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Evaluating the Protective Capacity of Aquifersat Uyoinakwaibom State, Southern Nigeria, using the Vertical Electrical Sounding(VES) Technique

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Abstract: This work entails evaluating the protective capacity of the aquifer using the Vertical Electrical method to assess the vulnerability of aquifers using resistivity parameters of the upper most geo-electric materials layer overlying the aquifer. Seventeen (17) vertical electrical sounding (VES) points were conducted at various locations within the study area. The result of the study shows that the longitudinal unit conductance values obtained from the study area ranges from 0.003864 to 0.059655mhos. The study revealed that aquifers within the area are susceptible to pollution since the protective capacities of the aquifers are generally poor. Vulnerability map of the study area produced from the longitudinal unit conductance indicates that the North central, northeast and south central of the map shows that the vulnerability rate is better off than the others i.e. the northwest, southwest and part of the eastern side of the map. Sand layer seems to provide lower longitudinal conductance generally in the study area and hence poor protective capacity. It can be inferred from this study that sandy soils have poor protective capacity due to its pore space and lessabsorption capacity compared to clayey and shaly soils thus providing a lesser protective capacity for groundwater. The results of this study have provided reliable information about the protective capacity of the materials overlying the aquiferous unit which should be considered for planning, development, siting of prospective water resource projects and serves as a guide for groundwater pollution control in the study area.

Keywords: Vertical electrical sounding, vulnerability assessment, longitudinal conductance, protective capacity, groundwater.

1. INTRODUCTION

Land and water are two broad components on which the entire biotic community thrives. The available surface water resources are inadequate to the entire water requirements for all purposes. So the demand for ground water has increased over the years. The current and continuing drought in many parts of the world, combined with ever increasing demands from both traditional and new water users, including municipal, industrial, agricultural and environmental needs, has impacted groundwater resources.

Underground water pollution is progressively emerging as a serious challenge in different countries in Europe, Asia and Africa. It gained international scientific interest during the last decades and has been studied using several approaches and techniques. The vulnerability of ground water qualitatively reflects the natural ability of the aquifer to be reached and affected by pollution from surfaces (landfill, industrial wastewater discharge, chemical fertilizers, pesticides, herbicides etc) (Sadkaoui et al. 2013). Electrical resistivity surveys have been used for many decades in hydro-geological, mining and geotechnical investigations. More recently, it has been used for environmental surveys. A number of geophysical exploration techniques are available which enables an insight to be obtained rapidly in the nature of water bearing layers and include geo-electric, electromagnetic, seismic and geophysical borehole logging (Alile, et al. 2008). These methods measure properties of formation materials, which determine whether such formation may be sufficiently porous and permeable to serve as an aquifer. The electrical resistivity method and seismic refraction method are the surface geophysical methods commonly used for groundwater exploration (Asawa, 2009). The protection of groundwater reservoir is given by the covering layers, also called protective layers. An effective groundwater protection is given by protective layers with sufficient thickness and low hydraulic conductivity (Aweto, 2011). It depends on the aquifer characteristics as well as the geological and hydrological environment. Specific vulnerability is determined by the aquifer intrinsic vulnerability and the contaminant loading that is applied to the specific point of the hydro-geological basin. The present study involves the use of electrical resistivity method to assess the vulnerability of aquifers using geo-electric parameters of the near-surface materials overlying the aquifer. This method is much easier, it is a well-established method, the equipment is inexpensive, mobile, easy to operate, provides relatively rapid areal coverage with the depth of penetration limited only by the ability to extend electrode spacing (U.S. Environmental Protection Agency, 2006). From the time the study area became the seat of government power (i.e the state capital) for the state, there has been enormous migration of people

