Research Article
Journal of Research and Review in Science, 62-67
Volume 7, December 2020
DOI: 10.36108/jrrslasu/0202.70.0190

ORIGINAL RESEARCH

DELINEATION OF AQUIFEROUS ZONES USING GEOPHYSICAL METHODS AND CONTAMINANT FLOW DIRECTION -A case study of dumpsite at Cassidy, Okokomaiko, LASU-Badagry Expressway, Lagos State, Nigeria

***Rafiu B. Adegbola[1], Olanike E. Abidoye[1] and Ibrahim Adaranijo[1]**

[1]Department of Physics, Faculty of Science, Lagos State University, Nigeria

Correspondence
Rafiu B. Adegbola, Department of Physics, Faculty of Science, Lagos State University, Nigeria
Email:adegbolaji@yahoo.com
+2348023070281

Abstract:

Introduction: The study area is a rapidly developing area with attendant growing population arising from the presence of University and popularly known Alaba market. Unfortunately, water supply by the water corporation is not always available. The inhabitants only rely on the surface water and groundwater extracted from hand dug wells and boreholes.

Aim: The study aimed to depict the aquiferious zones and establish the groundwater flow direction, with a view to averting subsurface contamination emanating from dumpsite within the area.

Materials and Methods: Twenty-Five (25) Vertical Electrical Sounding (VES) were acquired using Schlumberger Electrode Array, Four (4) 2-D Electrical Resistivity Imaging were obtained at four different traverses using Wenner electrode array. Manual groundwater flow direction was also established.

Results: The identified unconfined aquifer was sand/sandy clay which is overlain by peat/clay soil that is loose and may allow migration of the probable contaminant plumes to the confined aquifer. The electrical resistivity values acquired decreases upward, south and north. This implies increase in conductivity in such directions and as such indicating the contaminant could be more concentrated near-surface, north and south.

Conclusion: The implication of this with respect to vulnerability to groundwater pollution is that the southern section of the aquiferous zones is more susceptible to receive transported contaminants from the northern part of the study area.

Keywords: Aquiferous zones, unconfined, Contaminants, Apparent resistivity, groundwater flow

1. INTRODUCTION

Groundwater has a number of particular attributes both in terms of its physical properties as well as in its social uses, which justify its study. Groundwater is created by infiltration of precipitation, surface runoff, or water stored in surface bodies, including rivers and lakes, to an aquifer; the layer of earth, gravel or stone that can yield groundwater which is known as an aquifer.

Aquifers are basically of two types namely; confined aquifers and unconfined aquifers. Unconfined aquifers are aquifers into which water seeps (flow or leak) from the ground surface directly above the aquifer while confined aquifers are aquifers in which a permeable rock layer exists that prevents water seeping into the aquifer [1].

Groundwater investigation requires the use of integrated geophysical techniques for successful and comprehensive knowledge of its occurrence and status [2, 3]. Several geophysical methods have been employed in order to address the problems of groundwater pollution, caused by both natural and anthropogenic activities.

The most direct method of determining the direction of groundwater movement is by measuring the elevation of groundwater at multiple locations over the aerial extent of an aquifer [4]. It is necessary to know the direction of groundwater flow to determine the recharge zones and make sure that human activities in the area do not pose threat to the quality of the groundwater to enable a sustainable use of the resources. Given that water always flow from a region of higher head to a region of lower head [5]. It is found that groundwater use within an area at a higher water level directly affects the quality of water available to people living in regions of lower water levels [6].

The electrical resistivity technique is one of the most used geophysical methods to delineate subsurface geological structures and aquifer units in most geological terrains. It happens to be the most preferred method in groundwater contamination [7, 8]. From the electrical resistivity measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the minerals, fluid content, porosity and degree of water saturation in the rock [9].

Environmental pollution is a major concern in Nigerian states and country as a whole. One of the several environmental pollution threatens the lives of the populace in the country is the pollution of groundwater. A major factor that contributes to groundwater pollution is the improper disposal of solid waste especially in uncontrolled sites (Dumpsites) and it is one of the major environmental problems in most cities in Nigeria [10,11].

