Hydrogeologic and hydrochemical framework of the shallow regolith aquifer, southern Oban massif (Nigeria)

Cadre hydrogèologique et hydrogèochimique d'un aqufère de socle fracturè altèrè, massif du sud de l'Oban (Nigèria)

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Abstract Geoelectrical and hydrogeological data were used to delineate and characterize the regolith aquifers in a hardrock area (Oban massif, Nigeria). Groundwater chemistry in the area is controlled by silicate weathering and ion exchange. The water in the area is good for domestic and irrigation applications. The study also includes management issues for the area.

Introduction and objectives

The development of groundwater resources in the Oban massif basement complex area has been the focus of the government without much success due to the fact that basement complexes are problematic aquifers. Therefore this study was to contribute to groundwater development in a hardrock area.

Objectives

- ✓ To delineate and characterize the architecture of the regolith aquifer.
- ✓ Understanding the relations among groundwater chemistry and geology.

Study area, geological and hydrogeological setting

Tropical climate with average annual temperature and rainfall of 28°C and 3000 mm.
The main lithologic units in the Oban massif area are schists, gneisses and granodiorites (Fig 1).
The occurrence of groundwater in the area is controlled by weathering and fractures.

Lithological and geoelectrical data

The study involved surface geological mapping and geoelectrical measurements. The geological mapping was mainly to record the site geology. Lithological profiles from drill data were also used to describe the lithology and aquifer systems (fig 2).

During the geoelectrical survey, vertical electrical soundings (VES) data were acquired based on the Schlumberger array described by Zohdy et al. (1974) using ABEM SAS 300B terrameter. This apparent resistivity values were plotted against corresponding current electrode half separations (AB/2) on a log-log paper.

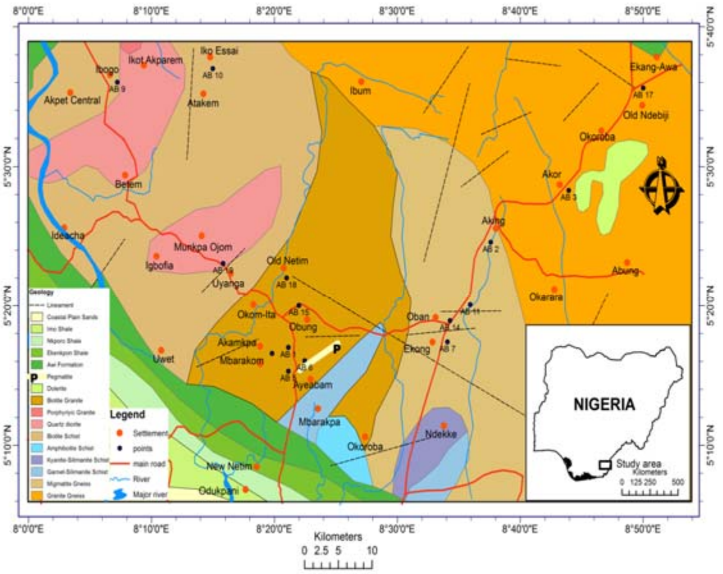

Figure 1 Location map of study area

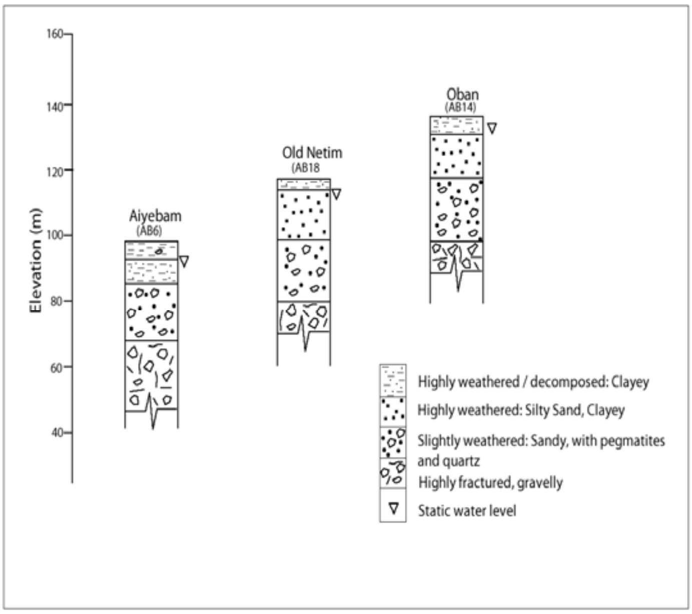

Figure. 2 Lithological profile across study area.