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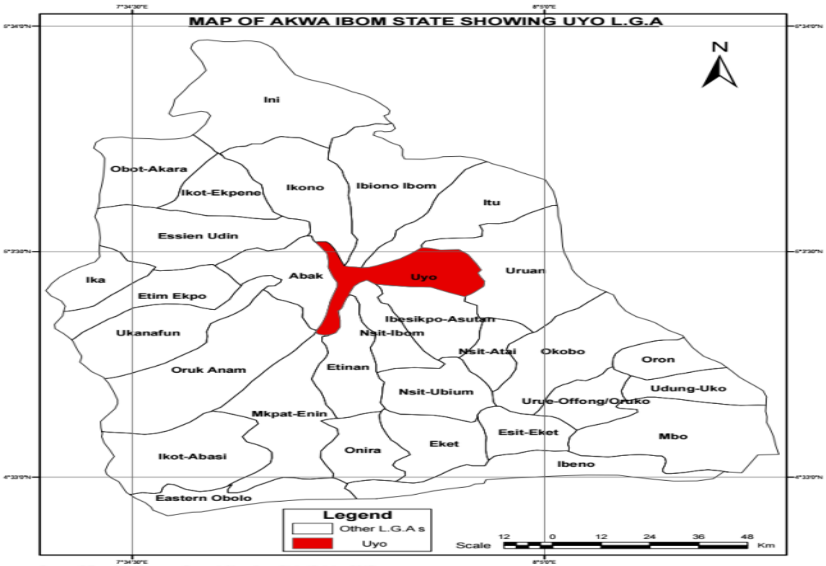
to the town. The increase in population and urbanization in the study area puts the groundwater resources at risk. Since potable surface water is not readily available in the study area, the alternative is to depend on groundwater source. Hence the major source of water in the study area is groundwater resource. There is need for constant monitoring and evaluation of the water resources in the region to prevent occurrence of epidemics and to adopt appropriate water management strategies. Hence this study aims at assessing with the use of electrical resistivity method the vulnerability of aquifer in the region to contamination.

Location and Geology

The study area Uyo, AkwaIbom State is located in the southern part of Nigeria between latitude 5^o 05’ North to 4^o 55’N and longitude 8^o 00’ East to 7^o 50’ East. Geologically, the study area belongs to the area classified as coastal plain sands known as the Benin Formation (Mbipom et al., 1996). The Benin Formation is the uppermost unit of the Niger Delta Complex and overlies the Agbada Formation. The Benin Formation is the youngest formation of the Niger Delta sedimentary basin. The essential features of the Benin formation have been reviewed by various authors: (Akpabio et al, 2003; Short and Stauble, 1967).



Source: Office of the Surveyor General Akwa Ibom State (October 2015)

Fig.

2. MATERIALS AND METHOD

Geoelectric sounding (VES) surveys in the area were conducted using ABEM Terrameter Self Averaging System (SAS) which apparent resistivity values can be computed from Ohm’s law.Seventeen electrical resistivity soundings were carried out with the Terrameter SAS 300B using the schlumberger electrode configuration. The total current electrode probe varied from 400m to800m depending on the access roads, topography, human settlement and general infrastructure. In other to convert the resistance reading to an apparent ground resistivity, a geometric factor was applied to the data, based on the schlumberger configuration used in this study. The apparent resistivity data were plotted against current electrodes separation and interpreted quantitatively. Computer-aided interpretation of the field data was done in two stages. In the first stage, all the manually smoothened sounding curves were subjected to forward modeling techniques run by Schlumberger sounding data processing and interpretation program, version 1.82 (Zhody and Bisdorf, 1989). This process yielded the initial estimates of the resistivity of the various geo-electric layers in assumed layered models for the computer iterative least-square inversion. A VES modeling for Schlumberger Automatic Analysis, version 0.92 (S.A.A.-V.0.92) developed by Hemkler in1985 was used to obtain the final curves. The Hemkler program computes resistivity and depth value at each measurement point. The Golden SURFER 8.2 was used to produce the aquifer vulnerability map of the study area. Thirteen (13) vertical electrical sounding (VES) points were conducted at various locations within the study area in order to study the variations in the resistivity distribution of the soil with depth. GPS device was used for measuring the spatial location (latitude and longitude) for the VES points (Table 2).

Groundwater potential and aquifer vulnerability studies (Golam et al. 2014; Oborie and Udom, 2014). High longitudinal conductance values usually indicate relatively high protective capacity and should be accorded the highest priority in terms of groundwater vulnerability assessment. The total longitudinal conductance (S) for each of geoelectric sounding (VES) stations was computed from the relation:

