Geophysical Assessment and Groundwater Quality in Michael Okpara University of Agriculture, Umudike, Abia State.

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ABSTRACT

This research presents a comprehensive geophysical and groundwater quality assessment in Michael Okpara University of Agriculture, Umudike, Nigeria. The major aims of this research are to delineate aquifers, assess the present quality of groundwater at Michael Okpara University of Agriculture, Umudike, and generate forecasting models of groundwater resources for use by farmers in the south-east agro-climatic zone of the country. Potential aquifer zones have been delineated using fourteen (14) geoelectrical resistivity soundings at maximum current electrode spread of between 600 and 800 m. Aquifer resistivity varied from 249.70 to 4192.30 Ωm. Twelve groundwater samples were collected within the university campus and its environs and analyzed for nine (9) groundwater quality parameters: pH, conductivity, acidity, alkalinity, temperature, turbidity, total solids, total dissolved solids and total suspended solids.

Results showed that the groundwater in the area was acidic with an average pH value of 5.47, which falls below the World Health Organization (WHO) standard for drinking water. They also showed high turbidity values ranging from 86.10 to 90.17 NTU which exceeds the WHO standard. The water samples have moderate to high values of total dissolved solids, TDS (100.00 to 900.00 mg/L), total suspended solids, TSS (100.00 to 1200.00 mg/L) and conductivity (66.67 to 600.03 μs/cm)The transmissivity values in the area ranged between 48.00 to 384.80 $m^2 day^{-1}$, while Kσ values ranged between 0.0009 to 0.0099 $(\Omega d)^{-1}$. The quality parameter pair curves for arsenic vs. sulphate ion and copper vs. chloride ion when plotted against well locations showed the highest peak at well number 6.

(Keywords: vertical electrical sounding, VES, aquifer, lithology, transmissivity, pair curves, resistivity, groundwater quality, pH, turbidity, conductivity, TDS)

INTRODUCTION

Groundwater is a natural resource that is of immense importance to life. Its characteristics are greatly determined by the properties of the immediate geologic formations. Groundwater is naturally stored in the pores spaces within soil compartments and between unconsolidated formations. Aquifer characteristics are greatly influenced by formation strata and terrain type (Akpokodje and Etu-Efetobor, 1987). Hence, the acquisition of viable deep water wells is mainly dependent on adequate and reliable empirical knowledge of the geology of the area and the depth of aquifer (Okolie *et al*., 2005).

Generally researches conducted in recent times using the surface electrical methods are fundamentally geared towards determining lithology (Abdu-Lateef, 1981; Aboh and Ozazuwa, 2004; George *et al.*, 2010; Evans *et al*., 2010), groundwater potential (Ibrahim *et al*., 2004; Kayode, 2004), and saltwater-freshwater interface (Oyedele, 2001; Usen *et al*., 2007).

Groundwater is never really chemically pure as water invariably dissolves some of the minerals it comes in contact with, at any given time (Akankpo *et al*., 2011). These dissolved minerals are contained in the groundwater which influences its hydrogeochemistry and ultimate quality (Nwankwo and Igboekwe, 2011). Poor management of solid waste materials has resulted to a lot of disastrous effects such as aesthetics, environmental hazards and pollution. Groundwater pollution may also occur due to the contamination potential of leachate from waste. Various methods by which waste can be disposed are open dumps, sanitary landfill, inceineration on-site disposal, animal feeding composting (Akankpo *et al*., 2011).

Meteorological events and pollution are a few of the external factors, which affect physico-chemical parameters such as pH and turbidity of the water. They have a major influence on biochemical reactions that occur within the water. Sudden changes of these parameters may be indicative of changing conditions in the water. Internal factors, on the other hand, include events which occur between and within bacterial and plankton population in the water body (Nwankwo and Igboekwe, 2011; Zamxaka *et al*., 2004).

This research was conducted in order to determine the hydrogeological parameters; hydrochemical parameters and formation strata of Michael Okpara University of Agriculture, Umudike and its environs in response to the increasing demand for portable water supply in the area.

GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

Michael Okpara University of Agriculture, Umudike (MOUAU) is located in Ikwuano Local Government Area of Abia State, Southeastern Nigeria. It is located within the deltaic marine sediments of Cretaceous to recent age, between latitude 5°28'N and 5°30'N and between longitude 7°31'E and 7°33'E. It has an elevation range of 60 to 180 m above mean sea level.

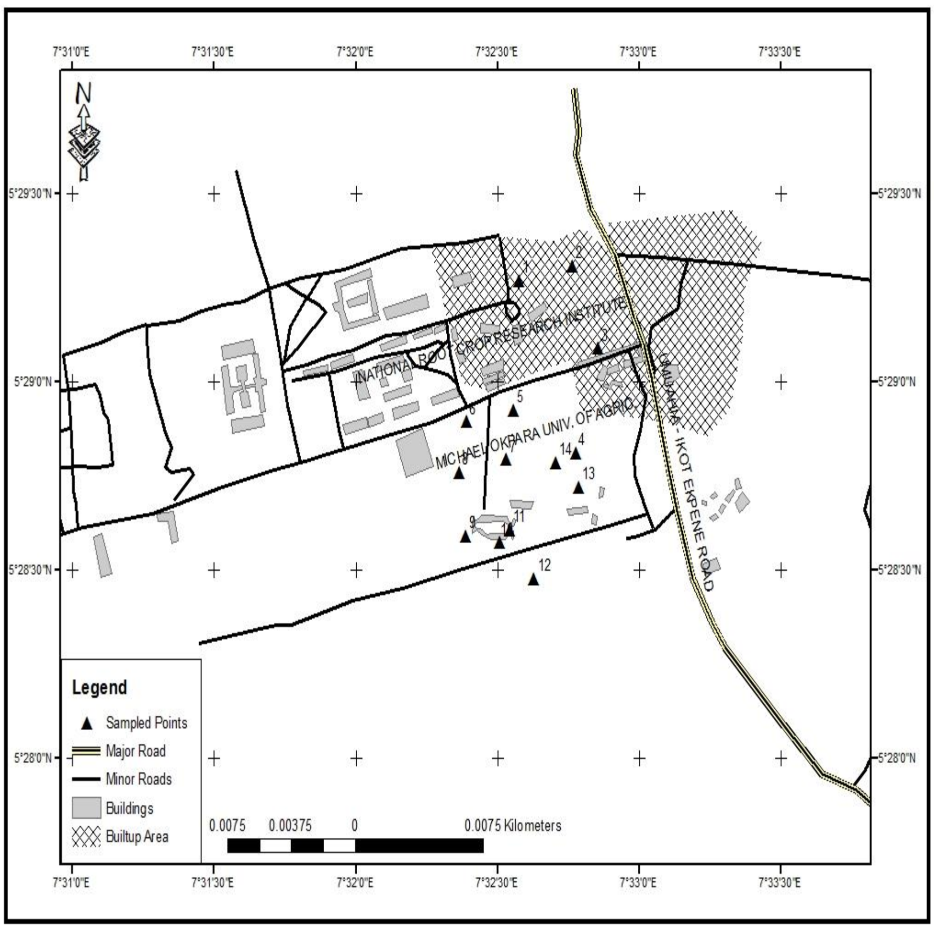

Figure 1: Map of the Study area showing VES Points

The Geology of the area is the deltaic marine sediment of Cretaceous to Recent age. There are two principal Formations in the area namely: the Bende-Ameki and the Coastal plain sands otherwise known as the Benin Formation. The Bende-Amaki Formation of Eocene to Oligocene age consists of medium to coarse-grained white sandstone, which may contain pebbles, gray-green sandstone, bluish calcareous silt, with mottled clays and thin limestone. Considerable lateral variation in lithology has also been observed.

