PAPER • **OPEN ACCESS**

Investigation of groundwater contamination from leachate migration: a case study of Bowen University dumpsite, Nigeria

To cite this article: O. O. Ajani *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **655** 012069

Investigation of groundwater contamination from leachate migration: a case study of Bowen University dumpsite, Nigeria

O. O. Ajani [1, 2], T. A. Adagunodo [3], A. A. Adeniji [1, 2], B. Fashae [1, 2], M. Omeje [3], O. O. Adewoyin [3]

[1] Department of Physics and Solar Energy, Bowen University, Iwo, Nigeria
[2] Space and Geoscience Research Observatory, Bowen University
[3]Department of Physics, Covenant University, Ota, Nigeria
Correspondence: adetunji.adeniji@bowen.edu.ng; theophilus.adagunodo@covenantuniversity.edu.ng

Abstract. A microstudy of soil physical properties in combination with geoelectric delineation were adopted for the evaluation of groundwater contamination prospect from leachate migration at Bowen University dumpsite location. Samples of soil were collected from five different locations, with five locations within the dumpsite and one control sample which is 200 m far away from the dumpsite locations. A core sampler which is attached to the soil auger is used to obtain each sample within 60 cm depth. Each sample is collected into a sample bag and properly labeled for laboratory analysis. Schlumberger electrode configuration was employed for the survey spread to delineate total of four (4) Vertical electrical sounding (VES) points with electrode spacing varying 60 to 100 m. This was done to obtain resistivity, thickness and depth within the dumpsite location. The results of the average value of the soil properties between the control and the dumpsite are compared such that the soil properties for control site reveal a bulk density (BD) of 1.45 g/cm^3, particle density (PD) of 2.63 g/cm^3 and porosity (PO) of 44.90%, respectively. Whereas, the mean soil properties of the dumpsite show that BD is 1.35 g/cm^3, PD is 2.93 g/cm^3, and PO is 54.07%, respectively. This signifies that the control location has high BD, low PD and low PO, while the dumpsite reveals an inverse of the control results. Also, the results from the interpreted VES data reveal the prospect of migration of contaminants from the topsoil to the alluvium, which could further percolate to the aquifer with time. It could be concluded that groundwater contamination is feasible within the study area, since an alluvium and porous soils could permit leachate migration to the aquifer.

Keywords: Groundwater contamination; Geoelectric sounding; Soil analysis; Leachate migration; Dumpsite; Vertical electrical resistivity sounding (VERS)

1. INTRODUCTION

The presence of contaminant in groundwater for industrial and domestic accomplishment can lead to a high severe risk on human health. The [42] has linked diseases which includes cholera, polio, diarrhea, typhoid, and dysentery, has some of the side effect of consuming water with contaminant and poor. The importance of groundwater to human cannot be over emphasized [38]. It is found useful both in households, farms, industries, and other essential places. The need to carry out investigation into groundwater exploitation especially areas with dumpsite facilities is crucial since the contaminant can migrate from topsoil to the aquifer. The contamination of groundwater in dumpsite facility has been attributed to the presence of leachate contaminant potential from the waste body. [26] defined leachate has serious pollutant existing from liquid embodiment of solid waste which affect the groundwater, human health and also the water bodies. [20] reported that these leachates are either suspensions or solutions of stabilized, basic and important organic or inorganic composite of biodegradation of solid wastes moving out from the dumpsite environment when saturated with rainwater continuously. [11] revealed that leachate present in municipal solid waste location are mostly accompanied with high ion concentrations and as a result shows very low resistivities. In this regard the geoelectrical method has been made very acceptable in mapping the extent of contamination of leachate. [36] have associated surface geophysical survey as a method suitable to locate leaches plume migration pathways due to the fact that it helps in acquiring physical properties of the waste disposal site. [15] also reported inadequate and low quality management of solid waste disposal drastically affects the environment leading to serious and diverse public health related hazard like communicable diseases and periodic epidemics

Generally, soil physical properties are important factors while evaluating the rate of leachate migration within the soil and down the groundwater. The study of soil physical properties such as classification of texture, distribution of the size of particles, porosity, moisture content, permeability and bulk density is essential due to the fact that they represent the parameter influence the flow pattern of leachate contamination into the soil. According to [14], buried waste is subjected to leaching by percolating surfacewater, groundwater or rainwater with the dumpsite environment. [34] also reported that the migration of leachate into the groundwater may enact dangerous difficulties with the present of heavy metal within the unsanitary land filling of solid waste which result in significant environmental related risk on soil and groundwater contamination. The present study utilized the microstudy of soil properties in combination with the vertical electrical sounding (VES) methods with the aim to evaluate leachate migration on groundwater resources**.** The VES helped to delineating some geophysical parameters such as the electrical properties, the basement pattern configuration, the distribution of fractures, and determination of overburden thickness. The microstudy of soil properties also helped in bulk density determination, particle density determination and porosity determination. Further works on groundwater quality are documented by [30], [2], [3], [21], [4], [8], and [7]

The study area is on the SW Basement complex of Nigeria (Fig. 1), which is chiefly composed of metamorphic and Precambrian basement complex [33] comprising predominantly migmatized and undifferentiated gneisses, schist, older-granite, dolorite, dykes, charnockitic rocks and quartzite of Precambrian age [19]; [36], [37]. [29] reported that the Precambrian Basement rocks of SW are grouped into Migmatite-Gneiss, metasedimentary and metavolcanic rocks (which is also referred to as Schist Belt), and Pan-African Older Granite which then characterized the geological units of Iwo.

