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Determination of aquifer position, aquifer protective capacity and groundwater quality in selected dumpsite in obubra local government area of south eastern Nigeria

Egor A. O *

Department of Physics, Cross River University of Technology, Calabar, Nigeria.

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Abstract

At Obubra Urban in Cross River State, aquifer position, aquifer protective capacity, and groundwater quality assessment were carried out. With a maximum electrode spacing of 480 meters, 12 vertical electrical sounding (VES) surveys were conducted. The data collected were processed using the IPI2win program. employing five locations for a 2D survey A resistivity map of the dumpsites was also produced using electrical resistivity tomography (ERT). While traditional laboratory techniques were utilized to examine the groundwater, tritium tagging investigations were also conducted to determine the extent of infiltration in the study area. Four to five geoelectric sections are shown in the study. The aquifer is located at depths of 51.7, 56.4, 34.5, and 56.4 meters in the third, fourth, and fifth layers, respectively. While other VES locations have values between 0.06g and 015 mhos and are classed as weakly protected, the over burden protection capacity has values of 0.3, 0.2, 0.18, and 0.17 mhos at VES 1, 4, 7, and 8, respectively. The area's aquifer system is likely extremely permeable with strong storativity because of the area's high porosity and transmissivity characteristics. The area has an infiltration value between 7 and 21 percent, according to the tritium tagging technique used to measure the extent of infiltration from the dumpsite.

The aquifer system in the research area is porous, according to the results of the procedures described above, and toxins will circulate through it quickly if they are contaminated. The investigation reveals that while magnesium and cadmium were present in quantities beyond the WHO-approved limits for portable water, all other psychochemical markers were within acceptable limits.

Keywords: Groundwater; Aquifer; Protective capacity, Transmisivity

1. Introduction

The chemical quality of groundwater is generally suitable for most uses and has excellent microbiological quality. Nearly all of the solutes in natural groundwater are made up of eight primary chemical components: Na, Ca, Mg, KHCO3, CL, SO4, No3, and Si. The proportion of these basic elements in the groundwater is a function of its geology and past, with trace and minor elements making up the remaining 1%. The presence or absence of these components typically results in health issues or renders products unfit for eating by humans or animals.

In Nigeria, there is a vast deal of groundwater as well as other mineral resources like hydrocarbons and solid minerals. One of the most important resources that every country's citizens can use is portable water (Alile, 2008). Every area of human activity, including manufacturing, agriculture, transportation, building, domestic use, and so fort, has found a purpose for water. The need for this resource has led to the development of novel technology to find it.

* Corresponding author: Egor A. O
Department of Physics, Cross River University of Technology, Calabar, Nigeria.

Ground exploration has been added to the surface search for water. Groundwater can be classified by factors including conductivity, porosity, permeability, and transitivity. Any geophysical technique, including magnetic, seismic, and gravity approaches, can be used to determine these characteristics. In this study, groundwater investigation uses the electrical resistivity approach.

In both porous and fissured media, geoelectrical resistivity studies are frequently employed to look for groundwater. When saturated with fresh water, clean sands and gravels with porosities always produce good aquifers.

Due to the fact that the lithological characteristics of the aquifer primarily affect electrical resistivity's value, electrical resistivity is also frequently regarded as a valuable metric for hydrogeological research (George et al, 2011). It can also be helpful in comparing the lithological facies of different wells (Bell, 1993, El Gamili et al, 2011). But resistivity readings are also sensitive to the aquifer's porosity and water content, as well as to groundwater mineralization and salinity (MacNiel, 1980; Parasins 1997, Posdyakova et al, 2001, choudhury & Saha, 2004) therefore, the information from lithology logs should be used to constrain the field data in order to effectively employ geoelectrical resistivity data for hydrogeological studies. Gafi et al 2011. This research aimed to confirm the existence of an aquifer.

Due to Nigeria's population and the relevant agencies' lack of seriousness in implementing government policies, the country faces a waste management challenge. Despite this, there are significant pockets of refuse dumps in Obubra Urban, particularly the dumpsite in the Mile One Market, which is surrounded by residential homes. The majority of these homes have both motorized and manual boreholes.

In open dumpsites or landfills, groundwater flow contact or infiltration from precipitation is common. Leachate, the initial interstitial water, is gradually released by the dumped wastes, and some of its degraded byproducts mix with water flowing through the waste deposit. These leachates build up at the bottom of the garbage, travel through the soil, contaminate the groundwater, and may contain mostly fulvic acids, which are forms of organic carbon. Typically, hazardous materials are present, especially when the waste is industrial in nature (Nwajei & Iwegbu 2007). Such groundwater resource contamination presents a serious threat to people, animals, and the environment.

Depending on the time of year and the season, the water table in the area ranges from 4.1 to 18 meters and from 20 to 69 meters, respectively. The water is vulnerable to contamination because of how close the water table is to the surface. It is necessary to use geophysical method to determine the transmissivity of the aquifer materials and protective capacity of the overburden layers in order to assess the impact of these waste materials, how far and quickly they will percolate the ground to the point of having a detrimental impact on the quality of the groundwater.

A key characteristic of an aquifer is transmissivity, which helps define rocks as water-conducting media or strata. A measurement of the overburden's protective capacity is its capacity to delay and filter percolating fluid (Belmonte et al. 2004, Ehirim and Nwankwo 2010). It can be exceedingly expensive and time-consuming to estimate these qualities from pumping tests. Using empirical relationships between hydraulic and geoelectric characteristics, surface geoelectrical methods provide an alternate, speedy, and cost-effective method for evaluating aquifers and determining the quality of groundwater (Hubbard and Rubin 2002, Kelly 1997).

The main goal of this study is to assess the aquifer features in terms of the Dar-Zarouk parameters and, as a result, the transmissivity of the aquifer, the protection capabilities of the rocks that make up the overburden, and the rate of leachate infiltration through the overburden. By inference, the findings of this investigation will point to the area's groundwater quality impairment, which can then be further confirmed by laboratory testing on water samples taken from boreholes inside the study area.

1.1. Theoretical Background

Based on an assessment of layer resistivities and thicknesses made possible by using computer software (RESIST). The relationship established by NIWAS and Signhal (1981a) made it possible to calculate the aquifer hydraulic parameters for each VES station. Niwas and Signhal (1985), Mbonu et al. (1991), and Ekwa et al. (2006) all used the Dar-Zarok Parameters of Transverse resistance (R) and Longitudinal conductance(s) as a starting point for their analyses of the aquifer's transmissivity and protective.

The Dar-Zarouk equations for a horizontal, homogeneous, and isotropic layer Transverse resistance R and longitudinal conductance S parameters are calculated as:

$$S_i = \sum_{i=1}^{n} \frac{h_i}{\rho_i} \quad - \quad - \quad - \quad - \quad (1)$$

$$R_i = \sum_{i=1}^{n} \rho_i h_i \quad - \quad - \quad - \quad - \quad (2)$$

Where;
ρ_i and h_i are the layer resistivity and thickness of the layer.