The lower part of the Formation consists of fine-coarse-grained lenses of sandstone with abundant calcarceous shales and thin shelly limestone. The Bende-Ameki Formation overlies the impervious Imo shale group of Paleocene age, which is characterized by lateral and vertical variations in lithology. The coastal plain sands otherwise known as the Benin Formation overlies the Bende-Ameki Formation and dips south-westward. The Formation sediments were deposited during the late Tertiary-early Quaternary period. The Formation is shallow and has an expected thickness of about 200 m (Igboekwe and Akankpo, 2011). The lithology consists of unconsolidated loosely medium to coarse-grained cross-bedded sands occasionally pebbly with localized clays and shales. Umudike soil is acidic with average pH range of 4.5 - 5.7

MATERIALS AND METHODS

Geoelectrical soundings were carried out in this study using an ABEM Terrameter SAS 4000 and its accessories. A total of fourteen vertical electrical soundings (VES) were made using the Schlumberger array with a maximum current electrode separation of AB/2 of 500 m (Figure 3). The resistivity inversion computer programme, RESIST was employed in the modeling of the VES data (Igboekwe *et al*., 2006). The Schlumberger electrode configuration was used in all the soundings.

Potential aquifer zones have been delineated using the fourteen (14) geoelectrical resistivity soundings at maximum current electrode spread of between 600 and 800 m. Aquifer resistivity varied from 249.70 to 4192.30 Ωm see Table 1. Apparent resistivity ρ_a is given by:

$$\rho_a = \pi R \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \qquad \textbf{(1)}$$

Groundwater Sampling Techniques

Twelve groundwater samples were collected within the university campus and its environs and analyzed for nine (9) groundwater quality parameters: pH, conductivity, acidity, alkalinity, temperature, turbidity, total solids, total dissolved solids and total suspended solids. The samples were stored in a sterilized 250ml bottles and transferred to the laboratory for analyses. The conductivity, total suspended solids and total dissolved solids were determined using a HACH 44600-00 Conductivity/TDS meter at a temperature of 20^0C. The pH was determined using a HACH sension 3 pH meter. The turbidity was determined using a spectrophotometer. The results are presented in a tabular form (Table 2).

Metal Ion Analysis

The water samples were analyzed for other ions using standard methods (APHA, 1989; Trivedi and Goyal, 1986).

The water samples ($500cm^3$) were acidified with $10cm^3$ of concentrated Nitric acid and concentration to $200cm^3$ using evaporation method (Parker, 1972). After Chelating, extraction and subsequent mineralization, calcium ion was determined by atomic absorption spectrophotometer and sodium was determined by flame photometry. The instruments were operated as per the instruments' manual. The blank was used for zeroing the instruments before each analysis. Concentration (mg/l) Value of Ions In Groundwater Samples Located Within The Premises of MOUAU – Umudike complied with WHO Standards see Table 2.

RESULTS AND DISCUSSION

Geoelectrical section BB^1

BB^1 profile traverses the W-E of the study area covering three VES points (MU_{13}, MU_{12}, and MU_9). BB^1 profile shows four geoelectric layers and is characterized with AK, HKHA and KHA curve types.

Table 1: Interpreted Layer Parameters from Vertical Electrical Soundings (resistivity in Ωm, thickness in m, and d depth in m).