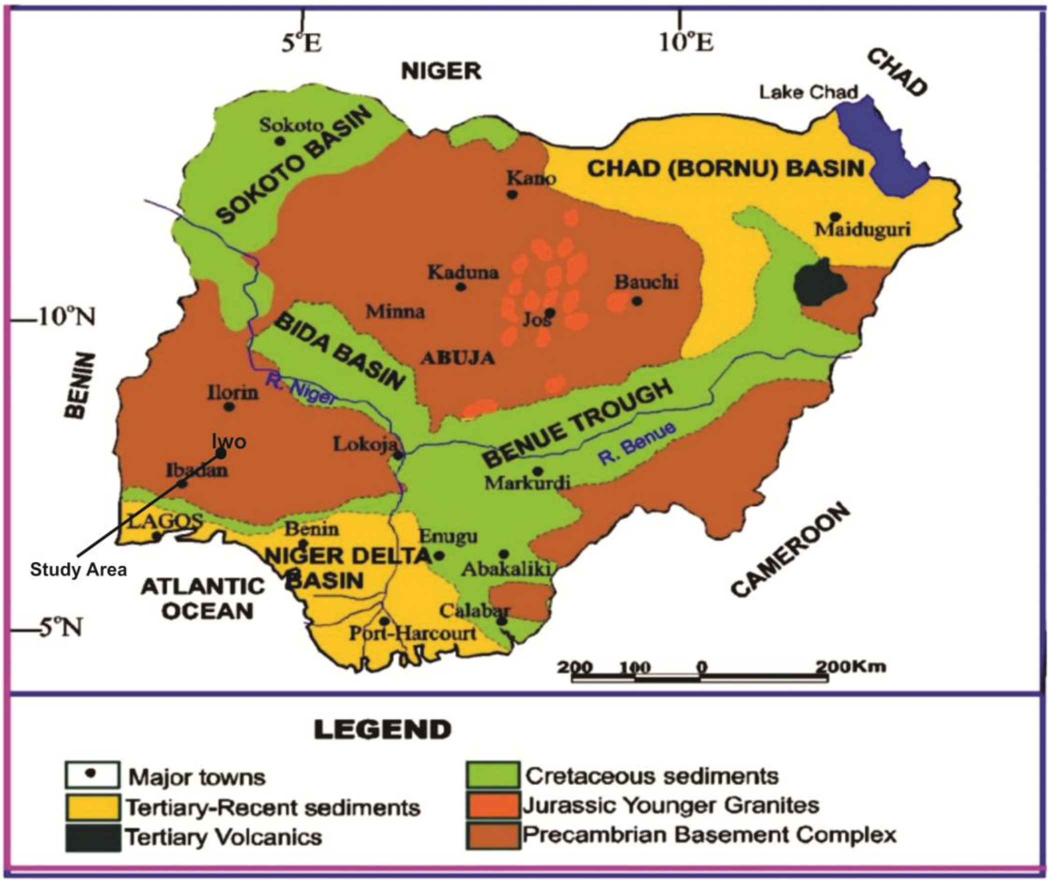

Fig. 1: Geological map of Nigeria indicating the study area [27].

2. MATERIALS AND METHODS

The study was performed within Bowen University, Iwo, over an area lying within latitude $7°\,50'$ to $8°\,00'$ N and longitude $4°\,00'$ to $5°\,00'$ E as shown from Fig. 2. The determination of BD, PD and PO were carried out from the microstudy of the soil properties. Samples of soil were obtained from selected wells-dug within the dumpsite location and also a preferred control well-dug (non-dumpsite) at depth of 60 cm as shown from the layout map in Fig. 2, using a core sampler which is attached to a soil auger. The control well-dug sample was taken at distance of 200 meters away from the dumpsite. The soil obtained from the different location was firmly tied in a sample bag and labelled for laboratory analysis.

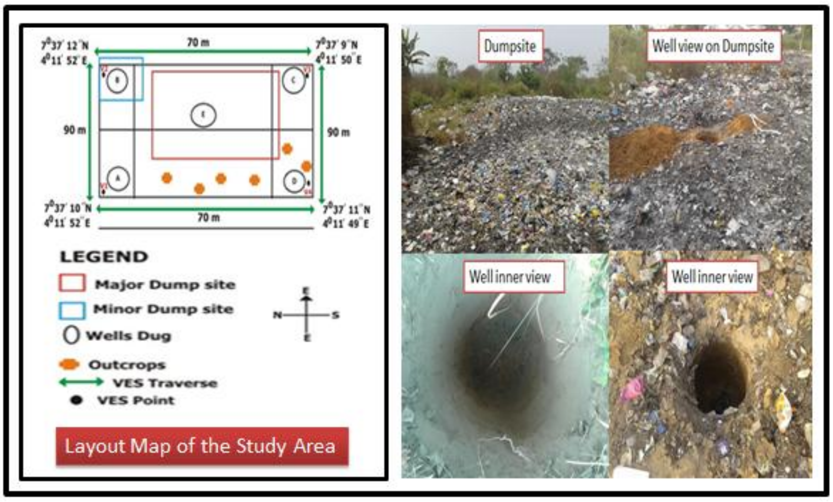

Fig. 2: Layout view of the study area.

The geophysical survey of the study was carried out using electrical resistivity method (ERM) employing the Schlumberger electrical array [43] (Fig. 3).