The aquifer transmissivity T is expressed as the product of the hydraulic conductivity (K) and layer thickness (h)

$$T = Kh \quad - \quad - \quad - \quad (3)$$

The hydraulic conductivity is inversely related to the resistivity of the aquifer for clean saturated aquifers whose natural fluid characteristics are largely constant (i.e., no appreciable impact on the overall ground water quality by surface pollutant loads) (Kelly 1977, Mbonu et al 1991, Obianwu et al 2015). This suggests that the hydraulic conductivity of the aquifer can be approximated to the actual resistivity of the aquifer based on geoelectric investigation in the absence of pumping test data (Hubbard and Robin 2002). Therefore

$$T = \quad kh = \rho h \quad - \quad - \quad - \quad (4)$$

But the transverse resistance (R), which is quantitatively equal to the transmissivity T, is the product of resistivity and thickness (Henriet 1975, Ward 1990).

$$T = R \quad - \quad - \quad - \quad (5)$$

The longitudinal conductance (S) gives a measure of the impermeability of a confining clay/shale layer such layers have low hydraulic conductivity (K) and low resistivity. Protective capacity Pc of the overburden layers in proportional to its longitudinal conductance (Braga et al 2006).

$$P_c = S = \sum_{i=1}^{n} \frac{h_i}{\rho_i} \quad - \quad - \quad - \quad (6)$$

The relation between formation factor (FF), aquifer porosity and geoelectric parameters is expressed by

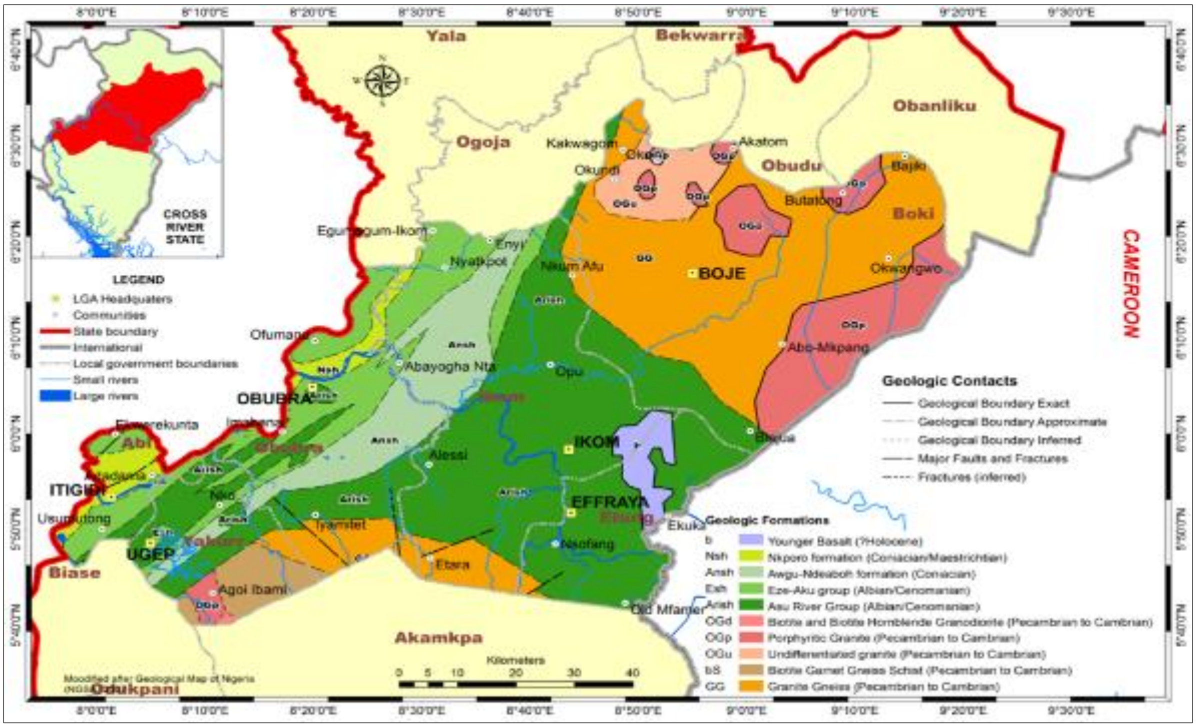
$$F = \frac{1.0}{\phi} = \frac{\rho_a}{\rho_w} \quad - \quad - \quad - \quad (7)$$

Where;
ϕ = aquifer porosity and
ρ_a and ρ_w are resistivity of the aquifer and groundwater respectively (Ayers, 1989).

The value of ground water resistivity in the area is 469 Ωm at 25 °C (GSN, 1990, Ehirim & Nwankwo 2010, Egor et al 2015, Obianwu et al 2015a, and Obianwu et al 2015b).

2. Location and geology of the study area

The research area, known as Obubra, is located in the Obubra Local Government Area of Cross River State between coordinates 427585E, 569868N and 429000E, 571500N, or between latitudes 5045' N and 5002' of the equator and between longitude 8012' E and 8016' E of the greenwich meridian (Fig 1). Geographically, the region is referred to as the Asu River Group (ARG). The earliest sedimentary rocks in the research area are the Albian ARG, which are essentially non-marine to marginally marine in character and predominately cover the eastern portion of the study area. They directly overlie the Precambrian basement. The ARG's sediments are made up of ammonites, impermeable shales, and limestone with minor sandstone intercalation. Odigi, & Amajor, 2009; Egor et al. 2015; NGSA, 2006;



Source: Modified after Geological Map of Nigeria – NGSA, (2006).

Figure 1 Geological map of the study area

On the basis of geological segmentation performed by the Cross River Basin Development Authority (CRBDA) in 1982, Peter (1989) identified four hydrological provinces, including the crystalline basement Province (CBP), Cross River Plain Province (NASP), and Alluvial Buried River Province (ABRP). Rills, rivulets, and streams inundate the plateau-like topography where local government area seats due to the area's dendritic drainage pattern.

3. Material and methods

Due to the interdisciplinary character of this study, a variety of data collection techniques were employed. First, the electrical resistivity method was utilized. Next, water samples were taken around the dumpsites and evaluated in the laboratory. Finally, the tritium tagging method was used to determine the degree of percolation and infiltration of water surrounding the dumpsite.

Vertical electrical sounding (VES) and horizontal profiling are the techniques used for the electrical resistivity survey. The Schlumberger setup with a maximum electrical spacing AB of 480m was chosen for the VES because it provides a depth of penetration AB/2 of 240m, and the Wenner array was used to conduct the 2D Electrical Resistivity Tomography (ERT) Survey. The Wenner array was chosen because it is sensitive to variations in the horizontal distribution of subsurface resistivity and is thought to be helpful in defining sedimentary strata. The Schlumberger array was employed as well since it is sensitive to both the vertical and horizontal resistivity distribution, which made it possible to pinpoint the location of the aquifer. A total of 12 VES stations were covered during the VES survey. The minimum current electrode spacing was 2 m at all of the stations, however due to severe space constraint, the maximum current electrode separation varied from place to place. The maximum current electrode separations typically range from 440 to 480 m. In a vertical electrical sounding survey, the current electrode spacing was extended symmetrically around the spread's center while the potential electrode was kept unchanged (Osang et al 2016).

In order to ensure that high-quality data was produced, the VES technique was supplemented with electrical resistivity tomography utilizing a Wenner array. To guarantee adequate coverage of the study area, measurements in the field were conducted systematically. For the first measurement, the first current electrode along the profile was designated as C1, the second electrode along the profile was designated as the first potential electrode P2, and the fourth along the profile was designated as the second current electrode C2. The switching between the electrode and different electrode separation was performed manually for the second round of measurement, in which electrodes 1, 2, 3, and 4 are used for C1, P1, P2, and C2 respectively. Up until the final sets of electrodes were used, this was repeated for the duration of the profile period. The second sequence of measurements, with electrode separation of 2a, was carried out after the first sequence of measurements, which has a minimum of 5m, was finished. Later, the distinction was raised to levels 3a, 4a, and 5a. The original position of C1 was always maintained during all measurement rounds, but it was observed that the number of measurements from the rounds before dropped by three when the distance between C1, P1, P2, and C2 grows. Five CRTs with a total profile length of 120m were completed.

