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Assessment of Effects of Cemetery Leachate on Groundwater Quality using an Integrated Approach in Edunabon, South-Western, Nigeria

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Abstract
The dependency of residents in the vicinity of cemeteries on groundwater from hand-dug wells as an alternative source of water supply for their domestic use without cognisance of the quality of such water has been a concern. So, this research assesses the effects of a cemetery on groundwater quality using an integrated approach in Edunabon, South-western Nigeria. Thirty groundwater samples from available hand-dug wells were collected and analysed for various physicochemical parameters. GIS cloud data collection server and Mobile Data Collector (MDC) were used to obtain these hand-dug wells' locations and spatial distributions. The determination in variation in physicochemical concentration parameters was obtained using the curve fitting technique of ARCVIEW GIS software and digital map. Physicochemical results were used to calculate Water Quality Index (WQI) of each sample. Two Schlumberger Vertical Electrical Soundings (VES) of 130.0m long were conducted at 10.0m intervals to the wall and the next VES, on each sideof the cemetery. Current spacing (AB/2) and apparent resistivity (ρ_a) data were plotted on a double logarithm paper, curved matched and iterated using IPI2Win software for qualitative and quantitative interpretation. WQI results ranged from (107.37–173.64), (76.60–93.37), (54.94–71.53), (31.29–48.01), and (10.84–25.31) for fourteen, seven, three, four and two hand-dug wells respectively, an indication that the water from these wells was unfit for drinking, very poor, poor, good, and excellent respectively. VES results revealed that first, second and third layers were mainly clayey topsoil (46.7–96.8Ωm), lateritic soil (169.0–551.3Ωm), and weathered layer (3.21–27.4Ωm), which favourably enhances the migration of leachate from the cemetery to the surrounding soils and groundwater. Lowest resistivity values recorded in the second and third layers indicated leachate presence at these hand-dug wells. The integration of GIS and electrical resistivity methods would be useful tools to assess groundwater quality around cemeteries.

***Keywords**: Groundwater quality, Mobile Data Collection, unfit for drinking, Vertical Electrical Sounding, Water Quality index*

Introduction

Water, an essential resource, can be obtained or tapped from two sources: surface water and groundwater. Surface water is the water that is available above the ground or earth's surface, and

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it includes water found in creeks, wetlands, reservoirs, lakes, oceans, rivers, streams, ponds, and the sea. In contrast, solid water (ice and snow) is found on the earth's surface are inclusive. The precipitation (rain, hail, snow, and sheet) seeps down through the soils until it reaches saturated rocks from Groundwater. Groundwater is stored in tiny spaces (pores) between particles of dirt and rocks or cracks and crevices in rocks. The amount of water available in all of these depends significantly on the types of rocks and dirt (United State Geological Survey (USGS), 1999). These two sources have several purposes for designated beneficial uses, including support for aquatic life, fish consumption, shellfish harvesting, drinking, primary contact (swimming), and secondary contact (boating). Its quality can determine the choice of which water to be used from these two sources.

Water quality describes the chemical, physical and biological status of a body of water. Naturally, these water sources are contaminated since they are in contact with the ground. Surface water tends to experience more pollution than groundwater since it is not covered. So, in the search for freshwater, humans shifted their attention to groundwater found in more hidden places. As the population increases, the pressure on groundwater increases. Groundwater travels very slowly downward at an angle (because of gravity) in the range of a few millimetres to a few meters each day along mineral surfaces in pores, crevices, and fractures of the unsaturated zone and the aquifers (Earle, 2019). This makes mineral ions (cations and anions) from soil particles, sediments and rocks dissolve in groundwater, which is enhanced because water is a universal solvent. When more of these natural ions are present, the electrical conductivity (EC) increases, affecting its quality. Despite these natural ions in groundwater, it is still tagged as freshwater and is declared as fit for drinking health-wise (The Groundwater Foundation, 2011). Groundwater becomes more contaminated when harmful chemical products deposited on land surface dissolved and percolated downwards; the products of decomposition from landfills find their ways downwards, improper design or constructed septic system allows harmful bacteria, viruses, and other chemicals to enter groundwater when there are accidental spills of petroleum products on the surface of the land, and during mining, quarries and other rock excavations (The Groundwater Foundation, 2007). Although some soils can remove bacteria, viruses, and chemicals as they percolate downwards, despite this, pathogens and chemicals are still found in large quantities in groundwater because their ability is exceeded. It was also reported that when dead bodies from the cemetery decomposed, they produce a liquid called leachate which, when leaving the point of production, percolates the soils into the groundwater. According to Silva (1995), when decomposed, the one-kilogram weight of the human body produces 0.4 – 0.6 litres of leachates of density 1.23 g/cm^3. Silva (1998) reported that this volume of leachate contains 60% water, 30% salts, and 10% organic substances. These salts, when analysed, were found to contain ions of

$NO_3^- \; PO_3^- \; CL^- \; HCO_3^-$ Ca^{2+}, Na^+, and compounds of metals such as

Ti, Cr, Cd, Pb, Fe, Mn, and Ni. Other components that may be present are chemicals applied in chemotherapy, embalmment (e.g. arsenic, formaldehyde, and methanol), and various additional items such as fillings, cardiac pacemakers, and others (Silva &Filho, 2011; Fieller*et al.*, 2012).

