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Effects of Geostructural Features on the Quality and Quantity of Groundwater in Abakaliki Area and Environs

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Abstract: **Understanding the availability and status of groundwater is pertinent to water use. The geology however influences greatly on the availability, distribution and the quality of groundwater of an area. The quantity and quality is further impacted on by other characteristic features including structural system. Comparing the geochemistry and structural system with the hydrogeochemistry and pumping test indicates the degree of influence. Both rock and water samples were analyzed. Geostructural system especially fracture orientation, length and width measurement were mapped. The analysis comparatively revealed high content of ions and dissolved particles such as Ca^{2+}, Mg^{2+}, HCO_3^- and SO_4^{2-} but fall within SON and WHO permissible limits for drinking water. Piper diagram plot shows that groundwater of the area is dominated by the Ca + Mg type suspected to have link to the geology as the source. Pumping tests results shows yield ranges between 3.3l/s to 5.8l/s uncommon to shale formation, hence structural influence inferred.**

Keywords: **availability, formation, geostructural, groundwater, hydrogeochemistry, ions, pumping test, shale.**

1. INTRODUCTION

Over the years, groundwater has been a source of potable water to man. It has critically remained valuable in sustaining industrial development, livelihood and environment. Nevertheless, residents of some areas are often times faced with inadequate water supply. This condition can be severe sometimes most especially during the dry season and or after a heavy drawdown. To make up domestic needs, residents resort going kilometers to neighboring communities in search of potable water. Inadequate availability and impairment of groundwater is always not unconnected to geology and structural system in an area. Okeke and Bartholomew (2014), Onwe *et al* (2015b) tried to determine the quantity and potability of groundwater and comparing the chemistry with the World Health Organization (WHO) standard limits for drinking water. Okogbue (2013) earlier worked on the quality of groundwater and elaborated on the high level of groundwater contamination as a result of sulfide ore deposits. Geogenic (hydro geochemical) activities including release of elements into the soil after rainfall, weathering and leaching of elements from the soil zone into groundwater regions increases the rate at which these mineral deposits through structural pathways within the rocks get into the groundwater. The plume disperses from the host rock/groundwater interface environment and introduces some geogenic reactions into the groundwater. The Abakaliki shale formation is the major lithology with an average thickness of more than 500m, (Nwajide, 2013). Depth to static water table ranges from 6.5m to 25m and in some locations up to 49.9m. Average values of K (hydraulic conductivities) estimated from joint/fracture density characteristics of the area is 6.06 x 10-3cm/s, (Ozoko (2015). Shales in its original state are not considered aquifers because of their non-interconnectivity and impermeability, Freeze and Cherry (1979). This makes them incapable of transmitting groundwater. However, shales can be regarded as secondary aquifers if they are either fractured or weathered enough to transmit stored groundwater, McDonald (2005). The characteristic features of the fractures within the underlying shales determines the groundwater availability of an area, hence this study.

Geology of the Area:

The study area, figure 1,

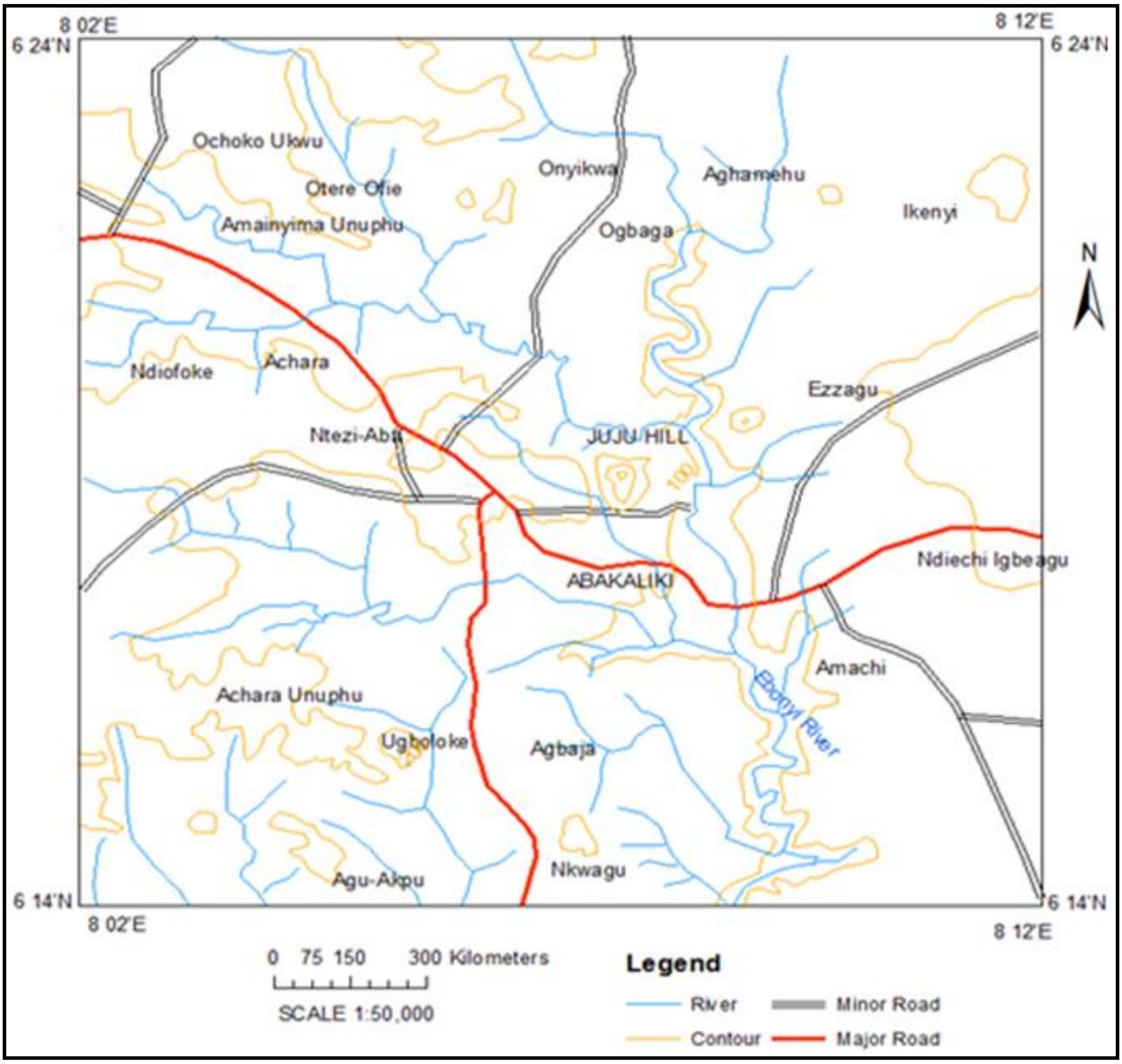

Fig. 1. Map of the study area

Abakaliki and its environs is geologically situated within the southern part of the lower Benue Trough which is located at a major re-entrance in the African continent. The southern Benue trough is part of the Benue trough depression which consists of the Anambra Basin to the west and the Afikpo Syncline and Abakaliki Anticlinorium to the east. Abakaliki and its environs is underlain by poorly bedded fissile shales of the Abakaliki shale formation of the Asu River Group. Reyment (1965) described the Asu River group as the oldest sedimentary rock in southeastern Nigeria. Abakaliki formation is predominantly shales; ranges from dark grey to black in color, with intercalations of sandstones, siltstones and limestone, which was believed to have started depositing during the Mid-Albian period. The Formation is folded, fractured and deeply cross-cutting faulted by sequences of tectonic activities with Lead-Zinc mineralization, (Cratcheley and Jones 1965; Wright 1968; Grant 1971; Burke et al., 1971; Burke and Whiteman 1973; Nwachukwu 1972; Olade 1975). The study area is also intruded by diorites and pyroclastics which intermingle with the continuous progression of marine argillites, limestone and evaporates of the Albian Asu River Group (Onwe *et al*, 2015a). The soil type of the study area dominantly consists of clay, loamy and clayey loam soil which is basically low in porosity and permeability.

2. RESEARCH METHODOLOGY

Structural features especially exposed fractures and faults were measured across the study area, figure 2.