The VES and ERT data were obtained using the IGIS model SSR-MP-ATS resistivity meter.

Three sites participated in tritium tagging research. The sites were chosen based on the resistivity values and degree of saturation of the soil layers in the specific study area. In the chosen sites various soil types were recorded.

By keeping an eye on the tritium injection's downward vertical trajectory, groundwater and leachate percolation were estimated. A peak in the tritium activity versus depth plot indicates the tracer's position. Six holes with circular geometries were simultaneously injected with a 40μcurie/Cm^3 tritium from the University of Calabar's nuclear laboratory at a depth of 70cm below the surface. At time the tritium was injected before the wet season and after 5 months later during the wet season, soil samples were taken (July 2019). The samples were taken with a hand auger at depths ranging from 10cm to 2m. In the laboratory of Cross River Water Board Limited standard gravimetric techniques were used to calculate the volumetric moisture content of each soil sample. According to fig 1.2 the volumetric moisture content was plotted against depth and ranged from 0.05 to 0.24. The amount of soil moisture extracted from each soil sample was measured using a liquid scintillation counter (L.SC) from the nuclear laboratory of physics department of the University of Calabar was used to measure the tritium activity of soil moisture extracted from respective soil sample. To calculate the shift in the injected tritium the centre of gravity (C.G) of the tritium activity peak was identified. Because of the effect of diffusion, hydraulic pressure, osmotic pressure and dispersion processes the tritium activity peak could not spike. For each site, Plots of count rates versus depth were created. Fig 1.3 illustrate a plot of count rate, centre of gravity of tritium and volumetric moisture content for one of the selected locations in the Eze Aku group. The depth of tritium injection and the peak's centre of gravity, were taken into account to determine the shift in the tritium peak, the shift position varied between 19.5 and 138.6cm for all three sites.

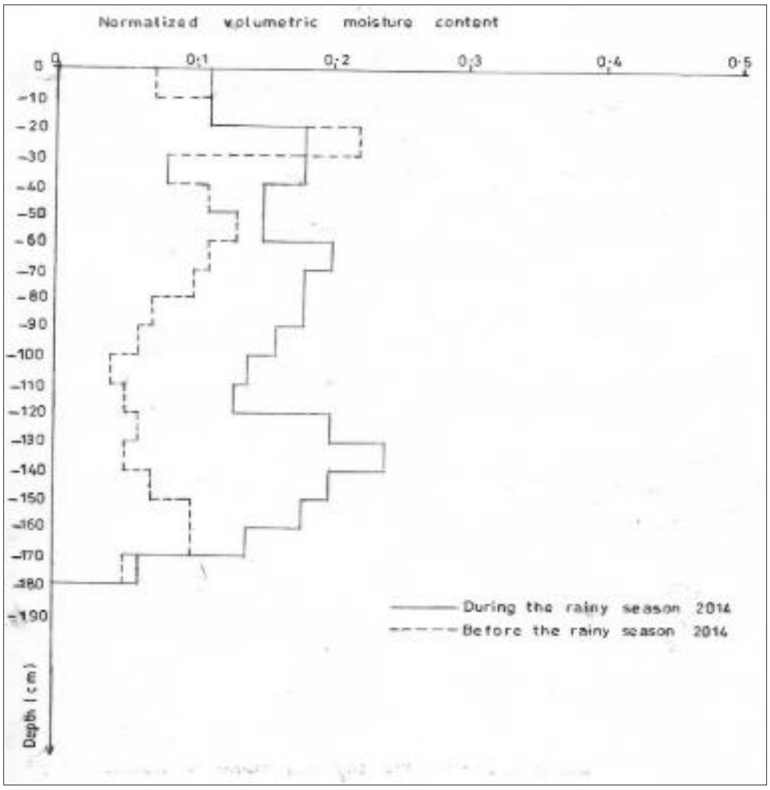


Figure 2 Movement of tritium peak and soil moisture at Ohana

By taking into account the product of tritium peak shift and effective mean volumetric moisture content in the tritium peak shift, the size of the percolation throughout the time interval of tritium injection (before the rainy season) and sampling (during the rainy season) was calculated (Zimmerman et al, 1967a, 1967b).

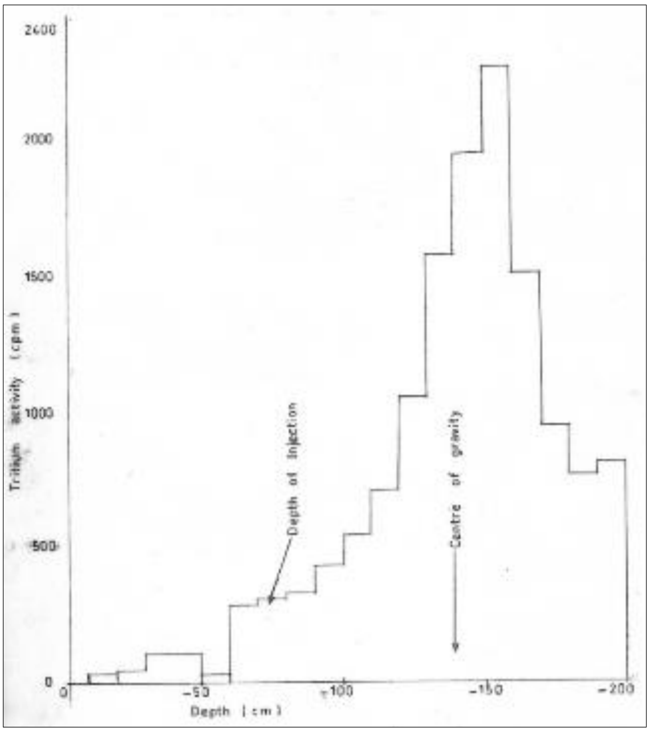


Figure 3 Tritium Peak Shift measured at one Station in the study area

Table 1 Tritium activity and depth

Tritium activity (cpm)	Depth (cm)
30	0
60	-10
80	-20
78	-30
130	-40
90	-50
300	-60
350	-70
450	-80
500	-90
1000	-100
1200	-110
1500	-120
1800	-130
2200	-140
2000	-150
1500	-160
500	-170
250	-180

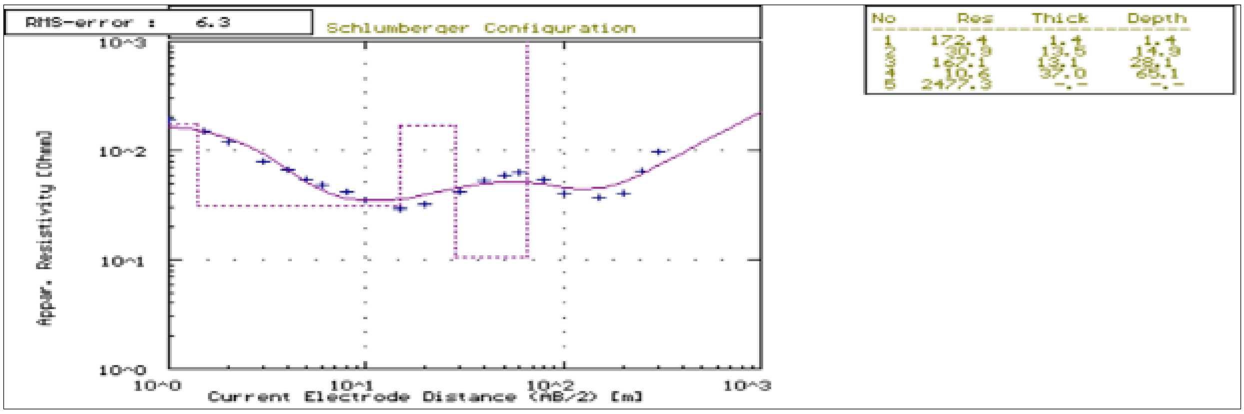
Equation (5) below can be used to mathematically determine the proportion of groundwater recharge

$$R \quad = \quad \tilde{v}\ * \quad \Delta S\ (100/p) \ldots\ldots 5$$

Where R is the percentage recharge to groundwater, $\tilde{V}$ is the effective mean volumetric moisture content in the tritium peak shift region, ΔS is the shift in tritium peak in cm and P is rainfall in cm. Data on rainfall was gathered from NIMET Calabar.

