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2d Geoelectric Evaluation and Imaging of Aquifer Vulnerability of Dump Site at Ozoro Isoko South Lga of Delta State

J. C. Egbai, P Efeya R. E, Iserhien-Emekeme,
Faculty of Sciences, Department of Physics, Delta State University, P.M.B 1, Abraka, Delta State, Nigeria
E-mail: jamesegbai@yahoo.com

Abstract

The Electrical resistivity survey was carried out to evaluate the aquifer vulnerability of a dumpsite in Ozoro Isoko South LGA of Delta State. Four Schlumberger vertical electrical soundings with maximum electrode separation of 350m and four dipole-dipole were carried out at a dumpsite. The data were presented as VES curves interpreted quantitatively by computer iteration using the Resist Software to obtain the first order geoelectric parameters. The vertical electrical sounding data were presented as VES curves interpreted quantitatively by computer iteration using the Resist Software to obtain the first order geoelectric parameters. The dipole-dipole data were present as Inverted 2D resistivity structure by computer inversion using DIPROfWin Software. The results of the geoelectric investigation have revealed five geoelectric layers namely the lateralitic topsoil, sandy clay soil, fine coarse sand, medium coarse sand and coarse sand that are in agreement with the actual lithology encountered from the hand dug well logs close to the dumpsite. The overburden protective capacity in an area was evaluated using the total longitudinal unit conductance values. The generated longitudinal conductance showed poor protective capacity (<0.1mhos) in all parts of the study area. The inverted 2D resistivity structure shows movements of leachate down toward the aquifer indicating that the aquifer is not protected. The low value of the protective capacity makes the aquifer in the study area vulnerable to contamination from the dumpsite.

Keywords: Aquifer vulnerability, Ozoro, 2D imaging, dumpsite, lithology

INTRODUCTION

Increase in population and urbanization on a daily basis in Niger Delta have led to a corresponding reduction in quality of groundwater in these areas. Groundwater reservoir quality can be affected by a number of factors such as movement of leachate to the aquifer or other anthropogenic interference (Abdul et al., 2000; Batayneh, 2006; Amadi et al., 2012). Most wells drilled to the subsurface to yield freshwater in this area have been abandoned due to contamination of leachate from waste disposal site as a result of infiltration of contaminants through the soil under these sites (Oyedele & Momoh, 2009).

Ozoro as a result of growth and urbanization will face critical problems pertaining to its groundwater resources in the coming years if the problem of waste disposal sites is not adequately addressed. The waste disposal sites in the dump sites studied lack top and bottom cover.

Groundwater can be explored using many methods which include the electrical resistivity method (Alile et al., 2008).

Groundwater resources in Ozoro are particularly used for domestic purposes partly because groundwater is of high quality and requires little treatment before use. According to (Sampat, 2001) fungi, bacteria and other biological pollutants are naturally filtered and diluted as the water percolates through the soil. Groundwater is also widely used because the provision of potable water via the water supply scheme is grossly inadequate for the needs of the people.

Pollution of groundwater under and near waste disposal site happens as a result of infiltration of contaminants through the soil under these sites. The contaminant is an aqueous liquid called leachate which is formed when rain falls on the dump, sinks into the waste and picks up contaminants as it seeps downward. Contamination of the groundwater takes place when the leachate reaches the water table (Meju, 2006).

Geoelectrical methods are used extensively in imaging dump sites for investigation of the vulnerability of aquifers and shallow aquifers themselves. The vulnerability of aquifers is closely related to the heterogeneity of the clay cap. The clay content of the formation defines the electrical formation resistivity with clayish less permeable formations showing low resistivities and sandy permeable formations showing high resistivities. The geoelectrical method is capable of imaging both low and high resistive formations and therefore a valuable tool for vulnerability studies (Chistensen & Sørensen 1998, Sørensen et al. 2005).

Geoelectrical resistivity surveying has greatly improved, and has become an important and useful tool in hydrogeological studies, mineral prospecting and mining, as well as in environmental and engineering applications (e.g. Griffiths et al., 1990; Griffiths and Barker, 1993 Olayinka and Yaramanci, 1999; Amidu and Olayinka, 2006; Aizebeokhai et al., 2010).

A geoelectrical measurement is carried out by recording the electrical potential arising from current input into the ground with the purpose of achieving information on the resistivity structure in the ground. In a homogeneous ground (halfspace) the current flow radially out from the current source and the arising equipotential surfaces run perpendicular to the current flow lines and form half spheres. In the common situation with both a current source and a current sink the current flow lines and the equipotential surfaces become more complex. In reality the current flow lines and the equipotential lines will form an even more complex pattern as the current flow lines will bend at boundaries, where the resistivities change.

Thus, the objectives of the study is to carry out I-D and 2-D geoelectric imaging at two dump site in Ozoro area to determine the geoelectric parameters (resistivity, ρ_i and thickness, h_i) and delineate the depth to the aquifer and its lateral extent and determine the aquifer protective capacity. Henriet (1976) showed that the combination of layer resistivity and thickness in the Dar Zarrouk parameters S (longitudinal conductance) and T (transverse resistance) may be of direct use in aquifer protection studies and for the evaluation of hydrologic properties of aquifer. Atakpo, (2013), shows that the aquifer protective capacity can be evaluated from the second order geoelectric parameter using electrical resistivity survey method.

LOCATION AND GEOLOGY OF THE STUDY AREA

The study area (waste dumpsite) is located in Ozoro municipality which is delineated by geographical co-ordinates of N05^0 15′ and N05^0 33′and E006^0 41′ and E006^0 47′. The waste dump site is accessible through a major road network that runs from Ala roundabout (Square) into Oleh where the wastes are being transported to the dump site.