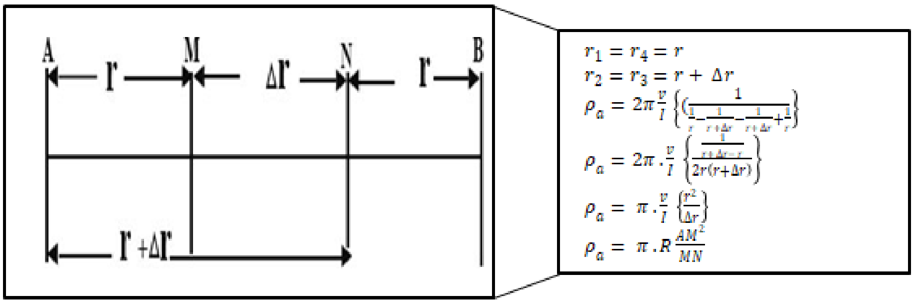

Fig. 3: Schlumberger electrical array [9]

2.1 Microstudy of Soil Properties

Determination of BD: BD is determined by calculating the density of the oven dry soil as a whole which includes solids and pore space. DB $= \frac{W_S}{V_t}$. Where Ws = Sample oven dry mass (g) and Vt = Sample total volume, solid volume + pore volume (cm^3).

Determination of PD: PD is determined only by the dry soil weight per unit volume of the soil solids. The pore space is neglected when considering the volume measurement.

Determination of PO: PO or void fraction (VF) of soil is determined by the measure of the void (empty) spaces in the soil. It is also the fraction of the voids volume over the total volume between 0 and 1, i.e as a percentage between 0 and 100%. The porosity of the soil is related to both the soil bulk density and particle density as shown in equation. $P_S = \frac{VP}{VT}$ and$P_S = 1 = \frac{DB}{DP}$ Vp = Volume of the pores and Vt = Total volume of the sample, solid volume + pore volume (cm^3).

2.2 Electrical Resistivity Method

According to [17], the theory of Ohm's law is reported to be the basis for electrical resistivity foundation. The theory is based on how current flows through a metallic conductor, which is directly proportional to the potential difference between its terminal points, provided that the temperature and other physical state or quantities remain, unchanged. Mathematically, the voltage is giving as: $V = IR$. (V= potential difference in volts (V); I = current in ampere (A); R = constant known as resistance in ohms (Ω)). An apparent resistivity (ρa) value can be deduced from the values of the current (I) and voltage (V) respectively. This can be represented by $\rho a = k\frac{V}{I}$ (the geometric factor is giving as K). The geometric factor 'k' depends on the arrangement of the electrodes spread. The Resistivity meters also known as Terrameter usually reveal the value of resistance to be $R = \frac{V}{I}$. In regards to this, the value of the apparent resistivity is determine by $\rho a = KR$

Four (4) VES stations were occupied along north-west direction as shown in Fig. 2. The electrical method was established withcurrent electrode spacing of maximum half width (AB/2), with interval 45 to 65 m which depends on the spread allowance and depth to basement. This was validated from [40] by varying the spread allowance between the current electrodes to ensure that the current penetrating changes with respect to depth range.

Geoelectrical sounding data was interpreted automatedly and the auxiliary and theoretical curves [22], [23] were curve matched in order to acquire the observed thicknesses, resistivity and depth values of each respective layers [1], [5], [6], [10], [18]. Forward modeling computer algorithm, WinResist version 1.0 software [41] was used to further processed the geoelectrical parameters in order to have an output results with low root mean square (RMS) values

3. RESULTS AND DISCUSSION

3.1 Results for Soil Properties

Table 1: Showing the Average BD, PD and PO of uncompacted soil per Wells-dug

Soil	ABD Compacted Soil (g/cm^3)	APD Compacted Soil (g/cm^3)	APo Compacted Soil (g/cm^3)
CONTROL	1.45	2.63	44.90
WELL A	1.41	2.78	49.64
WELL B	1.32	2.94	55.06
WELL C	1.41	2.86	51.38
WELL D	1.26	2.94	57.22
WELL E	1.36	3.13	57.03

Note: ABD = Average Bulk Density
APD = Average Particle Density
APo = Average Porosity

Table 2: Showing the Average percentage of BD, PD and PO of uncompacted soil per Wells-dug per %

Soil	ABD Compacted Soil (g/cm^3) per %	APD Compacted Soil (g/cm^3)per %	APo Compacted Soil (g/cm^3)per %
CONTROL	18 %	15 %	14 %
WELL A	17 %	16 %	16 %
WELL B	16 %	17%	18 %
WELL C	17 %	17%	16%
WELL D	15 %	17%	18 %
WELL E	17 %	18%	18 %

Note: ABD = Average Bulk Density
APD = Average Particle Density
APo = Average Porosity

3.2 Discussion of Soil Properties Results

Effect of dumpsite on Bulk Density (BD): The results revealed that the average controlled well (non-dumpsite) recorded the higher BD (1.45 gcm^{-3}) when compared with other well-dug (wells A – E) samples within the dumpsite with values of 1.41, 1.32, 1.41, 1.26, 1.36 (g/cm^3) (Table 1). This is in line with the study of [25] and [28], where they observed higher BD in wells outside the dumpsite than those within the vicinity of the dump.