Pollution of groundwater mostly occurred as a result of the infiltration of contaminants generated from a dumpsite [12, 13]. Contaminants generated from the dumpsite tends to percolate through the soil until it reaches a permeable rock layer (unconfined aquifer) as a result of the presence of pores or fractures in the permeable layer, the contaminants might also be traced in the confined layer, which now takes us to the use of geophysical methods to determine the “extent at which the contaminants have infiltrated the water table**”** of the vicinity thereby causing the pollution of groundwater in the vicinity that the dumpsite is been situated.

Boreholes or wells found within the premises of a dumpsite are frequently contaminated, due to the contamination of the aquifer by the contaminants generated from the dumpsite. This often results from leaking contaminants and percolation of water through waste accumulated from various ions in solution and forms plumes, which moves from the surface to subsurface (underlying aquifers).

Therefore, characterizing the subsurface with a view to establishing the aquiferous zones and identifying the flow direction of the groundwater becomes necessary because this will aid the sitting of the borehole for possible portable water and avoiding the existence of various water borne diseases.

The area of study is situated 100 m away from major dumpsite at Cassidy, Okokomaiko, Badagry Expressway, Lagos State, Nigeria. The land mark to the study is Lagos State University a distance of about 2 kilometres. It is located on Latitude 06^0 46^1 46^{11} to 06^0 46^1 87^{11} N and Longitude 03^0 18^1 87^{11} to 03^0 19^1 22^{11} E in the South Western part of Nigeria with elevation ranging from 21.35 to 41.87 m above sea level (Figure 1)

The geological setting of the study area reveals that it lies solely within the extensive Dahomey basin, the basin extending almost from Accra to Lagos. It is sedimentary basin. The littoral and lagoon deposit of recent sediment underlies the area. The coastal belt varies from about 8km near the Republic of Benin border to 24 km towards the eastern end of the Lagos Lagoon [14]

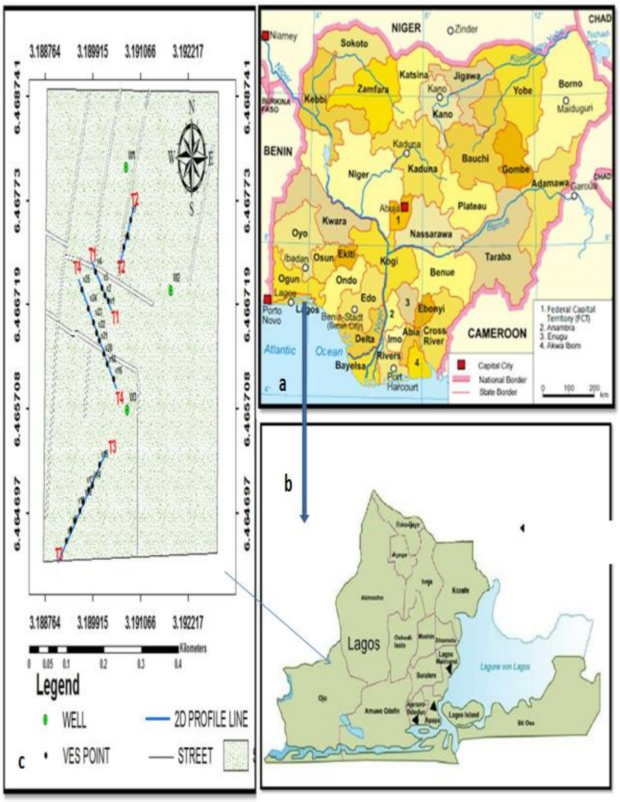

Figure 1: (a) Map of Nigeria showing the states (b) Map of Lagos State and the local governments (c) Base map of the study area situated in Ojo local government.

2. MATERIAL AND METHODS

Electrical Resistivity Survey using PASI 16GL Terrameter for resistivity measurements for both Wenner electrode array; two dimensional (2D) resistivity imaging data acquisition and Schlumberger electrode array; one dimensional (1D) data acquisition. For the 2D Measurements, these were made at sequences of electrodes at 10, 20, 30, 40, 50 and 60 m interval using four (4) electrodes for three traverses (A, C and D) covering a maximum distance of 200 m, while the forth traverse (B) measurement was made at sequences of electrodes at 5, 10, 15, 20, 25 and 30 m intervals using same four (4) electrodes covering a maximum distance of 80 m due to structural constraints.

