FUPRE Journal of Scientific and Industrial Research
Vol. 1 (2), 2017
ISSN: 2579-184 (Print) ISSN: 2578-1129 (Online)

Geophysical Investigation of Groundwater Contamination levels in Obiaruku Waste Dumpsite Using Vertical Electrical Sounding Method

Agbalagba, E.O. and Osimobi, J.C.

Department of Physics, Faculty of Science, University of Port Harcourt Rivers State, Nigeria
Department of Physics, Federal University of Petroleum Resources, Effurun, Nigeria

Abstract

The geophysical well logs investigation of groundwater contamination level in waste dumpsites using vertical electrical sounding method in Obiaruku- Amai dumpsite in Ukwani Local Government Area of Delta State has been conducted. Five VES points were strategically mapped within and around the study area (dumpsite) using the Global Positioning System (GPS). The resistances of the soil profile where examined at the different VES marked points. The ABEM SAS 4000 Terameter with the Schlumberger array configuration approach was used and the resistivity values were recorded. A computer iteration techniques using Resist Version 1 was used to evaluate the curves type and to determine the numbers of layers. The raw data was subjected to computer iteration and smoothened. The interpreted data show that four geoelectric layers underlie the study area. The vertical electrical sounding curves shows AA, HK, AH, AA and HA types for VES I to VES V respectively. The average resistivity values obtain down the aquifer ranged from 234 Ωm to 3475.1 Ωm for VES I; 229.2 Ωm to 8817.2 Ωm for VES II; 1514.3 Ωm to 3864.8 Ωm for VES III; 115.6 Ωm to 3864.8 Ωm for VES IV; 36.8 Ωm to 3101.1 Ωm for VES V. Locations 3 was analyzed to have the be best aquifer where boreholes could be sited with aquifer thickness of 22.5 m, though the close proximity to the dump site call for further investigation. It was observed from the result that VES II (on the dumpsite) has a relatively low resistivity at the top of the soil profile, thus pollutants can emerge from the landfill top and migrate downwards to contaminate the water table. The results obtained indicate that the leachates from the dump sites have increased the conductivity of the soil, thereby lowering the resistivity. Considering the implications of this ground water source contamination and the health implications on the populace, recommendations were made.

Keywords: Waste dumpsite, groundwater, contamination, VES.
Corresponding author (agbalagba.ezekiel@fupre.edu.ng)

Introduction

The environment is a very important aspect of man's existence, in that it forms the basis for his inhabitation. The problems associated with man and its environment is a concept worthy of note. These problem are seen under the umbrella that man's activities impact wastes to the environment and these over time had led to environmental degradation whose effects in turn comes back to man. The environment is a complex ecological system and an adverse impact on one part can ultimately affect other parts (Ezeh, 2011, 2012). The environment when exposed to deleterious substance can become polluted thus having harmful effect to man and his wellbeing (Adegoroge, 1993).

Pollution can be defined as any discharge of material or energy into water, land or air that causes an acute or chronic detrimental effect to the earth's ecological balance or lowers the quality of life (Dafny et al., 2006). Thus, environmental pollution is the act of contamination of the environment, by man-made substance or energy that has adverse effect on living and non-living matters. This contamination of air, water or soil material interferes with human health, the quality of life or the natural functioning of ecosystem (Braide et al., 2004, Egila and Terhemen, 2004; Abam et al., 2007). Water pollution causes imbalance of the natural state of the water bodies as a result of natural or man-made activities which has negative effects on aquatic organisms and the entire environment (Durible, et al., 2007; Bolaji and Tse, 2009).

Research has revealed cross-media contamination, which involves the movement of pollutants from one media (water) to another (air) and vice versa. Groundwater tends to move very slowly and with little turbulence, dilution or mixing. Therefore, once contaminants reach groundwater, they tend to form a ***concentrated plume*** that flows along with groundwater.

Figure 1: A side view of the dumpsite under investigation with different types of waste materials

As leachate migrates from a waste deposit in the direction of groundwater flow, the plume disperses (spreads) due to differing contaminant flow paths and flow velocities, (Abam et al., 2007). The processes for this migration includes **d**iffusion (from higher to lower concentration and infiltration (involves percolation)

Concentrations of both reactive and conservative contaminants decrease with distance along the groundwater flow path. In dumpsite where different types of materials are disposed, the contamination of the immediate site may give way to diffusion of pollutant or infiltration of pollutants into groundwater (Dafny et al., 2006). This will in turn flow to pollute or contaminate the immediate environment in the direction of groundwater flow as shown in figure 2.