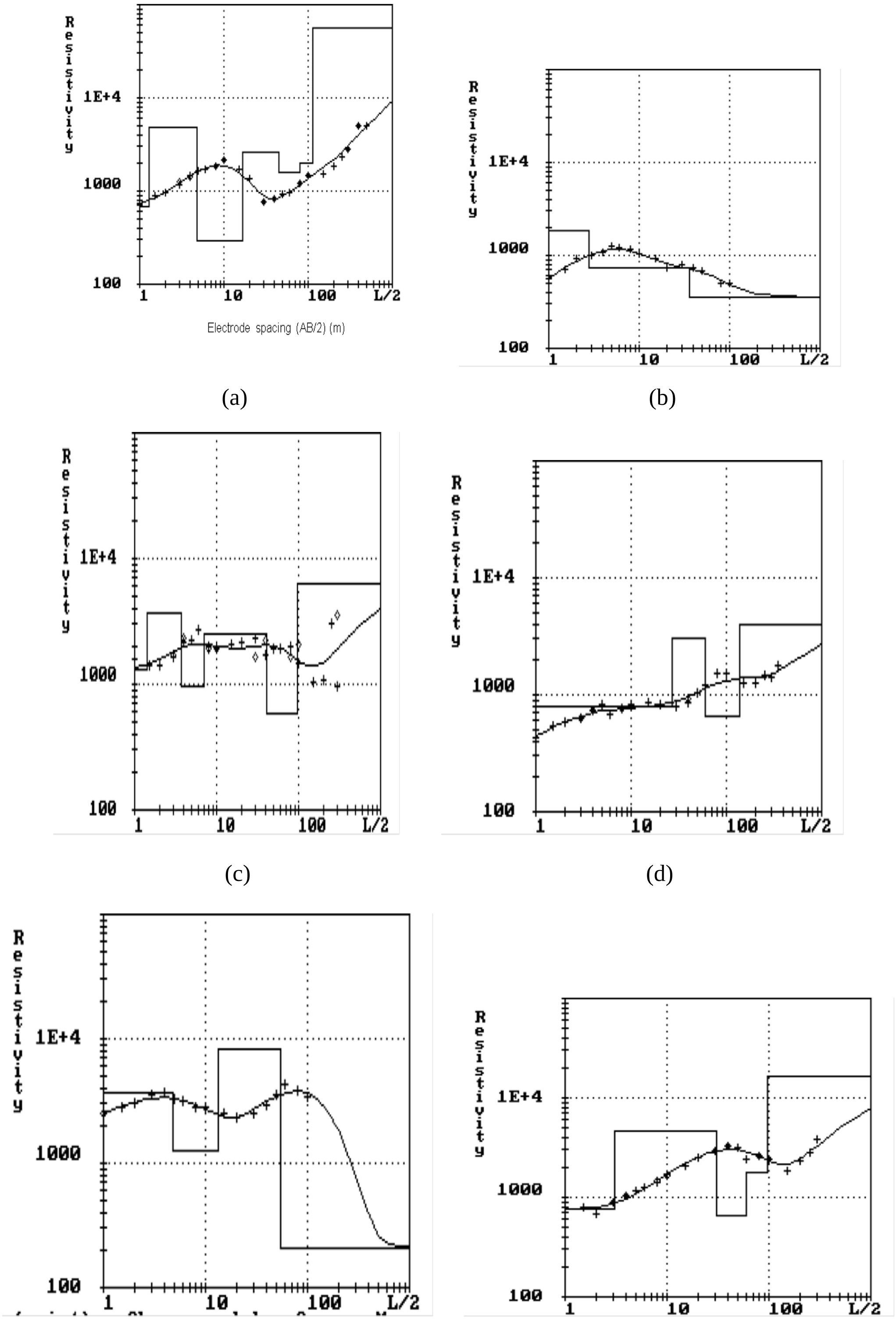
$$S = \Sigma (h_i/\rho_i) = h_1/\rho_1 + h_2/\rho_2 + \ldots + h_n/\rho_n \qquad (1)$$

Where S is the total longitudinal conductance, Σ is summation sign, hi is the thickness of the ith Layer and ρi is the resistivity of the ith layer. The total longitudinal conductance (S) values computed were plotted and contoured to produce the aquifer vulnerability map.

3. RESULTS AND DISCUSSIONS

3.1 **Geo-electric Sections**

The most important parameter in quantitative interpretation is the depth of the aquiferous units. Depth to water information is contained in the interpretation of the geo- electric curves. In VES 1 the sounding encountered six geo- electric units: top soil, coarse sand, clayed sand, fine sand, water saturated sand and fine sand. Furthermore, Fig. 2 is a typical interpretation results of geo-electric sounding data acquired in the area (VES 1, 4, 7, 10, 12 and 15)



(a) (b)

(c) (d)

(e) (f)

Fig 2: Typical interpretation results of geo-electric sounding data acquired in the study area (a) VES 1 (b) VES 4 (c) 7 (d) VES 10 (e) VES 12 (f) VES 15.