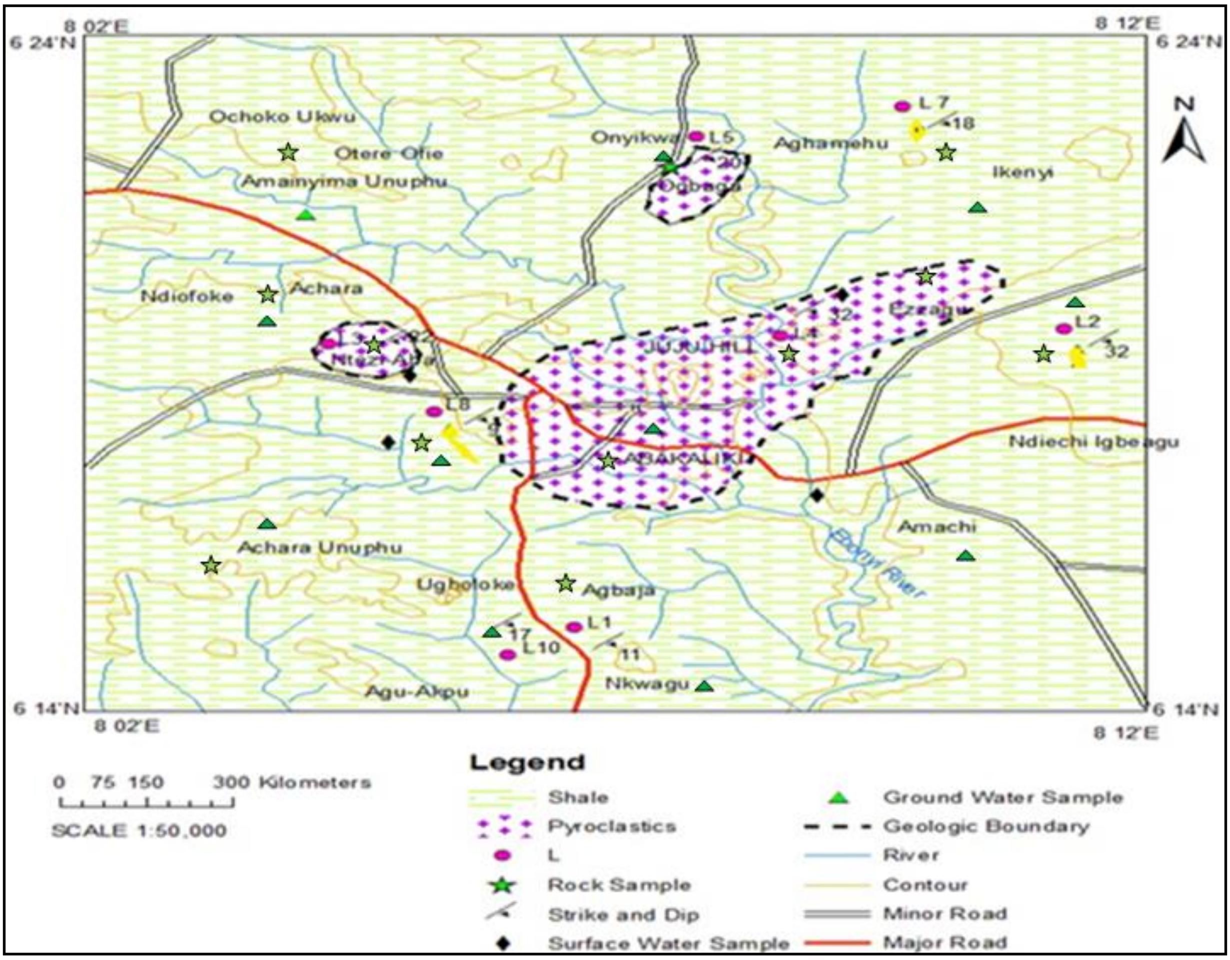

Figure 2. Geologic map of the study area showing sample locations plotted.

The physical characteristics of fractures such as orientation, aperture, trace length and spacing exposed on outcrops in the area were measured. Some of these were found along road cuts, quarry sites, drainage channels and also in areas where the overburden has been removed. Comparative analyses of rock and water (surface and groundwater) samples were carried out. Pumping tests were done in several boreholes across the study area.

3. RESULTS AND DISCUSSION

The results of fracture measurements is presented below, table 1.

Table 1. Results of fracture measurements

S/n	Coordinates		Azimuth	Length, L (m)	Width, W (m)
1	N 6° 19' 33.7" E 8° 11' 56.8"	Ndiechi-Igbeagu	28° NE-SW	0.089	0.0001
			44° NE-SW	0.9	0.001
			30° NE-SW	0.038	0.002
			158° NW-SE	0.065	0.001
			62° NE-SW	0.049	0.001
			170° NW-SE	0.073	0.001
			154° NW-SE	0.033	0.001
			44° NE-SW	0.057	0.002
2	N 6° 18' 58.7" E 8° 5' 35.2"	TTC (Igbeagu)	152° NW-SE	0.043	0.001
			158° NW-SE	0.025	0.001
			160° NW-SE	0.032	0.002

