l. the ionic concentration of the major anions and cations are generally below the standard limits set by the World Health Organization.

Table 2: Concentration of Major Cations and Anions in Mg/l

Sample No	Na+	K+	Ca2+	Mg2+	Cl-	SO4-	HCO3-
2	4.00	5.70	6.00	3.00	2.60	6.00	30.00
5	21.20	4.20	3.40	0.15	7.00	3.00	56.00
8	12.20	4.20	2.00	0.88	10.40	7.00	19.00
10	8.20	11.70	4.00	1.20	6.80	5.04	112.00
14	10.00	5.00	18.00	3.50	24.00	16.00	32.00
15	5.60	5.50	1.98	0.97	5.00	7.50	20.00
18	4.20	6.10	1.75	1.30	10.10	8.20	27.00
22	7.20	12.21	9.10	1.87	1.50	4.89	68.00
23	9.80	2.60	1.20	1.12	1.20	7.50	30.00
26	11.00	2.40	0.95	1.14	1.48	8.00	26.00
31	4.50	5.20	0.61	0.70	1.40	1.20	22.00
34	6.00	2.80	20.00	1.00	2.90	5.00	70.00
37	8.90	13.40	5.70	1.86	1.72	6.00	68.00
40	7.20	12.50	6.10	2.10	1.80	5.70	65.00
42	8.60	8.70	12.00	0.80	5.20	6.00	70.00
43	7.50	8.20	11.00	0.91	6.10	5.91	67.00
44	5.90	2.70	3.40	0.10	8.60	4.80	17.00
48	15.00	16.00	4.00	1.50	18.00	6.30	58.00
51	18.00	19.00	3.80	1.20	17.00	7.00	72.00
57	2.90	5.82	5.43	2.30	2.70	5.20	25.00
59	9.50	4.40	0.57	0.12	7.80	2.50	15.00
62	7.20	11.20	6.37	1.23	4.00	6.00	41.00
66	1.60	2.60	0.60	1.10	2.13	3.00	15.00
67	2.80	3.28	2.93	9.54	1.76	3.04	20.10
69	2.80	3.27	2.89	9.46	1.67	3.14	22.00
72	4.60	6.20	1.60	1.34	6.21	4.00	20.00
74	7.20	11.20	6.37	1.24	4.10	6.20	44.00
75	6.40	5.60	4.12	0.82	6.10	7.30	16.00
81	9.80	4.10	1.00	2.10	7.60	8.50	33.00
84	3.60	1.80	7.20	0.18	2.65	7.00	23.00

Discussions and Recommendations

From the analysis of the correlation between the static water level and the elevation of dug wells, a very low value of -0.0479 suggests that the static water level at any location in the area of study is hardly affected by the elevation. A strong positive relationship is indicated between the static water level and depth of dug wells from the calculated coefficient of correlation, which is 0.89. Thus it could be said that an increase in depth of wells, positively affects the static water levels in dug wells in the area of study.

The values of hydrogeological parameters such as yield, specific capacity and transmissivity are characteristic of basement aquifers. The varying quantities in yield of boreholes in the area reflect the effect of varied degree of fracturing and weathering of the basement rocks in the area. The values of specific capacity, which give a better indication of aquifer performance than yield , were generally less than $10m^3/d/m$. This supports the view that specific capacity of wells in the basement aquifers are generally low(Chilton and Smith-Carrington, 1984).
The correlation coefficient calculated for the variation of the overburden thickness with the Transmissivity, Specific Capacity and Yield were very low. Thus it is reasonable to assume that the overburden thickness does not play any significant role in determining the yield/specific capacity, in other words the productivity of the basement aquifer in Kaduna area. Rather, the hydraulic characteristics are suggestive of more important impact on the aquifer performance arising from the degree and extent of both fracturing and weathering of the crystalline basement rocks. However, the Transmissivity was observed to have a strong positive relationship with the specific yield.

Hydrogeochemical facies established for the ground waters in the Kaduna area is classified based on the dominant ions as Na-K and Bicarbonate type water. The Na-K and HCO_3 being the dominant ions from the Piper (1944) and Durov Diagrams (Fig. 4& 5). It is suggested that this is as a result of high weathering of feldspathic minerals in the area. The hydrochemical facies is a function of the lithology, solution kinetics and flow patterns of the aquifers (Back, 1960; 1966).