Effect of dumpsite on Particle Density (PD): PD is determined by the weight per volume of the solid portion of the soil. (Table 1) shows the results for the average particle density with the average control well (non-dumpsite) having the lowest PD (2.63) when compare with other well-dug (wells A – E), with values of 2.78, 2.94, 2.86, 2.94, 3.13 (g/cm^3) respectively within the study area. In this regards [16] reported that to characterize the soil particle density of a usual mineral soil, a standard value of 2.65 g/cm^3 has been recommended and if enormous evaluation of heavy minerals such as limonite, hematite and magnetite are present in the soil, the particle density will be increased.

Effect of dumpsite Porosity (PO): PO is calculated from the BD and PD respectively. It is the amount of void space or air space between soil particles. It is also called the volume of soil voids that can fill air or water. The result of the average PO (Table 2), shows that the average control well also has the least percentage value (44.90 %) when compare with other well-dug (wells A – E) within the located area (49.65 %, 55.06 %, 51.38 %, 57.22 %, 57.03 %). In regards to this, [12] reported that the differences in soil total porosity has been view to varying organic matter content of the sites such as leachates. This is because higher organic matter helps to build soil aggregates and increasing pore space.

3.3 Results for VES

Table 3: showing the detailed resistivity, thickness and depth of VES points

VS	L	R (Ωm)	T (m)	D (m)	LU
VES 1	1	1313.8	3.4	3.4	Lateritic topsoil
	2	136.1	6.6	10.0	Alluvium/ Groundwater
	3	3063.3	14.5	24.5	Fresh basement
	4	7211.0	-	-	Fresh basement
VES 2	1	419.1	1.8	1.8	Lateritic topsoil
	2	69.0	4.2	6.0	Groundwater (fresh)
	3	6311.6	645.4	651.3	Fresh basement
	4	1640.9	-	-	Fresh basement
VES 3	1	357.4	1.3	1.3	Lateritic topsoil
	2	60.1	2.8	4.1	Groundwater (fresh)
	3	5428.4	15.4	19.4	Fresh basement
	4	8424.8	-	-	Fresh basement
VES 4	1	689.3	1.8	1.8	Lateritic topsoil
	2	126.6	6.4	8.2	Alluvium/ Groundwater
	3	1751.8	12.3	20.5	Fresh basement
	4	2985.0	-	-	Fresh basement

Note VS = VES Station
L = Layers(s)
R = Resistivity
T = Thickness
D = Depth
LU = Lithology Units

3.4 Discussion of VES Results

The interpretation of the VES results was presented as resistivity, thickness and depth and four layered model was observed respectively. From (Table 3), it was observed that the top soil with depth ranging 1.3 to 3.4 m while weathered layer has a depth varying 4.1 to 10 m. In addition, VES 1 and VES 4 both layered 2, with resistivity value of 136.1 and 126.6 showed that there is a presence of alluvium due to the flowing of water to the subsurface. Also, from VES 2 and VES 3 with layered 2 respectively, it was observed that groundwater prospect is visible within the locations with resistivity of 69.0 and 60.1 respectively. The observed feature in VES 1 layered 1 with resistivity of 1313.8 shows the present of a laterite as reported by [39]. Laterites are composed principally of the oxides of aluminum, manganese, titanium and iron which are weathered material. They range from earthy, soft and porous soil to hard dense rock.The result of modeled resist graph of VES 1 to VES 4 with layered 3 to 4 shows that the study area is classified with metamorphic or igneous rock. Therefore, since the observed results revealed the present of alluvium due to present of flowing water to the subsurface, and also revealed the prospect of groundwater within the study area, leachate migration is thus visible within the study area.