3	N 6° 20’ 29.8” E 8° 8’ 36.8”	Ezzagu	172° NW-SE	0.038	0.001
			138° NW-SE	0.89	0.001
			132° NW-SE	0.033	0.001
			40° NE-SW	0.18	0.001
			44° NE-SW	0.9	0.001
			146° NW-SE	0.76	0.001
			56° NE-SW	0.099	0.001
			60° NE-SW	0.4	0.001
			40° NE-SW	0.145	0.001
			28° NE-SW	0.62	0.09
			140° NW-SE	0.78	0.001
			32° NE-SW	1.12	0.001
			90° E	0.59	0.001
4	N 6° 22’ 34.4” E 8° 7’ 01.2”	Echi- Aba	150°	0.73	0.001
			166°	0.44	0.001
			112°	0.92	0.013
			92°	0.89	0.001
			154°	0.46	0.001
			42°	0.56	0.001
			126°	0.67	0.1
			8°	0.034	0.001
			18°	0.043	0.001
			122°	0.13	0.001
			134°	0.1	0.001
			18°	1.0	0.001
5	N 6° 22’ 30.7” E 8° 7’ 01.3”	Echi -Aba	68°	0.40	0.003
			58°	0.31	0.001
			40°	0.22	0.005
6	N 6° 21’ 54.0” E 8° 9’ 51.0”	Ikenyi	68°	0.024	0.001
			42°	0.422	0.001
			52°	0.288	0.001
			38°	0.42	0.005
7			58°	1.2	0.001
			148°	0.323	0.001
			156°	0.448	0.001
			156°	0.36	0.012
			56°	0.495	0.001
			62°	0.37	0.001
			152°	0.38	0.002
			52°	0.289	0.001
			134°	0.334	0.001
			166°	0.430	0.001
			46°	0.87	0.001
			16°	0.2	0.001
			46°	0.32	0.004
			54°	0.12	0.001
8	N 6° 19’ 01.2” E 8° ‘ 41.6”	Ntezi Aba	64°	0.19	0.001
			52°	0.2	0.001
			84°	0.10	0.001
			160°	0.09	0.01
9	N 6° 18’ 38.8” E 8° 5’ 59.8”	Azuiyiokwu	156°	0.10	0.001
			150°	0.43	0.001
			68°	0.812	0.001
			160°	0.14	0.001
10	N 6° 18’ 31.5” E 8° 6’ 6.0”	Azuiyiokwu	4°	0.229	0.001
			4°	0.30	0.001
			4°	0.26	0.001
			4°	0.41	0.001
			54°	0.21	0.001
			168°	0.39	0.001
11	N 6° 15’ 04.3” E 8° 6’ 19.6”	Nkwagu	138°	0.23	0.12
			60°	0.21	0.001

The fracture characteristic measurements were used to plot a rose diagram or polar plot and the result is as below, figure 3.

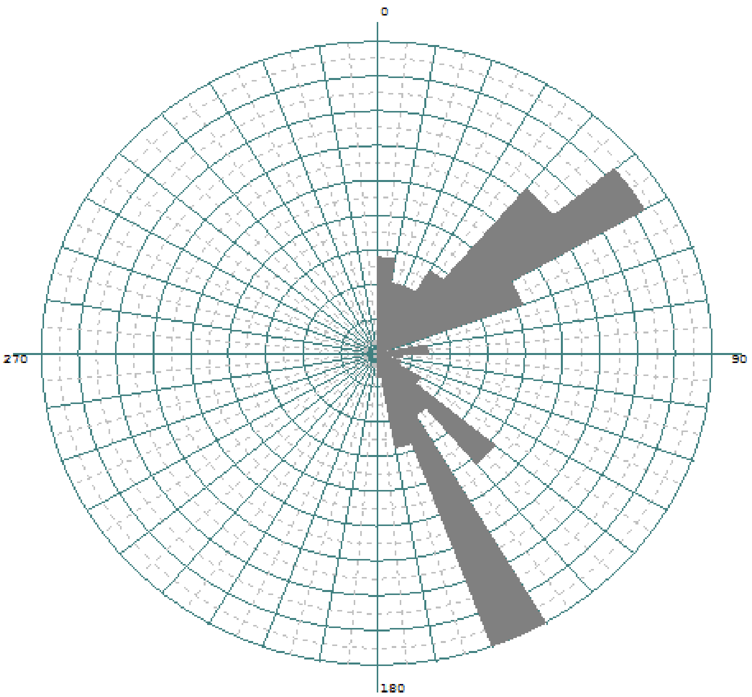

Figure 3: shows the polar plot of fracture azimuth.

Table 2. Results of Geochemical analysis major rock type of the study area (converted to weight percent oxide).

Sn	Oxides (%)	R1Pyroclastic (%)	R2 Shale (%)
1	Na_2O	5.41	13.32
2	K_2O	9.67	6.56
3	Fe_2O_3	28.08	20.21
4	CaO	8.71	11.66
6	MgO	10.81	6.64
7	MnO	14.73	1.67
8	Al_2O_3	11.59	1.78
9	SiO_2	6.67	4.59
10	P_2O_5	5.18	28.51
11	Fe_2O_3 + FeO	53.35	38.39
12	Na_2O + K_2O		

Table 3. Hydro-physical Analysis

Sn	**Location name**	**Cordinates**	**Sample type**	**pH**	**Temp (°c)**	**TDS (mg/l)**	**EC (µs/cm)**
1	Echi-Aba	N 6° 22’ 29” E 8° 7’ 03.1”	Groundwater	7.23	29.2	273	300
2	Azuiyiokwu river	N 6° 18’ 50.4” E 8° 05’ 45.1”	Surface water	7.68	26.2	43	88
3	Ugwu achara	N 6° 21’ 23.1” E 8° 04’ 37.8”	Groundwater	6.8	28.2	136	293
4	Ebonyi river	N 6° 18’ 28.4” E 8° 08’ 54.7”	Surface water	6.43	26.6	35	78
5	Nkwagu 1	N 6° 15’ 05.1” E 8° 06’ 20.1”	Groundwater	7.16	27.6	602.4	281
6	Nkwagu 2	N 6° 18’ 60” E 8° 05’ 30.4”	Groundwater	7.24	27.9	480	430
Minimum				6.43	26.2	35	78
Maximum				7.68	29.2	602	430
Average				7.09	29.3	261.6	245