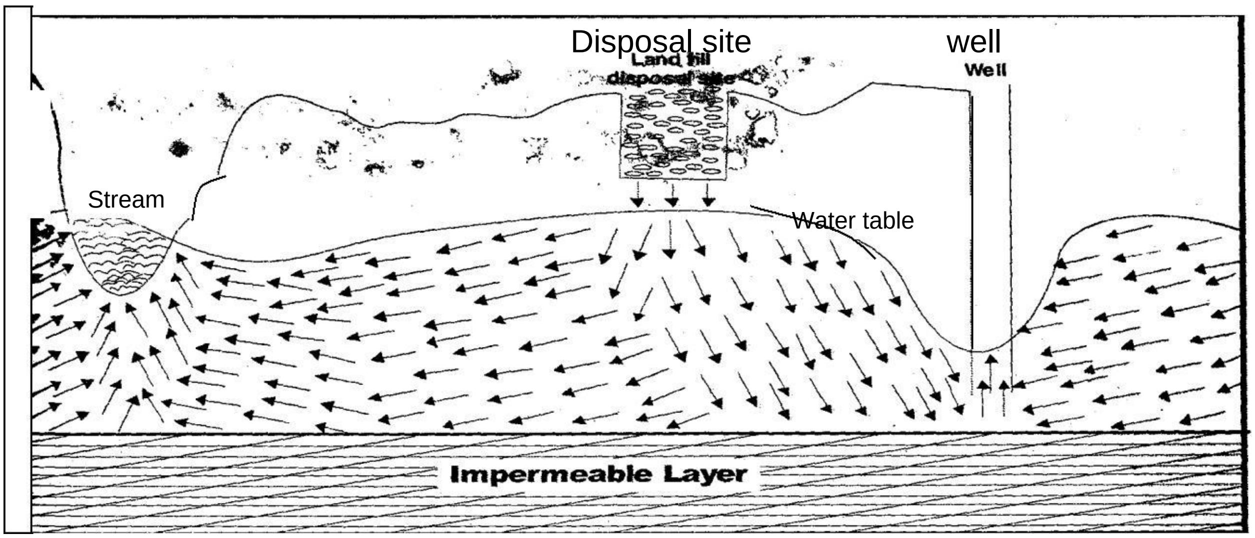


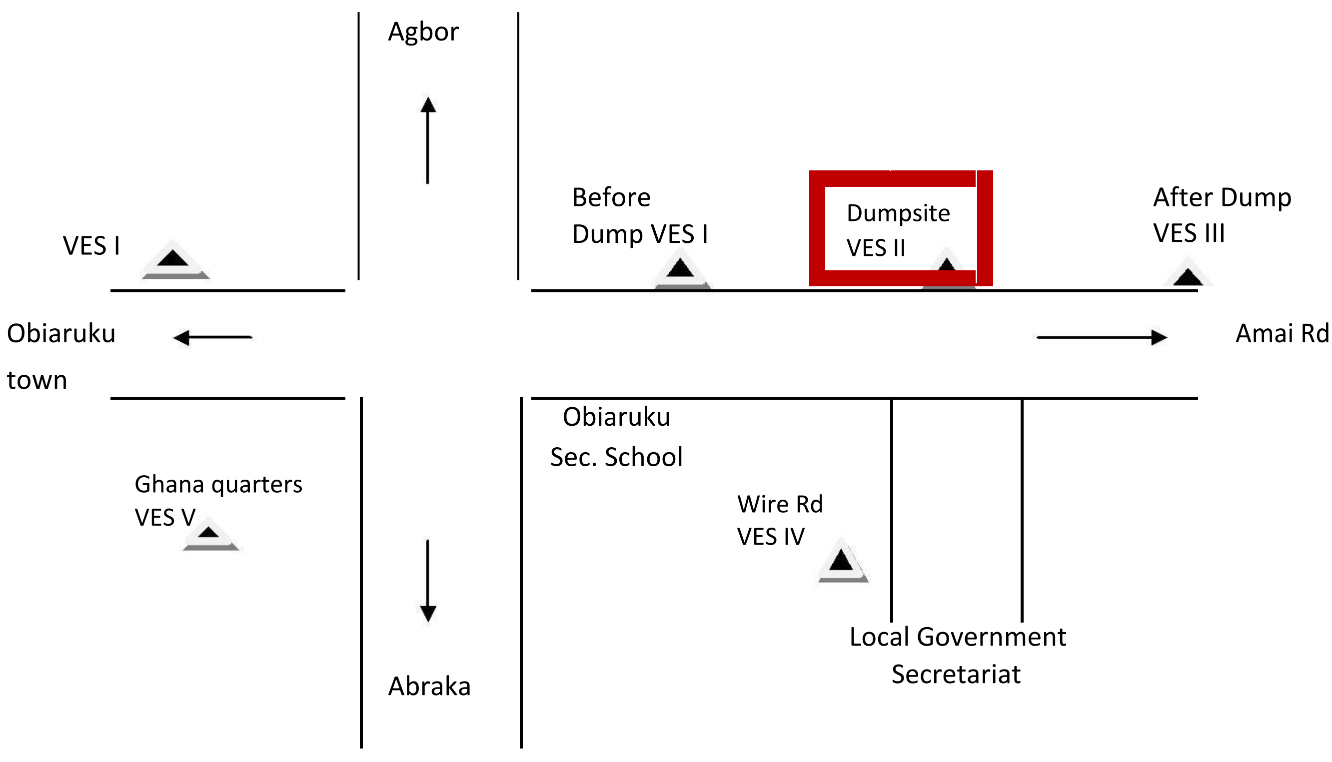
Figure 2: A diagram showing leachate from a waste disposal site moving towards the aquifer