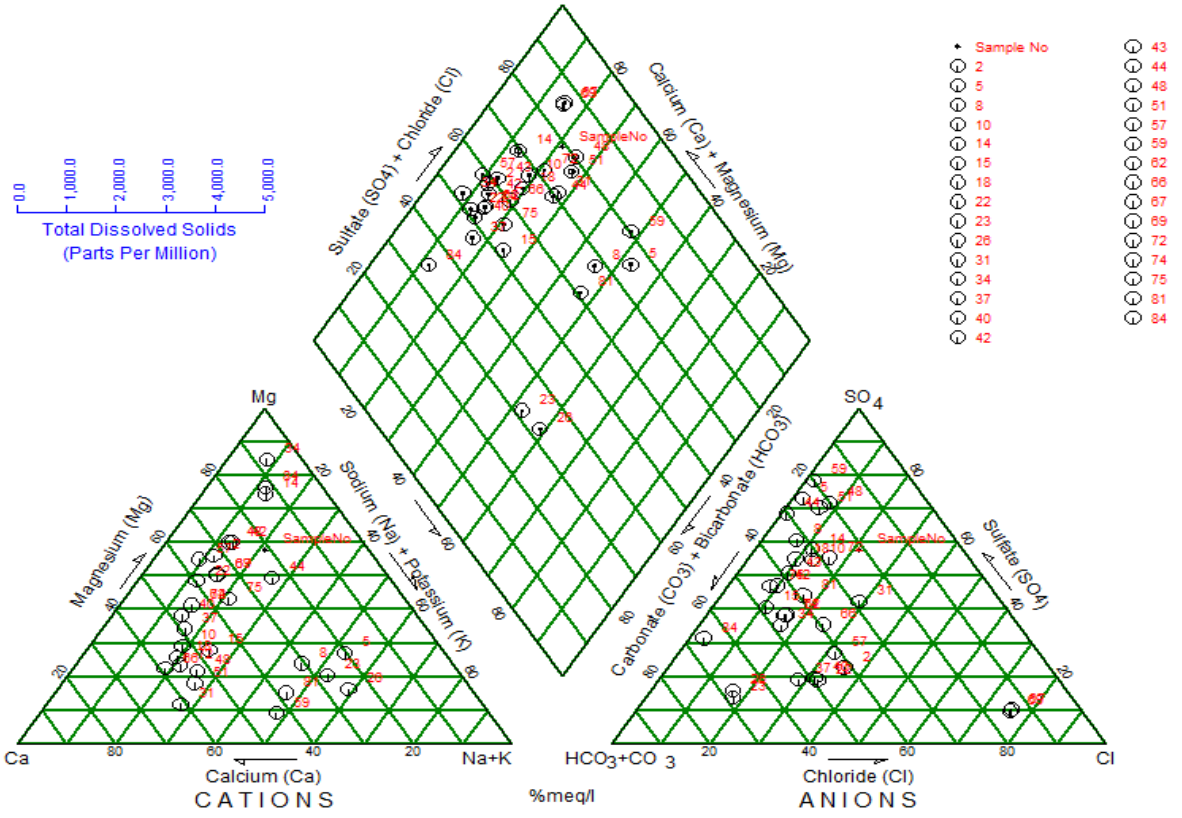

Fig.4: Piper diagram of water analysis from Hand dug wells in Kaduna area indicating their hydrochemical affinities

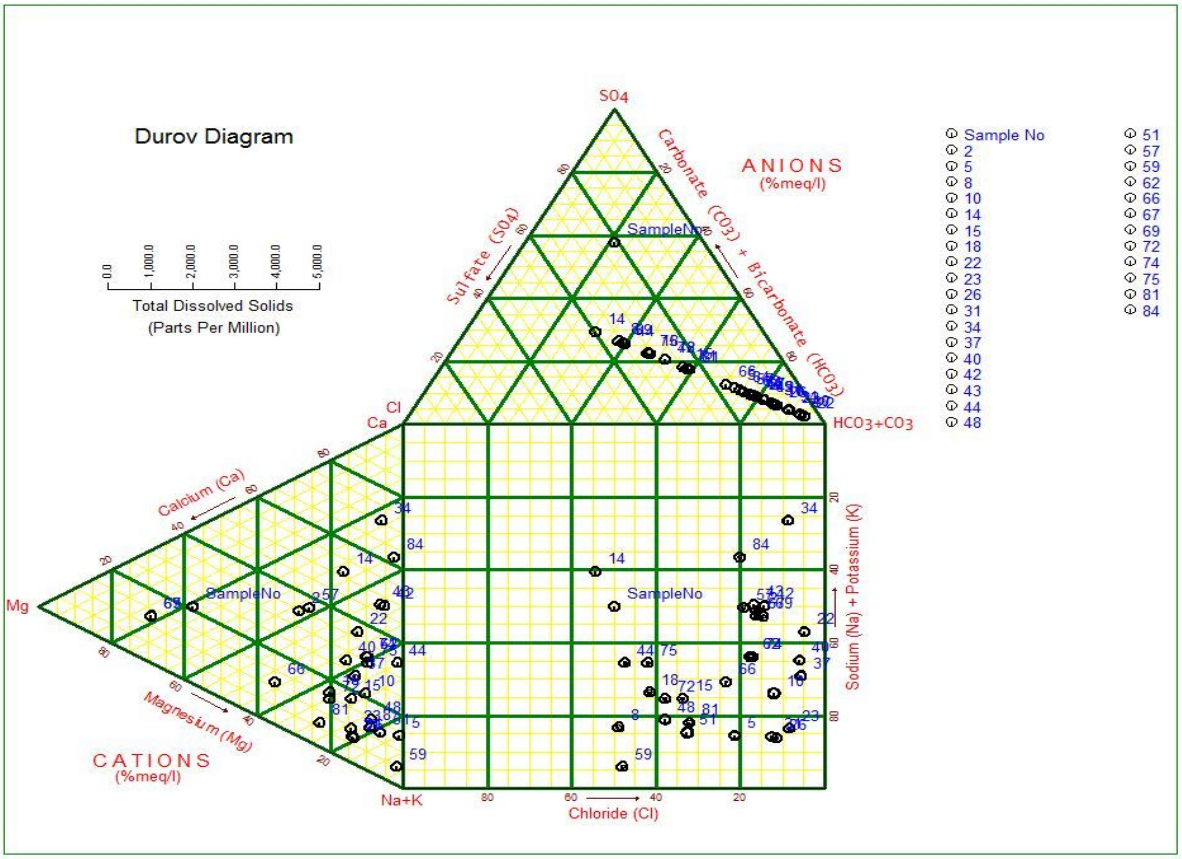

Fig.5: Durov diagram of water analysis from Hand dug wells in Kaduna area indicating their geochemical affinities

Significant between well variations in the compositions of the groundwaters were observed. The well to well variations are inferred to be the result of the degree of interaction between groundwaters and basement rock weathered by a given groundwater, and/or variations in groundwater redox conditions. (Mueller et al 2000).

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