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MULTI-CRITERIA ANALYSIS METHOD FOR AQUIFER VULNERABILITY INVESTIGATION USING GODT METHOD AT IDI-AYUNRE, IBADAN, SOUTHWESTERN NIGERIA

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ABSTRACT: *Geophysical investigation involving Vertical Electrical Sounding (VES) Schlumberger array was carried out across Idi-Ayunre, Ibadan, a typical basement complex area having a rock composition of migmatite-gneiss, quartzite, and biotite-hornblende. A total of forty (40) vertical electrical sounding data were acquired with maximum current electrode separation of 100m using resistivity meter and its accessories. The aim of the study was to evaluate the aquifer vulnerability of the study area to contamination. The VES results were both qualitatively and quantitatively interpreted using partial curve matching and were further subjected to computer iteration using WINRESIST. The longitudinal conductance, thickness of layer overlying aquifer and hydraulic conductivity were generated and synthesized to produce the vulnerability map. A GODT multi-criteria model which is an acronym of Groundwater occurrence, Overburden thickness, Depth and Topography developed from the hydrogeologic parameters were evaluated alongside the longitudinal conductance values to determine the aquifer vulnerability of the area and to classify the study area accordingly. The curve type obtained are H and HA. The interpretation revealed three to four geoelectric layers: the topsoil (18.9-178.9Ωm), clayey (9.0-70.6Ωm), fractured basement (31.9-43.1Ωm) and fresh basement (1131-2916Ωm). The longitudinal unit conductance ranges from 0.032-0.93mhos. And from the GODT model derivations, the study area shows 92.5% of high vulnerability rating, 2.5% of low-moderate and 5% of moderate rating; areas with high rating are prone to contamination than areas with low-moderate and moderate rating. Hence, zones of high vulnerability may be not be encouraged for groundwater exploitation and, if need be, constant water quality assessment should be carried out before consumption.*

KEYWORDS: Aquifer, Vulnerability, Electrical Resistivity, Longitudinal Conductance, Overlying lithology, Depth and Topography.

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INTRODUCTION

A valuable natural resource on every continent is groundwater. Globally, as population grows, there is a greater demand for the development of groundwater resources, making conservation of the resources essential. The infiltration of pollutants and subsequent contamination of groundwater caused by the leaching of septic tanks, refuse dumps, petroleum tanks, improper use, and disposal of pesticides have resulted in the abandonment of several groundwater developments after significant investment in them for a variety of reasons (Sampath, 2000). If a thorough vulnerability assessment had been conducted, significant financial loss (well abandonment) and a substantial health danger would have been avoided.

The ease or difficulty with which pollution or contamination might reach a producing aquifer is known as groundwater vulnerability. The idea of aquifer vulnerability is based on the notion that groundwater might receive a certain level of protection against contaminants entering the subsurface via physical geo-materials. (Robins *et al*., 2007). Consequently, the lithologic variations and the thickness of the unsaturated zone (vadose zone) which determines the inaccessibility of the underlying aquifer units (Wilson, 1983), constitute the focus in aquifer vulnerability assessment (Robins *et al.,* 2007).

Geophysical surveys have been used to characterize the subsurface decade ago. There are several geophysical exploration methods that allow quick insight into the physical properties of water-bearing strata. These methods include geo-electric, electromagnetic, seismic, and geophysical borehole logging. Research involving Hydro-geological, mining, and geotechnical methods have long employed the use of electrical resistivity approach including environmental assessments (Alile *et al*., 2008).

These techniques assess the components that make up the formation to determine if they are sufficiently porous and permeable to function as an aquifer. The covering layers, commonly referred to as protective layers, provide protection for groundwater reservoirs. These protective layers with adequate thickness and low hydraulic conductivity provide excellent groundwater protection (Aweto, 2011).

The geo-electrical characteristics of the near-surface materials sitting on top of the aquifer are used in the current study to estimate the vulnerability of aquifers using the electrical resistivity approach. This procedure is significantly simpler; it is a well-established procedure; the equipment is affordable, portable, and simple to use, and it offers reasonably quick area coverage with the depth of penetration only constrained by the capacity to increase electrode spacing (U.S. Environmental Protection Agency, 2006).

The groundwater dynamics describe how the groundwater reacts to environmental factors including the climate, the extent to which water is stored, how much groundwater is used, and other human activities (Minville *et al*., 2010).

However, using a vulnerability assessment model known as GODT that was described by Adeyemo *et al.* (2016) using four (4) hydrogeologic parameters, that is, Groundwater occurrence, overlying material, depth to aquifer and topography which are derived through interpolation of geophysical measurement and assessment of aquifer vulnerability at Idi-Ayunre in the basement complex terrain of Ibadan, Southwest Nigeria is made possible.

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Aim and Objectives of the Research

The aim of this project is to determine groundwater vulnerability assessment using geo-electric layer susceptibility indexing with the following objectives:

i. To determine the geo-electric layer in the study area.

ii. To determine the depth to basement.

iii. To determine the thickness of the aquiferous layers at various locations within the study area.

iv. To access the vulnerability potential of aquiferous zones in the study area to contamination using GODT models.

Description of Study Area

Idi-Ayunre and its surroundings in Ibadan, Southwest Nigeria, constitute the research area. It is situated between latitudes 7^{0}12'0"N and 7^{0}18'50"N, and between longitudes 3^{0}48'0"E and 3^{0}54'0"E. The climate of Ibadan is tropical wet and dry, with a long-wet season and stable temperatures throughout the year. The rainy season in Ibadan lasts from March to October, with a little decrease in precipitation in August. The rainy season is almost split into two distinct wet seasons because of this pause. The city's dry season, which lasts from November to February, is when Ibadan experiences the classic West African harmattan. While the average temperature is 28°C and relative humidity is high year-round at around 74.55%, the average annual rainfall is approximately 1,205mm (Egbinola *et al.,* 2014).

It is connected to the nearby settlements by a number of road networks, including Ajanla, Odo Ogun, and Ajao. The accessibility of the study area is fair using footpaths and roads as shown in Figure 1.

The research region, which is a portion of Ibadan, is surrounded by granite-gneiss, gneiss complex, pegmatite, and quartzite rocks (Adetoyinbo *et al.,* 2010).