Electrical resistivity method has been employed most for groundwater investigation, this is because the equipment is portable, simple, field logistics are easy and straight forward and the analysis of data is economical and less tedious than other methods (Zhody et al 1993, Egbai 2010). Groundwater is the water that lies beneath the ground surface, filling the pore space between grains in bodies of sediment and elastic sedimentary rocks and filling cracks and crevices in all types of rocks (Plummer et al, 1999; Olorunfemi and Fasuyi, 1993).

Observations have shown that a good deal of rainfall runs off over the surface of the ground into rivers and streams. Finally, some part of it sinks underground and becomes the groundwater responsible for springs, caves and wells. (Egbai and Asokhia, 1998; Dafny et al., 2006). For resistivity measurements, if the earth is assumed to be horizontally stratified, isotropic and homogeneous media such that the change of resistivity is a function of depth (as in the case in the study area), the Schlumberger configuration is the most widely used array. Thus, the Schlumberger array was chosen for the purpose of this research (Ezeh, 2012; Ohwona, et al., 2013). The array is less sensitive to the influence of near-surface lateral heterogeneities, smoothing and interpretation techniques are much more developed than other arrays.

The Study Area

The study site is an open dumpsite located along Obiaruku-Amai road, Ukwani L.G.A of Ndukwa land, Delta State. It is in the sedimentary regions of the Niger Delta basin and lies within longitude E6^{0}10’ and latitude N05^{0}49’, with an elevation of 100ft. The direction of groundwater flow is South west (Etu- Efeotor and Akpokodje, 1990), which favours the contamination of Obiaruku and Amai groundwater whenever there is an advance effect of ground water pollution from this dumpsite. This lay credence to the investigation of this waste dumpsite to determine its level of pollution due to the waste dump, it infiltration capacity being overlaid sedimentary rock and groundwater flow rate of 0.3m/s. Figure 3 shows the schematic layout of the study area describing the study site and various points where the VES data was taken.



-Represents the points where Vertical Electrical Sounding was carried out.

Figure 3: The Schematic layout of the study with VES points.

Materials and Methods

Data acquisition

The materials used for data acquisition includes, Terameter (SAS 1000), which is the main instrument used to send current into the ground so as to measure the resistance of the soil strata, electrodes, wire cables, sledge hammer, measuring tapes, cutlass for clearing and battery for powering the Terameter. The Vertical electrical sounding technique using the Schlumberger array approach was adopted for this investigation.