Twenty five vertical electric sounding (VES) data were acquired at different points using Schlumberger array method. The current electrode separation (AB) was varied out from a minimum of 2 to 200 m. On each 2D electrical imaging (EI) profile for traverse (A, C and D), five to nine VES points were carried out while on the traverse B, two to three VES points were carried out, in order to integrate the VES and the 2D. The VES resistivity data obtained were interpreted.
Garmin 12 GPS was used to record the longitude, latitude and surface elevations with respect to the mean sea level at selected borehole locations fairly distributed within the study area. The depths to the water table/static water level (SWL) in the boreholes when no pumping was taking place were measured directly and recorded.

2.1 DATA PROCESSING

2.1.1 2D Electrical Resistivity measurement

The DIPROWin software was used for the inversion of the 2D apparent resistivity data. The field data pseudo section and the 2D resistivity structure were produced after running the inversion of the raw data to filter out noise. The DIPROWin program amortizes the bulk data into a series of horizontal and vertical rectangular blocks, with each box containing a number of records. R-resistivity of each block was then calculated to produce an apparent resistivity pseudo section. The pseudo section was compared to the actual measurements for a good model fit. The difference between measured and observed gives the inversion resistivity model which represents the geology of the study area.

2.1.2 1D Electrical resistivity measurement

The acquired apparent resistivity data were processed both quantitatively and qualitatively. The quantitative interpretation of the depth sounding curves was carried out using the partial curve matching technique which involved the use of layer master curves and auxiliary type curves (H, K, A, and Q). The results of the VES curves obtained from the partial curve matching were then used to constrain the interpretation by the computer using inversion software known as WINRESIST. The result of the computer iteration shows the quantitative analysis to know the resistivity, thickness and depth.
The qualitative interpretation of the depth sounding 68curves was carried out based on individual geo-electric characteristics on the number of layers represented by the four types of the auxiliary curves (A, H, K, and Q) and also from the profiles and maps involves inspection for patterns/anomaly signatures that are diagnostic of the target.

2.1.3 Groundwater flow direction

A flow net was produced from the total head of three Well points, W_1, W_2, W_3 (Figure 2). The elevation above the sea level was determined by subtracting the Static water level from the surface elevation. Equipotential line projected from Well 2 to intercept Wells 1 and 3 at the centre and the flow direction. The groundwater flows under the force of gravity from the point of high static water elevation to a point of lower static elevation which shows the level at which the contaminant plume moves with the groundwater flow at a direction of North to South.

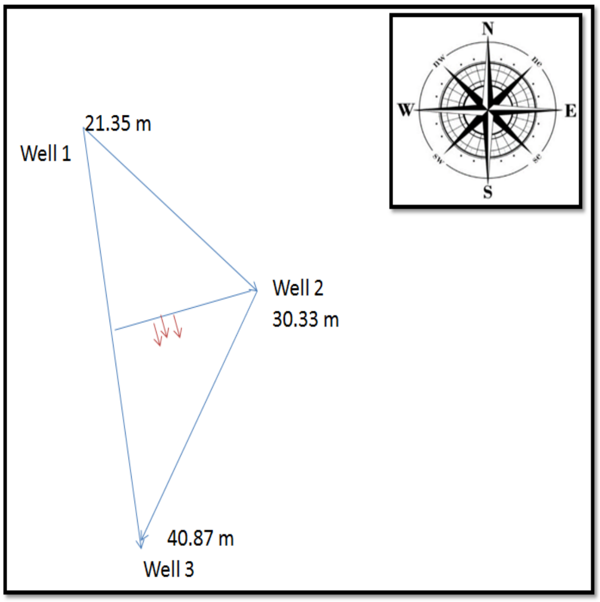

Figure 2: Manual determination of flow direction across sections of the study area

3. RESULTS AND DISCUSSION

3.1 RESULTS OF ELECTRICAL RESISTIVITY SURVEYS

Four pseudo sections were obtained from the plot of 2-D Wenner array data at four different traverses away from dump site, a typical one is as shown in Figure 3, its interpretation was based on the facts that contaminant plume has a low resistivity [15, 16].