VES No	Location	Elevation (m)	Latitude Longitude	No of layers	ρ_1 h_1	ρ_2 h_2	ρ_3 h_3	ρ_4 h_4	ρ_5 h_5	ρ_6 h_6	Depth (m)	Curve type
MU_1	Forest Base	111.0	5.4799 7.5422	4	83.30 1.10	9.90 2.00	2862.80 7.10	38626.40 ---	--- ---	--- ---	10.20	HA
MU_2	Pigery farm	112.9	5.4794 7.5394	5	145. 30 0.80	7.60 1.30	144.00 1.20	7147.30 6.00	100000.00 ---	--- ---	9.20	HA
MU_3	Stadium junction	115.6	5.4763 7.5418	4	183.60 1.20	77.6 2.70	13123.60 30.00	678.90 ----	--- ---	--- ---	33.90	HK
MU_4	College of engineering	106.6	5.4765 7.5398	5	83.70 1.40	507.70 1.20	3981.20 5.70	4192.30 11.60	5640.70 ---	--- ---	19.80	A
MU_5	Liman hall	114.5	5.4768 7.5424	4	835.40 2.00	3894.60 5.02	249.7 16.60	4100000.0 0 ---	--- ---	--- ---	23.80	KH
MU_6	VC's lodge	136.8	5.4848 7.5476	5	704.70 1.20	14.90 1.80	804.40 2.60	4100000.0 0 478.90	1063.50 ---	--- ---	484.50	HAK
MU_7	University Gate	129.4	5.4803 7.5461	5	135.90 1.60	97.00 2.20	308.50 1.60	17161.50 12.10	38638.0 ---	--- ---	17.60	HA
MU_8	Mechanic workshop	136.8	5.4787 7.5464	5	136.40 1.10	15.40 2.10	85677.50 377.50	1344.70 48.10	2177.90 ---	--- ---	428.80	HKH
MU_9	Petrol station	120.2	5.4831 7.5451	5	88.60 0.60	2354.30 3.30	425.00 7.70	7284.60 18.20	100000.00 ---	--- ---	29.80	KHA
MU_{10}	American quarters	138.9	5.4878 7.5429	5	113.90 1.00	1104.80 20.90	294.50 9.20	526.50 22.70	41182.30 ---	--- ---	53.80	KHA
MU_{11}	VC's lodge(back)	126.3	5.4885 7.5461	5	744.00 1.10	210.20 5.90	2268.00 10.90	16528.30 108.00	8985.90 ---	--- ---	125.90	HAK
MU_{12}	Afrihub	121.3	5.4821 7.5426	6	3799.70 0.40	65.40 0.80	666.80 2.30	51.00 6.70	3276.10 12.40	61787.50 ---	22.60	HKHA
MU_{13}	Umbrella tree	102.3	5.4816 7.5400	4	247.00 0.70	1029.30 16.70	4649.30 42.20	287.80 ---	--- ---	--- ---	59.60	AK
MU_{14}	Bishop's house	90.9	5.4746 7.5438	5	130.10 0.60	1199.30 3.30	219.60 8.50	8387.60 23.20	46697.90 ---	--- ---	35.60	KHA

The profile total thickness ranged from 22.60 to 59.60 m. The top layer has low resistivity values ranging from 88.60 to 247.00 Ωm, which is defined to be loamy.

The second layer has resistivity values ranging from 668.80 to 2354.30 Ωm which is lateritic sand. The third layer has resistivity values ranging from 425.0 to 3276.10 Ωm. The third layer is defined as medium grained sand (water bearing formation). The forth layer is defined as the conducting layer which is clay formation. The geoelectrical section for this profile is shown in Figure 3.

Table 2: Summary of some Physical and Chemical Properties of the Groundwater Samples.

Parameter	Minimum (location)	Maximum (location)	Mean (entire area)	WHO
pH	4.71(1)	6.94(7)	5.47	6.50-8.50
Conductivity(µs/cm)	66.67(2)	600.03(11)	336.12	500.00
Total dissolved solids (mg/L)	100.00(2)	1200.00(11)	504.00	500.00
Total suspended solids (mg/L)	100.00(7)	1200.00(11)	429.00	500.00
Turbidity (NTU)	86.10(4)	92.60(6)	90.17	5.00