The principles of VES are based on the fact that the wider the current electrodes separation, the deeper the current penetration. The current and potential cables were connected to the Terameter through the two plugs into the socket of the instrument. The Terameter was then switched on and the potential difference at electrodes, geometric factors and the resistance were recorded. The apparent resistivity (ρ) values were determined, taking the product of the resistance measured on the earth resistivity meter and the geometric factor that is independent of the type of the array used *(Egbai, 2011; 2013; Ezeh, 2012).*

The apparent resistivity (ρ_a) is determined using the relation *(Egbai, 2013; Ohwona et al., 2013)*

$$\rho_a = KV/I$$

Where, the voltage of the potential electrode is V, I is the current of the electrode while K is the geometric factor for the Schlumberger configuration which is expressed as:

$$K = \frac{\pi[^{AB}/_2]^2 - [^{MN}/_2]^2}{MN}$$

The interpretation of the field data was done using both qualitative and quantitative process through plotting of the apparent resistivity against the current electrode spacing that was interpreted by partial curve matching method and computer iteration techniques using Resist Version 1 to evaluate the curves type and to determine the numbers of layers *(Vander, 1988)*

VES I was taken just before the dumpsite, VES II was taken directly on the dumpsite, VES III was taken after the dumpsite, while VES IV and VES V were taken at wire road and Ghana quarters in Ubiaruku which are two different locations around the study area to act as control values.

Results and Discussion

Presentation of Data

Vertical electrical sounding was carried out using the Schlumberger array configuration on the various mapped out points and the results are as shown in Table 1. Table 2 shows the summary of the VES data.

Table 1: Summary of data for the five VES points in the Study Area

Electrode position	Electrode separation (AB/2) (m)	Potential Electrode separation MN/2 (m)	Geometry Factor K	Apparent Resistivity (ρ_a) VES I (Ωm)	Apparent Resistivity(ρ_a) VES 1I (Ωm)	Apparent Resistivity(ρ_a) VES 1II (Ωm)	Apparent Resistivity(ρ_a) VES 1V (Ωm)	Apparent Resistivity(ρ_a) VES V (Ωm)
1	1	0.5	6.28	2273	309	1631	125.00	2500.00
2	2	0.5	25.13	2650	272	2963	140.00	1700.00
3	3	0.5	56.55	2242	263	2639	179.89	1050.06
4	4	0.5	100.53	1760	277	3368	229.89	320.03
5	6	0.5	226.19	1335	274	5634	277.13	88.99
6	6	0.5	113.10	1308	225	2164	323.90	54.87
7	8	1.0	221.06	1259	260	2483	340.40	59.70
8	12	1.0	452.59	1360	341	3224	325.02	65.02
9	15	1.0	706.86	2081	395	4669	319.90	79.98
10	15	1.0	353.43	1467	367	5102	324.32	119.99
11	25	2.0	981.75	2056	560	2997	315.21	179.53
12	32	2.0	1608.50	2335	669	4030	405.56	236.58
13	42	2.0	2513.37	2558	740	3974	539.03	349.64
14	42	5.0	1005.30	2644	860	3145	796.01	481.80
15	65	5.0	2654.65	2687	995	3907	777.48	498.47
16	100	5.0	6283.19	3746	2637	2648	1071.80	678.00
17	100	10.0	3141.59	3289	3145	2693	1205.87	760.97
18	150	10.0	7068.58	3403	4903	1571	1393.92	900.24

Table 2: Summary of Vertical Electrical Sounding Results

VES	LAYERS	RESISTIVITY ρ(Ωm)	LITHOLOGY	THICKNESS	DEPTH (m)	Rms% Error	Curve Type
1	1	2421.1	Very coarse	0.0	0.9		
	2	2934.0	sand	1.3	2.2	6.90	AA
	3	234.0	Clayey sand	1.3	3.4		$\rho_1<\rho_2>\rho_3<\rho_4$
	4	3475.1	Gravel				
	1	299.2	Clayey sand	1.1	1.1		HK
2	2	243.4	Sand	10.3	11.4	7.20	$\rho_1>\rho_2<\rho_3>\rho_4$
	3	8817.2	Sand	228.8	240.2		
	4	3285.0	Medium sand				
	1	1514.3	Medium sand	0.8	0.8		AH
3	2	3864.8		9.4	10.2	12.30	$\rho_1<\rho_2>\rho_3>\rho_4$
	3	3603.5	Gravel	22.5	32.7		
	4	1839.6	Medium sand	1.0			
	1	115.6	Clay	1.0	1.0		AA
4	2	435.0	Silty sand	7.5	8.5		$\rho_1<\rho_2>\rho_3<\rho_4$
	3	218.9	Clayey sand	13.6	22.2	7.20	
	4	1448.8	Coarse sand				
	1	3101.1	Coarse sand	0.9	0.9		HA
5	2	36.8		3.2	4.1	3.40	$\rho_1>\rho_2<\rho_3<\rho_4$
	3	68.4	Gravel	4.3	8.4		
	4	1058.3	Medium sand				