Table 4. Results of chemical parameters of water samples within the study area

S/n	Coordinates	Sample type	Location	Na^+ (mg/l)	K^+ (mg/l)	Fe^{2+} (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Mn^{2+} (mg/l)	HCO_3^- (mg/l)	SO_4^- (mg/l)	Cl- (mg/l)
1	N 6° 22' 29" E 8° 7' 03.1"	Groundwater	Echi Aba (Ogbaga)	1.322	0.132	0.143	0.356	1.339	0.00	52	99.172	68
2	N 6° 18' 50" E 8° 05' 45.1"	Surface water	Azuiyiokwu	1.124	1.221	0.969	3.255	0.440	0.00	28	136.618	48
3	N 6° 21' 23.1" E 8° 04' 37.8"	Groundwater	Ugwu achara	3.178	8.921	0.181	5.60	7.986	0.568	64	274.82	56
4	N 6° 18' 28.4" E 8° 08' 54.7"	Surface water	Ebonyi River	4.663	3.133	3.959	3.443	12.663	0.461	46	123.861	84
5	N 6° 15' 05.3" E 8° 06' 20.1"	Groundwater	Nkwagu 1	9.723	12.422	0.01	24.496	6.36	0.220	80	304.22	120
6	N 6° 18' 60" E 8° 05' 30.4"	Groundwater	Nkwagu 2	2.782	6.688	0.080	14.239	9.911	0.03	366	400	72
	Minimum			1.124	0.132	0.01	0.356	0.440	0.00	28	99.172	48
	Maximum			9.723	12.422	3.959	24.496	9.911	0.568	366	400	120
	Average			3.799	5.419	0.890	8.565	6.449	0.213	106	236.6	76.66