The study area displays the characteristic features of seaward sloping flat and featureless Sombreiro-Warri Deltaic plain (Short and Stauble, 1967). Elevation is about 11m above sea level. The vegetation is typical of the rain forest except along drainage streams where swampy areas exist. The Niger Delta Petroleum province is underlain by three main stratigraphic units (Short and Stauble, 1967; Asseez, 1989). These are the basal Akata Formation of mainly marine shale and sand beds. This is overlain by the paralic sequence consisting of interbedded sands and shales of the Agbada Formation. The youngest

Benin Formation is a prolific aquifer and is penetrated everywhere in the modern Niger Delta by numerous water supply boreholes. However, the formation is masked in the Sombreiro–Deltaic plain by a sequence of silts, medium to coarse grained sands, sandy clays and clay bands which Oomkens (1974) believes are a result of interglacial marine transgressions that have occurred in the Quaternary. This sequence is indistinguishable from the underlying Benin Formation in borehole sections and is indeed the present day expression of this formation. The problem though is that the clay bands are not uniform in thickness and many boreholes have been abandoned because the entire clay sequence could not be penetrated in order to access the underlying water bearing sandy layers or the aquifer.

Figure 1.1 shows the map of Delta State indicating the location of the study area, figure 1.2 shows the map of Isoko North Local Government Area while figure 1.3 shows the map of Ozoro the study area.

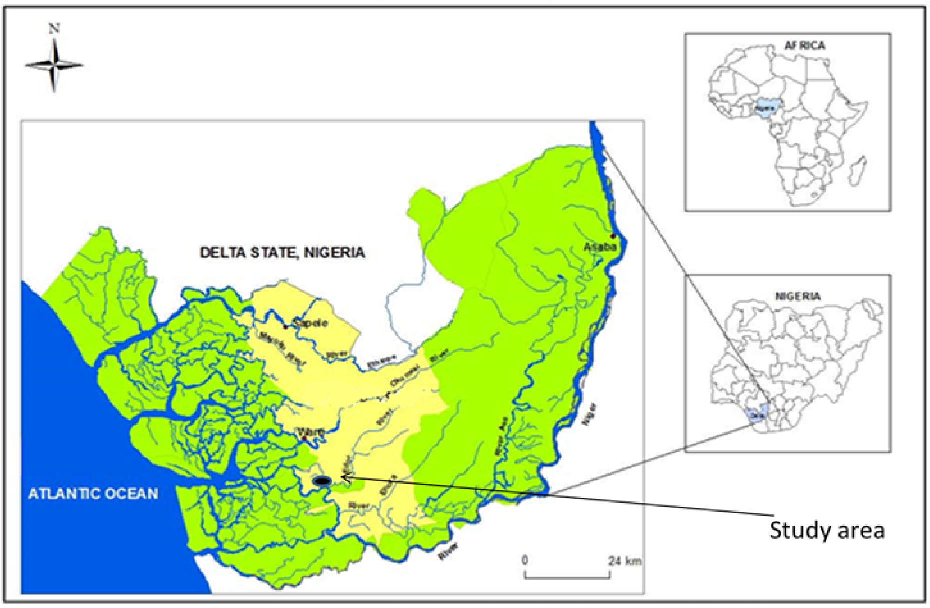


Fig. 1 Location Study area

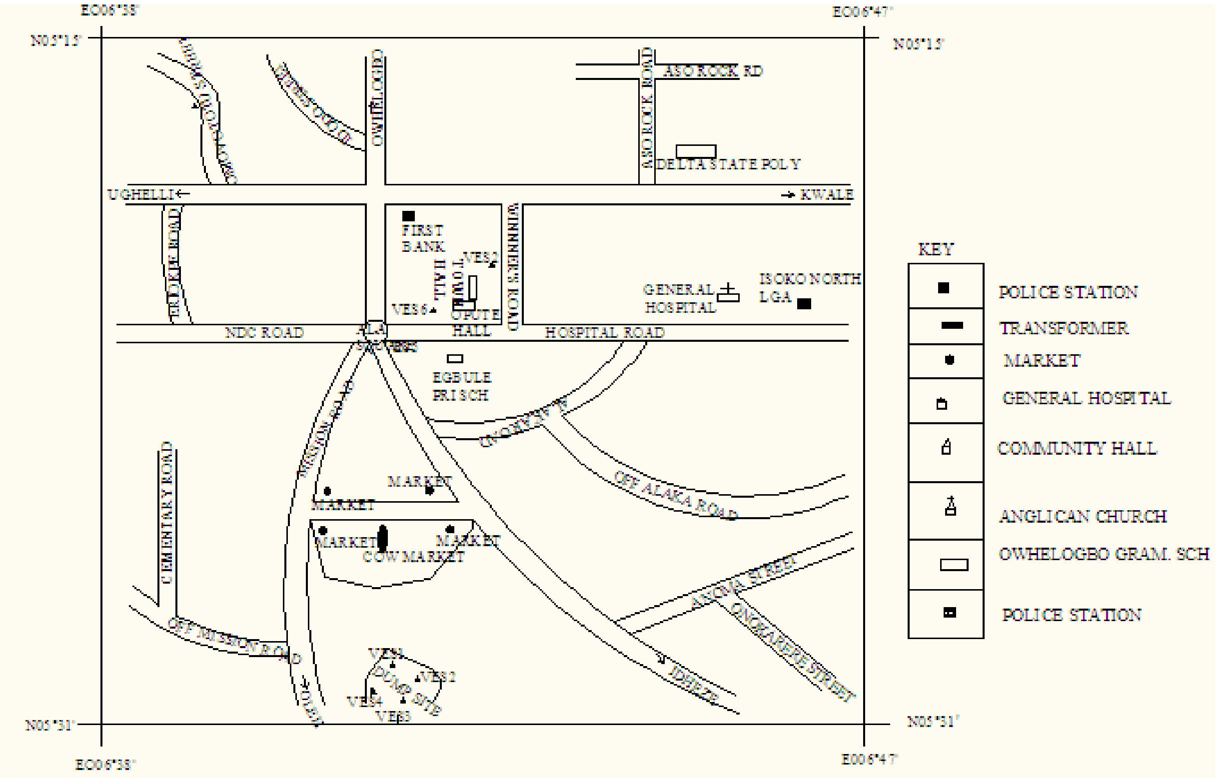


Figure 2: Showing Map of the Study Area

MATERIALS AND METHODS

Two array methods were used for the survey.Vertical electrical sounding was carried out using Schlumberger electrode configuration and horizontal profiling adopting the dipole-dipole configuration. The ABEM SAS 4000 Terrameter was used for the investigation. Four vertical electric soundings with electrode spacing of 350m were adopted for the survey. The apparent resistivity data were determined and plotted against half electrode separation (AB/2) using log-log graph. The data were initially interpreted using conventional partial curve matching techniques and later interpreted quantitatively by computer iteration with the aid of the Win Resist Software based on the work of Vander Velpen, (2004) to obtain the true resistivity and thickness of the layers delineated.