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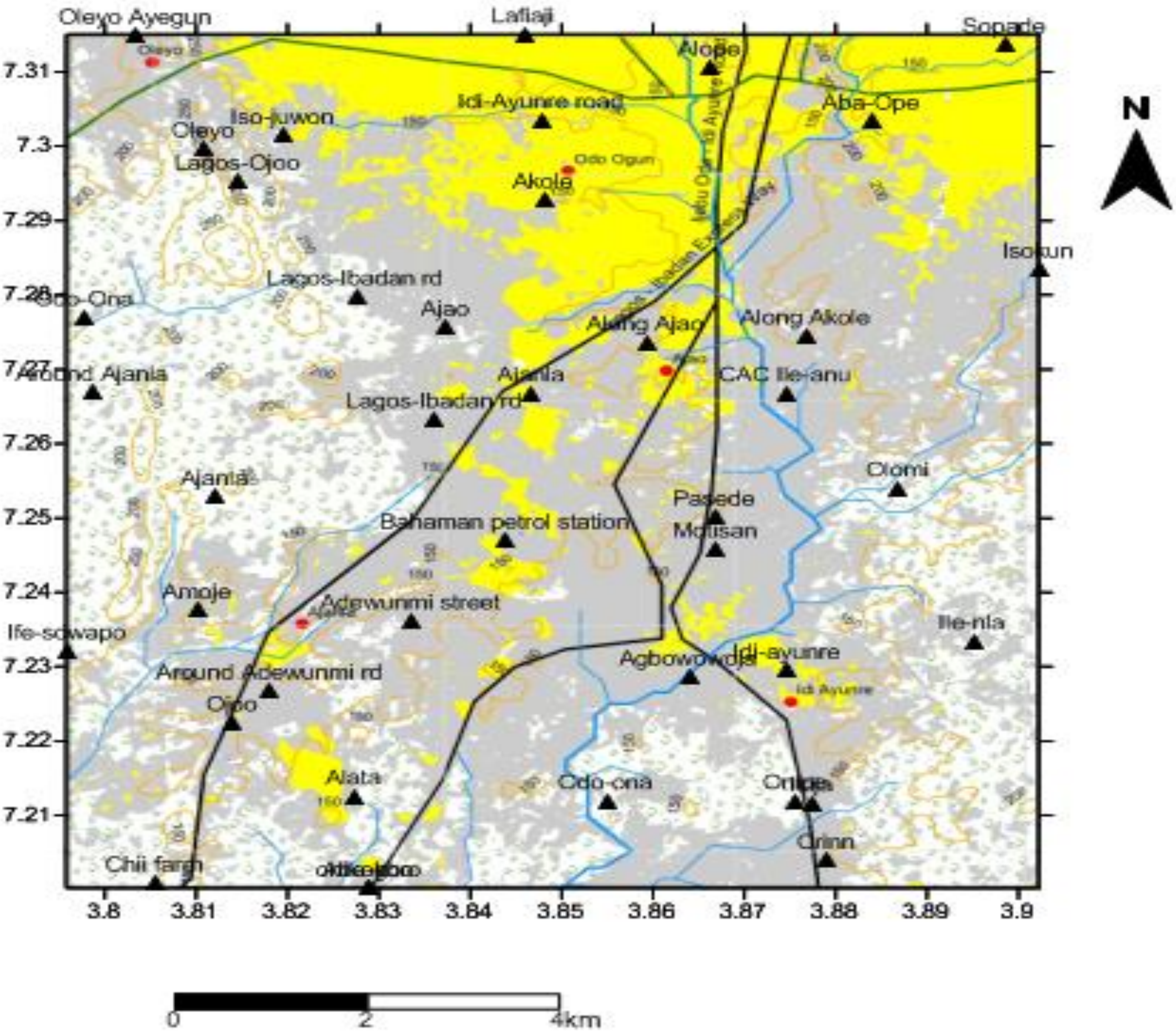

Figure 1: Map of the Study Area

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Figure 2: Field Exercise of the Study Area

MATERIALS AND METHODS

For the investigation, the Vertical Electrical Sounding (VES) Schlumberger array was used to determine how the lithology varied with depth. Two current electrodes send current into the ground and the resultant potential is measured with the help of potential electrodes. For the data collection, Allied Associates Geophysical Limited's Ohmega resistivity metre was utilised. Within the research region, forty (40) vertical electrical sounding stations were taken.

A mid-point location was selected, and an iron rod was hammered into the ground to mark the base station. From this midpoint, the MN/2 (potential electrode) spacing was calculated in both directions using the indicated midpoint and a measuring tape. On either side of the basement station, at a certain distance, potential electrodes are pushed in. The current electrodes were inserted on either side, and the spacing is shown as AB/2. The arrangement of the electrodes ensures that the line remains vertical. Ohmega terameter, four pairs of electrodes, measurement tapes, four hammers, cable spools, crocodile clips, batteries, field recording sheet, pen, camera, and global positioning system are among the field equipment utilised.

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Materials and Methods Contd.

GODT Method

GODT is a vulnerability assessment method developed in Great Britain. Like DRASTIC, GODT is an overlay and index method designed to map groundwater vulnerability based conventionally on three parameters: groundwater confinement; O, overlying strata; and D, depth to groundwater (Khemiri *et al.*, 2013); and T, topography which was modified after Adeyemo *et al*. (2016). The topography was produced using the research region's surface elevation measurements, and GODT parameters were derived from the vertical electrical sounding geo-electric parameter. This was done because we thought that topography may affect how pollutants moved across an area, since depressions allow surface water to seep into the groundwater and ridges are often linked with runoff rather than infiltration. It was also discovered that contaminants entering subsurface water might be regulated topographically, whereby contaminants are kept down the slope by gravity and prevented from moving upslope, as stated by Khemiri *et al.* (2013).

The lowest level for aquifer pollution vulnerability is attributed to values <0.1 (negligible), while the highest level is ascribed to values >0.7 (extreme) (Table 1). Scores are assigned to each of the three categories and then multiplied to yield a final score. The GODT index can be divided into five categories: negligible (0-0.1), low (0.1-0.3), moderate (0.3-0.5), high (0.5-0.7), and very high (0.7-1) (Foster, 1987; Foster *et al*., 2003; Adeyemo *et al.*, 2016). The higher number shows the greater relative pollution potential risk to another one.

The GODT index, which is used to evaluate and map the aquifer vulnerability caused by the pollution, was calculated by multiplication of influence of the three parameters using the following equation:

$$\text{GODT index} = G \times O \times D \times T \quad \text{.......................... Equation 1}$$

where G is the aquifer type, O is the overlying strata, D is the depth to the aquifer and T is the topography of the study area.