The entering of these into groundwater increases its electrical conductivity, so its quality is greatly affected. The presence of these contaminants has health implications. Davis (2013) reported that 25 000 people were killed globally, daily by water-borne diseases and that 5,000 children died per day due to water-related diseases, especially diarrhoea. According to a WHO report, about 80% of all diseases in human beings are caused by water (WHO, 2017). As a result of the decline in the water quality due to the presence of contaminants and to prevent water-borne diseases, standard guidelines are sets for drinking purposes and other uses for each of the three classes of the attribute of water quality (physical, chemical, and biological conditions of the water bodies). This will help in the assessment of water quality. This standard was described by WHO/UNICEF (2013) as the framework against which water samples can be considered satisfactorily safe for its use. Some regulatory bodies have reported these guidelines (WHO/UNICEF, 2013; US.EPA, 2001; Council of European Union (CEU), 1998; Health Canada, 2018; UNESCO/WHO/UNEP, 1996; Indian Standard Institution (ISI), 1983; Bureau of Indian Standards, 1991; South African National Standard (SANS), 2006; Ethiopian Standard Agency (ESA) 2013; Standard Organization of Nigerian (SON), 2007). However, in all of these, only WHO standard is made use of by developing and developed nations (UNESCO/WHO/UNEP, 1996). Therefore this work aims to assess the effect of leachate from the cemetery on groundwater quality in Edunabon cemetery using an integrated approach.

Study Area Description

The study site is a very active church cemetery located along a tarred road (Sekona – Ife Road) at Edunabon, a town in Ife North Local Government area of Osun State, Nigeria. The cemetery is situated in between latitude 7º 33.136′ N and 7º 33.067′ N and longitude 4º 26.968′E and 4º 26.887′E. The oldest corpse buried in the cemetery was in 1950~~,~~ as evident at the cemetery ground (see Fig. 1).The population of Edunabon as of the 2006 census was 153,694. It has a temperature range of 28ºC (82ºF) and 22ºC (72ºF), and about 1298 mm of precipitation falls annually. The climate of the study site is characterised by two seasons is arid to semi-arid with two rainy seasons (regular and long rainy season during the summer, May to September, Rainfall is intense during the period of mid-July to mid–August. the short infrequent rainy season during March and April). The total area of the cemetery is 3600 m^2.

Geological Description of the Study Site

Fig. 2 shows the geological map of the study site. The study site belongs to south-western Nigeria's Precambrian basement complex rocks

Figure 1: The Photograph of the Cemetery

(Rahaman, 1976). These complex rocks are rocks of older granite ((Oyedele *et al.*, 2011). Branded gneiss rocks predominantly occupy the study site while talc-schist, undifferentiated schist, and epidiorite are the other rocks found in Edunabon. The branded gneiss is the prevalent rock. The geology of the study area was classified based on the porosity and permeability of various resulting rock debris after weathering. These gneisses weather into higher permeability sandy clay, clayey sand, and sand with higher groundwater discharge capacity. Groundwater occurs under phreatic, semi-confined, to confirmed conditions in the weathered fractured portions of the crystalline formations and occurs in the semi-confined and confined conditions in deep-seated fractured and sedimentary formations. The weathered crystalline rocks form potential aquifers in the hard rock areas, and their thickness ranges from 4.5 to 21.0 m. The depth of dug wells in these formations ranges from 5.00 to 25.62 m. Dug wells, dug-cum-bore wells, and bore wells are feasible in these areas.