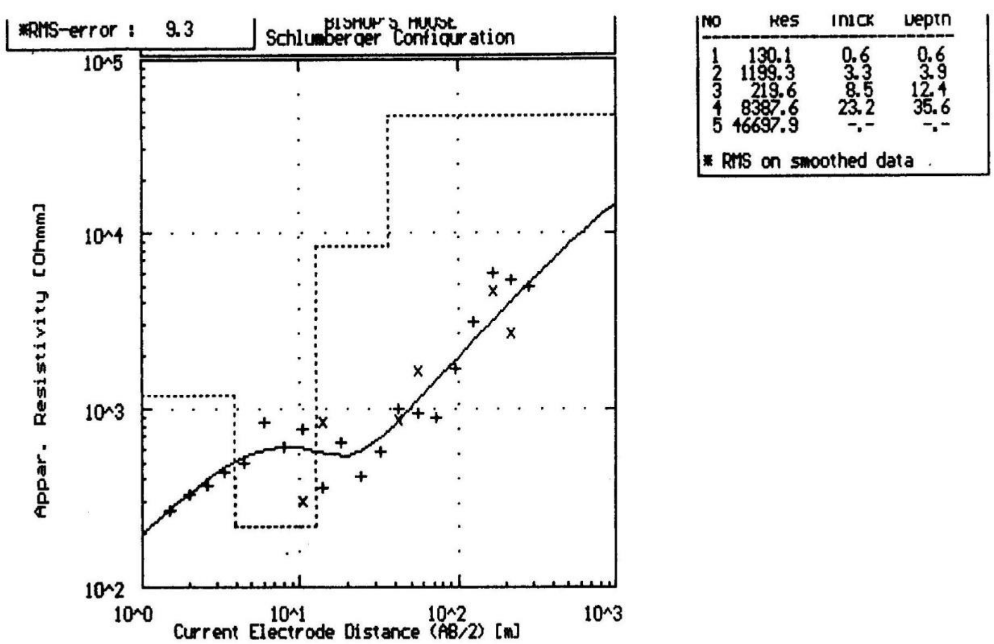

Figure 2: Typical Model Representing (KH, KHA, AK) Curve Types at $MU_{14.}$

Transmissivity is directly proportional to horizontal hydraulic conductivity (Kh_i) and thickness. Expressing Kh_i in m/day and the transmissivity (T_r) is found in units m^2/day. The transmissivity is a measure of how much water can be transmitted horizontally, such as to a pumping well.

The transmissivity values in the area ranged from 48.00 to 384.80 m^2day^{-1}, with an average transmissivity value of 156.53 m^2day^{-1}. Equation 2 describes the relationship between transmissivity and the layer thickness, h. and the hydraulic conductivity, k.