3.5 Correlation Observed from the Results

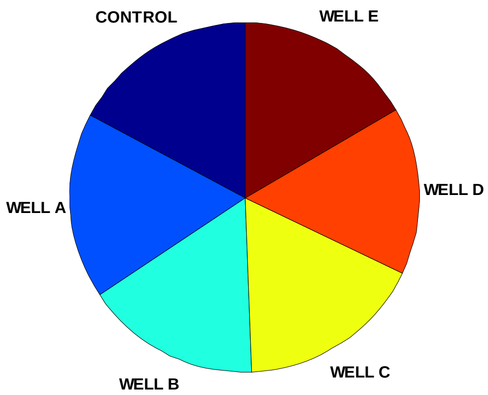

Fig. 4a: Statistical Modeling of Pie Chart Showing the Average BD

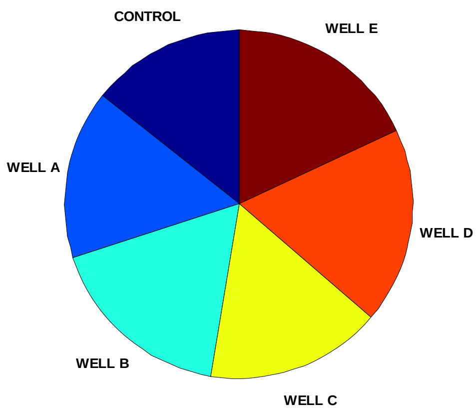

Fig. 4c: Statistical Modeling of Pie Chart Showing the average PO

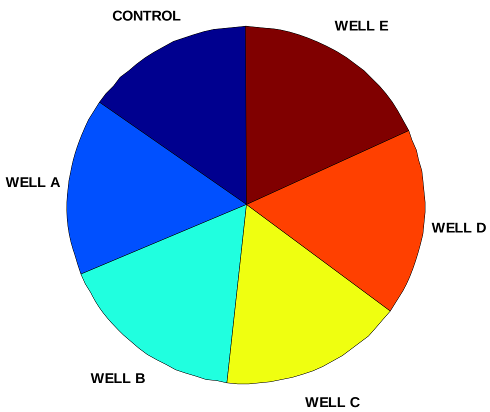

Fig. 4b: Statistical Modeling of Pie Chart Showing the Average PD

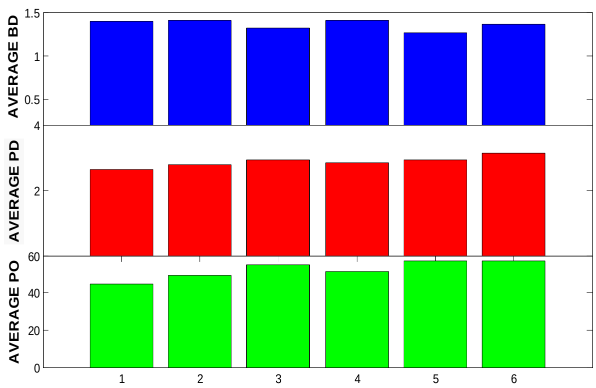

Fig. 4d: Statistical Modeling of Bar Chart Showing the Average BD, PD and PO

3.6 Discussion of the Statistical Modeling Observations

The statistical models (Fig. 4a - d) were based on the average percentage modeled results derived for BD, PD and PO (Table 2). It was observed that the control well-dug as the average highest percentage BD when compared with the average percentage of PD and PO. This is due to the fact that dumpsite areas has effect and reduces the BD of soil. The model also revealed that PD and PO were higher in average percentage within the dumpsite locations when compared with the control well-dug location. This suggested that locations with high percentage porosity and permeability encourage the seepage of leachate as reported by [31].