4. Results

The IP12Win software version 3.0 (2003) was used to process the summary of the apparent resistivity data a (m) from measurements in all of the sounding stations, which is shown in table 2. The data analysis revealed the 4-5 interpretable geoelectric layers type of HKH, HAK, QHK, and QHA curves (fig. 1.4). Table 2 -Summary of results of Geoelectric survey from computer modeling.



(Source:Author’s field work, 2019).

Figure 4 Apparent Resistivity model curve of obubra urban (VES 10) in the study area

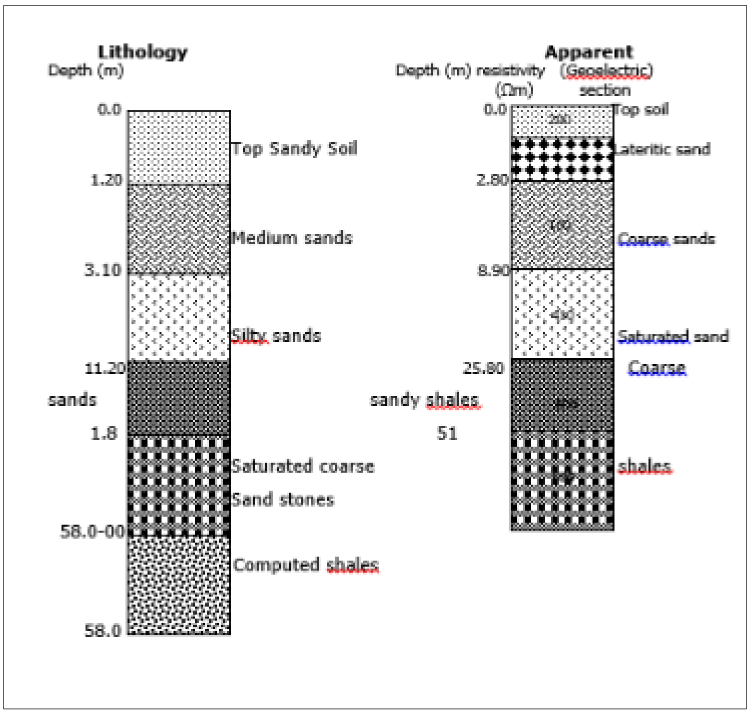


Figure 5 Lithology log from nearby borehole and Geoelectric section compared

The model results were quantitatively interpreted in terms of the true resistivity of the rock formations and with the aid of the lithologic log of nearby borehole penetrated to depths greater than 60.0m fig 5.

Table 2 Summary of results of Geoelectric Survey from computer modeling

VES Station No.	Location	No. of layers	Geoelectric layers Resistivities						Geoelectric layer thickness (m)					Depth to bottom of Geoelectric layer (m)				
			$\Sigma\rho$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	d_1	d_2	d_3	d_4	d_5	h_1	h_2	h_3	h_4	h_5
1	Obubra Mkt		1043	195	31	606	211	470	5.2	8.9	25.6	12.0	-	5.2	14.1	39.1	51.7	
2	Obubra Okwuniyang		1516	392	67	793	264	825	3.2	7.0	27.8	20.9		3.2	10.2	38.0	58.9	
3	Mile 1 Mkt East		1698	237	100	491	621	249	3.1	6.3	18.0	10.6		3.1	9.4	27.4	38.0	
4	Mile 1 Mkt South East		886	165	188	86	245	202	1.5	3.5	18.4	33.0		1.5	5.0	23.4	56.4	
5	Mile 1 Mkt western flank		1845	740	75	620	150	260	2.5	3.7	41.0	19.7		2.5	6.2	47.2	58.9	
6	Mile 1Mkt Northern flank		1891	491	86	744	259	311	3.7	8.2	13.3	9.7		3.7	11.9	25.2	34.0	
7	Mile 1 Mkt. by Old First bank		846	176	156	98	320	96	2.8	1.6	21.1	22.0		2.8	13.4	34.5	56.5	
8	Aunty Rose Sec. Sch.		1374	165	120	103.0	574	412	4.1	15.0	19.0	22.1		4.1	19.1	38.1	60.2	
9	Police Barrack Obubra		1345	496	210	106	320	240	2.4	8.8	15.1	19.6		2.4	11.2	26.3	45.9	
10	Opa Model Schools		643	157	148	128	210	290	3.1	10.8	21.0	28.0		3.1	13.9	34.9	62.9	
11	Ghadfi hotel site		2038	490	180	150	798	420	7.3	8.9	11.6	20		7.3	16.2	27.8	47.8	
12	Assemblies of God flank		1230	299	190	181	460	120	6.1	10.6	19.1	20		6.1	16.7	35.8	55.8	

Table 3 displays the study area's geoelectric characteristics and Dar Zarrouk Parameter. Oladapo et al. (Mbipom et al. 1996) changed the longitudinal conductance (mhos) ratings as follows: >10, excellent; 5 to 10, very good; 0.7 to 4.9 good; 0.2 - 0.69, moderate; 0.1 to 0.19 weak; 0.1; poor; and these ratings were used to evaluate the protective capacity of the layers.

The study area is moderately protected at VES 1, 2, 3, 5, and 12, weakly protected at VES 6, 9, and 11, and poorly protected at VES 4, 7, 8, and 10. These longitudinal conductance values indicate that the study area is moderately protected at VES 1, 2, 3, 5, and 12. The aquifers have no boundaries. Because there is a substantial lack of clay in the overburden materials in the research region, the protective capacity appears to be poor, which inadvertently facilitates the infiltration of contaminated leachate into the aquifer. The garbage on the dumpsite has left some venerability in the local aquifers.