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3.2 Assessment of Aquifer Vulnerability

The earth is made of soil particles of different types. The earth medium acts as a natural filter to percolating fluid, the ability of the earth to filter fluid is dependent on the aquifer thickness, the covering materials and the protective capacity of the overlying overburden of the aquifer. Silts and clays are suitable aquitards which often constitute protective geologic barriers and when they are found above an aquifer they constitute a protective cover (Lenkey et al. 2005), they thus protect the aquifer from surface and near-surface contamination, because their low hydraulic conductivity leads to high residence time of percolating water. Table1 presents longitudinal conductance/protective capacity ratings. The table enables the classification of the study area into various grades. The areas that are classified weak and poor are most susceptible to contamination, while the good, very good and excellent classification indicates high protective geological formation to contamination.

Table 1: Longitudinal Conductance/Protective Capacity Rating (Ogungbemi et al. 2013)

Longitudinal Conductance (mhos)	Protective Capacity Ratings
>10	Excellent
5-10	Very Good
0.7-4.9	Good
0.2-0.69	Moderate
0.1-0.19	Weak
<0.1	Poor

Sandy overburden has been reported by several authors to be characterized by relatively low longitudinal conductance, which offers very little protection to the underlying aquifer (Golam et al. 2014; Anomohanran, 2013; Rădulescu, et al. 2006). Table 2 shows the soil layers, geo-electrical resistivity, aquifer thickness, lithology, longitudinal conductance and the protective capacity of the VES points. The study area lithology is characterized with sand, fine and coarse with very little clay deposit. Protective layers in this study seem to offer lower longitudinal conductance in the absence of clay. The longitudinal unit conductance (S) values obtained from the study area, ranges from0.003864 to 0.059655mhos. The results of assessment of the aquifer vulnerability (Table 2) shows that the protective capacity at the study area is poor, these regions are characterized by thin or no shale or clay layers, it therefore implies that the aquifer in these locations are vulnerable to contamination. This is as a result of the type of the soil formation within the study area, which is predominantly sandy in nature (Mbipom et al., 1996). Moreover, sandy soils have a larger pore space which enables easy passage of water, hence they are vulnerable compared to clayed to clay and shale (Chukwuma et al., 2015).

Table 2: Geo-electric parameters, lithological delineation and protective capacity of the study area

VES No.	Layers	Resistivity (ohm-m)	Thickness (m)	Lithology	Longitudinal Conductance	Protective Capacity
1	1	695	0.48	Top sand	0.000691	0.059655 (Poor)
	2	4900	4.52	Coarse sand	0.000922	
	3	290	12.48	Clayed sand	0.043034	
	4	2500	37.52	Fine sand	0.015008	
	5	1700	43.80	Saturated sand		
2	1	800	29.00	Top sand	0.036250	0.046583 (Poor)
	2	3000	31.00	Fine sand	0.010333	
	3	700	119.00	Saturated Sand		
						0.003864 (Poor)
3	1	2200	7.80	Top Sand	0.003545	
	2	32000	10.20	Coarse Sand	0.000319	
	3	1800	59.80	Saturated Sand		
4	1	1900	2.90	Top Sand	0.001526	0.040526 (Poor)
	2	900	35.10	Sand	0.039000	
	3	320		Saturated Sand		
5	1	2900	2.80	Top Sand	0.000966	0.029148 (Poor)
	2	220	6.20	Clayed Sand	0.028182	