Four survey profiles were laid in the study area in order to map the contaminated zone. Profiles 1, 2, 3, and 4 were within the polluted area while profiles 5 and 6 were outside the dump site area. The 2D resistivity imaging technique using the dipole-dipole array method was adopted for the survey with the aid of the SAS 4000 Terrameter. A Dipole spacing of a =5 and a=10m apart were used for the profiles. The stored data in the Terrameter was transferred to a computer for processing and inversion using DIPROfWin Software 4.01. The software was developed by Dr. Jung Ho Kim of the Korea Institute of Mining and Geology (KIGAM) (Aminu *et. al* , 2014). DIPROfWIN is a fully automated two and half-dimensional (2.5D) inversion routine based on a finite difference modeling (FDM) or finite element modeling (FEM) approximations to the calculation of model responses. The software inverts the data using the smoothness-constrained least-squares inversion algorithm to achieve stable results. The program uses the active constraint balancing (ACB) method which accounts for the use of variable Lagrangian multiplier at each of the parameterized blocks of themodel during the inversion process to enhance both resolution and stability(Aminu *et. al.* , 2014 as cited in SEG Annual meeting, 1998).

The inversion of the field resistivity data was carried out with the aim of delineating the subsurface geologic sequence present in the study area, and determine their geoelectric parameters.

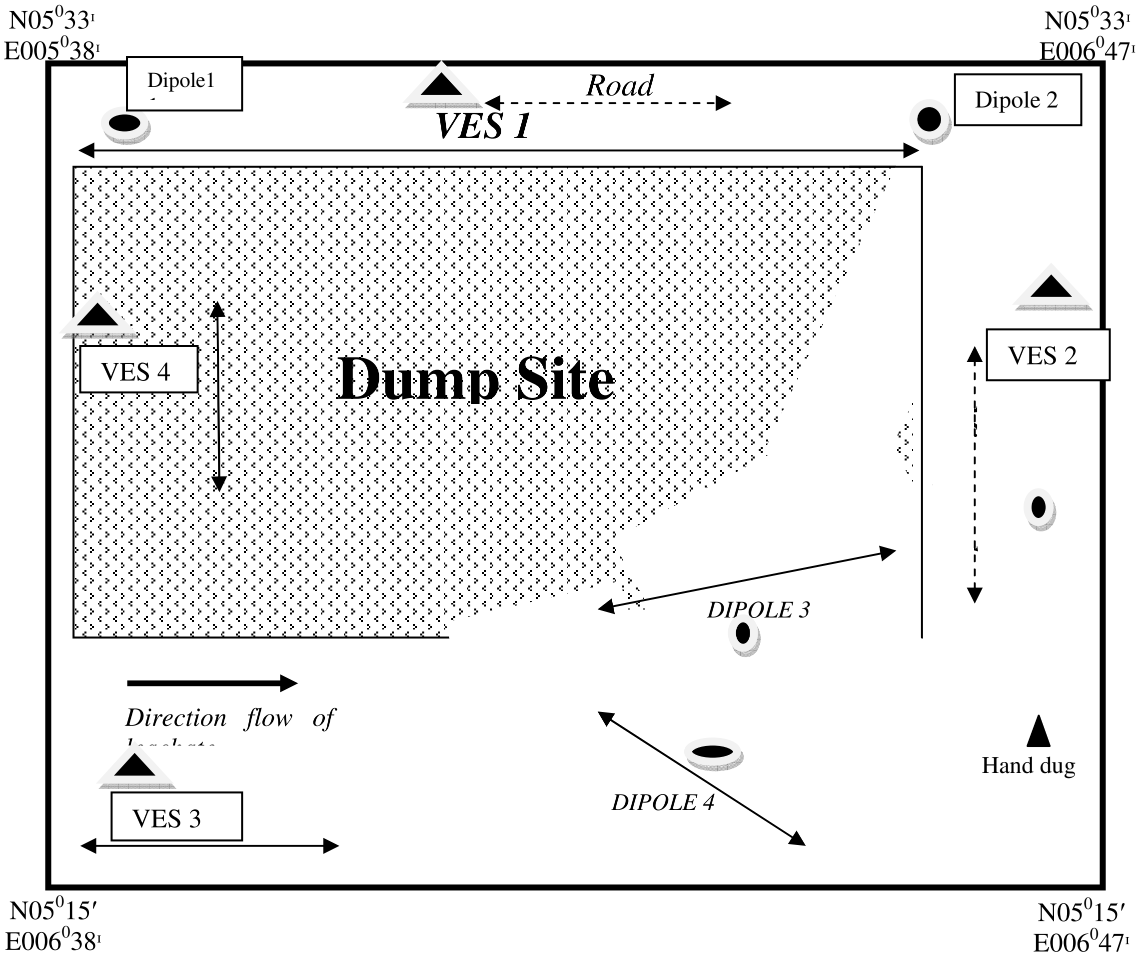


Fig 3: Data Acquisition map of the study area.

DISCUSSION OF RESULTS

The Formation strata of the subsurface layers around the dump site obtained from the vertical electrical sounding (VES) shows KHA, KQH, KHK and KHA curve types. The subsurface resistivity layer parameters of the four vertical geoelectrical soundings were analyzed to determine the aquifer vulnerability around the dumpsite area. The geoelectric section correlate with a hand dug wells close to the dump site.

