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Hydraulic Properties of Abakaliki Shale-Regolith Aquifer, In Ebonyi State South Eastern Nigeria

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Abstract

This work aims at calculating the hydraulic properties of the Abakaliki shale-regolith aquifer which provides water to Abakaliki Metroplex via shallow wells on the basis of pumping test data, geoelectrics and joints density analysis.

Results from pumping test analyses show that the highest value of hydraulic conductivity K for the shales occurs in Ndu-Otara Ebie Unuhu(0.417m²/s) while the lowest value is 0.132m²/s in Ochobo. Also with this method transmissivity varies from 7.97m²/day at Obusia Amechi to 1.59m²/day at Ochobo while the storativity ranges between 6.98 x 10^{-8} at Abulechi Agbaja to 7.35 x 10^{-4} at the Rice Mill . Results from joint density analysis show that lowest value of K occur at Nwafor Ogu (2.12m/²day) while the highest value was obtained at Ochobo (6.35m²/day). Also using joint density measurements, the highest value of T, 7.05×10²m/day was obtained at Ochobo while the lowest value of 2.3 ×10^{-3}m²/day was found at Nwafor Ogu. Values obtained from geoelectrical method show that the highest K value occur at Amanata was 17.49x 10^{-4} m²/s while the lowest value occur at Achara Unuhu is 0.106 x10^{-4} m²/s. Highest T value of 109.3m/day occur at Obusia Amaechi while the lowest value of 3.26m/day occur at Simon Okpo . The average value of transmissivity (T) using the three methods was found to be 4.85m²/day. Also the average values of storativity and hydraulic conductivity are 9.2 ×10^{-1} and 2.762 ×10^{-4}m²/s respectively
Keyswords: aquifers; hydraulic, conductivity; transmissity; storativity

1. INTRODUCTION

Most attempts at groundwater development usually resolve around the search for prolific aquifers. Aquifers are rocks that can store and transmit groundwater in economically viable quantities. When aquifers are absent, the alternative is to turn to surface water bodies like rivers. The role of surface water bodies can however be curtailed if the volume of water supplied by the river is not enough to meet the water needs of the city or if the surface water is seriously polluted. In any case, the need for potable water in cities will continue to increase due to rising population and industrialization. Todd (1980) discusses the importance of combining both groundwater and surface water in meeting the needs of the cities. This is known as conjunctive use of water.

Abakaliki(the study area) was declared the capital of Ebonyi State in 1996. As a state capital, its rising population and industrialization has led to increasing water demand. The Ebonyi River which is the main source of water for the state has become "stressed" as a result. Residents have had to dig hand – dug wells in search of potable water. Agbo (1992) described the existence of a shallow, unconfined shale-regolith aquifer in Abakaliki while Ozoko (2012) investigated the hydrochemistry and microbiale; characteristics of the waters from that aquifer. No attempts have been made to determine the hydraulic properties of the shale-regolith aquifer. Shales may be considered aquiferous if they are fractured, weathered and jointed enough to permit the storage and transmission of groundwater. When such shale aquifers are found, it is necessary to determine their hydraulic properties. This work is an attempt at that.

2. GEOHYDROLOGIC SETTING

Abakaliki Shales generally consist of fine grained grayish to whitish sand stones, grey to dark grey shales and subordinate limestones. The sand stones have yellowish /dark brown iron stains due to ferruginsation and occasional streaks of carbonaceous material. In the study area, these fine gained sand stones posses calcareous cement but around the Water Works area, there is indication of siliceous cementation. The grey to dark shales are exposed along the channels of the Ebonyi River and in a few hand dug wells where there are trace of intrusive activities show some evidence of induration. In Juju Hill area , occasionally there are limestone lenses within the shales but they are not thick enough to be mapped. Dips of the Abakaliki Shales Formation range from 55° to 70° to the southeast.

Ozoko (2012) observed two aquifer horizons in the area. This comprises an upper horizon which occurs in the uppermost 15 -25m of the formation and a lower horizon that occurs at depths greater than 25m. The upper horizon is highly fractured and weathered. Both horizons behave hydraulically as low-yield unconfined regolith aquifer.