Results and discussion

Hydrogeologic Framework

Geoelectrical results reflect two, three and four geoelectric layers. This was used to develop a generalized hydrogeologic model for the Oban massif (Table 1).

Table 1 Average Geoelectric Data for different layers for Oban Massif (a). *The data has been used to development a hydrogeologic frame work (b).*

a

No of geoelectric	Layer resistivity (Ω m)				Layer thickness (m)		
layers	ρ_1	ρ_2	ρ_3	ρ_4	t_1	t_2	t_3
2	310			1750	1.2		
3	150	423		1600	1.0	27.4	
4	433	850	350	2067	0.9	11.1	77.1

b

Hydrogeoelectric layer	Geoelectric Layers	Resistivity range	Thickness range	Remarks
(regolith layer)		(Ω m)	(m)	
1	1	150-433	0.9-1.2	highly-moderately weathered
2	2 and 3	350-850	11.1-77.1	moderately-slightly weathered
3	4	1600-2067		slightly weathered-fractured bedrock

Groundwater abstraction in these locations here is through hand dug well (regolith layer 1), hand pump fitted shallow boreholes (regolith layer 2) and deep boreholes from regolith layer 3 and fractured bedrock.

Regolith aquifer parameters

The estimated and field hydrogeologic data for each identified hydrogeologic layer is presented in Table 2

Table 2 Aquifer parameters from field surveys and empirical relations

Regolith	*Degree of*	*Estimated parameters*						*Field parameters*			
Layer	*weathering*	Specific	Transmissivity	Hydraulic	Formation	Porosity	Saturated	Average	Average	Depth to	Depth to
		capacity		conductivity	factor	%	thickness	resistivity	saturated thickness	bedrock	water level
		$m^3/d/m$	m^2/d	m^2/d			m	ohm m	m	m	m
1	High	1.32	48.65	3.73	11.11	42.44	15.10	371.50	1.05	< 20	2.99
2	Moderate	3.70	350.63	7.82	12.39	29.46	45.33	1166.67	20.40	20-40	6.67
3	Slight	5.56	527.00	12.18	11.99	31.25	43.50	1810.00	77.13	>40	5.17

Groundwater Chemistry and Quality

The physicochemical parameters are presented in (Table 3). The concentrations of majority of the physicochemical parameters considered are within common average values and the WHO (1993) standard for the drinking and domestic purposes.

Table 3 Physicochemical data for groundwater for the different hydrogeologic layers

Geoelectric layer	Temp.	EC	TDS	pH	DO	TH	SAR	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	SO_4^{2-}	HCO_3^{-}	Facies
Regolith layer 1	27.80	336.33	525.03	6.60	3.27	42.23	1.30	14.93	4.12	20.58	8.83	31.83	47.94	1.59	63.73	$Ca^{2+}Na^{+}HCO_3^{-}$
Regolith layer 2	28.93	101.00	157.53	6.60	3.73	54.44	0.67	14.78	3.77	10.79	2.60	4.87	10.70	3.55	68.21	$Ca^{2+}Na^{+}HCO_3^{-}$
Regolith layer 3	28.24	65.92	102.90	6.48	3.54	19.99	0.66	4.96	1.74	3.67	2.84	7.94	14.92	1.49	23.56	$Ca^{2+}Na^{+}HCO_3^{-}$
WHO		1400*	1000*	6.5-8.5*		< 75		25.7	4.25	200	2.18	250*	10*	250*		

EC Electrical conductivity ((µS/cm), TDS Total dissolved solids (mg/l), DO Dissolved oxygen (mg/l), TH Total hardness (mg/l), SAR Sodium absorption ratio, *After WHO (1993)

Sources of ions in groundwater

A Na^{+}/Cl^{-} ratio greater than 1 reflects Na^{+} released from silicate weathering reaction (Meybeck, 1987). Silicate weathering is the probable source for Na^{+} in groundwater in parts of study area especially regolith layers 1 and 2, the ratio of Na^{+}/Cl^{-} < 1 in regolith layer 3 meaning another source is contributing chloride to the groundwater.