Discussion of Results

The results of the data collected from the field in each of the VES sites are presented in Table 1. The data were first curve matched, which were then built into the computer for iteration. The VES data were interpreted using Zohdy's iterative program for automatic interpretation of the Wenner and Schlumberger sounding curves (Zohdy, 1989; Egbai, 2012). The interpreted data show that four geoelectric layers underlie the study are of Ubiaruku. The interpretation of the vertical electrical sounding curves show that of AA, HK, AH, AA and HA types for VES I to VES V respectively. The iterated results analyzed shows that the layers are generally four and root mean square percentage error ranged from 3.40 to 12.30.

Location 1 at Obiaruku- Amai road has 4 layers with resistivity values ranged from

234.0 Ωm to 3475.1 Ωm with thickness varying from 0.0 m to 1.3 m. It is made of very coarse sand, clayey sand, sand, and gravel. The aquifer is located in the third layer with thickness 1.3 m at a depth of 3.4 m. Location 2 which is at the dump site along Obiaruku- Amai road is made up of 4 layers with resistivity values ranged from these 229.2 Ωm to 8817.2 Ωm with thickness 1.1 m to 228.8 m. The dump side location is made of clayey san, sand, sand and medium sand. The aquifer is located in the third layer with thickness 228.8 m at a depth of 240.2 m. While location 3 which is also situated along Obiaruku- Amai road has also 4 layers with resistivity values ranged from these 1514.3 Ωm to 3864.8 Ωm with thickness 0.8 m to 22.5 m. Medium sand, medium sand, gravel and medium sand is the lithology of the location, while the water aquifer is located in the third layer with thickness 22.5 m at a depth of 32.7 m. These values obtained in the study area compared well with the values reported by Egbai, 2010 at Ozanogogo, Egbai, 2012 in Abavo, and Ohwona et al., 2013 in Abavo and Urhonigbe all within the Benin formation.

Locations 4 and 5 at Ubiaruku town are the control experiments, have 4 layers with resistivity ranged from 115.6 Ωm to 3864.8 Ωm at a depth of 1.0 m to 22.2 m for location 4 while location 5 has resistivity ranged from 36.8 Ωm to 3101.1 Ωm at a depth of 0.9 m to 8.4 m. The aquifers for these two locations are embedded in the third layer with thickness of 13.6 m and 4.3m at depths of 22.2 m and 8.4 m respectively for locations 4 and 5. Locations 3 and 4 show very good aquifer where boreholes could be sited with thickness 22.5 m and 13.6 m respectively. These values obtained agreed with the reported values in Nsukka by Uma, (2003). But of these two locations, 3 is the best having a depth of 32.7 m, however, it proximity to the dump site pose a threat of seepage, contaminated groundwater flowing into the aquifer etc.

A reliable interpretation was made by having a look at the lithological borehole descriptions and geophysical well logs within these surveyed locations, which was purely in conformity with the vertical electrical survey results. It could be observed from the results analysis of the various VES points that VES II (on the dumpsite) has a relatively low resistivity at the top of the soil profile, this is an indication that the leachates from the dump will increased the conductivity of the soil, thereby lowering the resistivity. Also, the clay which could have acted as a buffer and filter has a very poor thickness and this shows that the effects from the dump could easily move down to the aquifer thereby contaminating the groundwater.

Conclusion

The investigation of groundwater contamination by dumpsite using vertical electrical sounding had been conducted. The VES survey reveals that the studied locations have unconfined aquifer since the areas are free from clay and basement terrain. However, where clay exists, it occurs as clayey sand having very thin thickness and does not affect the aquiferous layers. It was observed that the leachate from the dump through infiltration and percolates into the soil to the water aquifer has the potential of contaminating the ground water. Since pollutants emerging from the landfill top migrates toward the water table as shown in the lithology of the dump site, it can greatly impair the ground water quality that may result to health detriment to the people of the area that consume the water. There is therefore need to monitor and safeguard the groundwater sources to avoid continuous contamination. The authors herein recommend that groundwater from the studied area be treated before drinking. Government should design a model of landfill which will guarantee ground water safety in the country and should be adopted by all states. Moreso, government should provide suitable land for dumpsites, monitor and regulates it use.