The vertical electrical sounding showed a thin layer of lateralitic topsoil with thickness varying from 1-1.6m and resistivity values ranging from176.3-1144Ωm at the first layer. This is directly underlain by the second layer made of sandy clay soil with thickness varying from 7.3-8.7m with resistivity values ranging from 285.3-2250.5Ωm. This is followed by the third layer of fine coarse sand with resistivity ranging from 131.2-2103.8Ωm and thickness varying from 10.9-19.0m. The thickness of the fourth layer varies from 13.6-237.6m with resistivity values ranging from 525.3-1015.3Ωm The third and fourth layers constitute the aquiferous zones in the area. The resistivity values of the fifth layer ranges from 154.9-2625.0Ωm indicating coarse sand. The thickness of fifth layer cannot be determined as the current electrode terminated at this layer. The curves for the four VES locations are shown in figures 4-7

Table 1 Curve Types and Lithologic Delineation of Study Area

VES	Layer	Lithology	Type Curves
VES1	1 2 3 4 5	Lateralitic Topsoil Sandy Clay Soil Fine Coarse sand Medium Coarse Sand Coarse Sand	$\ell_1<\ell_2>\ell_3<\ell_4<\ell_5$ KHA
VES2	1 2 3 4 5	Lateralitic Topsoil Sandy Clay Soil Fine Coarse sand Medium Coarse Sand Coarse Sand	$\ell_1<\ell_2>\ell_3>\ell_4<\ell_5$ KQH
VES3	1 2 3 4 5	Lateralitic Topsoil Sandy Clay Soil Fine Coarse sand Medium Coarse Sand Coarse Sand	$\ell_1<\ell_2>\ell_3<\ell_4<\ell_5$ KHK
VES4	1 2 3 4 5	Lateralitic Topsoil Sandy Clay Soil Fine Coarse sand Medium Coarse Sand Coarse Sand	$\ell_1<\ell_2>\ell_3<\ell_4<\ell_5$ KHA

Table 2, shows the geoelectric parameter of the study area. The aquifer protective capacity characterization is based on the values of the longitudinal unit conductance of the overburden rock units in the area. The longitudinal layer conductance (S) of the overburden at each station was obtained from the equation:

$$S = \sum_{i=1}^{n} \frac{h_i}{\rho_i}$$

where h_i is the layer thickness, ρ_i is layer resistivity while the number of layers from the surface to the top of aquifer varies from i= 1 to n.

The portion where the conductance value is greater than 10 is classified as excellent protective capacity, where the conductance ranges between 5 and 10 mhos is classified very good, where the conductance ranges between 0.7 and 4.9 mhos is classified good, where the conductance ranges between 0.2 and 0.69 mhos is classified as zones of moderately protective capacity. The zones which have conductance value ranging from 0.1 and 0.19 mhos is classified as zones of weak protective capacity and where it is less than 0.1 mhos is considered as poor aquifer protective capacity (Oladapo & Akintorinwa, 2007).

Table 2: Geoelectric Parameter of the Study Area.

S/N	Layers	Resistivity	Thickness	$S = \sum_{i=1}^{n} \frac{h_i}{\rho_i}$	Longitudinal Conductivity of Protecting Layers	Protective Capacity Rating
VES1	1 2 3 4 5	1144.0 1484.7 887.7 917.4 1580.0	1 8.7 12.9 18.1 ---	0.00088 0.00586 0.01453 0.01973 ---	0.01025	Poor
VES2	1 2 3 4 5	915.0 2201.9 2103.8 759.4 1581	1.6 7.4 10.9 27.6 ---	0.00175 0.00336 0.00158 0.03635 ---	0.01076	Poor
VES3	1 2 3 4 5	176.3 285.3 131.2 525.3 1541	1.1 7.3 19.0 13.6 ---	0.00624 0.02559 0.14462 0.02589 ---	0.02059	Poor
VES4	1 2 3 4 5	1002.3 2250.5 757.8 1015.3 2625.0	1 8.6 16.2 18.6 ---	0.00010 0.00381 0.02138 0.01832 ---	0.01090	Poor

The results of the 2D resistivity inversion in Ozoro are shown in Figures 8-11 as 2D inverted resistivity structures. The electrode separation between adjacent electrodes was 10m. The profile length ranges from 140 to 180m.

The inverse 2D resistivity model of profile 1 within the dump site is shown in Figure 8. The inverted resistivity model shows variation of resistivity values ranging from about 44.4 to 654Ωm. The profile shows lateralitic topsoil with resistivity values ranging from 44.4 to 112Ωm and thickness of about 4m. The second layer is made of sandy clay soil with resistivity values ranging from 44.9 to 103Ωm and thickness of about 6m. The second layer is directly underlain by fine sand with resistivity values ranging from 63.9 to 234Ωm and thickness of 10m. The fourth layer is medium to coarse sand with resistivity values ranging from 160 to 444Ωm and thickness of about 16m. The fifth layer is coarse sand with resistivity values ranging from 359 to 654Ωm. The thickness of this cannot be measured as the current and potential electrode terminated at this layer.