$$T_r = K\sigma R = \frac{KS}{\sigma} = Kh \qquad \textbf{(2)}$$

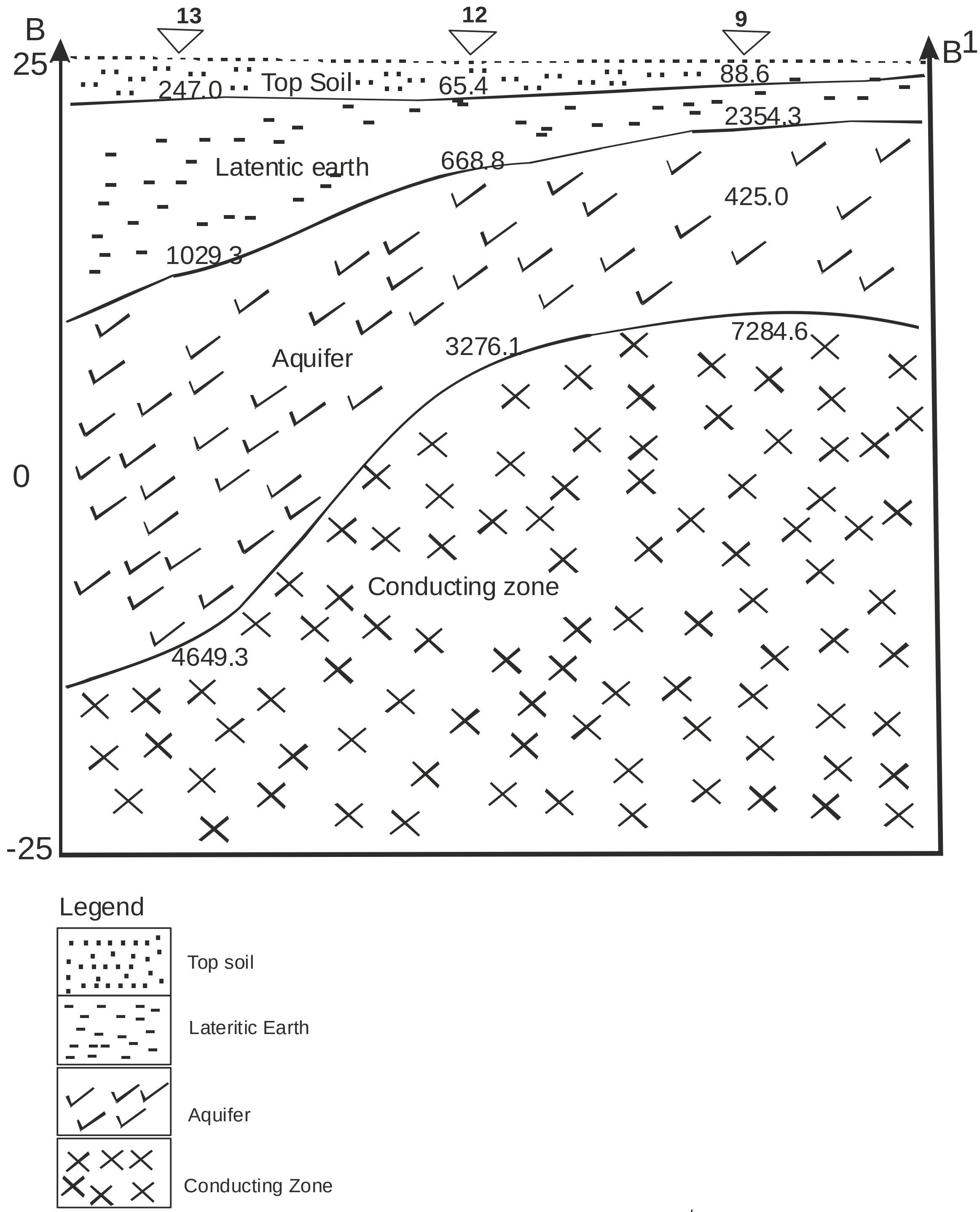

Figure 3: Geoelectrical section along BB/.

The average transmissivity value shows that the area has moderate aquifer potential. The transmissivity values increases towards the south eastern part of the area, as well as towards the western central area of the area. The values of aquifer transmissivity calculated from the observed values of k and h parameters were used in drawing the contour map showing the distribution of aquifer transmissivity in Figure 4.