Table 1: GODT Model Parameters Attribute (Modified after Khemiri *et al.*, 2013; Adeyemo *et al.*, 2016)

Aquifer type	**Note**	**Lithology (Ωm)**	**Note**	**Depth to aquifer (m)**	**Note**	**Topography**	**Note**
Non-Aquifer	0	< 60	0.4	< 2	1	Ridge	0.7 - 0.8
Artesian	0.1	60 - 100	0.5	2-5	0.9	Depression	0.9 - 1
Confined	0.2	100 - 300	0.6	5 - 10	0.8		
Semi – Confined	0.3 - 0.5	300 - 500	0.7	10 - 20	0.7		
		500 - 600	0.8				
Unconfined	0.6 - 1.0	> 600	0.9	20 - 50	0.6		
				50 - 100	0.5		

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RESULT AND DISCUSSION

Results were interpreted using both qualitative and quantitative methods. The quantitative interpretation refers to a curve matching and computer assisted programme called iteration while the qualitative interpretation was accomplished by displaying the obtained Resistivity data on the log-log paper, which links the Resistivity data to the geology of the research region. The interpretation of forty (40) Schlumberger sounding conducted in the study area indicated that the subsurface lithologically is of 3 to 4 layers. Topsoil, Weathered Layer (Clayey Sand, Clayey Layer), and Fresh Basement are the subsurface layers inside this research region according to the relevant resistivity values discovered throughout the interpretation. The following table provides a summary of the lithological parameter, which comprises Thickness, Depth, Resistivity, and Curve Type in Table 2.

Table 2: Typical Geoelectric Parameters of the Study Area

Ves no	Resistivity	Thickness	Depth	Lithology	Inferred	Curve
1	178.9	0.9	0.9	Topsoil	P1>P2<P3	H
	42.9	4.6	5.5	Clay		
	1693			Fresh Basement		
2	23.2	1.1	1.1	Topsoil	P1>P2<P3	H
	9.6		9.6	Clay		
	1131.8			Fresh Basement		
3	28.5	0.8	0.8	Topsoil	P1>P2<P3	H
	9.9	4.8	5.5	Clay		
	1346.9			Fresh Basement		
4	21.1	1	1	Topsoil	P1>P2<P3	H
	9	3.3	4.2	Clay		
	31.9			Fractured Basement		
5	18.4	0.9	0.9	Topsoil	P1>P2<P3	H
	10.2	4.5	5.4	Clay		
	41.7			Fractured Basement		
6	45.9	0.7	0.7	Topsoil	P1>P2<P3	H
	13	9.7	10.5	Clay		
	37			Fractured Basement		
7	45.2	0.8	0.8	Topsoil	P1>P2<P3	H
	12.9	9.6	10.3	Clay		
	36.8			Fractured Basement		
8	27.3	0.7	0.7	Topsoil	P1>P2<P3	H
	12.2	6.3	7	Clay		
	43.1			Fractured Basement		

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9	149.7	1	1	Topsoil	P1>P2<P3	H
	62.5	4.7	5.7	Clay		
	1787.8			Fresh Basement		
10	137.7	1.4	1.4	Topsoil	P1>P2<P3	H
	39.7	2.8	4.2	Clay		
	1601.7			Fresh Basement		
11	147.2	0.9	0.9	Topsoil	P1>P2<P3	H
	65.3	5	6	Clay		
	1929.2			Fresh Basement		
12	170.9	0.7	0.7	Topsoil	P1>P2<P3	H
	70.6	5.7	6.4	Clay		
	2125.7			Fresh Basement		
13	138.5	1	1	Topsoil	P1>P2<P3	H
	65.8	5	6	Clay		
	1854.6			Fresh Basement		

GEOELECTRIC SECTION

INTERPRETATION OF TRAVERSE 1: This traverse is made up of three (3) VES Points which include VES 9, VES 6 and VES 1; the resistivity of the topsoil ranges between 45.9Ωm and 178.9Ωm; the topsoil depth ranges between 0.7m and 1.0m. The second layer, which is the weathered layer, has a resistivity value range of 13.0Ωm to 62.5Ωm; the depth to the second layer ranges between 5.5m and 10.5m. The resistivities of the last layer are 1787.8Ωm, 1137Ωm and 1693.0Ωm respectively (Figure 3).

INTERPRETATION OF TRAVERSE 2: This traverse is made up of three (3) VES Points which include VES 10, VES 12 and VES 13; the resistivity of the topsoil ranges between 137.7 and 170.9; the topsoil depth ranges between 0.7m and 1.4m. The second layer, which is the weathered layer, has a resistivity value range of 39.7Ωm to 70.6Ωm; the depth to the second layer ranges between 4.2m and 6.4m. The resistivities of the last layer are 1601.7Ωm, 2125.7Ωm and 1854.6Ωm respectively (Figure 4).

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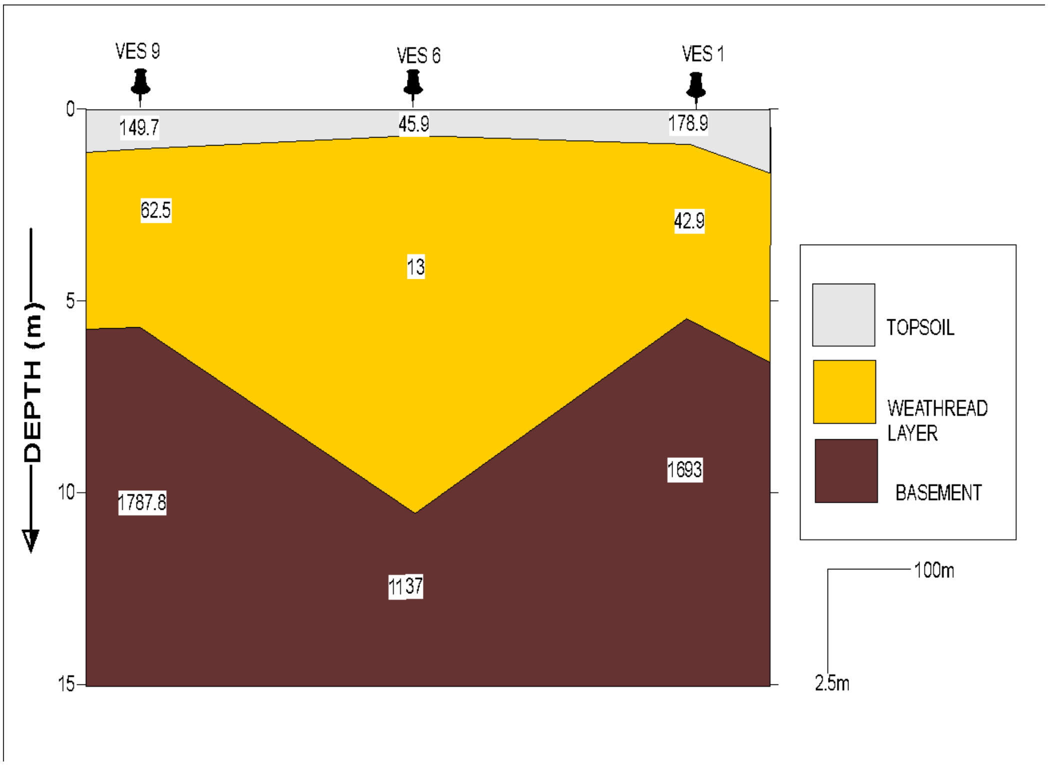