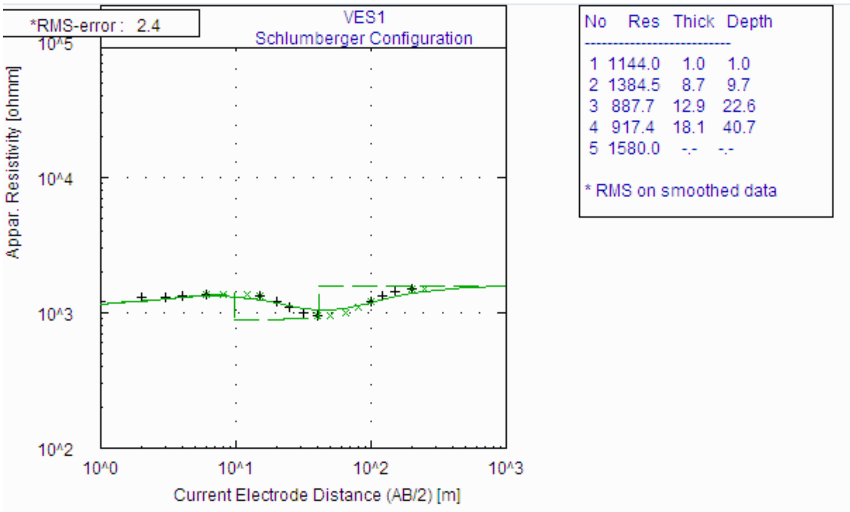
The inverse 2D resistivity model of profile 2 within the dump site is shown in Figure 9. The inverted resistivity model shows variation of resistivity values ranging from about 94.4 to 1484Ωm. The profile shows lateralitic topsoil with resistivity values ranging from 96.4 to 203Ωm and thickness of about 5m. The second layer sandy clay soil with resistivity values ranging from 138 to 337Ωm and thickness of about 5m. The second layer is directly underlain by fine sand with resistivity values ranging from 264 to 722Ωm and thickness of 10m. The fourth layer is medium to coarse sand with resistivity values ranging from 344 to 1011Ωm and thickness of about 15m. The fifth layer is made of coarse sand with resistivity values ranging from 428 to 1484Ωm. The thickness of this cannot be measured as the current and potential electrode terminated at this layer.

The inverse 2D resistivity model of profile 3 within the dump site is shown in Figure 10. The inverted resistivity model shows variation of resistivity values ranging from about 42.7 to 2604Ωm. The profile shows lateralitic topsoil with resistivity values ranging from 42.7 to 249Ωm and thickness of about 5m. The second layer is made of sandy clay soil with resistivity values ranging from 81.1 to 222Ωm and thickness of about 5m. The second layer is directly underlain by fine sand with resistivity values ranging from 79.7 to 525Ωm and thickness of 11m. The fourth layer is medium to coarse sand with resistivity values ranging from 68.9 to 1473Ωm and thickness of about 16m. The fifth layer is coarse with resistivity values ranging from 49 to 2604Ωm. The thickness of this cannot be measured as the current and potential electrode terminated at this layer.

The inverse 2D resistivity model of profile 4 within the dump site is shown in Figure 11. The inverted resistivity model shows variation of resistivity values ranging from about 83 to 459Ωm. The profile shows lateralitic topsoil with resistivity values ranging from 93.4 to 165Ωm and thickness of about 4m. The second layer is made of sandy clay soil with resistivity values ranging from 124 to 332Ωm and thickness of about 6m. The second layer is directly underlain by fine sand with resistivity values ranging from 83.4 to 459Ωm and thickness of 10m. The fourth layer is medium to coarse sand with resistivity values varying from 132 to 360Ωm and thickness of about 15m. The fifth layer is of coarse with resistivity values ranging from 150 to 291Ωm. The thickness of this cannot be measured as the current and potential electrode terminated at this layer.

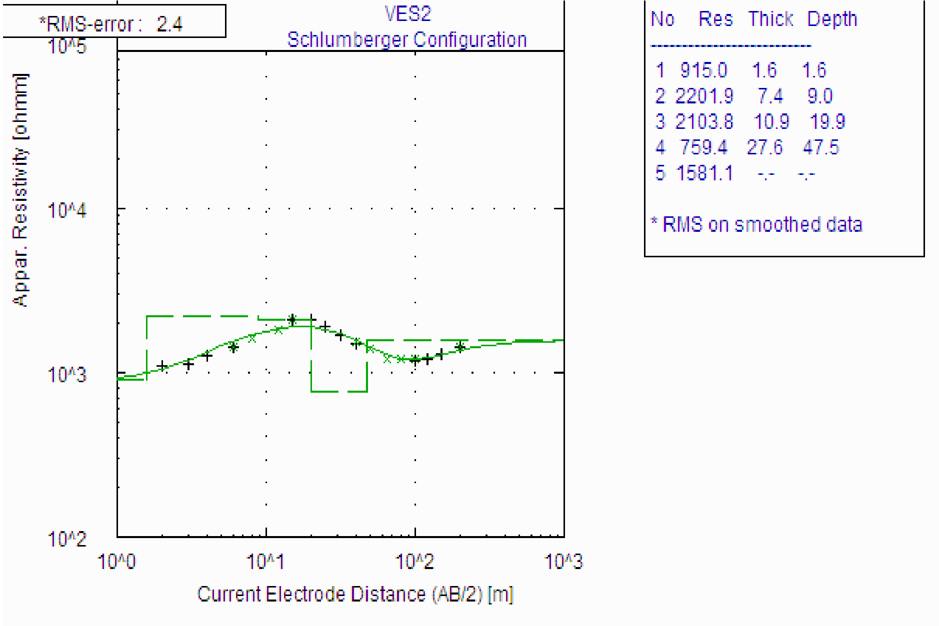
The lithology of the third, fourth and fifth layers are sandy. The low resistivity values obtained in these layers shows the movement of contaminants down towards aquifer. This is more pronouncing in profile 3.The low resistivity values in the third, fourth and fifth layers as shown in profile 1, profile 2 and profile 3 ranges from 49.0 to 79.7m. This low resistivity value may be as a result of the movement of leachate toward the aquifer. The interpretation of the 2D resistivity structures correlates with the vertical electrical sounding structure.

The longitudinal conductance obtained from this study shows that the dumpsite area is not protected since the protective capacity rating is poor (< 0.1) in all parts of the study area. The low value of the protective capacity is as a result of the absence significant amount of clay as an overburden impermeable material in the study area thereby enhancing the percolation of contaminants into the aquifer. The aquifer in dumpsite area is therefore prone to contamination.