Materials and Methods

Water Samples Collection and Analysis

Thirty (30) groundwater samples were collected using clean plastic jugs and poured into plastic sample containers that had been previously washed, rinsed and dried. The sample containers were labelled correctly to indicate the sample code, the well, and the date. Standard methods were used for sample preservation. The samples

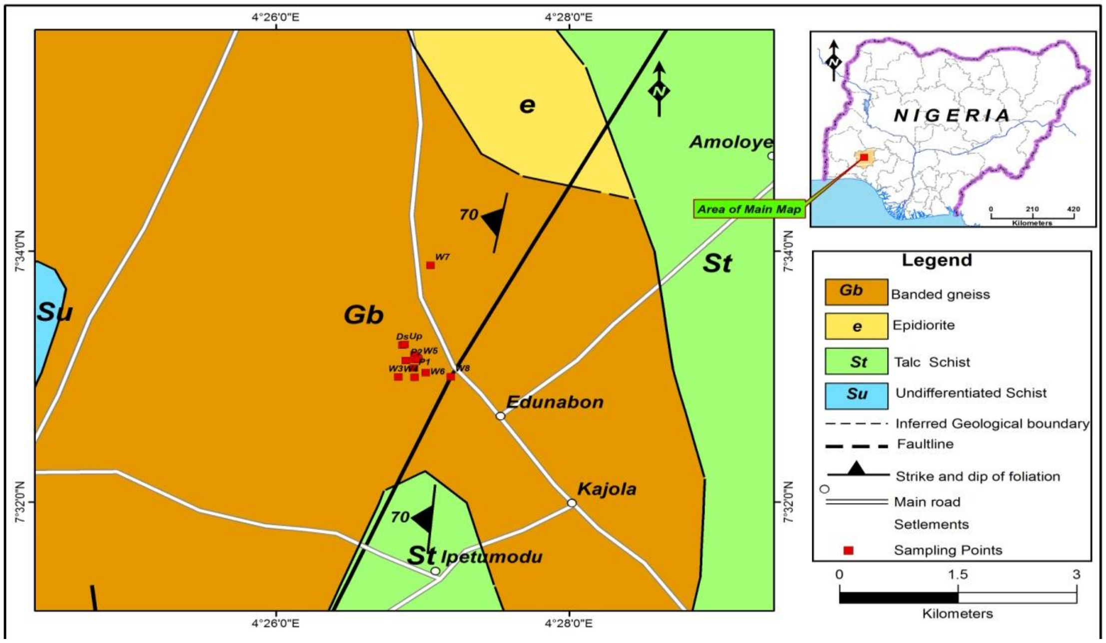

Figure 2: Geological map of the study site (Grant, 1970).

were analysed for pH (by electrometric method), alkalinity (by acid-base titrimetry), chloride (mercuric nitrate colourimetric method), total hardness, calcium and magnesium (by EDTA titrimetry), total dissolved solids and total solids (gravimetric method), nitrate (phenol sulphonic acid colourimetric method), phosphate (phosphomolybdatecolourimetric method), and sulphate (turbidimetric method) as detailed in the standard procedures of the Society for Analytical Chemistry manual, Society for Analytical Chemistry, (1973) and the APHA-AWWA-WPCF Manual (1985). The water quality data thus obtained formed the attribute database for the present study (Table 1). Mobile Data Collector (MDC) software with Global Positioning System (GPS) receiver embedded into it was used in conjunction with the GIS cloud data collection server to obtain sampling locations and spatial distribution over the study area. In addition, the water quality attribute information of each well was also input to a digital map using the MDC and ArcGIS 10.5 software to identify the variation in concentrations of the parameters in the groundwater at various locations of the study site using the curve fitting technique of ARC/VIEW GIS software. The paper map of the town has a 1: 25,000 scale, which was digitised to Universal Transverse Mercator (UTM) coordinate system by applying the on-screen digitising method.

Table1: Water Quality Parameters, ICMR/WHO Standards, and Assigned Unit Weights.

Parameters	Standard (Sn & Si)	Weightage (Wn)
Alkalinity	120	0.0101
Chloride	250	0.0048
Fluoride	1.5	0.809
Nitrates	50	0.0242
pH	8.5	0.1428
Sodium	200	0.0060
Sulfate	250	0.0048
Total Hardness	300	0.0040
TDS	1000	0.0012

Estimation of Water Quality Index (WQI)

Different countries and organisational bodies (e.g. WHO) have different guidelines on different water quality parameters. The interpretation of these various parameters separately is usually a difficult task for the general public as well as decision and policymakers. Therefore, the need to calculate the general Water Quality Index (WQI) is essential so that water quality can be adequately communicated in better and more understandable ways. Calculating the WQI, different approaches have been put in place to calculate WQI for drinking water purposes. Tiwari & Mishra (1985) proposed a method for calculating the weighted Arithmetic water quality index. Others adopted this method (Gupta *et al.*, 2001; Asadi *et al.*, 2007; Ramakrishnaiah *et al.*, Dimka, 2010; Jagadeeswari& Ramesh, 2012). Using this adopted method, the WQI was computed for drinking purposes using the following formula (Department of Water and Sanitation (DWS), 1998; WHO, 2017).