Figure 3: The Geoelectric Section of Transverse 1

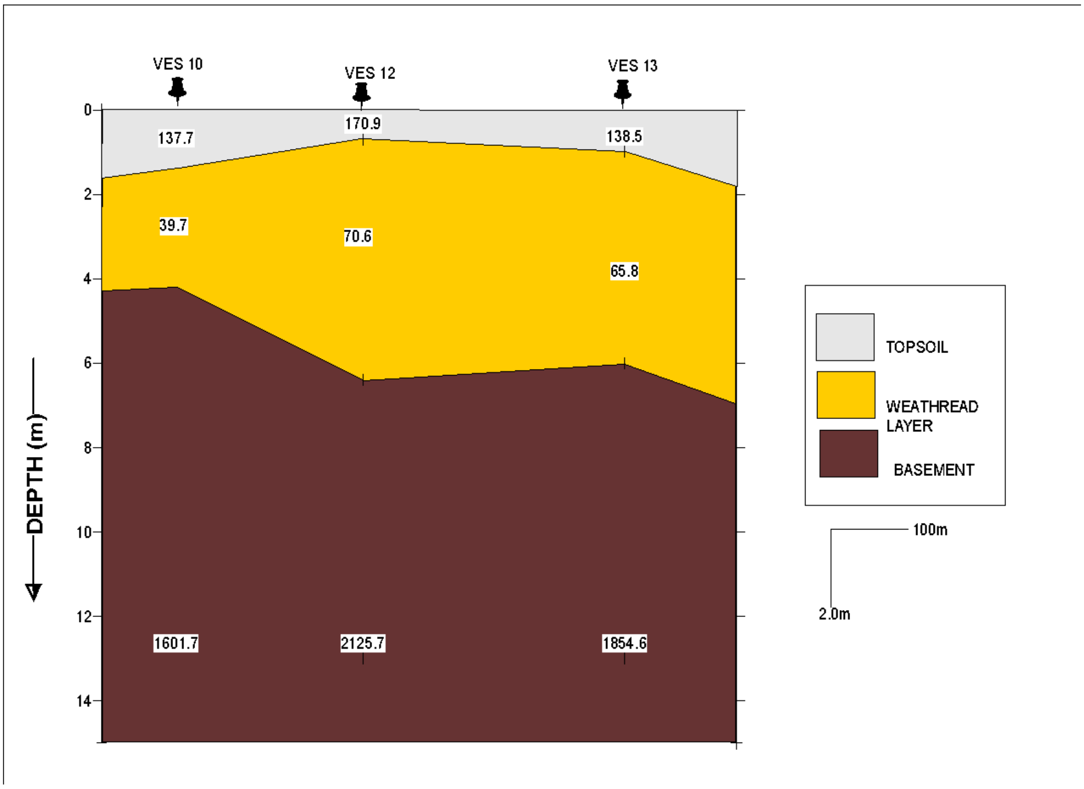

Figure 4: The Geoelectric Section of Transverse 2

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GODT Parameters for Aquifer Vulnerability Assessment

Groundwater Hydraulic Confinement (G): Aquifers are natural systems and, as a result, they have a high degree of variability. This variability helps in describing the hydraulic properties of an aquifer. The groundwater confinement of the study area is confined and semi-confined. Its values range from 0.2 to 0.7.

Overlying Lithology Of The Aquifer (O): The resistivity overlying the aquifer layer in a typical basement terrain as in this case study is the resistivity value before the basement rock (since the aquiferous layer in the basement terrain is within the fractured basement region). The Overlying Lithology 2D and 3D map is represented in Figure 5.

Depth to Groundwater Table (D)

This was established by using the last depth obtained before aquifer, which is the total sum up of all the thickness of the layer occurring above the aquifer and it is also called the overburden thickness. The depth to groundwater aquifer 2D and 3D is represented in Figure 6.

Topography

The topography used for this rating was obtained from Google Earth pro software for each of the VES point established, and average topography was established. The calculated average topography was determined from the arithmetic mean approach which was then correlated with the individual elevation value established for each points obtained using GPS. An increase in the value above the average value indicates a Ridge and a decrease in the value above the average value reveals a Depression. The topography map is represented in Figure 7 and its value ranges from 0.7-1.0.

The vulnerability map of GODT rating, according to the GODT model, shows 92.5% of high rating, 2.5% of low moderate and 5% of moderate rating in the study area (Table 3, Figure 8).