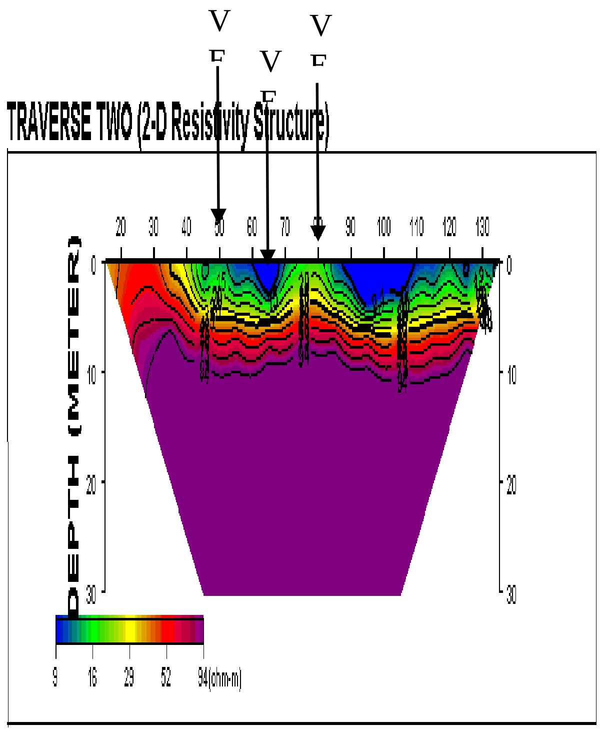

Figure 3: A typical field data pseudo section on traverse two with three VES points

Figure 3 depicted lateral variation of resistivity spreading to length of 140 m and to depth of 30 m. The resistivity ranges between 9 – 94 Ωm. Resistivity spread observed is of replica to other traverses which showed that the resistivity decreases upward, and north south. This implies increase in conductivity in such directions and as such indicating the leachate plumes could be more concentrated at the surface, northward and southward. This was confirmed by near surface low resistivity values at the upper part of the pseudo section. However, the direction of the contaminants could not be established on the pseudo section but a signature of resistivity distribution both horizontally and vertically may be confirmed especially with the low resistivity as a signage of leachate.

3.2 Result of Vertical Electrical sounding (VES)

Looking over the whole results obtained, the data reveal significant variations of electrical resistivity of the substratum testifying its heterogeneity. The depth of investigation reached was about 40 m maximum