$$WQI = \text{Antilog}\left[\sum W_{n=1}^{n} \log_{10} q_{ni}\right] \quad (1)$$

where W is the Weightage factor, and it is computed using the following equation

$$W_n = \text{K/S}_\text{n} \quad (2)$$

and K is a proportionality constant which is derived from,

$$K = \left[\frac{1}{\left(\sum_{n=}^{n} \frac{1}{\text{S}_\text{i}}\right)}\right] \quad (3)$$

S_n and S_i are the WHO / ICMR standard values of the water quality parameter (see Table 1)

q is the quality rating is calculated using the formula.

$$q_{ni} = 100\left[\left(\frac{\text{V}_{\text{actual}} - V_0}{V_{standard} - V_0}\right)\right] \quad (4)$$

where,

q_{ni} = Quality rating of i^{th} parameter for a total of n water quality parameters

V_{actual} = Value of the water quality parameter obtained from laboratory analysis

V_o = Value of that water quality parameter can be obtained from the standard tables.

V_o for pH = 7, and other parameters, it is zero.

$V_{standard}$ = The maximum permissible level set by WHO / ICMR (WHO/UNICEF, 2013; WHO, 2017 and WHO, 2012) as shown in Table 2.

This study calculated the overall WQI for each of the water samples from each hand-dug well. The values of WQI obtained was used to determine the groundwater quality and were rated as excellent, good, poor, very poor, and unfit for human consumption (Table 3). Tables 2 and 3 are thestandard WQI rating categories and the observable values.

VES Data Acquisition and Treatment

The decomposition of corpses in cemeteries led to the production of a liquid called leachate that could penetrate and migrate out of any cemetery to mix with both the soils and groundwater to affect them; this is so because ions in this leachate have sufficiently high contrast in physicochemical properties against the host media due to an increase in dissolved salts in the soils and groundwater and a resulting pore water resistivity

Table 2:Water Quality Index Rating Categories

Water quality index	Description
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for drinking (UFD)

thereby changes their resistivity (Meju, 2010). It was measured using Electrical Resistivity Method. In order to measure the change in the groundwater resistivity in this study, two stainless steel electrodes A and B, with connecting cables from a battery in a piece of equipment called Resistivity Meter (ABEM SAS 1000), were hammered downward to introduce electric current to the earth. Any variations of the subsurface resistivity will alter the flowing electric current, which in turn affects the distribution of the developed electric potential. Another pair of electrodes (M and N) with electric cables were connected to a Resistivity Meter and inserted intothe earth purposely to convey the amount of the developed potential to the meter. At the same time, the values of the introduced electric current were also read and recorded on the same equipment, which automatically converted these data into resistance. The apparent resistivity (ρ_a) is

Table3: Physicochemical Properties of the Water Samples and their Water Quality Index (WQI)

Sample No	Well Distance (m)	Physicochemical properties of the water samples										Water Quality Rating
		Alkalinity	Cl^-	F^-	NO_3^-	pH	SO_4^{2-}	Na^+	Total Hardness	TDS	WQI	
1	17.9	16.0	33.0	1.44	5.0	6.99	188.0	210.0	480.0	114.1	78.26	Very Poor
2	21.0	6.0	90.0	1.40	10.0	6.89	100.1	20.00	130.0	284.9	88.31	Very Poor
3	21.9	16.0	42.0	0.25	0.0	7.02	169.0	330.0	222.0	133.7	10.84	Excellent
4	39.6	18.0	32.0	1.89	5.0	7.45	165.0	200.0	416.0	317.9	154.45	UFD
5	40.0	20.0	33.0	1.67	0.0	7.17	187.0	150.0	514.0	97.2	71.53	Poor
6	51,8	26.0	52.0	1.32	0.0	7.11	98.0	450.0	430.0	348.9	54.94	Poor
7	85,4	34.0	55.0	0.61	10.0	6.87	213.0	370.0	512.0	249.1	46.92	Good
8	86.7	28.0	35.0	0.65	0.0	7.89	211.0	350.0	328.0	121.5	25.31	Excellent
9	122.2	30.0	50.0	0.72	10.0	7.19	124.0	480.0	336.0	175.5	76.60	Very Poor
10	175.9	50.0	49.0	0.89	0.0	7.33	105.0	530.0	550.0	432.0	48.01	Good
11	202.0	8.0	26.0	1.35	40.0	7.11	98.0	20.0	146.0	162.7	159.55	UFD
12	257.9	16.0	35.0	1.40	20.0	7.02	119.0	100.0	110.0	378.0	110.32	UFD
13	283.0	6.0	59.0	1.49	15.0	7.02	110.0	80.0	234.0	76.9	107.37	UFD
14	290.0	12.0	78.0	1.23	10.0	7.22	166.0	250.0	108.0	149.9	141.82	UFD
15	436.0	10.0	78.0	1.18	10.0	6.91	79.0	150.0	382.0	338.2	93.37	Very Poor
16	440.0	11.0	80.0	1.43	5.0	7.14	67.0	200.0	242.0	66.3	106.06	UFD
17	448.6	16.0	21.0	1.35	30.0	7.19	197.0	150.0	68.0	330.1	163.04	UFD
18	506.0	8.0	40.0	1.23	5.0	7.65	122.0	250.0	170.0	220.0	142.38	UFD
19	508.0	10.0	40.0	1.43	10.0	7.00	118.0	170.0	186.0	406.4	91.13	Very Poor
20	545.1	20.0	47.0	1.49	5.0	7.34	156.0	260.0	244.0	139.1	110.06	UFD
21	562.0	12.0	45.0	0.29	10.0	7.11	171.0	200.0	122.0	252.2	31.29	Good
22	564.4	26.0	55.0	.1.21	25.0	7,89	201.0	300.0	226.0	65.2	226.95	UFD
23	572.0	10.0	44.0	1.23	5.0	6.99	132.0	350.0	162.0	67.5	68.34	Poor
24	602.0	32.0	42.0	1.91	0.0	7.23	207.0	40.0	1000.0	243.7	83.36	Very Poor
25	606.4	16.0	64.0	1.18	45.0	7,87	69.0	150.0	244,0	126.9	201.35	UFD
26	633.7	20.0	48.0	1,43	15.0	7.03	65.0	150.0	100.0	201.8	111.03	UFD
27	672.2	14.0	42.0	1.43	45.0	7.12	101.0	430.0	150.0	100.6	173.64	UFD
28	719.3	14.0	63.0	1,23	5.0	7.66	133,0	450.0	146.0	158.6	121.72	UFD
29	812.9	15.0	62.0	0.33	5.0	7.56	174.0	480.0	142.0	413.1	39.95	Good
30	822.7	14.0	55.0	1.23	15.0	6.97	92.0	40.0	132.0	365.9	88.56	Very Poor