Table 3 Computed aquifer and Dar-Zarouk Parameters of the Geoelectric sections

VES No	Aquifer average apparent resistivity ρ_a(Ωm)	Aquifer depth (m)	Aquifer thickness (m)	Protecting capacity Pc	Protective capacity rating	Porosity %	Transmissivity	Recommender aquifer depth for groundwater development (m)
1	302.6	51.7	12.0	0.1708	Weak	67.05	2532	51.7
2	468.2	58.3	20.9	0.1245	Weak	55.62	5519.6	58.3
3	339.6	38.0	10.6	0.111	Weak	52.55	2639.4	38.0
4	177.2	56.4	33.0	0.3183	Moderate	72.75	8085	56.4
5	369.0	58.9	19.7	0.1596	Weak	50.41	2955	58.9
6	378.2	34.0	9.7	0.0899	Poor	49.80	2512.3	34.0
7	169.2	34.5	21.1	0.2039	Moderate	74.45	2067.8	34.5
8	274.8	38.1	19.0	0.1390	Moderate	58.42	1957	38.1
9	274.4	26.3	15.1	0.0959	Poor	59.05	1653.6	26.3
10	186.6	34.9	21.0	0.1870	Moderate	85.40	2688	34.9
11	407.6	27.8	11.6	0.0682	Poor	47.96	1740	27.8
12	246.0	35.8	19.1	0.1455	Weak	61.74	3075.1	35.8

4.1. Physicochemical analysis of groundwater

Groundwater samples were collected from four boreholes around the vicinity of the dumpsite at horizontal surface distances of 120m, 138m and .150 from the 1st, 2nd, 3rd and 4th boreholes respectively from the dumpsite. The collected samples were examined for a variety of physicochemical parameters in the CRSWBL laboratory, including pH, temperature, electrical conductivity, Total Dissolved Solids (TDs), NH4+, Al3+, Zn2+, Ni2+, Fe2z, Pb2+, Pb2+, Cadmium, DO, Nitrogen, Copper, TCC, FCC, salinity, TSS, NO2, odor, color, Cyanides and fluorides.

Water is one of the most prevalent naturally occurring mineral compounds that we are aware of. It is vital to life on earth and has significant philosophical, scientific, and even religious significance (Barber 1986). The components of water quality are the physical, chemical, and biological elements that affect the useful use of water (Boyd and licht-koppler, 1979). The amount of species, composition, diversity, stability, production, and the physiological conditions of the native population are all impacted by water quality (Apha 1975). The physical, chemical, and biological features of groundwater, which in turn depend on the region's geology and the intensity of human activity there, are important indicators of the quality of the water (Ezeigbo 1989).en, Copper, TCC, FCC, Salinity, TSS, NO_2, Odour, Colour, Cyanides, fluorides, Nitrate, Residual Cl_2, Sodium, BOD.

Water is about the most commonly naturally occurring mineral compound known to man, it is essential for life on earth and occupies a very important space in science, philosophy and even religion (Barber is 1986). The physical, chemical and Biological factors that influence the beneficial use of water constitute the water quality (Boyd and licht-koppler, 1979). Water quality affects abundance of species, composition, diversity, stability, Production, Physiological conditions of indigenous population (Apha 1975). Groundwater quality is greatly adjudged by its physical, chemical and biological characteristics which in turn depends the geology of the area and magnitude of human activities in the area (Ezeigbo 1989).

Table 4 lists the findings of the parameters' laboratory measurements.

Table 4 Result of water quality parameters

s/n	Parameter/Unit	Borehole 1	BH_2	BH_3	BH_4	NISDWQ	Value	Remarks
1	Ph	4.8	5.6	5.0	8.1	6.5-8.5		BH4
2	Temperature (^oc)	28.5	28.0	29	28.0		28.37	
3	Electrical conductivity (Ec)	µs/cm 81.5	98.3	85.1	99.0	400	90.97	
4	TDS (mg/t)	21.1	16.4	0.40	0.6	500	9.65	
6	Colour	<5	<5	<	<5		<5	
7	Odour	Unobjectionable	Unobj	Unobj	Unobj	-		
8	Fluorides (mg/l)	0.10	0.15	0.10	0.13		0.12	
9	Nitrates (mg/l)	2.20	2.50	4.1	2.0	50	2.7	
10	BOD (mg/l)	2.50	2.41	3.50	2.10		2.63	
11	DO (mg/l)	13.54	16.80	15.17	16.67	5.0	15.53	
12	Cyanides (mg/l)	0.01	0.01	ND	0.01		0.01	
13	Residual (CL_2 (mg/l)	0.01	0.11	0.10	0.15		0.11	
14	Sodium ((mg/l))	1.53	2.76	2.30	1.08		1.91	
15	Copper ((mg/l))	0.19	0.016	0.021	0.012		0.059	
16	Al_{3+}((mg/l))	0.04	0.02	<0.08	0.10		0.06	
17	NH_{4+} (mg/l)	0.17	0.17	0.15	0.16		0.16	
18	Zn_{2+}(mg/l))	0.18	0.20	0.6	0.15	3.0	0.14	
19	Ni_{2+} (mg/l)	0.008	0.011	0.026	0.013		0.014	
20	Fe_{2+}(mg/l)	0.17	0.20	0.26	0.26	0.3	0.22	
21	Pb_{2+} (mg/l)	0.01	0.02	0.06	0.05	0.01	0.035	
22	TCC 100 ml/cfu	0	0	26	0		6.5	
23	FCC 10 ml/cfu	0	0	8	0		2	
24	TTSS (mg/l)	0.001	0.002	0.017	0.12	500	008	
25	Cadmium (mg/l)	0.02	0.02	0.010	0.06	0.003	0.027	
26	Total Alkalinity	40	60	55	90	120 mg/l		Not adequate
27	Total Hardness							
28	Turbidity	0.17 NTU	0.71NTU	0.16atu	0.20NTW		0.18	Not adequate
29	Salinity (PPm)	82.2	93.1	48.0	51.3	200 mg/l (WHO)	68.65	
30	Magnesium	4.0	5.0	5.0	8.0	0.20	5.5	
31	No_2	0.05	0.04	0.05	0.03		0.04	

NSDWQ =Nigerian Standard for drinking water quality; ND=None Detected

5. Discussion

The tritium tagging tracing technique was used to estimate the amount of leachate infiltration in the research region. The results showed that leachate infiltration ranges between 7 and 21%, and that the properties of the unsaturated topsoil layers directly affect leachate penetration. This is consistent with the knowledge from ground resistivity studies that the soil's resistivity depends on the type of soil, its saturation level, the age of the rocks, its degree of cementation, and its infiltration characteristics. Low permeability soils produce low resistivity values, and high permeability soils produce high resistivity values (Israil M et al 2006). From the resistivity survey information gathered from the research region, the top layers prior to the aquifer's resistivities were computed. As illustrated in Fig. 6, a linear relationship between the estimated infiltration percentage and the overburden layers' resistivity was discovered. This empirical relationship is known as the infiltration model for the research area.

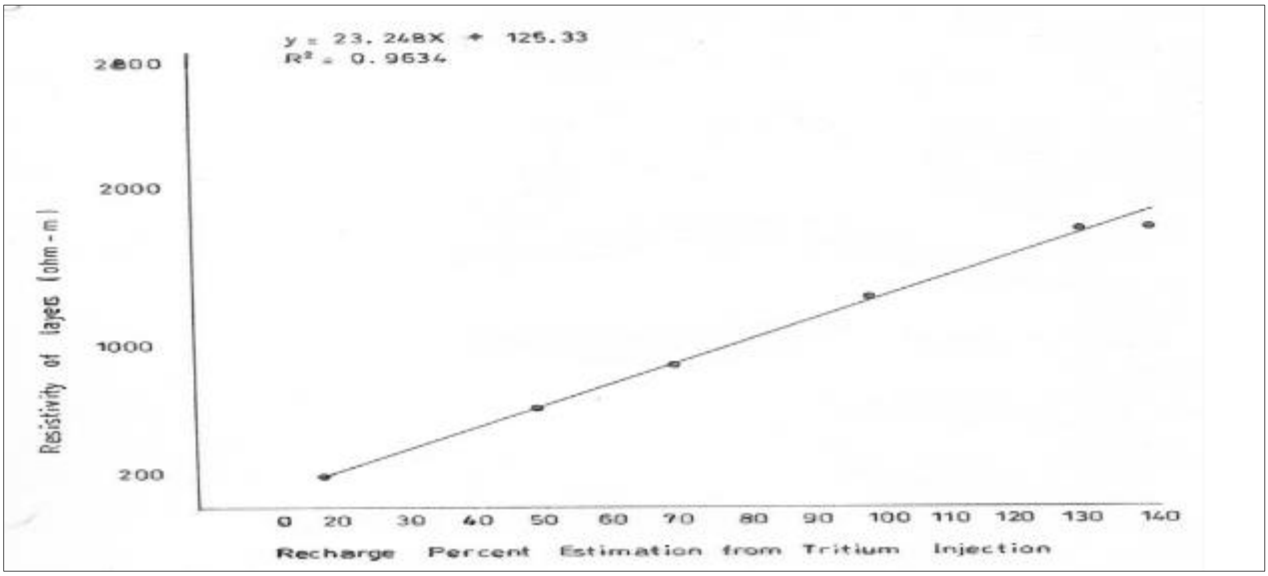


Figure 6 Correlation of recharge / percolation Per cent Estimated from Tritium Tagging Technique and resistivity of the layers of the soil