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Table 3: Representative GODT Index Rating Table

VES	G	O	D	T	GODT INDEX	Rating
1	0.2	0.7	5.5	0.8	0.616	High
2	0.2	0.4	9.6	0.8	0.6114	High
3	0.2	0.4	5.5	0.8	0.352	Moderate
4	0.2	0.4	4.2	0.9	0.3024	Low moderate
5	0.2	0.4	5.4	0.8	0.3456	Moderate
6	0.2	0.4	10.5	0.7	0.588	High
7	0.2	0.4	10.3	0.7	0.5768	High
8	0.2	0.4	7	0.8	0.448	High
9	0.2	0.7	5.7	0.8	0.6384	High
10	0.2	0.7	4.2	0.9	0.5292	High
11	0.2	0.7	6	0.8	0.672	High
12	0.2	0.7	6.4	0.8	0.7168	High
13	0.2	0.7	7	0.8	0.784	High
14	0.2	0.7	4.8	0.9	0.6048	High
15	0.2	0.7	5.8	0.8	0.6496	High
16	0.2	0.7	6.2	0.8	0.6944	High
17	0.2	0.7	5.9	0.8	0.6608	High
18	0.2	0.7	5.5	0.8	0.616	High
19	0.2	0.7	4.7	0.9	0.5922	High
20	0.2	0.7	5.9	0.8	0.6608	High
21	0.2	0.7	5.8	0.8	0.6496	High
22	0.2	0.7	5.9	0.8	0.6608	High
23	0.2	0.7	5.8	0.8	0.6496	High
24	0.2	0.7	5.6	0.8	0.6272	High
25	0.2	0.7	6.2	0.8	0.6944	High
26	0.2	0.7	5.9	0.8	0.6608	High

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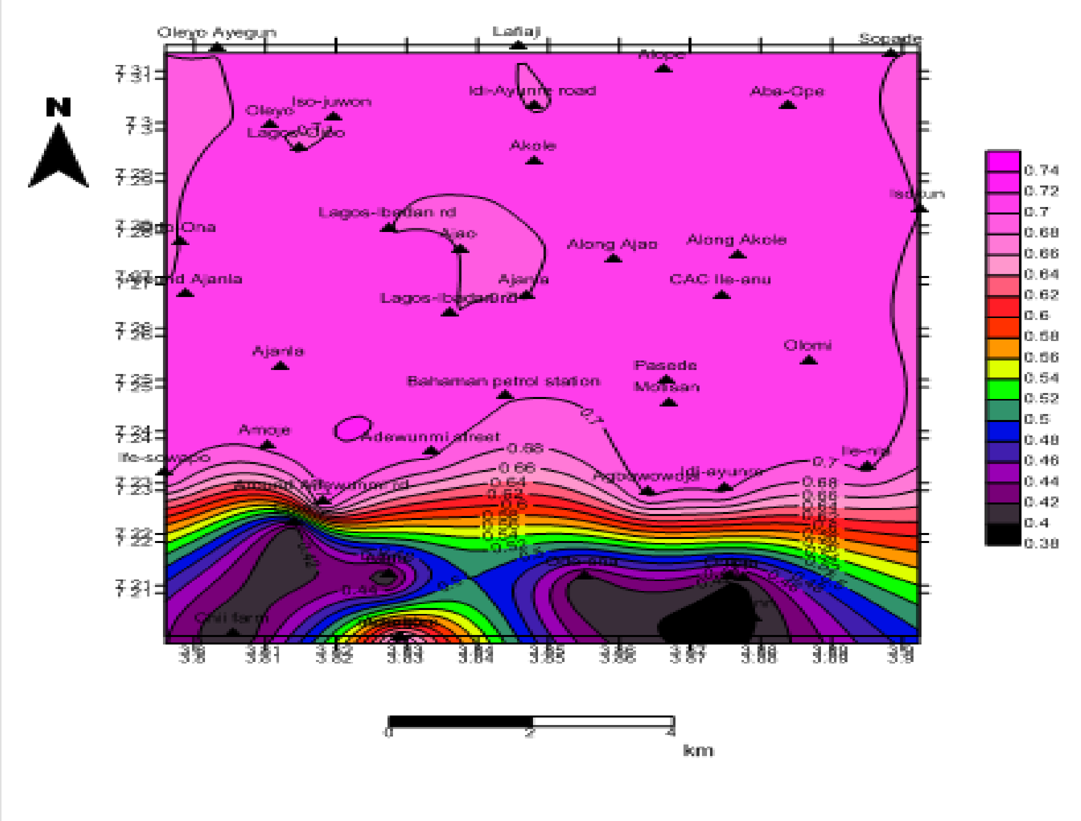