References

Abam T.K.S., Olu A.W. And H. Nwankwoala, (2007). Groundwater Monitoring for Environmental Liability Assessment. *J. Nig. Environ. Soc.*, *4*(1):42-49.

Adegoroge, G. (1993): Environmental Regulators & Enforcement in Nigeria in the special reference to industrial sector- paper presented at National Workshop on Pollution Control Organized by Manufactures Associate of Nigeria.

Bolaji T.A. and C.A. Tse, (2009). Spatial variation in groundwater geochemistry and water quality index in Port Harcourt. *Scientia Africana 8*(1): 134-155.

Braide S. A., Izonfuo W.A.L, Adiukwu P.U., Chindah A.C. and C.C. Obunwa, (2004). Water quality of Miniweja Stream, A swamp forest stream receiving non-point source waste discharges in Eastern Niger Delta, Nigeria. *Scientia Africana 3*(1): 1-8.

Dafny, E., Burg, A., and H. Gvirtman, (2006). Deduction of groundwater flow regime in a basaltic aquifer using geochemical and isotropic data. The golden height, Israel case study. *J. of Hydrology*, *330*, 3-4, 506 – 524.

Durible. J.O., Ogwuegbu M.O.C. and J.N. Egwurugwu, (2007). Pollution profiles of non-metalic inorganic and organic pollutants of drinking and potable waters due to mining activities in Ishiogu, Ebonyi State, Nigeria. *International Journal of Physical Science*, *2*: 234-238.

Egbai J.C. (2010). Vertical electrical soundings for the investigation of kaolin deposits in Ozanogogo area of Ika South Local Government Area of Delta. Nigeria. JETAS, 2(1): 147-151.

Egbai, J.C. and M.B. Asokhia, (1998). Correlation between resistivity survey and well logging in Delta State, Nigeria. *Journal of NAMP*. *2*:163 – 175

Egbai, J.C., (2012). Geoelectric evaluation of groundwater potential in the sedimentary Region of Abavo, Delta State Sate and Urhonigbe Edo State, Nigeria. Int. *Journal of Research and Review in Applied SC. (IJRRAS) 10*(3): 491-498.

Egila J.N. and A. Terhemen, (2004). A preliminary investigation into the quality of surface water in the environment of Benue Cement Company Plc. Gboko, Benue State. Nigeria. *Int. J. Sci. Tech., 3*(1): 12-17

Etu – Efeotor J.O. and E.G. Akpokodje, (1990). Aquifer Systems of the Niger Delta. Journal of Mining Geology 26(2): 279-294.

Ezeh, C.C., (2011). Geoelectrical studies for estimating aquifer hydraulic properties in Enugu State, Nigeria, *International Journal of the Physical Sciences. 6(14); 3319-3329.*

Ezeh, C.C., (2012). Hydrogeophysical Studies for the Delineation of Potential Groundwater Zones in Enugu State, Nigeria. *International Research Journal of Geology and Mining (IRJGM) (2276-6618). 2* (5); 103-112.

Ohwona, O.C., Marere, S.O., Burutu, L.K. and C. U. Ohwovorione, (2013). Delineation of depth of water table and groundwater potentials from geoelectric evaluation in Abavo, Delta State and Urhonigbe, Edo State area of the Niger Delta, Nigeria. *Standard Scientific Research and Essays 1*(13): 340-346.

Olorunfemi, M.O and S.A. Fasuyi, (1993). Aquifer types and the geoelectric/ hydrogeological characteristics of parts of the central Basement terrain of Nigeria (Niger State). *Journal of African Earth Sciences 3* (3):309-317.

Plummer, C.C., McGeory, D. and D.H. Carlson, (1999). *Physical Geology* 8th Edn, McGrew Hill Co. Inc, New York, pp. 48 – 56.

Uma, K.O., (2003). Hydrogeology of the perched aquifer systems in the hilly terrains of Nsukka town, Enugu State, Nigeria. *Water Resources. J. NAH. 14: 85 - 92.*

Vander V.B., 1988. Resist Version1, MSc Project ITC, Deft, Netherland.

Zohdy, A.A.R., Martin P., and R.J. Bisdorf, (1993). A study of seawater intrusion using Direct Current Soundings in the Southeastern part of the Oxnard Plain, California U.S Geological survey, Open file Report. Pp 93 – 523.

Zohdy, A.A.R., (1989). A new method for the automatic interpretation of Schlumberger and Wenner sounding curves, *Geophysics 42*, 245-253.