The aquifers are inferred to be between the 3rd, 4th and 5th geoelectric layers with resistivity range of 1692Ωm to 468.2Ωm, with depths between 26.3m to 58.9m and layer thicknesses well above 9.7m. The protective capacity (P_c) of the overburden rock materials range from 0.068 to 0.318 Siemens. The low values of the protective capacities of <1.0 Siemens, is an indication of overburden rock materials with no significant impermeable clay/shale overlying strata. This is an indication of high infiltration rate of surface contaminant into the aquifer. This is interpreted as overburden layers with smaller capacity of protection to contaminant and probable risk to soil and groundwater contamination.

The transitivity values were quite high, well above 400Ωm^2 in all the VES stations. The high values suggest that the aquifer materials are highly permeable to fluid movement within the aquifer, which could serve as a favorable condition for migration, infiltration and circulation of contaminant in the groundwater aquifers.

The computed porosities of the groundwater range between 49.8 to 85.4%. The high porosities values are due to the unconsolidated nature of the aquifer materials. High porosities are associated with aquifers of relatively low resistivity, fine to medium grained sands and high water content.

Fig 7 (Profiles; a, b, c, d and e) are tomograms of the results from 2D resistivity inversion of the study area. The profile length is 120m while inter profile spacing was 25m, there were sharp variations in the values of the resistivity observed displaying high and low resistivity values at different stations in the 2D image, suggesting leachate plume in the aquifer at different depths.

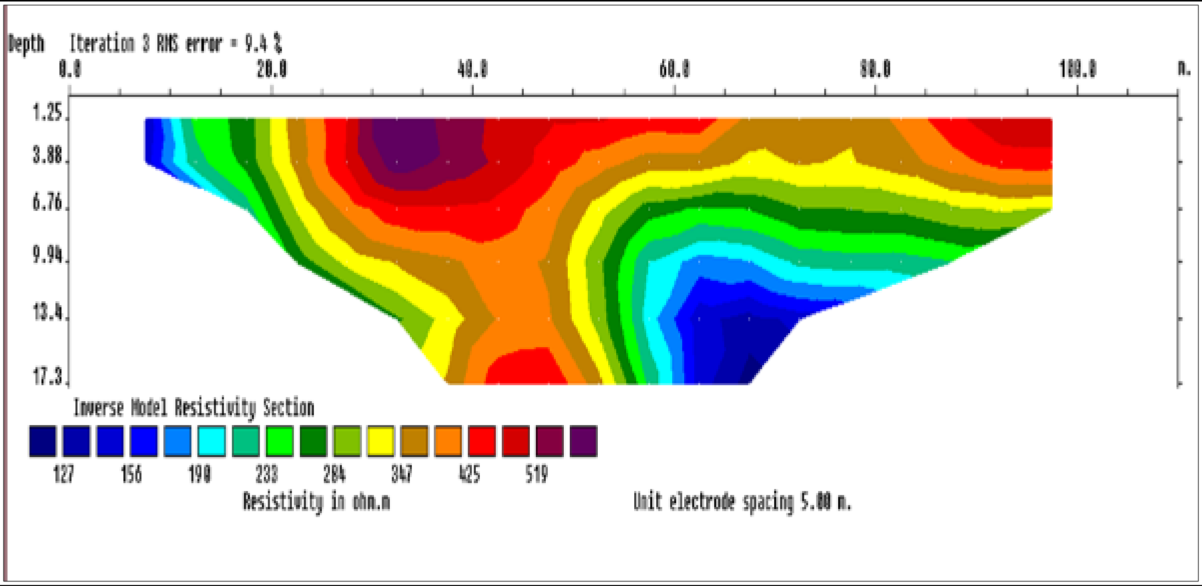
In profile 1, the resistivity of the top soil varied from 127 to 519 Ωm and thickness of 4.13m. The resistivity of the second layer is between 156 to 347Ωm and thickness of 5.6m, the third layer's resistivity lies between 198 to 425 Ωm and thickness of 4.5m, while the fourth layer has resistivity of 120 to 500Ωm and thickness of 6.8m leachates plume is nonexistent and the area is well protected.

In profile 2, the resistivity of the topsoil varied from 65.1 to 834 Ωm and the thickness in 4.9 in the resistivity of the 2nd layer is between 94.3 and 579 Ωm the area is well protected.

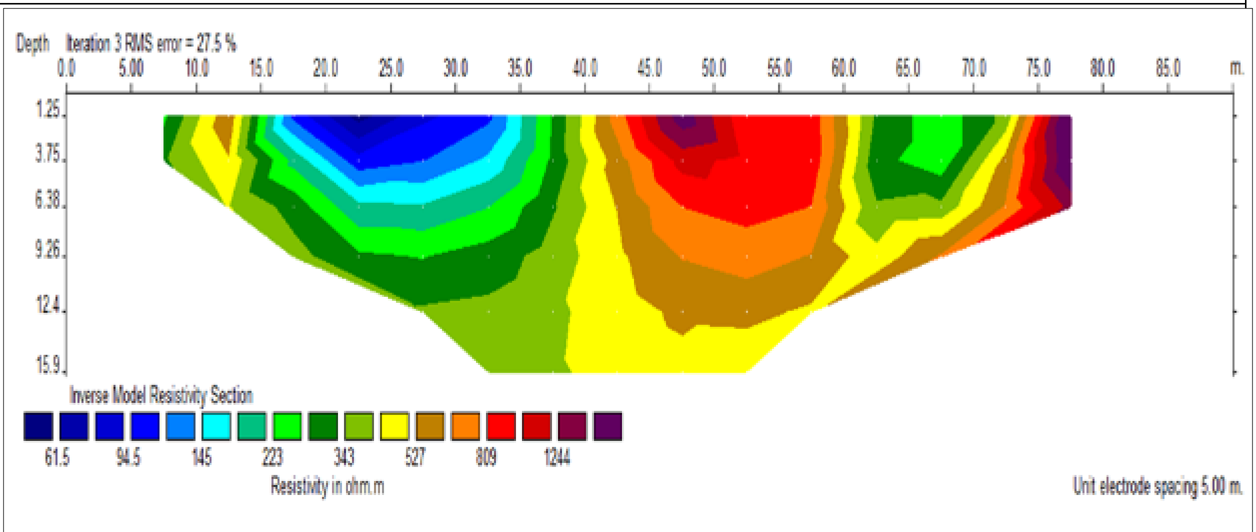
In station 3, the 1st layer has resistivity of 61.1 to 662 Ωm and thickness of 4.01m. The resistivity of the second layer varied from 90.0 to 550Ωm, thickness of 2.8m while the third layer has resistivity between 250 and 980 Ωm with a thickness of 5.3m. The fourth layer has resistivity between 202 and 560 Ωm and thickness of 6.2m. Leachate plume is not found in any layer and the area is adequately protected.