Figure 5: 2D Map of Overlying Lithology Map

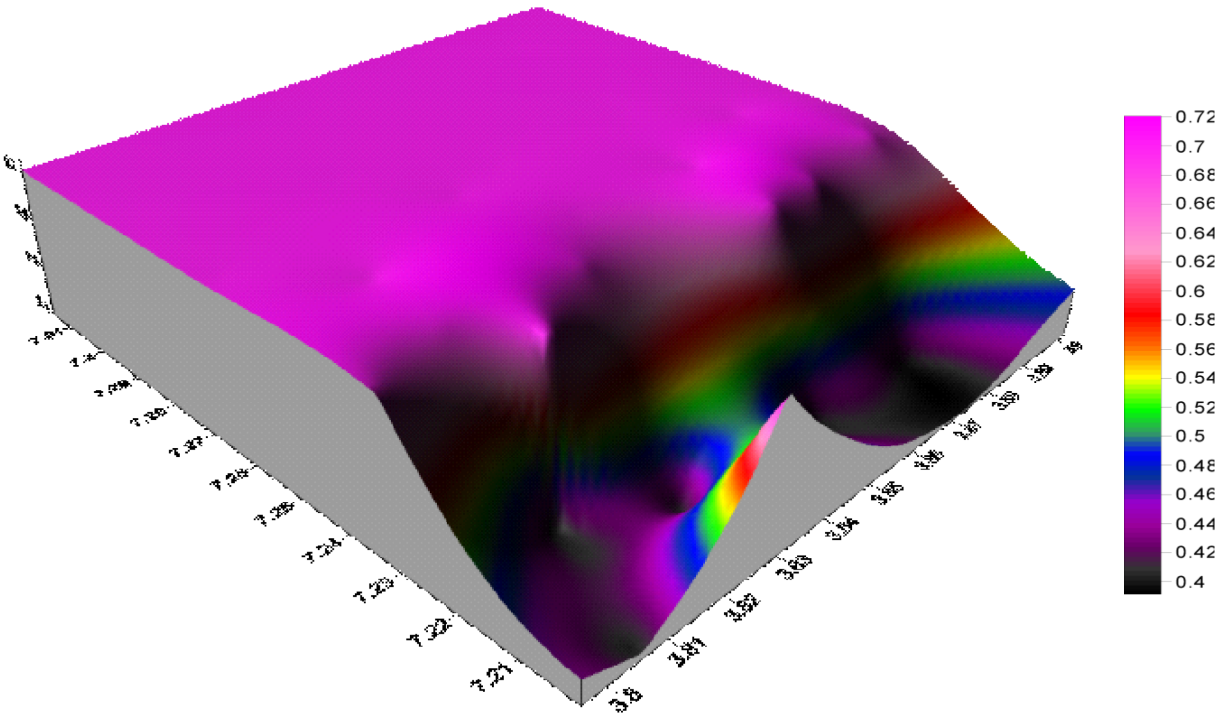

Figure 6: 3D Map of Overlying Lithology Map

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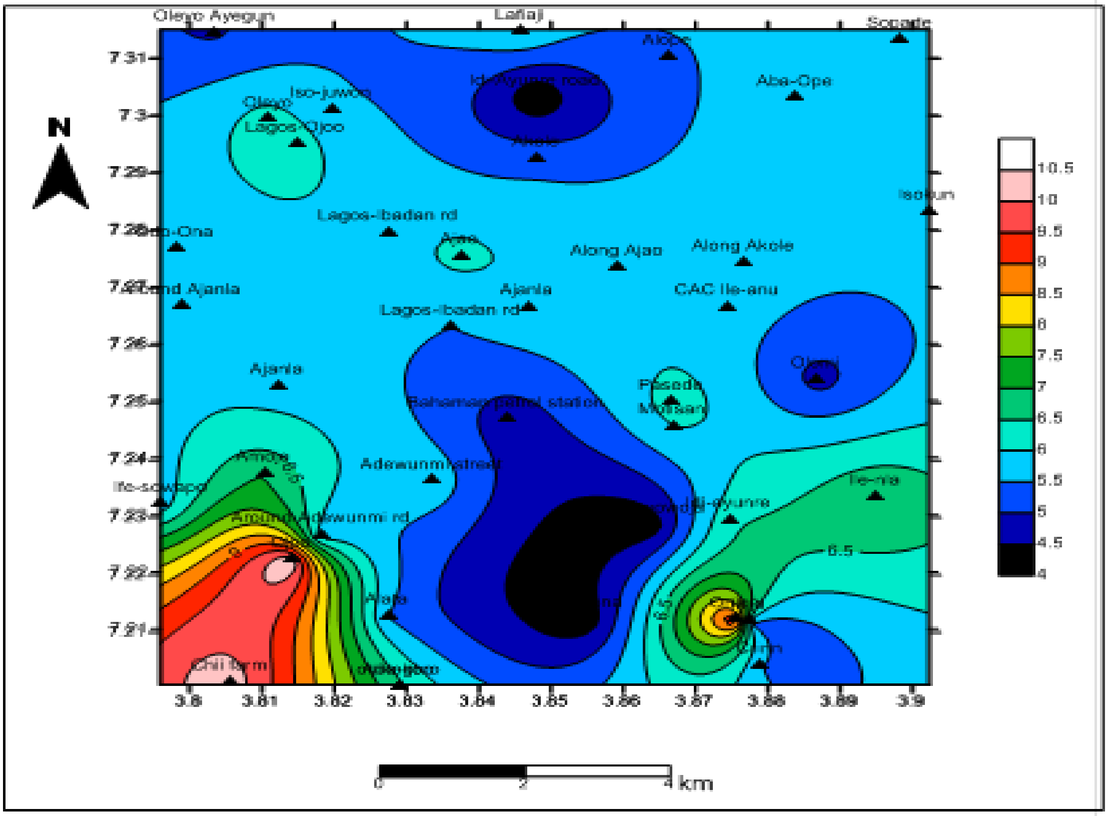