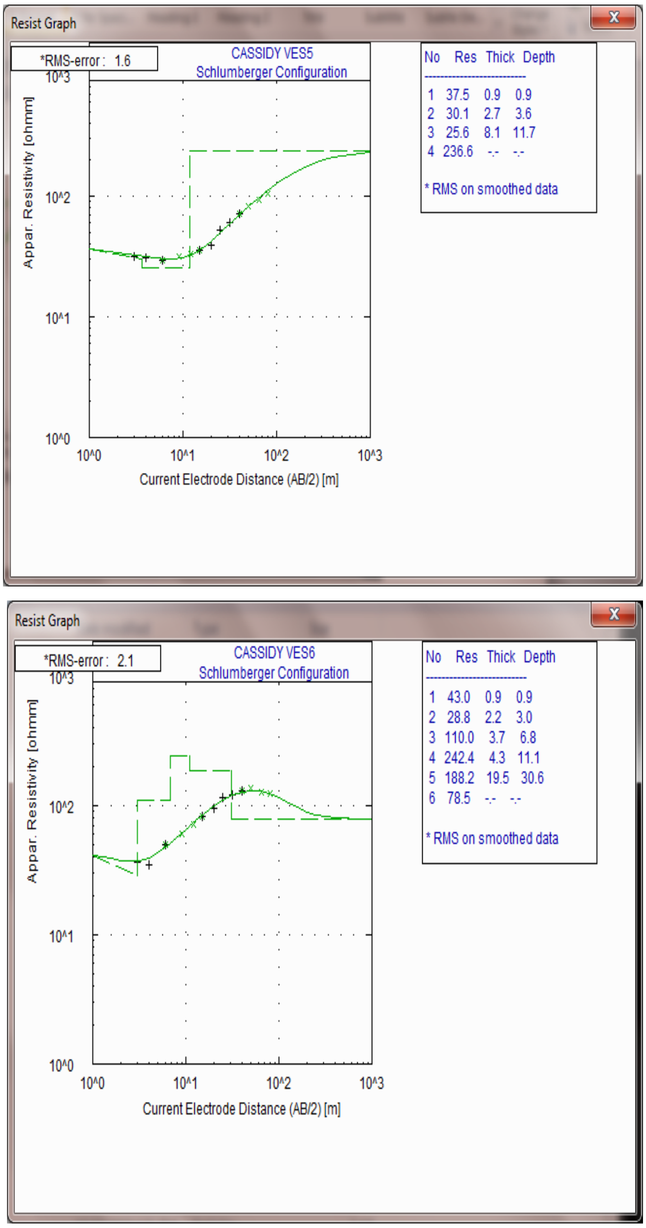

Figure 4: Samples of apparent resistivity curves obtained from the study area

The samples of apparent resistivity curves obtained from the interpretation of the twenty five (25) VES data

are as shown in Figure 4. The section reveals four to six geoelectric layers which varies from topsoil, peat/ clay, clayey sand, sandy clay and sand. The resistivity data obtained ranged between 13 - 519 Ωm with an average thicknesses between 0.8 to 34 m. From the curves obtained the top soil has resistivity in the range 13 to 221 Ωm and thicknesses ranged between 0.3 and 1.0 m. The second/third layers are most conductive and have dominance of low resistivity. A signature of peat/leachate (probable contaminant zone), resistivity ranging from 13 to 50 Ωm and the thicknesses undulate between 1 to 5 m.
The observations beneath the probable contaminant zones in most points are relatively high resistivity which could be potentials groundwater zones but not protected because of proximity to the leachates.

3.3 Result of Groundwater flow

The results obtained from the manual workings of the groundwater flow system within the study area shows that overall groundwater flow is dominantly from north-south. The data as tabulated (Table 1) suggest that groundwater will flow from higher elevation to lower elevation in the direction of maximum change in elevation.

Table 1: Parameters for Determination of Groundwater Flow Direction

WELL NO.	ELEVATION (m)	STATIC WATER LEVEL (m)	ELEVATION ABOVE THE SEA LEVEL (Total head) (m)
W1	23.0	1.65	21.35
W2	31.0	0.67	30.33
W3	44.0	2.13	41.87

4. CONCLUSION

Groundwater investigation using electrical resistivity method, a combination of vertical electric sound and electrical profiling has been conducted at few meters away from the Dumpsite situated in Cassidy, Okokomaiko, Lasu- Badagry Expressway, Lagos State South-Western Nigeria with the aim of depicting aquiferous zones in most ideal direction. Migration pattern of the contaminant was also established using manual groundwater flow method.

The interpreted results of the electrical resistivity effectively identified the existence of polluted zones from the surface down to about 5 m and strong tendencies of migrating deeper. Hence the aquiferous zones observed are not protected. The water elevation schematic figure of study area revealed that groundwater flows from the north toward the southern part of the region. The implication of this with respect to vulnerability to groundwater pollution is that the southern section of the aquifer is more susceptible to receive transported contaminants from the northern part of the study area. It is therefore advisable to site municipal boreholes in the north eastern while location of landfills and solid waste dumpsites should be restricted to the south-western sections of the study area. Thus non-invasive geo-electrical methods provide quick, efficient, and cost-effective methods for detecting, monitoring, and characterizing leachate migration patterns in dump sites environment.

ACKNOWLEDGEMENTS

We recognize the efforts of Mr Taofiq (UNILAG) and Mr Ponmile (UNILAG) for their support during the data acquisition on the field.

COMPETING INTERESTS

There is no competing interest.

AUTHORS' CONTRIBUTIONS

1st Author designed the project to provide solution to the problem. 2nd and 3rd Authors managed the field work. All Authors carried out the processing of the data, interpretation of the results and the discussions. All Authors wrote the first draft of the manuscript. All authors read and approved the final manuscript.