3. METHODOLOGY.

The basic hydraulic properties of an aquifer include such parameters like hydraulic conductivity, transmissivity (T) and storativity (S). Evaluating them usually involve pumping test analysis and the solution of well known flow equations. Alternatively when the sedimentological properties of the aquifer are well known, it is possible to use the equations of Haarleman at all,(1963) and Masch and Denny (1996)to determine values of K (hydraulic conductivity) or T (Transmissivity). Since shales are not considered as aquifers, it is uncommon for their hydraulic properties to be estimated. But since weathered horizons of the Abakaliki Shales display limited aquiferous properties, there is a need to determine their hydraulic characteristics. Three methods were used to determine the hydraulic conductivity (K) and Transmissivity (T) of the shales. The usual pumping test techniques were employed in eleven boreholes within the city. The Cooper-Jacob's method of analysis as described in (Freeze and cherry,1979) and (Todd, 1980) were employed to determine K (hydraulic conductivity) and T (Transmissivity) values. The second method was the use of geoelectic techniques as described by Salat (1968) and Niwas and Singhal (1990). It has now become well known that the hydraulic properties of an aquifer can be determined from the results of geoelectrical surveys. Based on this, results of resistivity surveys in 24 locations of Abakaliki city were used to calculate the hydraulic properties of the shale aquifer.The third method involved the use of the Seraphin equation as described in Hamill and Bell(1986). This equation provides for the estimation of hydraulic conductivity (or coefficient of permeability) for jointed and fractured rocks like shales. In other words, if the joints and fracture in a rock system can be properly mapped and measured, it is possible to use the obtained data to estimate the behavior of fluids through the rocks or the hydraulic properties of the rock itself. The result of the hydraulic properties obtained from these different methods were then averaged to gain an idea about the hydraulic properties of the Abakaliki Shales.

4. RESULTS AND DISCUSSION

From the study carried out using the three methods, it was deduced that transmissivity T, varied between 9.97m²/day at Obusia Amechi to 1.59m²/day at Ochobo for the pumping test method. Also the same method had the lowest value of K (0.112m²/day) at Obusia Amaechi while the highest value for K (0.4708m²/day) occurred at Ndu-Otara. At Ebie Unuhu the lowest storativity value of 6.98 $x10^{-8}$ occurs at Abulechi Agbaja while highest S value of 2.303$x10^{-3}$ was obtained for Eligba Unuhu.

The results from joints density analysis based on the Seraphin equation are shown in Table 3. Again, the results are expectedly higher than those from pumping tests but nearly equivalent to the K values from geoelectrical calculations. The minimum K value is 2.12m²/s which occurs at Nwafor- Agu while the maximum value is 6.35m²s at Ochobo. The lowest T value is 2.35 $x10^{-3}$ m²/ day at Nwafor –Agu while the maximum value is 7.05 $x10^{-3}$ m²/day at Ochobo.

Table 4 shows the comparison of the results obtained from the three different methods. The variations in K T,S values could be due to a number of factors such as variations in the degree of weathering of the shales from place to place, salinity of the fluid content within the shales and the degree of jointing. From the calculations, the average K (hydraulic conductivity) value is 0.9202m²/s. These values definitely classifies this shale as having limited aquiferous conditions and is therefore worthy of proper development.

5. CONCLUSION

Abakaliki Shales, though not considered as an aquifer is a significant source of groundwater in the Abakaliki metroplex. Already, there is indiscrimate siting of hand dug wells by city residents which might lead to the eventual destruction of the “aquifer”. Now that it has been proven that these shales posses aquiferous charactistics, it is pertinent to explore ways of properly developing the available shallow ground water trapped in the shales.

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TABLE 1: HYDRAULIC PROPERTIES OF THE SHALE- REGOLITH AQUIFER DETERMINED FROM PUMPING TEST ANALYSES

LOCATION	K(m^2/s)	T (m^3/day)	S
RICE MILL ABAKALIKI LGA	3.92	7.35 X 10^{-4}	0.245
NDU –OTARA JUNCTION EBIE UNUHU	5.65	4.855 X 10^{-7}	0.4708
ELIGBA UNUHU	2.311	2.303 X 10^{-3}	0.1926
EDUKWU AMAGU ONISHA ABAKALIKI	3.77	1.4144 X 10^{-7}	0.3142
ABULECHI AGBAJA	1.94	6.98 X 10^{-8}	0.1617
ETENWOGWU HEALTH CENTER	1.95	1.27 X 10^{-7}	0.1625
ONUGUZOR EZEOGO AGBAJA	2.68	1.88 X 10^{-7}	0.2233
SIMON OKPO ENTRANCE	2.54	1.65 X 10^{-7}	0.217
OCHOBO	1.59	1.26 X 10^{-7}	0.132
NWAFOR AGU	1.74	1.146X 10^{-7}	0.145
OBUSIA AMAECHI	7.97	6.700X 10^{-7}	0.112