Figure 7: 2D Map of Depth to the Basement

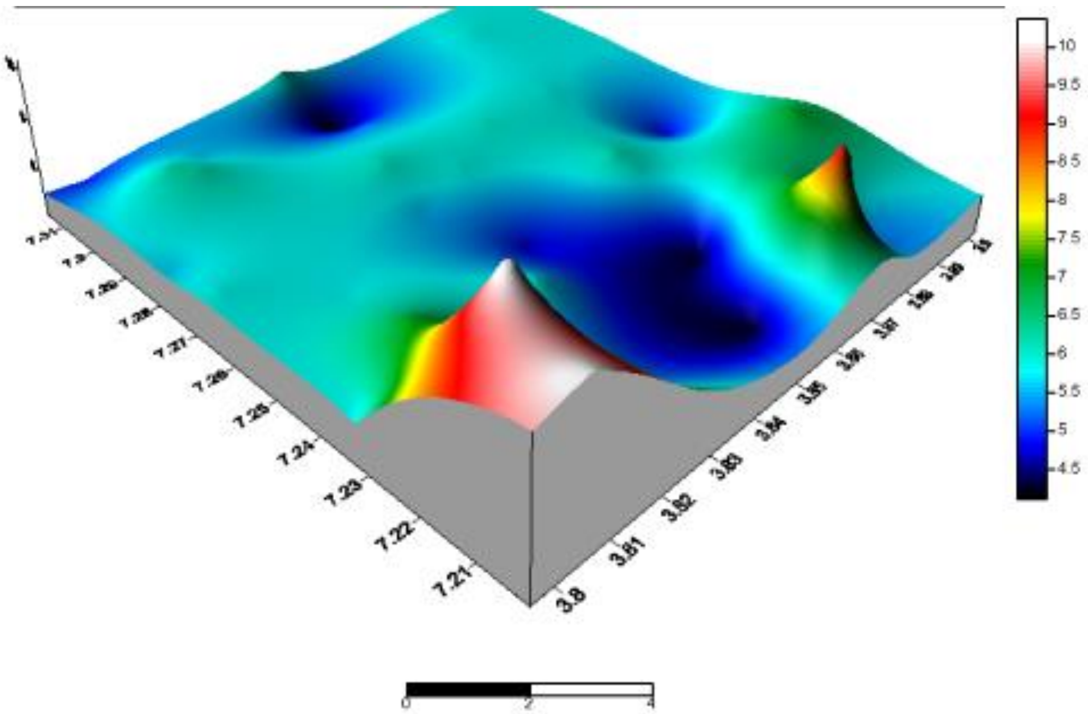

Figure 8: 3D Map of Depth to the Basement

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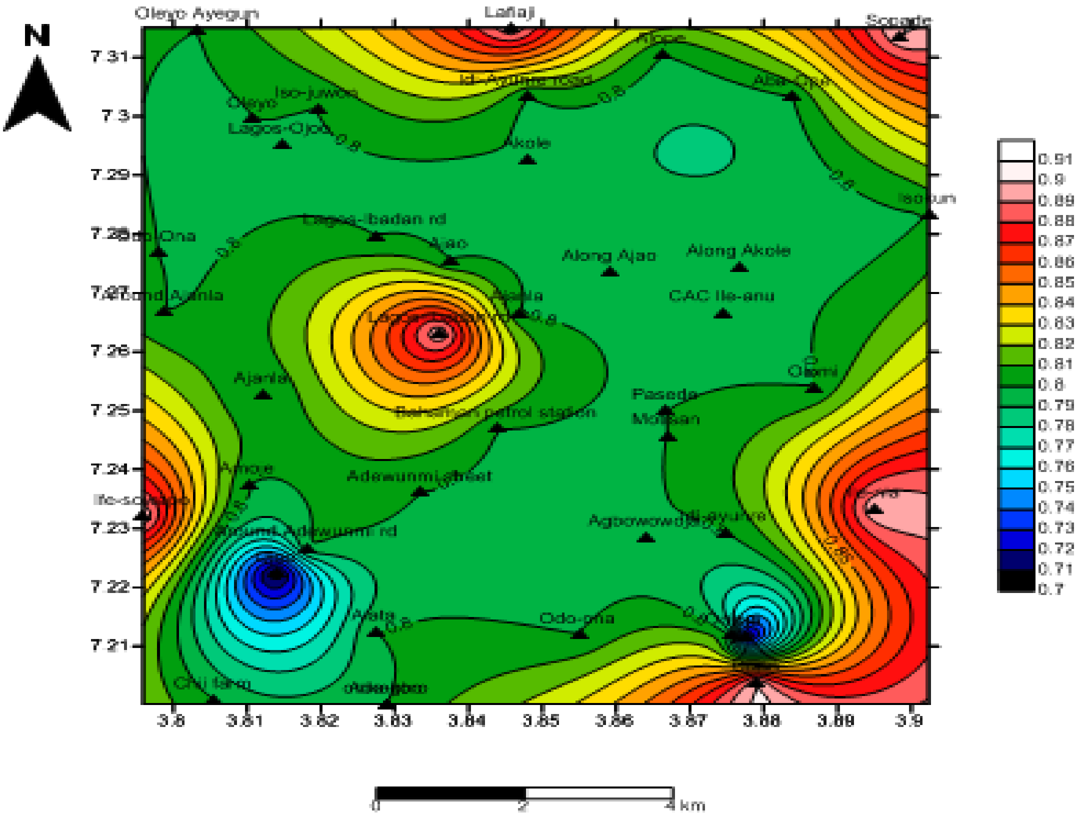