The unit of all the water parameters was in mg/L except pH

TDS: Total Dissolved Solid;WQI: Water Quality Index; UFD: Unfit for Drinking calculated by multiplying the resistance with the Geometric Factor (K). In this study, Schlumberger Electrode Configuration was used because it is economical, faster, and more accessible. In this study, the minimum and maximum half current electrodes (AB/2) spacings were 1.00 m and 100.00 m, respectively, while the minimum and maximum half potential electrodes (MN/2) spacing were 0.25 m and 5.00 m, respectively. In this work, two Vertical Electrical Sounding (VES) were conducted away at an interval of 10.0 m to the cemetery boundary and to the subsequent VES point to cover a distance of 20.0 m on each side of the four sides of the cemetery to find how the resistivity varied with distance. At every VES point, the electrodes were spread in a straight line, and inter-electrode spacing was gradually increased about the fixed point until the distance was covered. Each VES point's position, location, and elevation were recorded using Geographic Positioning System (GPS). The current AB/2 and the apparent resistivity data obtained were plotted against each other on a double logarithm paper, curved, matched and iterated using computer software IPI2Win for qualitative and quantitative interpretation. The output of this software was apparent resistivity of each layer, thickness, and depth from the surface of each layer.

Results and Discussions

Physicochemical Analysis of the Water Samples

The results of the physicochemical analysis of all the water samples from the thirty different hand-dug wells are as shown in Table 3. The results indicated that the pH, alkalinity, chloride, nitrates, sodium and total dissolved solids (TDS) are within the tolerance level recommended by ICMR/WHO. Sax (1974) reported that fluoride is a natural contaminant of water because it is dissolved by geological formation. The fluoride levels in most of the water samples were within the tolerance levels except water samples from hand-dug wells 4, 5, and 24, whose values were 1.89, 1.67, and 1.91mg/L, respectively. The distances of these wells ranged from 85.4 to 602.0 m. Most water samples from hand-dug wells of the study site had sodium levels that fell within the permissible limits of WHO.

In contrast, water samples from hand-dug wells 7, 8, 22, and 24 had high concentrations of sodium with values of 213.0, 211.0, 201.0, and 207.0 mg/L, respectively. These are attributed to leachate from the cemetery. Forty per cent of the water samples had high sulfate concentrations ranging from 260 mg/L (well 20) to 530 mg/L (well 10). This is an indication that the leachate had migrated to a distance of about 813.0 m. The high elevation of total hardness was recorded in more than thirty per cent of the total water samples analysed, as indicated in Table 3. The value of this parameter in hand-dug well 1 was 480.0 mg/L at a distance of approximately 18.0 m from the cemetery on the western part, while hand-dug well 24 had the highest value of 1000.0 mg/L at a distance of 602.0 m. The hardness of the water from these wells may be attributed to the contaminants (leachates) from the cemetery that had found their way to the wells. Low levels of these parameters were recorded in other wells because they were not along with the directions of migration of the leachate plumes.