In the 4th profile, the top layer resistivity range from 60 to 520 Ωm with a thickness of 4.3m, the second layer has 145 to 750Ωm resistivity and a thickness of 3.6m there is no leachate plume and the area is adequately protected.

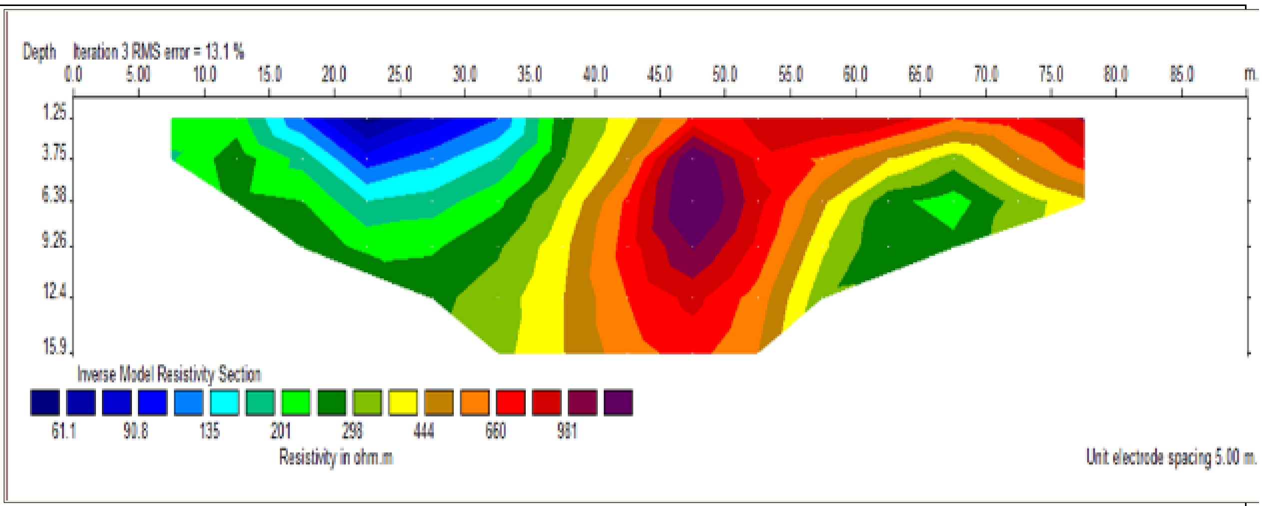
The fifty profile's topsoil has resistivity range 52.0 and 479Ωm with a thickness of 17.1m. Leachate plume is not found around and the area is well protected.



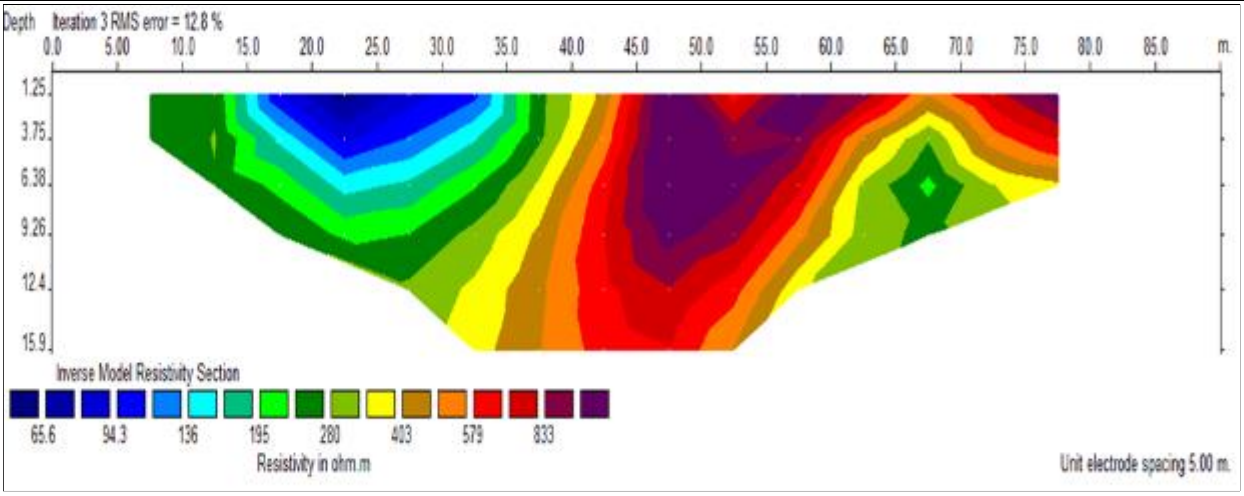
a ; PROFILE 1



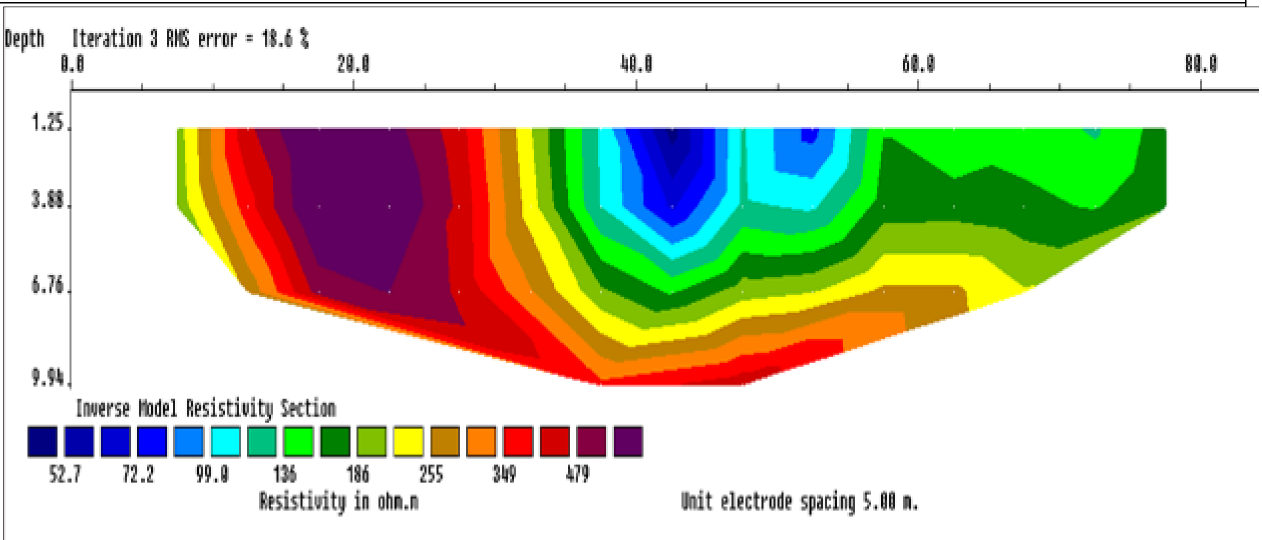
b; PROFILE 2



c; PROFILE 3



d; PROFILE 4



e; PROFILE 5

Figure 7 a, b, c, d and e; Tomograms of 2D resistivity inversion of the study area

A careful look at table 1.5 shows that the pH values (which is a measure of concentration of hydrogen ions present in the water samples) varied between 4.8-8.1, with an average value of 5.88 this generally suggest that the water samples are all acidic excerpt BH4 whose value is within the acceptable limits. The low values recorded in the other three boreholes may be due the presence of organic matter or acidic substances such as microorganism, excessive levels of $CO_2(g)$ and $SO_2(g)$. Although some researchers believe there is no direct health implications attributed to human consumption of water with PH value deviating from the required standards, but the body preference for proper function tend to favour slight alkalinity hence the human tends to maintain a delicate alkalinity-acidity balance.