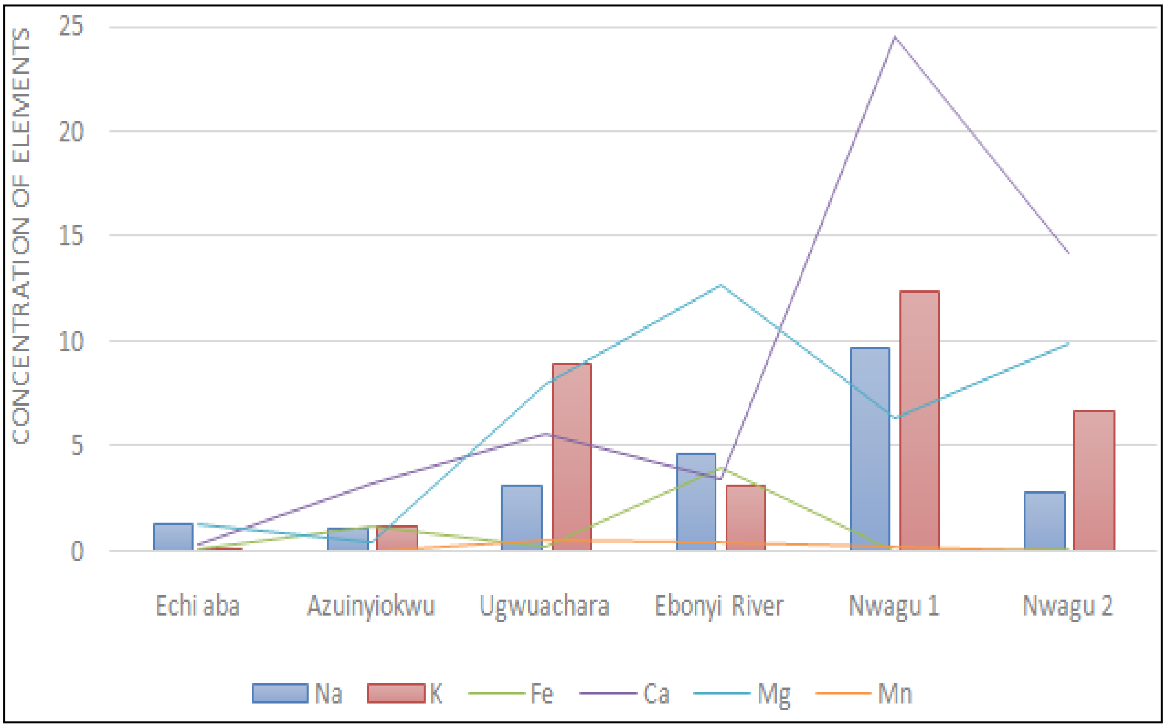

Fig 4. Chart showing concentration of chemical elements in the sampled waters

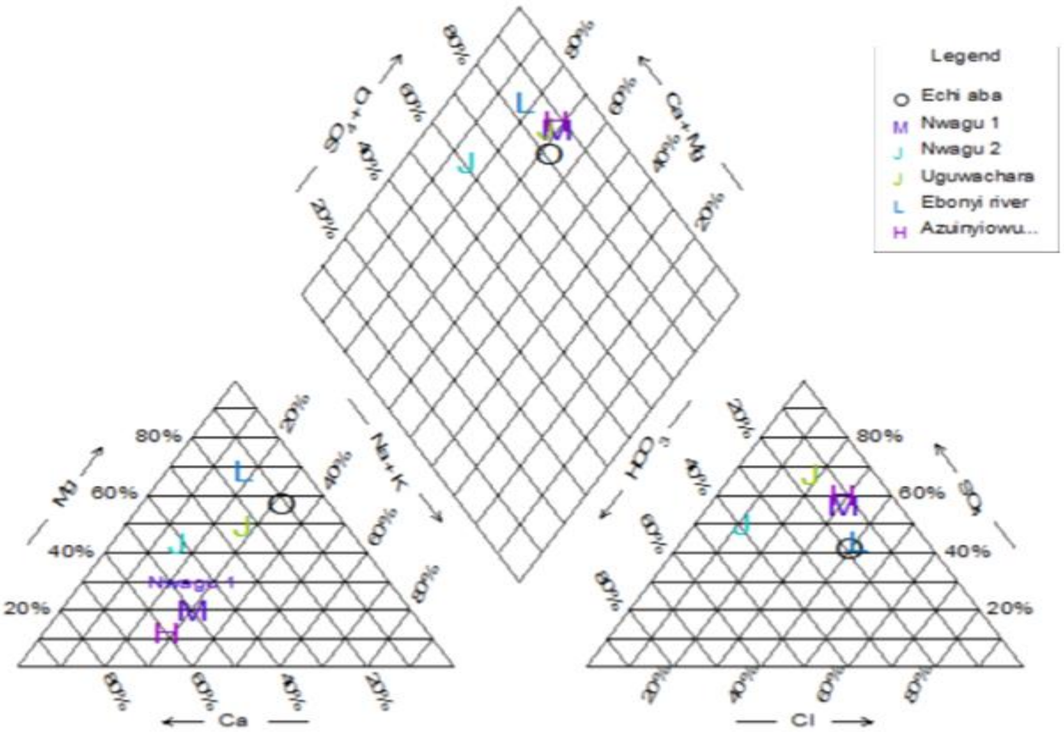

Fig 5. Piper Trilinear Plot of the concentration of major cations and anions in the sampled waters

Table 5. Physiochemical comparison of sampled water with SON and WHO standard limits for drinking water.

Parameters	SON standards	WHO standard limit		Results obtained
		Highest desirable level	Max. permissible	
pH	6.5-8.5	7 – 8.5	6.5 – 9.2	6.43-7.68
TDS	500	500	500	35-602.4
Na^{+}	NA	NA	NA	1.124-9.723
K^{+}	10	NA	NA	0.132-12.422
Fe^{2+}	0.3	0.1	1.0	0.01-3.443
Ca^{2+}	75	75	200	0.356-24.496
Mg^{2+}	20	50	150	0.440-12.663
Mn^{2+}	NA	NA	NA	0.00-0.568
SO_4^{2-}	NA	200	400	99.2-400
HCO_3^{-}	NA	1	NA	28–366
Cl^{-}		200	250	48–120

Table 6. Results of pumping test on boreholes within Abakaliki area.

Location	Yield (l/s)
Obeagu Uwoma Agbaja	4.2 l/s
Obulechi Agbaja	3.3 l/s
Achara Unuhu	3.3 l/s
Tycoon Hotel	5.8 l/s
Onuoguzor Ezeagu	4.2 l/s
Afoezunna St. Abakaliki	5.8 l/s
Nsukka St. Abakaliki	5.8 l/s
Regional Market	5.8 l/s
Eke-Aba Market	4.2 l/s
Ogoja Road Abakaliki	3.3 l/s

4. DISCUSSION

The area is predominantly underlain by shales (the Abakaliki formation) of Asu River Group with intercalations of sandstones and limestone. The shales are hard, fissile, laminated and fossilified. The shales in the area have been deformed by tectonic events with the dominant structures being folds, cross-cutting fractures and faults, plate 1, 2. These fractures form secondary porosity for the transmissivity and storage of groundwater. The tectonic activities intruded the shales and emplaced pyroclastics and diorites in some places, plate 3. Results of fracture orientation measurements shows that fractures trend more in the NE-SW direction. The azimuth ranges from 4°─90°NE-SW and 92°─172° NW-SE while fracture width ranges from 0.3cm (0.003) – 1cm (0.01). The fracture density and intensity at Ikenyi and Echi-Aba are higher which indicates that aquifer yield in these areas will be higher than the other locations because shales yield water most where they are highly fractured.