3.7 Geoelectrical Modeling Observations

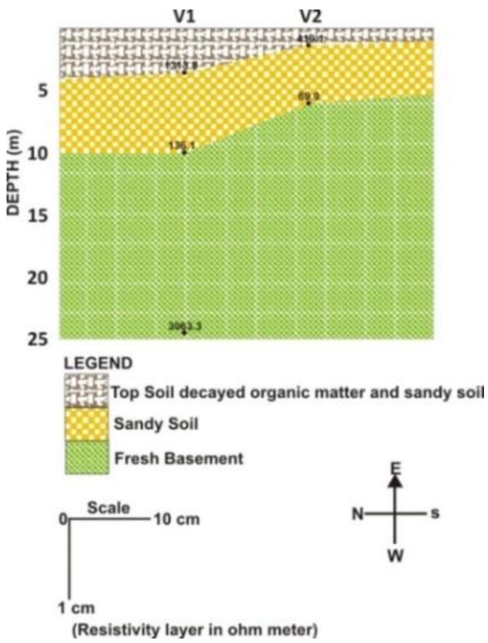

Fig. 5a: Modeled Geoelectric section Beneath VES 1 and 2

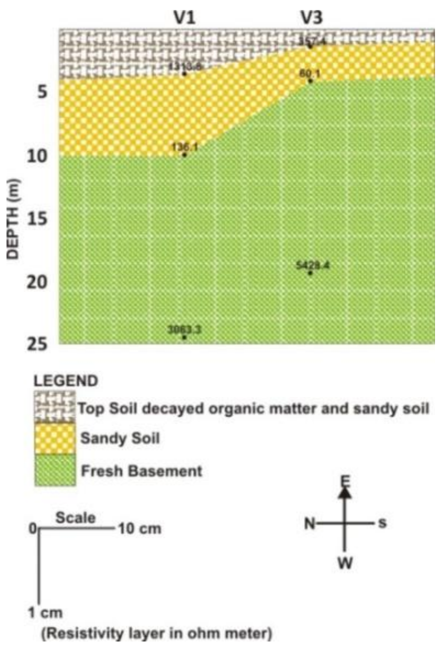

Fig. 5b: Modeled Geoelectric section Beneath VES 1 and 3

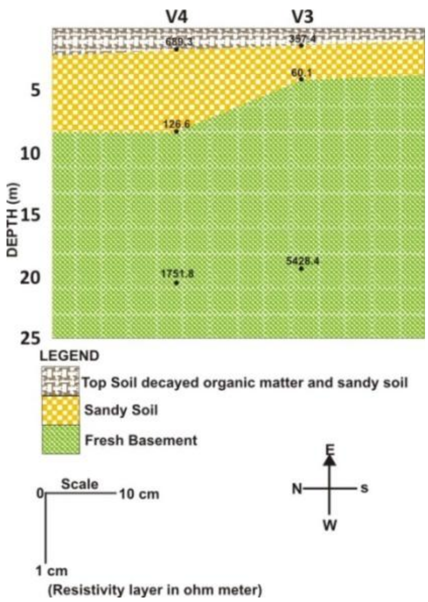

Fig. 5c: Modeled Geoelectric section Beneath VES 4 and 3

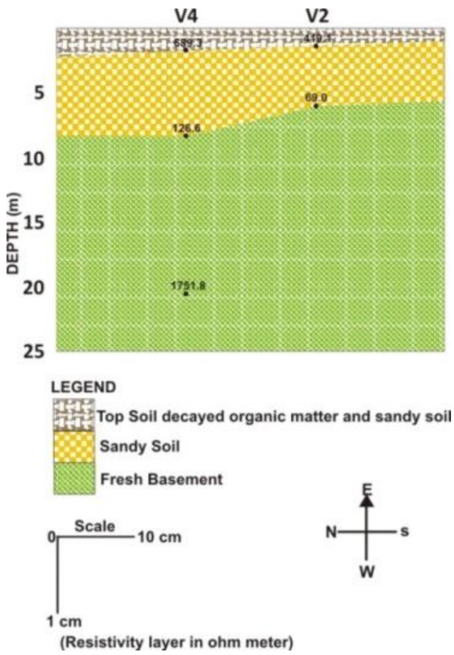

Fig. 5d: Modeled Geoelectric section Beneath VES 4 and 2

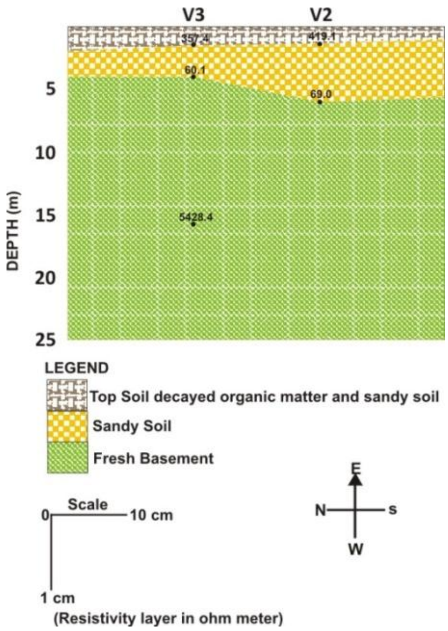

Fig. 5e: Modeled Geoelectric section Beneath VES 3 and 2

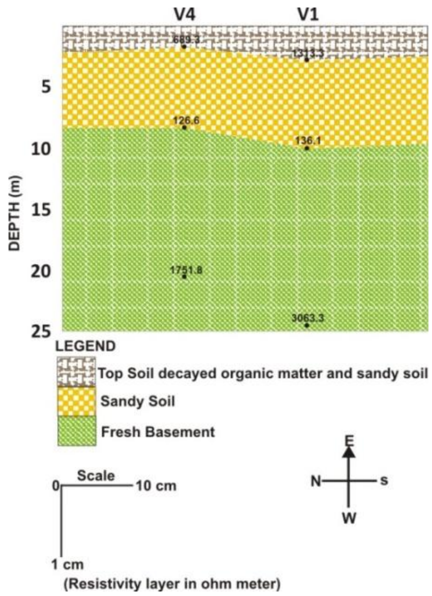

Fig. 5f: Modeled Geoelectric section Beneath VES 4 and 1

3.8 Discussion of Geoelectrical Modeling Observations

The variations in the subsurface resistivity are primarily reflected by the electrical method [32]. The electrical resistivity variations between lithological orders [13], [24] within the subsurface structure are often satisfied to affirm the delineation of the geoelectric layers and also identify the aquifer or non-aquifer zones [35]. Three geoelectric layers were reveals from the VES interpretation, which comprises of the topsoil consisting of decomposed organic matters and sand soil; the weathered layer which is made up of alluvium and sandy soil and the third layer constituting the bedrock which is majorly the fresh basement as shown in (Fig. 5a – f). The geoelectric sections reveal the variation in the electrical resistivity along the profiles and attempt to correlate the geoelectric sections across the profiles. However, low resistivity values represented in these layers are subjected to pollution which resulted from the high permeability and porosity of sandy/alluvium soil characteristics which encouraged the seepages of the leachate plumes to a maximum depth of 24.5 m within the subsurface but extreme at VES 3 to maximum depth of 651.3 m. Low resistivity value of 60.1 Ωm and 69.0 Ωm were revealed at the dumpsite where older wastes are deposited beneath the region of VES 2 and 3 with layer 2 respectively. It was also reveals that at VES 1 and 4, an elevation in the resistivity values was observed. This was deduced as a result of the leachate originated from the environment where older wastes deposit are migrated and spread out in all direction thereby polluting the subsurface surrounding in the process. The geoelectric observations principally served as the first investigation within the study area.

4. CONCLUSION

Going by the correlations observed from the statistical models generated from the microstudy of the soil properties and the geoelectrical models interpretations, it can be concluded that groundwater contamination is possible within the study area since an alluvium and porous soil allows the flow of surface water from the topsoil into the subsurface at different depth which then can allow the leachate from the dumpsite to migrate to the groundwater table. Periodic water samples analysis from groundwater sources should be recommended within the study area so as to build on the possibilities of contamination that can result since nobody canpredict the specific time the contaminant can affect the groundwater in the study area. This will help to ensure that constant intake of quality portable water consumption is available for some years before the water-table is contaminated.

ACKNOWLEDGMENT

We appreciate the publication support received from Covenant University, Nigeria. We acknowledge the support for the use of field facilities from AA Delve Company and Allied Associate Geophysical LTD.

REFERENCES

[1]. Adagunodo T.A., Adeniji A.A., Erinle A.V., Akinwumi S.A., Adewoyin O.O., Joel E.S., Kayode O.T. (2017). Geophysical Investigation into the Integrity of a Reclaimed Open Dumpsite for Civil Engineering Purpose. Interciencia Journal, 42(11): 324 – 339.