Water Quality Index (WQI)

Individual parameters in any water sample are not sufficient to determine water suitability for drinking and other domestic uses. The water quality index will perform this task (United Nations World Water Assessment Program (WWAP), 2014). The result of the water quality index of the water samples indicated that water from hand-dug wells 3 and 8, at distances of 21.9 m and 86.7 m respectively, from the cemetery were of excellent quality with WQI in the range 0 – 25, an indication that the leachate from the cemetery did not affect these wells. Four samples whose WQI fall in the range 26 – 50, at distances of 85.4 m, 175.0 m, 562.0 m, and 812.9 m, respectively, were of good quality and were best for drinking and domestic uses. The WQI of three water samples from hand-dug wells 5, 6, and 23, at distances 40.0, 51.8, and 572.0 m, respectively, were of poor quality and cannot be used for drinking purposes. The cemetery has contaminated the water from these wells; their

562.0 m, and 812.9 m, respectively, were of good quality and were best for drinking and domestic uses. The WQI of three water samples from hand-dug wells 5, 6, and 23, at distances 40.0, 51.8, and 572.0 m, respectively, were of poor quality and cannot be used for drinking purposes. The cemetery has contaminated the water from these wells; their WQI was in the range of 51–75. Seven water samples from the hand-dug wells 1, 2, 9, 15, 19, 24, and 30 which were at distances of 17.9 m, 21.0 m, 122.2 m, 436.0 m, 508.0 m, 602.0 m, and 822.7 m, respectively, from the cemetery had WQI ranged from 76 – 100 indicating that they were of very poor quality because leachate from the cemetery had greatly affected them and so was polluted. Fourteen water samples (about 47%) were unfit for drinking since their WQI values were above 100. The leachate from the cemetery had greatly affected these water samples from their various hand-dug wells, so; they cannot be used for drinking and domestic use. This indicates that the leachate from the cemetery had migrated to a distance of 719.3 m away from the cemetery.

Geophysical Method

All the eight VES data were subjected to qualitative and quantitative interpretations.The samples of such typical double log plot curves obtained for each cemetery side were shown in Figs. 4 (a) – (d). The curves obtained were type KHA, HA, and A. The qualitative interpretations revealed the presence of three to five-layers subsurface in the study site, but four-layer subsurface is the most prevalent. The lithology present in the study area is the clayey topsoil, laterite, weathered layer, and basement. The resistivity values of the clayey topsoil ranged from 46.7 Ω m (VES 4) to 96.8 Ω m (VES 3). The depth of occurrence of the clayey topsoil varied from 0.289 m (VES 7) to 1.60 m (VES 4). The laterite resistivity values in the study site varied from 169.0 Ω m (VES 6) to 551.3 Ω m (VES 2). The analysis results indicated that laterite could be found at the depth range of 1.04 m (VES 1) to 57.2 m (VES 2). The weathered layer, the third layer of the study site, is the aquifer and had its resistivity values in the range of 3.21 Ω m (VES 3) to 18.1 Ω m (VES 6). The low resistivity values recorded at this layer indicated that the migrated leachate from the cemetery was present here and that the layer served as a path for the contaminants (the leachate) and could be the possible host of the contaminants. The weathered layer was located at the depth range of 1.2 m (VES 3) to 3.1 m (VES5).The summary of such interpretation is indicated in Table 4. The presence of the migrated leachate confirmed the results obtained from the water quality index (WQI values from Table 3), which indicated the quality of the water samples in the study area to be poor, very poor, and unfit for drinking. The migration of the leachate from the cemetery took place in all directions (N, S, E, and W). The basement resistivity values varied from 901.0 Ω m (VES 3) to 91849.0 Ω m (VES 4)