The ion exchange process is characterized by an (HCO^{-}_3+ SO_4^{2-}) excess over (Ca^{2+}+Mg^{2}), while the reverse ion exchange is marked by an excess of (Ca^{2+}+Mg^{2}) over (HCO^{-}_3+ SO_4^{2-}) (Cerling et al. 1989; Fisher and Mulican 1997). For the area, the ratio (Ca^{2+}+Mg^{2})/(HCO^{-}_3+ SO_4^{2-}) < 1 was obtained showing a ion exchange.

Irrigation applications

According to Karanth (1987), if the percent of Na^{+} is more than 50% in irrigation water, Ca^{2+} and Mg^{2+} will exchange with Na^{+} thus causing deflocculation and reduction in permeability of soil. In the study area, %Na^{+} varied between 22 and 46% indicating suitability of the water for irrigation. This is also confirm by the values of sodium absorption ratio, SAR (sodium hazard) and electrical conductivity, EC (salinity hazard) which shows that water samples are in classes C_I-S_I (low sodium hazard-medium salinity hazard) based on the United States Salinity Laboratory (1954) diagram.

Management Issues

For proper development and management of groundwater in the area, it is essential that pre drilling investigation be carried out to identify and characterize the water bearing layers.

For quality control, it is essential that shallow hand dug wells be properly constructed and waste disposal sites are located away from them.

Conclusion

Geoelectrical method has been used to delineate and characterize the different groundwater bearing units of the Precambrian Oban massif. The proper harnessing of the groundwater resource will depend on the identification and evaluation of the water bearing unit on a site-to-site basis, the demands of each community, harnessing of the surface water and proper waste disposal.

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References

Cerling T E, Pedrson B L and Damm K L V (1989). Sodium-calcium ion exchange in weathering of shales. Implications for global weathering budgets. Geology 17:552-554.

Custodio E, Llamas R (1983) Hidrologia Subterránea [Hydrogeology] 2nd edn. Omega, Barcelona

Ekwueme BN (1987) Structural orientations and Precambrian deformational episodes of Uwet area, Oban massif, SE Nigeria. Precambrian Research 34:269-289

Ekwueme BN (1995) Geochemistry of crystalline basement rocks in SW Ugep, Nigeria. Decford Journal of Pure and Applied Sciences 1:15-28

Fisher R S and Mulican W F (1997). Hydrochemical evolution of sodium-suphate and sodium-chloride groundwater beneath the Northern Chihuahua desert. Trans-Pecos, Texas, USA. Hydrogeol J 5(2):4-16

Karanth KR (1987) Assessment, development and management of groundwaters. 1st edn. Tata McGraw Hill, New Delhi, India

Meybeck M (1987). Global chemical weathering of surficial rocks estimated from river dissolved loads. Am J Sci 287:401-428

Schoeller, H., 1959. Arid zone hydrology. Recent developments UNESCO, Paris pp 54-83

Subrahmanyam K, Yadaiah P (2001) Assessment of the impact of industrial effluents on water quality in Pantancheru and environs, medak district, Andhra Pradesh, India. Hydrogeology Journal 9:297-312

United States Salinity Laboratory, 1954. Diagnosis and improvement of saline and alkaline soils. US Department of Agriculture. Washington DC

World Health Organisation (WHO) 1993. Guidelines for drinking water quality. Vol 1 Recommendations Geneva, Switzerland.

Zohdy AAR, Eaton GP, Mabey DR (1974) Application of surface geophysics to groundwater investigations. United States Geological Survey book 2 Chapter DI

Zohdy AAR (1989) A new method for the automatic interpretation of Schlumberger and Wenner sounding curves. Geophysics 54:245-253