REFERENCES

1. Salako, A. O., & Adepelumi, A. A., "Aquifer, Classification and Characterization", IntechOpen, pp. 11-31, (2018).
2. Rosli, S., Nawawi, M.Z.M., Mohamad, E.T., "Groundwater detection in alluvium using 2-D electrical resistivity tomography (ERT)", Elec. J. Geotech. Engr. 17: 369-376, (2012).
3. Sunmonu, L.A., Olafisoye, E.R., Adagunodo, T.A., Alagbe, O.A., "Geophysical and hydrophysicochemical evaluation of hand-dug wells near a dumpsite in Oyo state, Nigeria." Arch. Appl. Sci. Res., 5 (6): 29-40, (2013).
4. Buddemeier, R.W. & Schloss, J.A., "Groundwater Storage and Flow", (2000) www.kgs.ku.edu.
5. Wehrmann H.A., "Groundwater Occurrence and Movement: An Introductory Discussion with Applicator to North-eastern Illinois, Centre for Groundwater Science Illinois State Water Survey", pp. 12- 45, (2007).
6. Oborie E. and Nwankwoala H.O., "Determination of Groundwater Flow Direction in Yenagoa, Bayelsa State, Nigeria". Journal of Scientific Achievements Vol. 2(9), pp: 23-27, (2017)
7. Adeoti, L., Bello, M.A., Olatinsu, O.B., Adiat, K.A.N., "Application of Geoelectrical and

Chemical methods for groundwater assessment. A Case Study of Isheri- North, Ogun state, Nigeria". Sci. Res. Ess. 35(1): 24-38, (2015).
8. Adeoti, L., Ijezie, N.T., Adegbola, R.B., Ojo, A.O., Afolabi. S.O., and Adesanya, O.Y., "Geoelectrical Investigation of Groundwater Potential at Riol Farm, Owode, Abeokuta, Ogun State",' J. Nig. Assoc. Math. Phys. 34: 4, 25 – 43, (2016).
9. Vafai, F., & Abolghasemi, H., "Investigation of sea and groundwater level changes on seawater intrusion in an unconfined coastal aquifer", Journal of Middle East Applied Science and Technology.(20), 684-688, (2014).
10. Joshi, S. D., "Hydrogeophysical Investigation of Contaminant Distribution at a Closed Landfill in Southwestern Ontario, Canada (M,Sc), University of Windsor, Canada, (2013).
11. Yang, J. W., & Joshi, S. D., "Hydro-Geophysical Investigation of Contaminant Distribution at a Closed Landfill in Southwestern Ontario, Canada", Journal of Geoscience and Environment Protection, 2, pp. 8-15, (2014).
12. Ojo, J. S., Olorunfemi, M. O., Aduwo, I. A., Bayode, S., Akintorinwa, O. J., Omosuyi, G. O., & Akinluyi, F. O., "Assessment of surface and groundwater quality of the Akure Metropolis, Southwestern Nigeria". Journal of Environment and Earth Science, Vol. 4, No. 23, pp. 150-168, (2014).
13. Olla, T. A., Akinlalu, A. A., Olayanju, G. M., Adelusi, A. O., & Adiat, K. A.. "Geophysical and Hydrochemical Investigation of a Municipal Dumpsite in Ibadan, Southwest Nigeria", *Journal of Environment and Earth Science, 5*(14), 99-112, (2015).
14. Alabi, A. A., Bello, R., Ogungbe, A. S., & Oyerinde, H. O., "DETERMINATION OF GROUND WATER POTENTIAL IN LAGOS STATE UNIVERSITY, OJO; USING GEOELECTRIC METHODS (Vertical electrical sounding and horizontal profiling)", Vol. 2, pp. 68-75, (2010).
15. Adepelumi, A.A., Ako, B. D., Afolabi, O. and Arubayi, J. B., “Delineation of Contamination Plume around Oxidation Sewage-ponds in Southwestern Nigeria” Environmental Geology 48, 1137 – 1146, (2005).
16. Bayode S., Olorunfemi M. O. and Ojo, J. S., “Geoelectric Mapping of Some Ancient Dumpsites and the Associated Pollution Plume in Akure Metropolis, Southwestern Nigeria”, International Journal of Physical Science Vol. 3, No.1, pp 68 – 80, (2011).