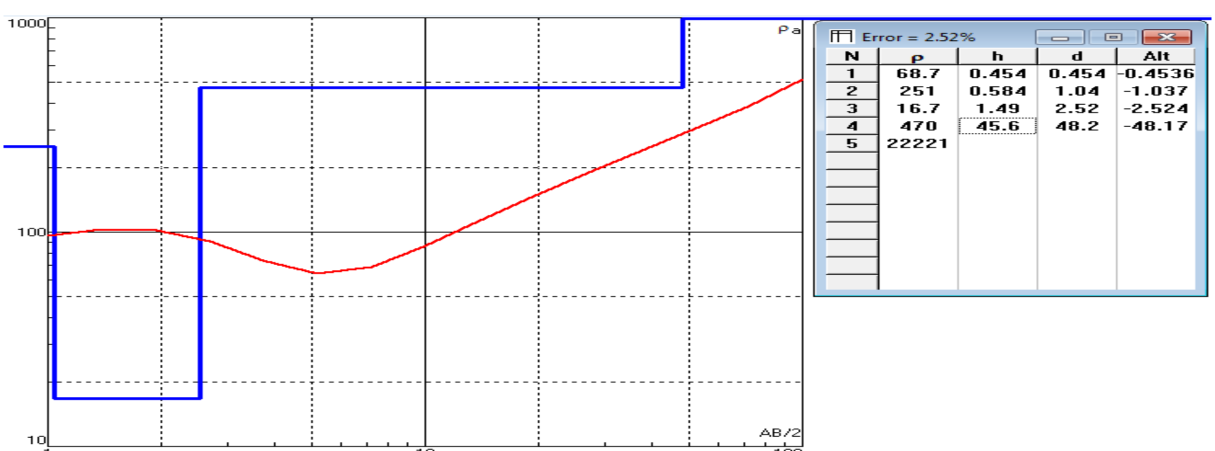

Figure 4 (a): Typical Double log Plot of VES 1

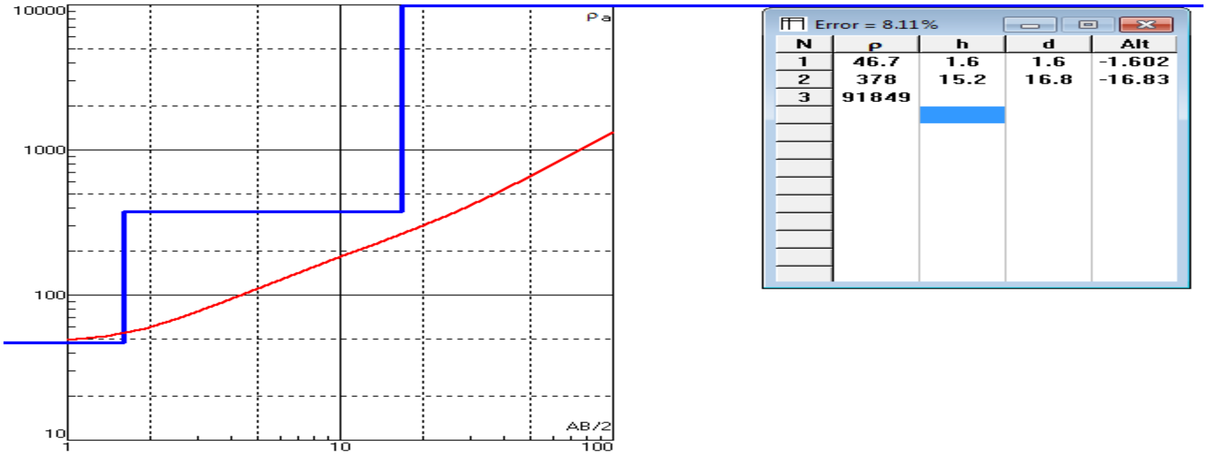

Figure 4(b): Typical Double log Plot of VES 4

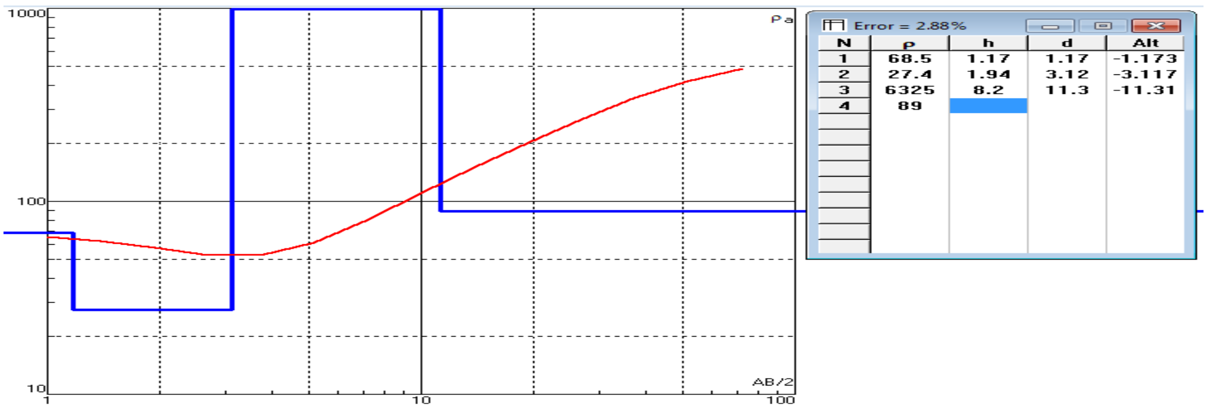

Figure 4(c): Typical Double log Plot of VES 5

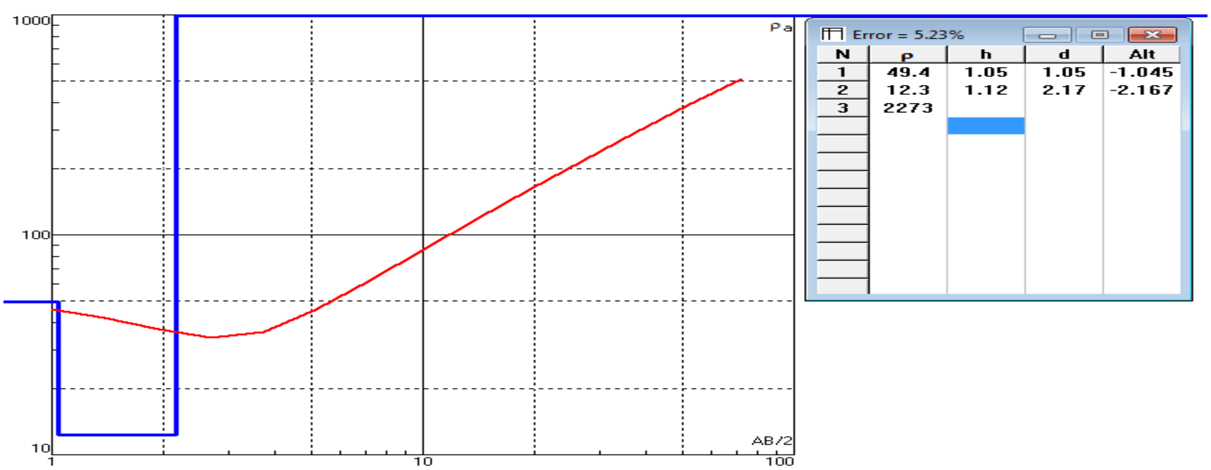

Figure 4(d): Typical Double log Plot of VES 8

Table 4: Vertical Electrical Sounding Summary

VES No	Location	Elevation (m)	Curve type	Resistivity (Ω m)	Thickness (m)	Depth (m)	Lithology
	04º 26.968' E	238.5	KHA	68.7	0.45	0.45	Clayey topsoil
1	0703.111' N						
				251.0	0.59	1.04	Laterite
				16.7	1.48	2.52	Weathered layer
				470.0	45.68	48.2	Laterite
				22221.1		---	Basement
2	04^0 26.960 E	238.0		94.74	1.16	1.16	Clayey
	07^0 33.124 N		HA				Topsoil
				15.04	1.35	2.51	Weathered layer
				551.3	54.69	57.20	Laterite
				17212		---	Basement
	04^0 26.952 E	237.0		96.8	1.00	1.00	Clayey topsoil
3	07^{0}33.136 N		HA	3.21	0.20	1.2	Weathered layer
				901			Basement
	04^0 26.887 E	234.8		46.7	1.6	1.6	Clayey topsoil
4	07^0 33.130 N		A	378	15.2	16.8	Laterite
				91849			Basement
	04^0 26.856 E	241.1		68.5	1.17	1.17	Clayey topsoil
5	07^0 33.071 N		HA	27.4	1.94	3.11	Weathered layer
				6325	8.2	11.31	Basement
				89			Basement
	04^0 26.945 E	244.0		82.4	1.12	1.12	Clayey topsoil