[2]. Adagunodo Theophilus Aanuoluwa (2017a). Groundwater Contamination: Performance, Effects, Limitations and Control. Chapter 3 in Book: Groundwater Contamination: Performance, Limitations and Impacts, 1 – 135. ISBN: 978-1-153611-017-3; 978-1-53611-003-6.

[3]. Adagunodo Theophilus Aanuoluwa (2017b). Groundwater Pollution and Control: An Overview. Chapter 1 in Book: Groundwater Contamination: Performance, Limitations and Impacts, 1 – 135. ISBN: 978-1-153611-017-3; 978-1-53611-003-6.

[4]. Adagunodo T.A. (2018). Simple Approach to Groundwater study for Domestic uses in RuralArea. Journal of Fundamental and Applied Sciences, 10(3): 129 143.http://dx.doi.org/10.4314/jfas.v10i3.11.

[5]. Adagunodo T.A., Akinloye M.K., Sunmonu L.A., Aizebeokhai A.P., Oyeyemi K.D., Abodunrin F.O. (2018a). Groundwater Exploration in Aaba Residential Area of Akure, Nigeria. Frontiers in Earth Science, 6: 66. https://doi.org/10.3389/feart.2018.00066.

[6]. Adagunodo T.A., Sunmonu L.A., Oladejo O.P., Hammed O.S., Oyeyemi K.D., Kayode O.T. (2018b). Site Characterization of Ayetoro Housing Scheme, Oyo, Nigeria. IOP Conference Series: Earth and Environmental Science, 173: 012031. https://doi.org/10.1088/1755-1315/173/1/012031.

[7]. Adagunodo T.A., Adejumo R.O., Olanrewaju A.M. (2019). Geochemical Classification of GroundwaterSystem in a Rural Area of Nigeria. In: Chaminé H., Barbieri M., Kisi O., Chen M., Merkel B. (eds) Advances in Sustainable and Environmental Hydrology, Hydrogeology, Hydrochemistry and Water Resources. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham. https://doi.org/10.1007/978-3-030-01572-5_31.

[8]. Adejumo R.O., Adagunodo T.A., Bility H., Lukman A.F., Isibor P.O. (2018). Physicochemical Constituents of Groundwater and its Quality in Crystalline Bedrock, Nigeria. International Journal of Civil Engineering and Technology, 9(8): 887 – 903.
[9]. Bakhtiar Q.A. (2010). Note on Introduction to Electrical Resistivity. University of Sulaimani, Iraq.
[10]. Bayowa O.G., Adagunodo T.A., Adewoyin O.O. (2019). Geoelectrical investigation of foundation failure in Akowonjo, Ogbomoso, Nigeria. IOP Conf. Series: Earth and Environmental Science, 331: 012065. https://doi.org/10.1088/1755-1315/331/1/012065.
[11]. Bernstone C., Dahlin T., Ohlsson T., Hogland W. (2000). DC-resistivity mapping of internal landfill Structure: two pre-excavation surveys. Environ Geol. 39: 3-4.
[12]. Brevik EC., Cerda A., Mataix-Solera J., Pereg L., Quinton JN., Six J., Can Oost K. (2015). The Interdisciplinary nature of soil, 1: 117 – 129.
[13]. Dodds A.R., Ivic D. (1988). Integrated Geophysical Methods Used for Groundwater Studies in the Murray Basin, South Australia. In: Geotechnical and Environmental Studies. Geophysics, Vol. II. Society of Exploration Geophysics, Tulsa, OK. 303-310.
[14]. Eslamian S.S., Shaeri K.S., Eslamian F. (2011). A country case study comparison on groundwater and surface water interaction. Int. J. Water, 6: 117-136.
[15]. Fasunwon O.O., Jaiyeola G.B., Adesugba F.F. (2010). Impacts of a dumpsite on the Neighborhood of a part of Southwestern, Nigeria. Journal of Agriculture and Biology Sciences, 6(3): 204-214.
[16]. Freeze R.A. and Cherry J.A. (1979).Ground Water. Englewood cliffs, NJ: Prentice-Hall.
[17]. Grant F.S. and West G.F. (1965). Interpretation Theory in Applied Geophysics. McGraw-Hill, New York.
[18]. Joel E.S., Olasehinde P.I., Adagunodo T.A., Omeje M., Oha I., Akinyemi M.L., Olawole O.C. (2020). Geo-investigation on Groundwater Control in some parts of Ogun State using Data from Shuttle Radar Topography Mission and Vertical Electrical Soundings. Heliyon, 6(1): e03327. https://doi.org/10.1016/j.heliyon.2020.e03327
[19]. Jones H. and Hockey R. (1964). "The Geology of Southwestern Nigeria," Geology .Survey of Nigeria Bull, 31: 101.
[20]. Kassenga G.R. and Mbluligwe S.E. (2009). Impacts of a Solid waste Disposal Site on Soil, Surface Water and Groundwater Quality in Dar es Salaam city, Tanzania. Journal of Sustainable Development in Africa, 10(4): 7394.
[21]. Kayode O.T., Odukoya A.M. and Adagunodo T.A. (2017). Saline Water Intrusion: Its Management and Control. Journal of Informatics and Mathematical Sciences, 9(2): 493 – 499.
[22]. Keller G.V. and Frishchnecht F.C. (1966). Electrical Methods in Geophysical Prospecting. Pergamon Press: New York, NY. 96.
[23]. Koefoed O. (1979). Geosounding Principles, 1.Resistivity Sounding Measurements. Elsevier Scientific Publishing: Amsterdam, Netherlands. 275.
[24]. Lashkarripour G.R. (2003). An investigation of Groundwater Condition by Geoelectrical Resistivity Method: A Case study in Korin Aquifer, Southeast, Iran. Journal of Spacial Hydrology, 3(1): 1-5.
[25]. Njoku C. and Okoro G.C. (2015). Effect of flooding on soil properties in Abakaliki Eastern Nigeria. Scholarly Journal of Agricultural Science, 5(5): 165 – 168.