Geochemical analysis shows silica SiO_2 content of the pyroclastics (6.67%) is higher than that of shale (4.59%), table 2. The Fe_2O_3 and MgO contents of the rocks are relatively high with Fe_2O_3 ranging between 20.21% and 28.08% and MgO between 6.24% and 10.81% for shale and pyroclastic respectively. CaO content is high for shale (11.66%) than pyroclastic (8.71%). The total alkali (Na_2+K_2O) content for pyroclastic rock is 15.08%. MnO is very high for pyroclastic (14.73%) compared to that of shale with has a percentage of 1.67%. Both rock sample has zero concentration of Zn.

Pumping test results of selected boreholes, table 6 indicate yield ranges from 3.3l/s to 5.8l/s with an average of 4.6l/s. This falls within low yield for groundwater potential of Allan Macdonald et al (2005). The area is considered an aquiclude and can only store and transmit groundwater through network of fractures From the results of facture orientation measurements, it can be said that the groundwater would flow more in the NE-SW direction. Furthermore, rivers in the area discharges between $1.9m^3/s$ to $10.4m^3/s$ with an average of $5.4m^3/s$. Under natural conditions, streams are the primary discharge outlet for groundwater: rainfall percolates unto the ground and recharges the groundwater system, and then through infiltration water flows very slowly through the groundwater system via the structures, eventually discharging to streams. Groundwater discharge to streams provides the base flow of streams and is often a primary component of the total streamflow.

The physical properties of groundwater determine its suitability for domestic, industrial and agricultural purposes as set by guide lines or standards. The physical parameters measured are: total dissolved solids (TDS), hydrogen exponents (pH) and temperatures. The total dissolved solids (TDS) of the samples analyzed range from 43mg/l to 602.4mg/l with an average of 261.6mg/l, table 3. TDS falls within WHO maximum permissible limit except for Nkwagu 1 which had the highest value of 602.4. The pH of groundwater ranges from 6.8 to 7.24 with an average of 7.1. Temperature values recorded range from 26.2°C to 29.2°C, with an average of 29.3°C. The recorded water temperatures of the sampled wells and boreholes ranges from 27.6°C to 29.2°C with an average of 25°C, table 3. pH value of groundwater ranges from 6.8 to 7.24 (weak acidic to alkaline) with an average of 7.10 which falls within WHO maximum permissible limits. High pH most times results from the presence of bicarbonates, carbonates and hydroxides of calcium, magnesium, potassium and sodium. Low pH may also be caused by precipitation of iron in stored water sampled before testing, especially if several days elapsed between sampling and testing. Electrical conductivity of groundwater ranges from 281µs/cm to 430µs/cm with an average of 326µs/cm. this indicates no fresh water.

Results of elemental analyses of boreholes and surface water samples spread across the study area were presented in table 4. Elements analyzed are: Sodium, (Na^+) has concentration ranging from 1.12mg/l to 9.723mg/l with an average of 4.2mg/l. In groundwater, sodium is believed to be released by weathering of plagioclase feldspars. Potassium, (K^+) has concentration of between 0.13 mg/l and 12.422mg/l, with an average of 5.42mg/l. It is suspectedly released into water by weathering of orthoclase and microcline feldspars in the subsurface. Calcium (Ca^+) concentration of groundwater ranges from 0.36mg/l to 24.5mg/l, with an average of 8.57mg/l. The calcium is however suspected to have been released from the limestone units. Iron, (Fe^{+3}) concentration in groundwater ranges from 0.01 mg/l to 0.181mg/l, with an average of 0.28mg/l. Bicarbonate (HCO_3^{-2}) concentration is from 28mg/l to 366mg/l, with an average of 106mg/l. the bicarbonate is as a result of the interplay between groundwater and limestone. Chloride, (Cl^-) concentration in groundwater range from 56mg/l to 120mg/l, with an average of 94mg/l. Sulphate, (SO_4^{-2}) concentration in groundwater is high and ranges from 99.2mg/l to 400 mg/l, with an average of 269.6mg/l.

The chemical parameters of the water samples plotted on Piper trilinear diagram using AqQa 1.5 software show trends of major ions. The major ions of Ca^{2+}+ $Mg^{2+}$and HCO_3^{2-} plots at the top of the diamond, the region of hard waters hence, classifying the water type as Ca + Mg type (Fig. 4.) which indicates the groundwater of these areas is generally hard. However, groundwater of the study area is within SON and WHO's safe and potable limits.

5. CONCLUSION

The study area is underlain by shale formation (the Abakaliki shale) with pyroclastic deposits in some parts. The shales have been deformed due to tectonism resulting in folds, fractures and faults. These structural system forms the aquifer zone, storing and transmits groundwater in the area. Hydrochemical analyses revealed that the groundwater within the study area is moderately alkaline and mostly hard in nature, categorized as Ca + Mg type. The slightly high average electrical conductivity (245µS/cm) of the water samples implies that some of the groundwater samples are saline rather than fresh in nature. This could be linked to the hydrothermal and salt deposit occurrence near and around the study area. Results of the analysis obtained were compared with the Standards for Drinking Water of SON, (2007); WHO, (2011) and Nigerian Industrial Standard, NIS (2007). All the chemical constituents fell below the official safe limits.