6	07^0 33.053 N		HA	18.1	1.77	2.89	Weathered layer
				169	6.77	9.66	Laterite
				39479			Basement
	04^0 26.918 E	237.7	KHA	69.4	0.289	0.289	Clayey topsoil
7	07^0 33.076 N			394	0.55	0.839	Laterite
				17.2	1.96	2.799	Weathered layer
				3183			Basement
	04^0 26.935 E	238.0		49.4	1.05	1.06	Clayey topsoil
8	07^0 33.067 N		HA	12.3	1.12	2.18	Weathered layer
				2273		---	Basement

Conclusion

This study has successfully integrated GIS, remote sensing, and Electrical resistivity methods to assess water quality in the vicinity of a cemetery at Edunabon, south-western Nigeria. The outcome of the physicochemical analysis of the sampled water showed that water parameters such as Cl^- NO_3^-, SO_4^{2-} and F^- had higher elevation concentrations traced to the leachate from the cemetery. In addition, the WQI of most of the sampled water had values greater than 50, indicating that qualities of these water samples were significantly affected by the leachate from the cemetery, thereby making the water from these hand-dug wells unfit for drinking. These results were supported by the results of the analysis of the electrical resistivity data, which showed that each side of the cemetery had low resistivity values (16.7 and 15.04 Ωm, 3.21 Ωm, 27.4 Ωm and 18.12 Ωm, 17.2 Ωm, and 12.3 Ωm)

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