Further looks on table 4 shows that the first three boreholes have alkalinity values between 40-60 mg/l while the fourth had 90 mg/l, these are all below the WHO stipulated maximum of 120 mg/l for portable water consumption and recreational uses. It is note-worthy to mention that oftentimes, a mild level of alkalinity is advisable for water in order to neutralize its acidic effects.

The salinity values (which gives a measure of the salt content of the water samples) varied from 48.00 mg/l to 93.10 mg/l with an average value 68.65 mg/l, this implied that the water can be used domestically as each of the values fall below the stipulated WHO maximum salinity level of 200 mg/l for portable water, hence reducing the chances of hypertension on the part of human consumers.

The four boreholes had turbidity values of 0.16NTU-0.20NTU and an average value of 0.18NTU, these values are lower than WHO stipulated maximum turbidity value of 5.00NTU for portable water. Turbidity is the measure of the clarity or cloudiness of water, it is brought by the presence of colloidal matter or suspended particles in water.

Eletrical conductivity (EC) (Which is the degree of electric current transmission, due to ionic concentration) of the water samples from the four borehole varied from 81.5 µS/cm to 99.0 µs/cm with a mean value of 90.97 µs/cm. These values are far below the stipulated WHO maximum EC values of 400µS/cm for portable water. It should be noted that pure water is naturally a bad conductor of electricity and heat. Higher values of EC can only exist if there is excessive increase in the concentration of dissolved ionic solids within the water samples.

The temperature of the water samples varied from 28.0^0c to 29^0c across the four boreholes with an average value of 28.37^oc, these values are lower than the stipulated WHO maximum temperature level of 40^0c for portable water. There is no ill-health effect associated with water having temperature values higher than the WHO maximum of 40^0c, this is because the water can always be allowed to cool down to room temperature within a short time before it is consumed. Magnesium (Mg) had values between 4.0 mg/l to 8.0 mg/l spread among the four boreholes, with an average value of 5.5 mg/l, all these values were lower than the WHO and NSDWQ stipulated maximum magnesium level of 150.0 mg/l for portable water.

The value of the Nitrate $(NO_3)(ag)$ contained in the water samples ranged from 2.00 mg/l to 4.1 mg/l with an average value of 5.5 mg/l, again the values were all below the stipulated WHO maximum Nitrate value of 50 mg/l..

Total Dissolve solid (TDS) have values between 0.4 to 21.2 mg/l with an average of mg/l these values were below the allowable WHO maximum TDS value of 600.0 mg/l for portable water.

On the other total suspended solid (TSS) values ranged between 0.001 to 0.017 mg/l with an average of 9.6 mg/l. the values are lower than the stipulated WHO maximum TSS values of 600. mg/l for portable water.

Dissolved oxygen (DO) had values ranging from 13.4 mg/l at BH_3 to 16.80 mg/l at BH with an average of 15.5 mg/l while the values of Biochemical oxygen Demand (BOD) ranged from 2.10 mg/l at BH_4 to 3.50 mg/l at BH_3 with an average value of 2.63 mg/l, all the values were lower than the stipulated WHO maximum BOD value of $\geq$ 6.0 mg/l for potable water, a condition which implied that each of the boreholes has less organic pollution.

Heavy metals like Pb_{2+}, Zn_{2+}, Fe_{2+} were detected in the samples, Pb_{2+} had values ranging from 0.01 mg/l at BH_1 to 0.06 mg/l at BH_3 with an average value of 0.035 mg/l, the values of Pb_{2+} at BH_2 to BH_4 are higher than the stipulated WHO maximum Pb_{2+} value of 0.01/ mg/l which is very damaging to the human body, as it could trigger the process of the growth of cancer cells and could have effect on nervous system. The value of Pb_{2+} at BH_1 is in tender with WHO standard.

Zn_{2+} has values of 0.18 mg/l to 0.6 mg/l across the four boreholes which are all below the stipulated WHO maximum Zn_{2+} value of 5.00 mg/l and to NSDWQ stipulated maximum value of 3.00 mg/l for potable water, it is important to remark that at the moment, no negative health implication has been clearly linked to excessive levels of zinc in drinking water. All the samples showed values of Fe_{2+} which are higher than the stipulated WHO maximum Fe_{2+} value of 0.100

mg/l but lower than the stipulated NSDWQ of 0.300 mg/l for potable water. There are still no clear ill-health effected traceable to excessively high values of Fe_{2+} in portable (drinking) water.

The value of cadmium in the Boreholes ranged from 0.01/ mg/l to 0.02 mg/l and an average value of 0.027 mg/l, all the values are higher than the stipulated WHO and NSDWQ maximum cadmium level of 0.003 for potable water. Excessive consumption of cadmium can cause kidney related illnesses in humans.

In the aspect of the total coliform count (TTC), the WHO requirement is that for potable (safe drinking) water, the water must be completely free of the presence of total coliform, but unfortunately the third borehole had 26 (100 ml/cfu) level of TCC. It is worthy of note that even the smallest trace amount of TCC most likely confirm the dreaded reality of fecal waste contamination of the affected water sample. WHO had already stipulated that a sample with TCC range of 1-10 counts/100 ml is a low risk contamination.

5.1. Recommended aquifer and waste management practices

The following aquifer and waste management practices have been recommended to sustain groundwater quality in the area.

- The use of inorganic chemical fertilizers, especially those enriched with nitrogenous compounds around the low-lying northern zones should be properly regulated. This approach is the most practically acceptable and standard measure in abating groundwater pollution resulting from the application of fertilizers, in such shallow aquifer areas.
- The period of application of inorganic fertilizers should be carefully planned, so that it does not correspond with the peak period of leaching, which in the area will coincide with the peak period of rainfall (June and July). Thus, fertilizer application must be done at the period of maximum crop uptake.
- Regulations to protect important water supply aquifers should be adopted.
  - The adoption of good sanitary habits and practices. Septic system management practices, such as periodic pumping and inspection (e.g., at intervals of 5 years), should be adopted.
  - Chemicals should not be dumped on drains or on the ground. Environmentally friendly methods of waste management, such as waste recycling, should be adopted to reduce the impact of industrial wastes on the environment.
  - Waste dumpsite should be sited far away from Town and proper ground preparation should be carried out before sitting a dumpsite.

6. Conclusion

Arising from the study, it is clear that four to five geoelectric layers were accessed and the depth of penetration was not more than 60.0m, but it is interesting to note from the study that the area's aquifer system are likely extremely permeable with strong storactivity, high porosity and transmissivity characteristic with an infiltration value beteween 7 and 21 percent. On the other hand, results of analyzed groundwater samples showed that most of physiocochemical parameter values lie within the approved NSDWQ standard values except the values of Pb_{2+} at BH_2 to BH_4 which are higher than the stipulated WHO maximum Pb_{2+} value of 0.01/ mg/l and is very damaging to the human body.

Compliance with ethical standards

Acknowledgments

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