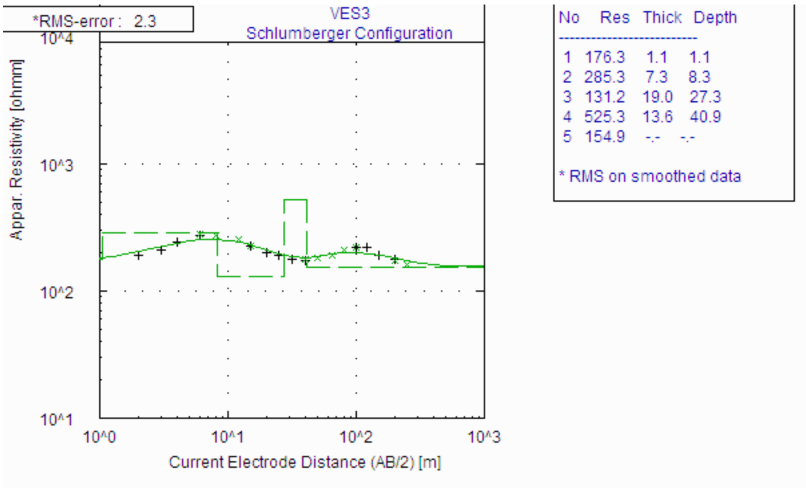
No	Res	Thick	Depth
1	1144.0	1.0	1.0
2	1384.5	8.7	9.7
3	887.7	12.9	22.6
4	917.4	18.1	40.7
5	1580.0	-.-	-.-

Figure: 4 Typical Sounding curves for OzoroHydrogeophysicalInvestigation VES1



No	Res	Thick	Depth
1	915.0	1.6	1.6
2	2201.9	7.4	9.0
3	2103.8	10.9	19.9
4	759.4	27.6	47.5
5	1581.1	-.-	-.-

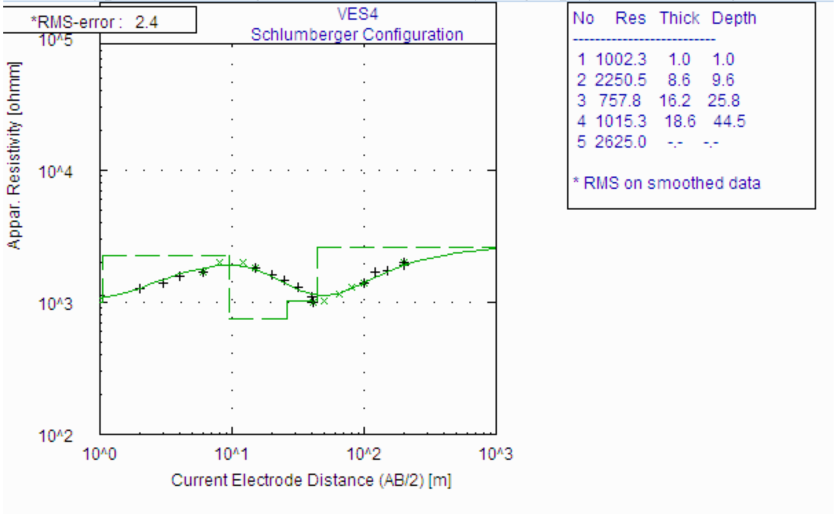
Figure: 5 Typical Sounding curves for OzoroHydrogeophysical Investigation VES2



No	Res	Thick	Depth
1	176.3	1.1	1.1
2	285.3	7.3	8.3
3	131.2	19.0	27.3
4	525.3	13.6	40.9
5	154.9	-.-	-.-

* RMS on smoothed data

Figure: 6 Typical Sounding curves for OzoroHydrogeophysical Investigation VES3



No	Res	Thick	Depth
1	1002.3	1.0	1.0
2	2250.5	8.6	9.6
3	757.8	16.2	25.8
4	1015.3	18.6	44.5
5	2625.0	-.-	-.-

* RMS on smoothed data

Figure: 7 Typical Sounding curves for Ozoro Hydrogeophysical Investigation VES4

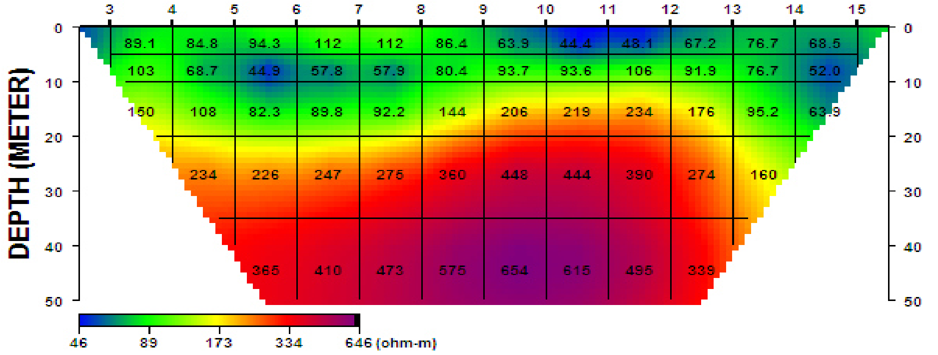


Figure 8: Inverted 2D Resistivity structure along Dipole-Dipole profile 1 in Ozoro Dump Site

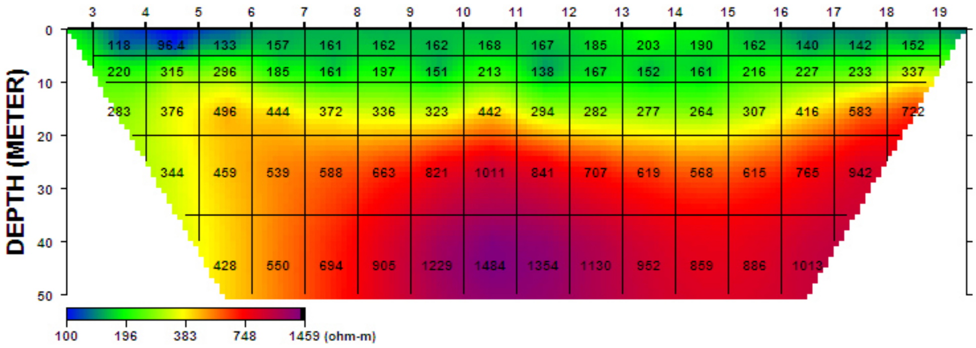


Figure 9: Inverted 2D Resistivity structure along Dipole-Dipole profile 2 in Ozoro Dump Site