Figure 9: 2D Map of Topography

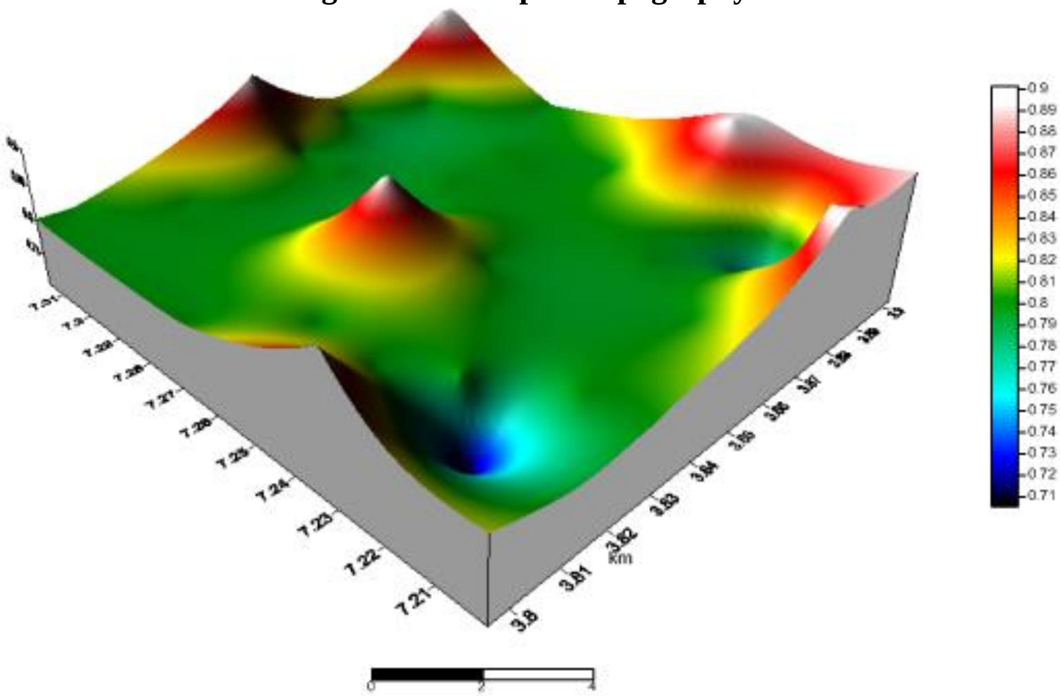

Figure 10: 3D Map of Topography

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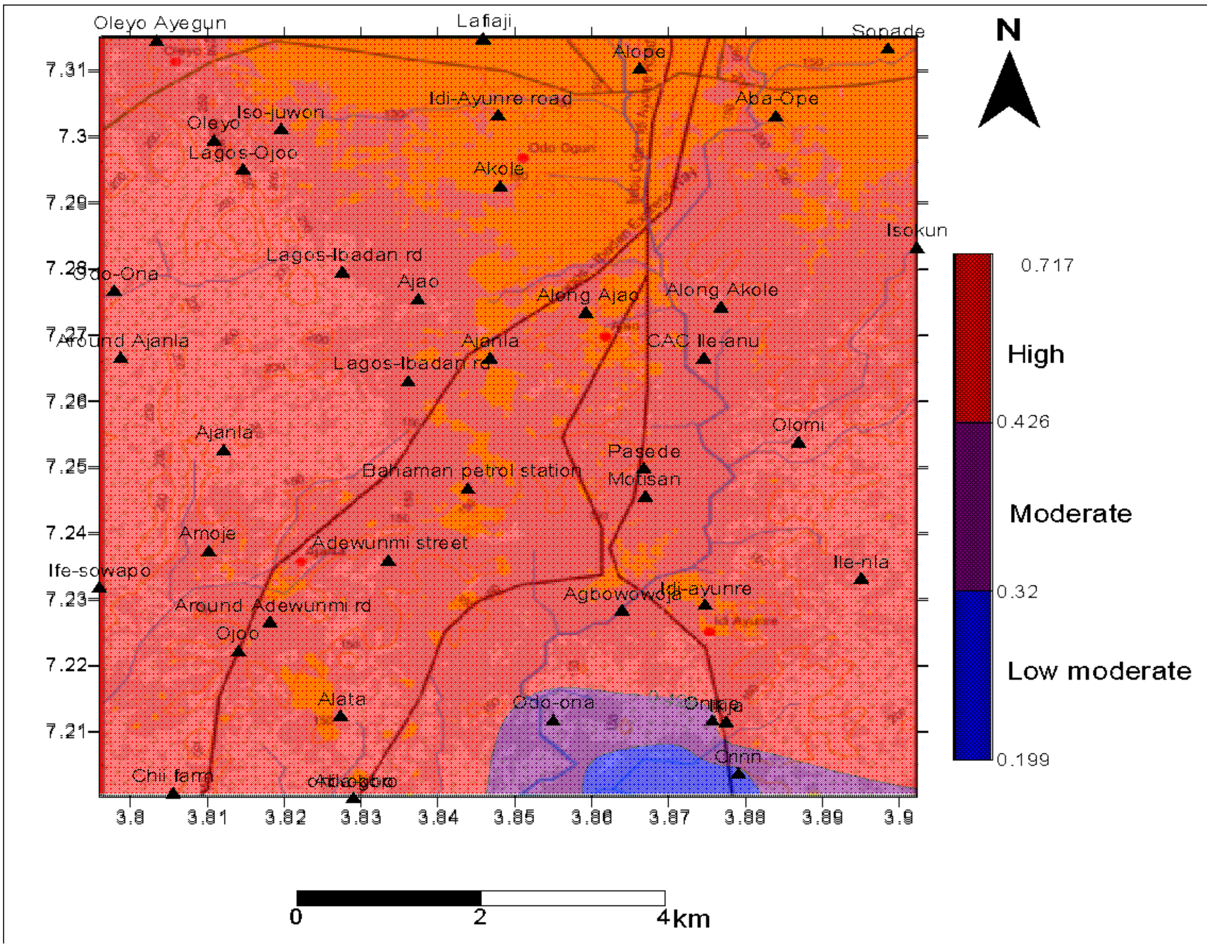

Figure 11: The Vulnerability Map of GODT Rating

CONCLUSION

This study used the GODT indexes to evaluate the multi-criteria analysis approach for ground water vulnerability inquiry in Idi-Ayunre and its surroundings in Ibadan, Southwest Nigeria. The resistivity, depth to base, and thickness of the research region have all been successfully and somewhat accurately disclosed using geoelectrical imaging. We used partial curve matching to analyze forty (40) Schlumberger VES data. The obtained curves are of the H and HA types.

Three to four subsurface geologic layers were delineated from the study area which consist of topsoil, clay, sandy clay, fractured basement, and fresh basement. From this research work, areas with high rating are prone to contamination than areas with low moderate and moderate rating. From the result of the aquifer vulnerability potential assessment carried out in the study area, areas that show high to moderate vulnerability potential are to be carefully monitored and prevented from further contamination be it from anthropogenic factors which are most common or geogenic although this may not be totally possible, yet certain effort could still be made to mitigate their occurrence. And water sources at these locations should be readily subjected to water quality assessment, such as physical and chemical analysis before consumption.

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Septic tanks, petroleum tanks, contaminated facilities, industrial waste, and agricultural discharge should all be carefully avoided in low vulnerability zones because their introduction could make the area even more vulnerable in the near future and put the water beneath the zone in danger.

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Competing Interests

Authors declared that no competing interests of any kind exist.

REFERENCES

Adetoyinbo, A.A., Popoola, O.I., Hammed, O.S and Bello, A.K (2010). An Assessment of Quarry Blasting Vibration Impacts in Ibadan and Abeokuta, Nigeria. Envir. J. Sci. Res., 4. pp. 228-252.

Adeyemo, I.A., Olowolafe, T.S and Fola-Abe, A.O (2016). Aquifer vulnerability assessment at Ipinsa-Okeodu Area, Near Akure, Southwestern Nigeria, using GODT *J. Environment and Earth Sciences* ISSN 2224-3216. Pg 9-17.

Alile, M.O, Amadasun C.V.O and Evbuomwan Al. (2008) Application of vertical electrical sounding method to decipher the existing subsurface stratification and groundwater occurrence status in a location in Edo North of Nigeria. International Journal of Physical Science, 3(10):245-249.

Aweto, K.E (2011). Aquifer vulnerability assessment at Oke-Ila area, South Nigeria.J. phys.sci,6(33) (2011), pp. 7574-7583.

Egbinola, C.N and Amanambu, A.C (2014). Groundwater contamination in Ibadan, South-West Nigeria. *SpringerPlus* 2014, 3:448.

Foster, S.S.D (1987). Fundamental concepts in aquifer vulnerability, pollution risk and protection strategy.

Foster, S.S.D. and Chilton, P.J. (2003) Groundwater: the processes and global significance of aquifer degradation, *Phil. Trans. R. Soc. Lond. B., 358*, 1957-1972.

Khemiri, S., Khnissi, A., Alaya, B.A., Saidi, S., and Zargrouni, F., (2013). Using GIS for the comparison of intrinsic parameter methods assessment of groundwater vulnerability to pollution in scenarios of semi-arid climate. The case of foussana groundwater in the central of Tunisia. J. Water Resource Prot., 835-845.

Minville, M. K, Brisette, F and Leconte, R. (2010) Behaviour a performance of a Water source system in Quebec (canada) under adopted operating policies in a climate change context water Resour Mang 24:1333-1352.

Robins, N.S., Chilton, P. J and Cobbing, J.E (2007). Adapting existing experience with aquifer vulnerability and groundwater protection for Africa Journal of African Earth Sciences 47:30-38.

Sampath, P. (2000). Deep trouble. The hidden threat of groundwater pollution. World watch working paper, 154, Washington.

U. S. Environmental Protection Agency (EPA) (2006). Drinking water contamination.

Wilson, L.G (1983). Monitoring in the vadose zone : part3 Groundwater monitoring review 3 (1), 155-166.

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