REFERENCES

[1] Celestine O. Okogbue and Stephen N. Ukpai. (2013). Geochemical evaluation of groundwater quality in Abakaliki area, Southeast Nigeria.

[2] Jordan Journal of Earth and Environmental Sciences. Vol. 5, Number 1 (ISSN 1995-6681)

[3] Cratchley C.R., Jones G. P. (1965). An interpretation of the geology and gravity anomalies of the Benue Valley, Nigeria. Overseas Geol. Surv. Geophys. 1:26.

[4] D.C. Ozoko (2015). Heavy Metal Pollution of Natural Waters in Abakaliki, Ebonyi State, Nigeria. International Journal of Science and Research, Vol. 4 Issue 6, 482-486.

[5] Freeze, R. A. and Cherry, J. A., Groundwater. Englewood Cliffs N. J., 1979.

[6] Grant, N. K. (1971). The South Atlantic, Benue Trough and Gulf of Guinea Creteceous Tripple Junction. Geological Society of American Bulletin, 82, 2295-2298.

[7] http://dx.doi.org/10.1130/0016-7606(1971)82[2295:SABTAG]2.0.CO;2

[8] Macdonald, A., Davies, J., Carlow, R. and Chilton, J., Developing Groundwater. Intermediate Technology Development Group, 2005.

[9] Nwachukwu S. O. (1972). The tectonic evolution of the southern portion of the Benue Trough, Nigeria. Geol. Mag. 109:411-419.

[10] Nwajide, C.S., Geology of Nigeria's Sedimentary Basins. CSS Bookshops, Lagos. (2013).

[11] Olade M. A. (1975). Evolution of Nigeria's Benue Trough (aulcogen): A tectonic model. Geol. Mag. 112:575-578.

[12] Reyment, R. A., Aspects of the Geology of Nigeria. Ibadan University Press., 1965.

[13] Rock Onwe Mkpuma, Nwankwor G. I. and Ahiarakwem C. A. (2015a). An Aspect of Water Distress Level Evaluation in Abakaliki Area and Environs Southeast Nigeria. International Journal of Scientific & Engineering Research, Volume 6, Issue 2.

[14] Rock Onwe Mkpuma, Nwankwor G. I. and Ema Michael Abraham. (2015b). Groundwater characterization and impacts on health and environment in Abakaliki area and environs, Southeastern Nigeria. International Journal of Scientific & Engineering Research, Volume 6, Issue 4, April-2015.

[15] Standard Organisation of Nigeria (SON), Guidelines for drinking Water quality. (2011).

[16] Wright J. B. (1968). South Atlantic continental Drift and the Benue Trough. Tecto.

[17] World Health Organisation, Guidelines for drinking Water quality. (2011).

APPENDIX - A

Plate 1. Gently folded shale outcrop at Ikenyi

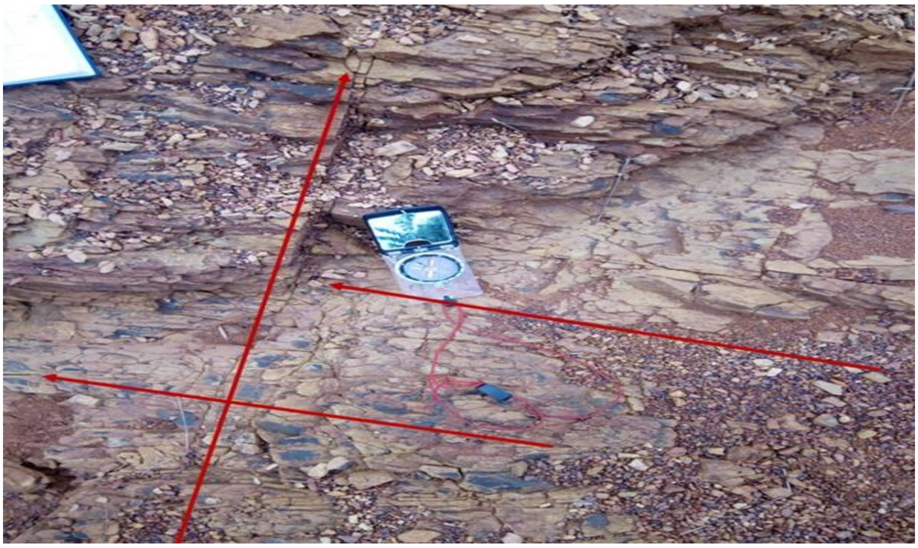

Plate 2. Outcrop with cross cutting fractures

Plate 3. Echi Aba pyroclastic deposit