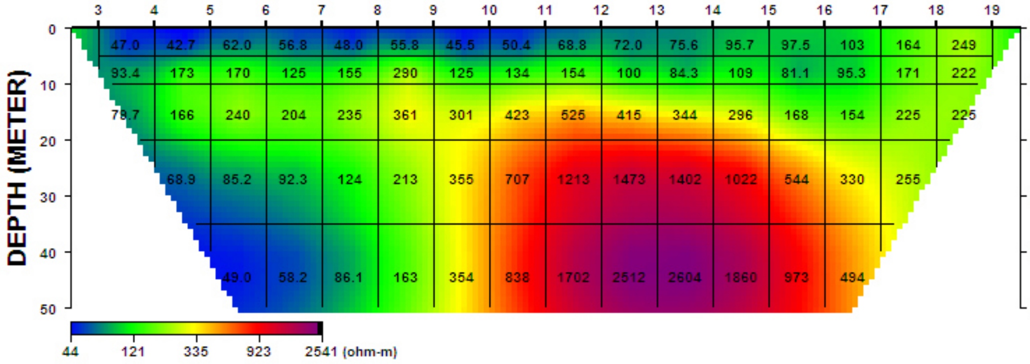


Figure 10: Inverted 2D Resistivity structure along Dipole-Dipole profile 3 in Ozoro Dump Site

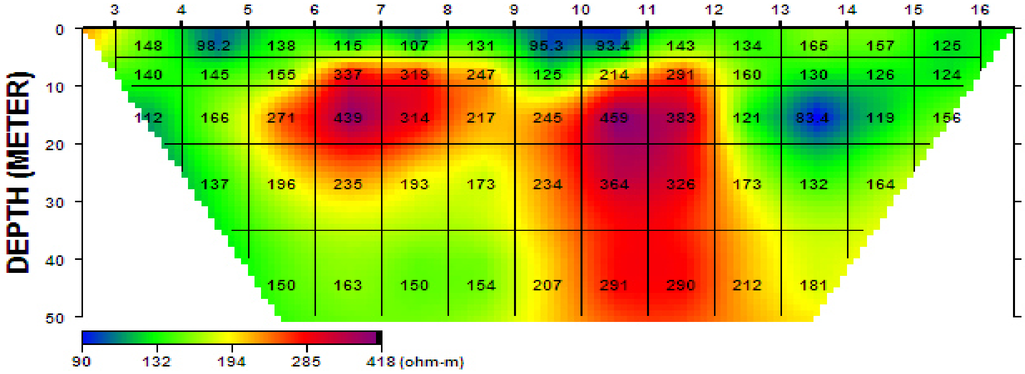


Figure 11: Inverted 2D Resistivity structure along Dipole-Dipole profile 1 in Ozoro Dump Site

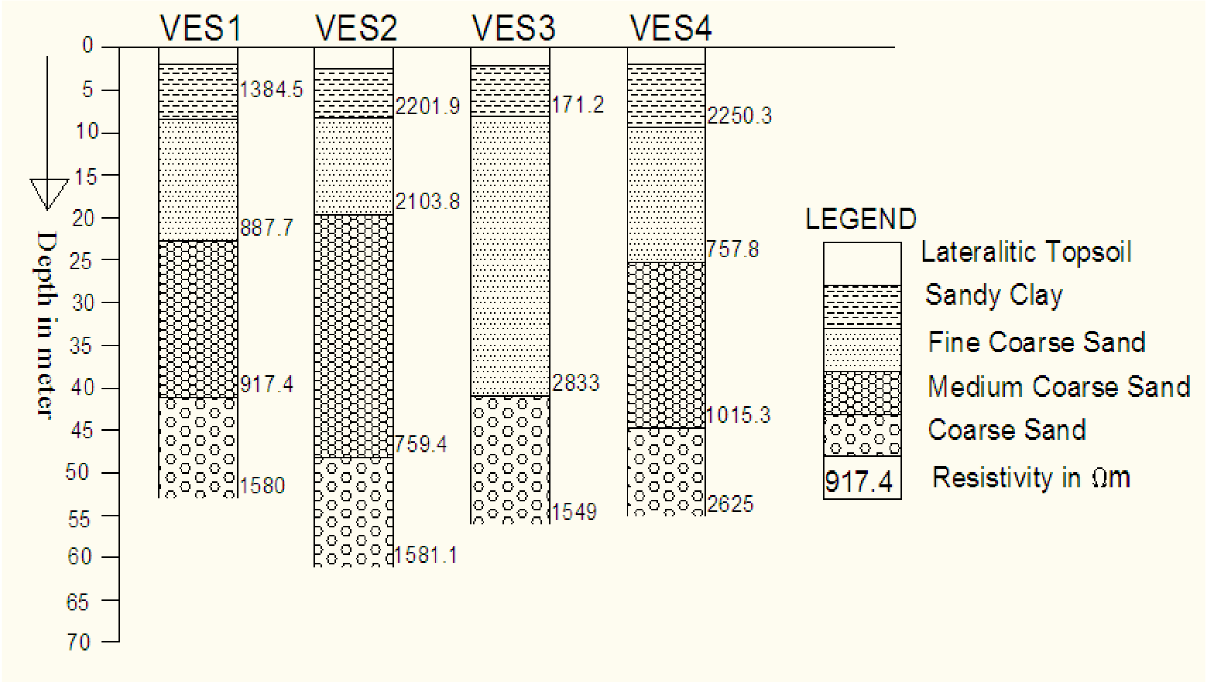


Figure 12: Geoelectric Section of the Dump Site.