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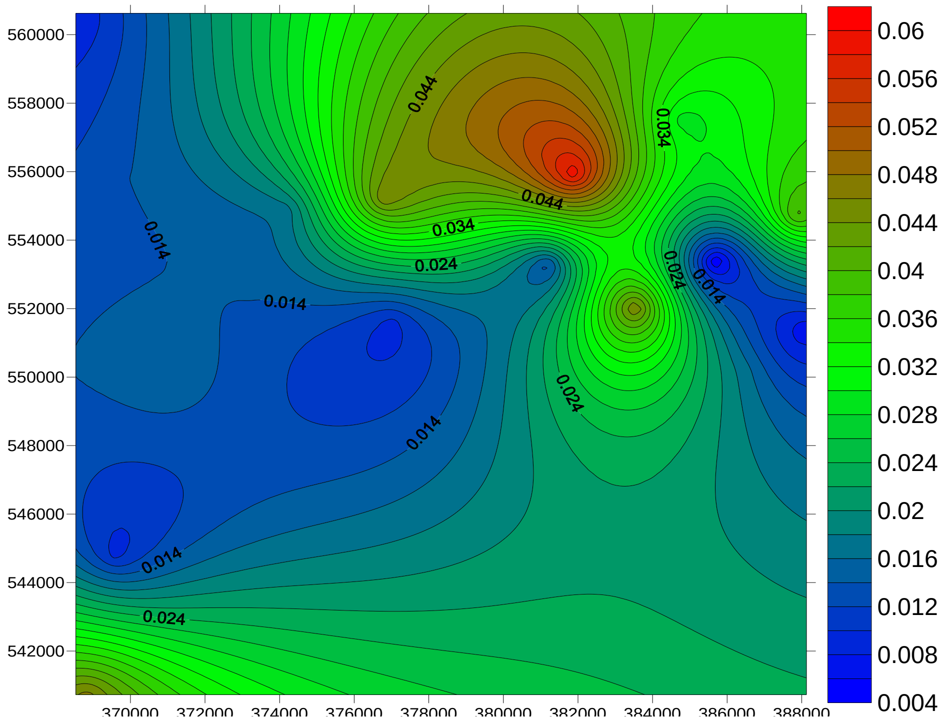
	3	1600	153.80	Saturated Sandstone		
6	1	5000	2.80	Top Sand	0.000560	0.006281 (Poor)
	2	1800	6.20	Fine sand	0.003444	
	3	6500	14.80	Coarse sand	0.002277	
	4	500	27.20	Saturated Sand		
7	1	1500	1.55	Top sand	0.001033	0.016323 (Poor)
	2	4900	2.25	Coarse sand	0.000459	
	3	998	4.75	Fine sand	0.004760	
	4	3500	35.25	Coarse sand	0.010071	
	5	600	64.75	Saturated Sand		
8	1	500	1.30	Top Soil	0.002600	0.012859 (Poor)
	2	750	3.60	Fine sand	0.004800	
	3	8500	46.40	Coarse sand	0.005459	
	4	310	101.60	Saturated Sand		
9	1	2500	2.00	Top Sand	0.000800	0.009300 (Poor)
	2	1000	3.00	Fine sand	0.003000	
	3	4000	22.00	Coarse sand	0.005500	
	4	600	33.00	Saturated Sand		
10	1	800	28.00	Top Sand	0.035000	0.045667 (Poor)
	2	3000	32.00	Fine sand	0.010667	
	3	650	118.00	Saturated Sand		
11	1	2800	1.60	Top Sand	0.000571	0.017337 (Poor)
	2	190	1.20	Clayed Sand	0.006316	
	3	19000	13.80	Coarse sand	0.000726	
	4	2900	28.20	Fine sand	0.009724	
	5	500		Saturated Sand		
12	1	3900	4.90	Top Sand	0.001256	0.013994 (Poor)
	2	1300	9.10	Fine sand	0.007000	
	3	8000	45.90	Coarse sand	0.005738	
	4	220		Undefined		
13	1	2000	1.95	Top Sand	0.000975	0.013994 (Poor)
	2	700	6.55	Sand	0.009357	
	3	5200	33.45	Coarse sand	0.006433	
	4	1500	76.55	Saturated fine sand		
14	1	900	9.00	Top Sand	0.010000	0.015897 (Poor)
	2	3900	23.00	Coarse sand	0.005897	
	3	590	77.00	Saturated Sand		
15	1	790	3.00	Top Sand	0.003797	0.009307 (Poor)
	2	4900	27.00	Coarse sand	0.005510	
	3	670	33.00	Saturated Sand		
16	1	800	29.00	Top Sand	0.036250	0.046917 (Poor)
	2	3000	32.00	Coarse sand	0.010667	
	3	630.00	118.00	Saturated Sand		
17	1	2800	1.60	Top Sand	0.000571	0.008008 (Poor)
	2	390	2.30	Clayed sand	0.005897	
	3	5000	7.70	Coarse sand	0.001540	
	4	920	64.30	Saturated fine sand		

By using the resistivity values measured from the geo-electric survey, longitudinal unit conductance of the overlying overburden was evaluated. Vulnerability map of the study area was produced from the longitudinal unit conductance (Figure 3), which gives detailed information on the pattern of the protective capacity of the natural overburden over the aquifer in the study area.



4. CONCLUSION

The vulnerability map shows that aquifers within the study area are vulnerable to pollution. The North central of the map though may be poor has a higher protective capacity, followed by parts of the north east, southwest and south central (VES 1,2,4,10& 16). Southwest and northwest of the map showed the lowest level of protection. In conclusion, pollution is as a result of several activities that tends to aggravates it, thus since the aquifers within the study area are susceptible to pollution, preventive measures should be taken to protect the aquifer from degradation and ensure groundwater development for quality and sustainable water supply through instrumental approach, community participation and adaptive measures.

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