[26]. Nwankwoala H.O. and Onukogu V.K. (2018). Characterization and Environmental Assessment of Leachates Generated Around Solid Waste Disposal Sites in Port Harcourt, Nigeria. Journal of Waste Management and Disposal, 1: 104

[27]. Obaje N.G. (2009). Geology and mineral resources of Nigeria. *Lecture notes in earth sciences*, 120: 221.

[28]. Okonkwo C.L., Arinzechuwu P., Njoku C. (2013). Changes in Physical and Chemical Properties of Soil in Timber Saw Mill Dumpsite. British Journal of Environmental and Climate Changes, 3(2): 215 – 228

[29]. Oladejo O.P., Adagunodo T.A., Sunmonu L.A., Adabanija M.A., Isibor P.O., Enemuwe C.A. (2020). Aeromagnetic mapping of fault architecture along Lagos-Ore axis, southwestern Nigeria. Open Geosciences, 10.1515/geo-2020-0100.

[30]. Olafisoye E.R., Sunmonu L.A., Ojoawo A., Adagunodo T.A. and Oladejo O.P. (2012). Application of Very Low Frequency Electromagnetic and Hydro-physicochemical Methods in the Investigation of Groundwater Contamination at Aarada Waste Disposal Site, Ogbomoso, Southwestern Nigeria. *Australian Journal of Basic and Applied Sciences*, 6(8): 401–409.

[31]. Olafisoye E.R., Sunmonu L.A., Adagunodo T.A., Oladejo O.P. (2013). Impact Assessment of Solid Waste on Groundwater: A Case Study Of Aarada Dumpsite, Nigeria. ARPN Journal of Earth Sciences, 2(2): 45-53

[32]. Omosuyi G.O., Adeyemo A., Adegoke A.O. (2007). Investigation of Groundwater Prospect using Electromagnetic and Geoelectric Sounding at Afunbiowo, near Akure, Southwestern Nigeria.

[33]. Rahaman, M.A., (1976). Review of the basement Geology of Southwestern Nigeria. In: Geology of Nigeria. Kogbe C.A., (Ed). Elizabeth Publishing Lagos Nigeria. 20-41.

[34]. Raman N. and Sathiya D.N. (2008). Impact of Solid Waste Effect on Ground Water and Soil Quality nearer to Pallavaram Solid Waste Landfill Site in Chennai. Rasayan Journal of Chemistry, 1(4): 828-836.

[35]. Schwarz S.D. (1988). Application of Geophysical Methods to Groundwater exploration in the Tolt River Basin, Washington State. In: Geotechnical and Environmental Studies. Geophysics, Vol. II.Society of Exploration Geophysics, Tulsa, OK. 213-217.

[36]. Sunmonu L.A., Adagunodo T.A., Olafisoye E.R., Oladejo O.P. (2012). The Groundwater Potential Evaluation at Industrial Estate Ogbomoso, Southwestern Nigeria. RMZ-Materials and Geoenvironment, 59(4): 363-390.

[37]. Sunmonu, L.A., Alagbe, O.A., Mabunmi, S.A., Adeniji, A.A., and Olasunkanmi, N.K., (2013). Geophysical Investigation into the Cause(s) of Structural Failure within BACOSA and Faculty of Science Buildings, Bowen University Temporary Site, Iwo. *Advances in Physics Theories and Applications*. 25: 1-17.

[38]. Sunmonu L.A., Adagunodo T.A., Adeniji A.A., Oladejo O.P., Alagbe O.A. (2015). Geoelectric Delineation of Aquifer Pattern in Crystalline Bedrock. Open Transactions on Geosciences, 2(1): 1 - 16

[39]. Sunmonu L.A., Adagunodo T.A., Adeniji A.A., Ajani O.O. (2018). Geoimaging of subsurface fabric in Awgbagba, Southwestern Nigeria using geomagnetic and geoelectrical techniques. Malaysian Journal of Fundamental and Applied Sciences, 14(2): 312-324

[40]. Telford W.M., Geldart L.P., Sherif R.E. and Keys D.A. (1976). Resistivity Methods, Applied Geophysics. Cambridge University Press, and Cambridge. 632 – 701.

[41]. Vander Velpen B. P. A. (2004). WinRESIST Version 1.0. Resistivity Sounding Interpretation Software. M.Sc. Research Project, ITC, Delft Netherland.

IOP Conf. Series: Earth and Environmental Science **655** (2021) 012069 doi:10.1088/1755-1315/655/1/012069

[42]. World Health Organization (WHO), (2015). Guidelines for Drinking water Quality; Final Task Group Meeting; WHO: Geneva, Switzerland. [Google Scholar]

[43]. Zohdy A.A.R., Eaton G.P., Mabey D.R. (1974). Application of Surface Geophysics to Groundwater Investigations. Techniques of Water Resources Investigations of U.S. Geol. Survey: Book 2, Chapter DI. U.S. Government Printing Office: Washington, D.C., USA. 66.