TABLE 2 AQUIFER PARAMETERS OBTAINED FROM GEOELECTRICAL DATA

LOCATION	RESISTIVITY OF SATURATED FORMATION OHM-M	THICKNESS OF AQUIFER	BULK RESISTIVTY	FORMATION FACTORS	1/fa	K(10^{-A} m/s)
SIMON OKPO ABAKALIKI LGA VES 1	33	9	72.60	2.2	0.45	3.074
SIMON OKPO ENTANCE VES 2	30	16	66.00	2	0.50	2.65 X 10^{-4}
RICE MILL ABAKALIKI VES 2	23	16	35.26	1.53	0.65	1.654 X 10^{-4}
ONUGUOR EZEOGU AGBAJA	30	14	28.00	2	0.15	2.65 X 10^{-4}
ELINWOGU HEALTH CENTRE	14	13	12.6	0.9	1.11	0.345 X 10^{-4}
IYARIYA	34	20	77.07	2.3	0.43	0.3286
MGBABO	41	41	112.07	2.7	0.37	4.134
UMUAKU	82	80	448.27	5.5	0.18	10.07
NWAOFR AGU	25	50	41.67	1.7	0.59	2.014
ACHARA UNUDU	12	35	5.45	0.87	1.25	0.106
NWAFOR AGU	22	40	32.34	1.47	0.68	1.5264
AMANATA	135	24	12.15	9	0.11	17.49

NDECHI	**18**	**18.55**	**22.69**	**1.2**	**0.83**	**0.954**
OCHOBO	**24**	**32.06**	**37.00**	**1.6**	**0.63**	**1.802**
NCHOKO	**13**	**46.21**	**11.27**	**0.9**	**1.11**	**0.318**
NDIOFFA	**7**	**55**	**3.26**	**0.5**	**2**	**0.53**
AMAGU	**28**	**39**	**50.4**	**1.8**	**0.56**	**2.23**
OCHOKO OKWE	**85**	**35**	**481.67**	**5.7**	**0.18**	**10.49**
OKPETUMO	**18**	**62**	**21. 6**	**1.2**	**0.83**	**0.954**
OBUSIA AMAECHI	**92**	**71**	**564.27**	**6.1**	**0.16**	**11.342**
NDIEKPE	**50**	**48**	**166.07**	**3.3**	**0.30**	**5.406**
NDIBAM	**32**	**29**	**81.67**	**2.3**	**0.43**	**3.286**
NWAOFOR AGBAJA	**48**	**33**	**153.6**	**3.2**	**0.31**	**5.194**

TABLE 3: TRANSMISSIVITY (T) AND HYDRAULIC CONDUCTIVITY (K) VALUES OBTAINED FROM JOINT DENSITY ANALYSES

LOCATION	T (m^3/DAY)	K(m^2/S)
RICE MILL ABAKALIKI LGA	5.27 X 10^{-3}	4.76
NDU-OTARA EBIE UNHU	2.544 X 10^{-3}	2.21
ELIGHAGBA UMUCHU	6.35 X 10^{-3}	5.72
EDUKWU AMAGU	4.23 X 10^{-3}	3.81
ABULECHI AMACHI	2.76 X 10^{-3}	2.48
ELUROGURU	3. 02 X 10^{-3}	2.72
ONUGURU EZEOGO	3.97 X 10^{-3}	3.57
SIMON OKPO ENTRANCE	3. 73 X 10^{-3}	3.36
NWAFOR AGU	2.35 X 10^{-3}	2.12
OBUSIA AMAECHI	3.17 X 10^{-3}	2.85
OCHOBO	7.05 X 10^{-3}	6.35

TABLE 4 COMPARISON OF RESULTS FROM DIFFERENT METHODS

LOCATION	PUMPING TEST ANALYSIS			GEOELECTRICS	JOINT DENSITY ANALYSIS	
	T(m^3/s)	S	K(m^2/S)	K(m^2/S)	K(m/S)	T(m^3/DAY)
RICE MILL, ABAKALIKI LGA	3.92	7.35 X10^{-4}	9.3267	0.245	5.17 X10^{-3}	4.76
SIMON OKPO	2.54	1.65 X10^{-7}	0.217	3.264	3.73X10^{-3}	3.36
NDU-OTARA JUNCTION EBIE UNUHU	5.65	4.855 X10^{-7}	0.4708	2.99	2.54X10^{-3}	5.72
ELIGBAGBIA UNUHU	2.75	2.303X10^{-3}	0.1926	-	6.54 X10^{-3}	5.72
ONUGUZOR EZEOGO AGBAJA	2.68	1.88X10^{-7}	0.2233	13.6	3.97X10^{-3}	3.57
ELINWOGWU	1.95	1.27X10^{-3}	0.1625	6.25	3.02X10^{-3}	2.72
NWAFOR AGU	1.74	1.146X10^{-7}	0.145	10.88	2.35X10^{-5}	2.12
OBUSIA AMAECHI	7.97	6.706X10^{-5}	13.6	19.3	3.17X10^{-3}	2.85
OCHOBO	1.59	1.26X10^{-7}	0.132	3.54	7.05X 10^{-}	6.32
EDUKWU AMAGU ONISHA ABAKALIKI	3.77	1.4144X10^{-7}	0.3142	10.6	4.23X10^{-3}	3.81