CONCLUSION

This paper describes the determination of the overburden protective capacity using the electrical resistivity survey. Four Schlumberger vertical electrical soundings with maximum electrode separation of 350m and four dipole-dipole (2D resistivity survey) were carried out at a dumpsite area in Ozoro of Delta State. The vertical electrical sounding data were presented as VES curves interpreted quantitatively by computer iteration using the Resist Software to obtain the first order geoelectric parameters. The dipole-dipole data were present as Inverted 2D resistivity structure by computer inversion using DIPROfWin Software 4.01 was developed by Dr. Jung Ho Kim of the Korea Institute of Mining and Geology (KIGAM). The results of the geoelectric investigation have revealed five geoelectric layers namely the lateralitic topsoil, Sandy clay soil, fine coarse sand, medium coarse sand and coarse sand that are in agreement with the actual lithology encountered from the hand dug well logs close to the dumpsite. The geoelectric parameters were utilized in deriving the longitudinal unit conductance (S). The overburden protective capacity in an area was evaluated using the total longitudinal unit conductance values. The generated longitudinal conductance maps showed poor protective capacity (<0.1mhos) in all parts of the study area. The inverted 2D resistivity structure shows movements of contaminants (leachate) down toward the aquifer indicating that the aquifer is not protected. The study area is not protected hence the aquifer in this dumpsite area is prone to contamination by waste from the dumpsite. Awareness should be created by discouraging the inhabitants from drinking water from hand dug wells which can be easily polluted. Groundwater monitoring wells should be provided in the community and regular water quality analysis conducted.

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REFERENCES

Abdul, N.S.S., M.H. Loke, C.Y. Lee and M.N.M. Nawawi, (2000). Salt-water intrusion mapping by geoelectrical imaging surveys. Geophys. Prospect., 48: 647-661.

Aizebeokhai, A.P., Olayinka, A.I., Singh, V.S., (2010). Application of 2D and 3D geoelectrical resistivity imaging for engineering site investigation in a crystalline basement terrain, southwestern Nigeria. Journal Environment Earth Science 41: 1481-1482

Alile, O.M., Jegede, S.I. and Ehigiator, O.M., (2008). Underground water exploration using electrical resistivity method in Edo State, Nigeria, Asian Journal of Earth Science 1(1):38-42.

Amadi, A.N., Nwankwoala, H.O. Olashinde, P.I. Okoye, N.O. Okunlola I.A. and Alkali, Y.B. (2012). Investigation of aquifer quality in bonny island, Eastern Niger Delta, Nigeria using geophysical and geochemical techniques. Journal of Emerging Trends in Engineering and Applied Science, 3(1):183-

187.

Amidu, S.A. and Olayinka, A.I., (2006): Environmental assessment of sewage disposal systems using 2D electrical resistivity imaging and geochemical analysis: A case study from Ibadan, Southwestern Nigeria, Journal of Environment, Engineering and Geosciences, 7(3): 261-272.

Aminu, M.B., Akande, T.M. and Ishola, O.A. (2014). 2D Geoelectric Imaging of the Uneme- Nekhua Fracture Zone. International Journal of Geophysics. Vol. 2014.Pp.1-8 Doi.org/10.1155/2014/842812

Atakpo, E.A., (2013). Aquifer Vulnerability Investigation Using Geoelectric Method in Parts of Sapele Local Government Area of Delta State, Nigeria, Nigerian Journal of Basic and Applied Science, 21(1):11-19

Batayneh, A.T., (2006). Use of electrical resistivity methods for detecting subsurface fresh and saline water and delineating their interfacial configuration: A case study of the Eastern Dead sea coastal aquifers, Jordan. Hydrogeology Journal, 14: 1277-1283.

Christensen, N.B., Sørensen, K.I., (1998): Surface and borehole electric and electromagnetic methods for hydrogeological investigations. European Journal of Environmental and Engineering Geophysics 3: 75–90.

Griffiths, D.H, Turnbull, J. and Olayinka, A.I., (1990). Two-dimensional resistivity mapping with a complex controlled array. First Break*,* 8: 121-29.

Griffiths, D.H. and Barker, R.D., (1993). Two dimensional resistivity imaging and modelling in areas of complex geology. J. Appl. Geophy., 29: 211-226.

Henriet, J.P., (1976). Direct application of the Dar Zarrouk parameters in groundwater surveys. *Geophysics Prospective*, 24: 344–353.Investigations in Geophysics 13: 585–603.

Meju, M. A., (2000) Geoelectrical Investigations of Old/Abandoned, Covered Landfill Sites in Urban Areas: Model Development with a Genetic Diagnosis Approach, *Journal of Applied Geophysics*, 44:115-150.

Olayinka, A.I. and Yaramanci, U. (1999). Choice of the best model in 2-D geoelectrical imaging: case study from a waste dump site. Europe Journal of Environment, Engineering and Geophysics 3: 221-244.

Oomkens, E., (1974). Lithofacies relations in the late quaternary Niger Delta Complex. AAPG Bulletin, 24: 195-222

Oyedele, K.F. and Momoh, E.I., (2009). Evaluation of sea water intrusion in freshwater aquifers in a lagoon coast: A case study of the University of Lagos Lagoon, Akoka, Nigeria. New York Science Journal, 2(3): 32-42.

Sampat, P., (2001). The hidden threat to groundwater pollution. USA Today Magazine, pp. 130 World Health Organization. 1992. Guidelines for drinking water quality (WHO Geneva 1992).

Short, K.C. and Stauble, A.J.(1967). Outline of Geology of Niger Delta: AAPG Bulletin, 51: 761-779.

Sørensen, K.I., Auken, E., Christensen, N.B., & Pellerin, L., (2005): An Integrated Approach for Hydrogeophysical Investigations: New Technologies and a Case History. – In Butler D. K. (ed.) Near-Surface Geophysics 2,

Vander Velpen. B.P.A. (2004). Win RESIST Version 1.0. M.Sc Research Project. ITC, Delft, Netherlands.