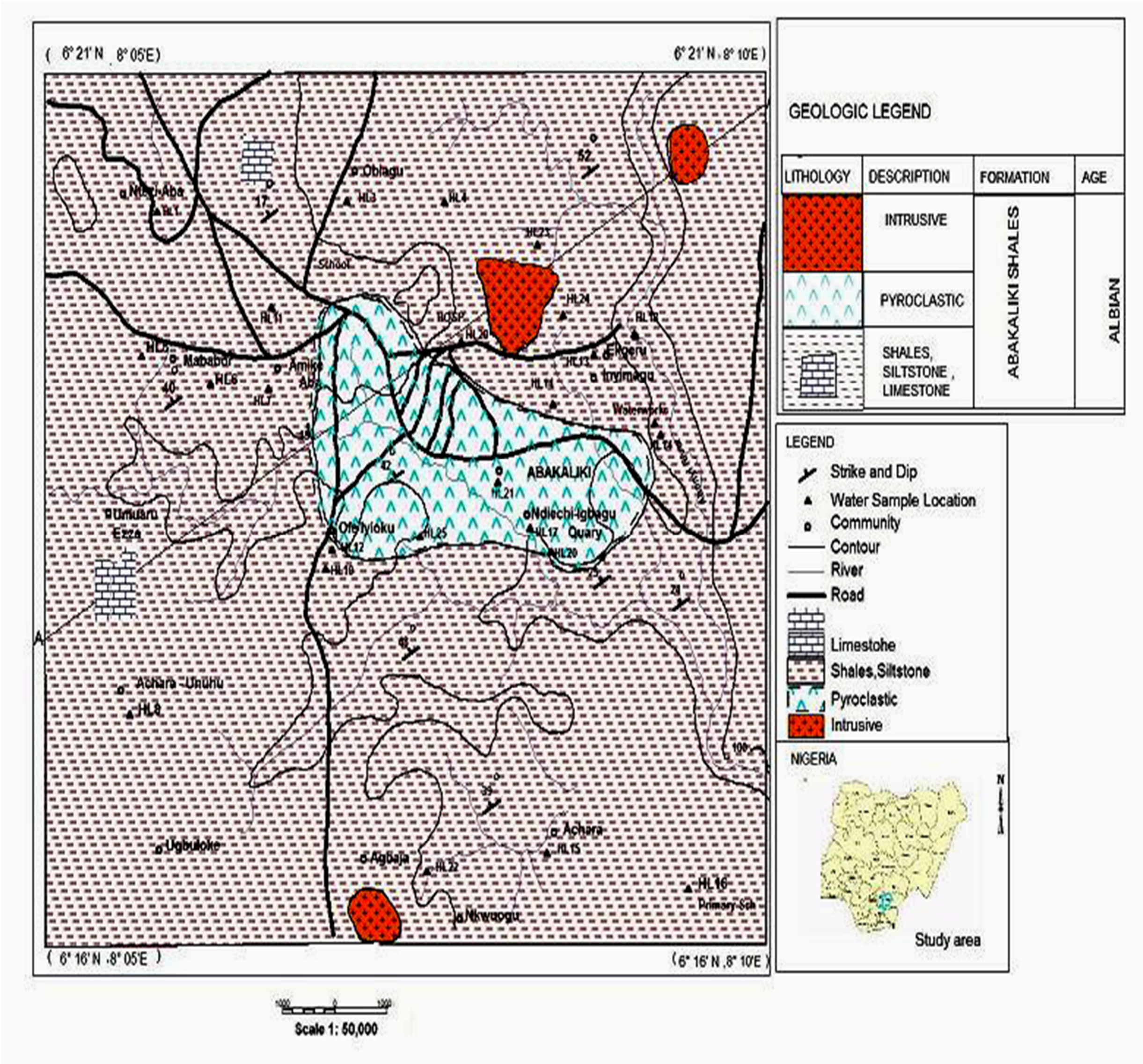

FIGURE 1. GEOLOGIC MAP OF ABAKALIKI AND ENVIRONS.