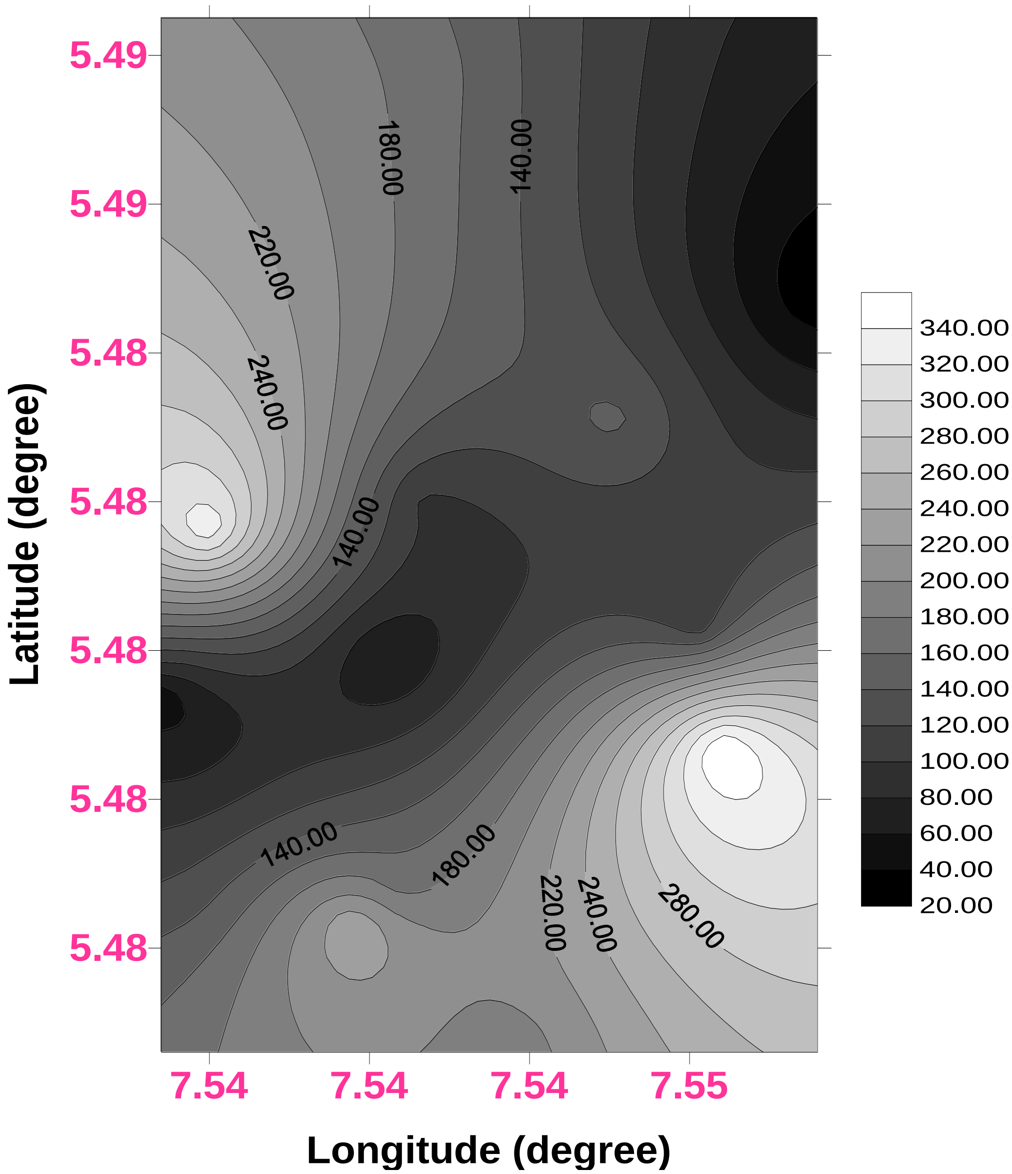

Figure 4: Transmissivity Values of the Study Area.

GROUNDWATER QUALITY ASSESSMENT

Some Physical and chemical properties of the groundwater were analyzed see Table 2. The results of the analysis showed that the groundwater in the area was acidic with an average pH value of 5.47, which falls below the World Health Organization (WHO) standard for drinking water.

They also showed high turbidity values ranging from 86.10 to 90. 17 NTU which exceeds the WHO standard. The water samples have moderate to high values of total dissolved solids, TDS (100.00 to 900.00 mg/L), total suspended solids, TSS (100.00 to 1200.00 mg/L) and conductivity (66.67 to 600.03 μs/cm)The transmissivity values in the area ranged between 48.00 to 384.80 $m^2 day^{-1}$, while Kσ values ranged between 0.0009 to 0.0099 $(\Omega d)^{-1}$.

TRACE ELEMENTS AND HEAVY METALS

Hardness of water depends mainly upon the amount of calcium or magnesium salts or both. The limits of Ca and Mg ions in portable water range from 75 to 2000 mg/L and 50 to 100 mg/L respectively (ICMR, 1975). In the present study, the calcium ion content of the water samples range from 2.35 to 15.11 and that of magnesium between 1.00 to 3.41 and is well within the maximum permissible limit.

The maximum concentration of nitrate for public water supplies is 50mg/L (WHO). The concentration of nitrate in the groundwater samples of the study area ranges from 0.4 mg/L to 2.4mg/L which is within the maximum permissible limits. This indicates that the no danger is posed to the consumers due to nitrate ions.

Chloride ion impacts a salty taste to water. The limit for domestic purposes is fixed at 250mg/L. In the present study, chloride ion content in groundwater samples ranged from <0.1 to 2.1 mg/L showing that they are fit for domestic purposes. The phosphate ion content in the water samples studied lies below the permissible limit of 3.5mg/L for domestic applications. The sodium ions content in the ground water samples were well within the desirable limits of 200mg/L.

The copper, arsenic, iron, potassium ions content in the groundwater are 2.0mg/L, 0.01, 1.0m/L and 75mg/L, respectively. They were within the maximum permissible limits and pose no threat to the quality of the groundwater sample. The maximum concentrations of lead (Pb^{2+}) in the groundwater samples lies above the maximum permissible limit of 0.01. All the samples of the groundwater contain a high Lead content. Lead is a metal with no known biological benefit to humans. Lead can combine with other chemicals to form lead compounds or lead salt. Some lead salts can dissolve in water. It is known to be harmful to humans if inhaled or ingested. Too much lead can damage various systems of the body including the nervous and reproductive systems and the kidneys and it can cause high blood pressure and anemia. At high levels lead can cause convulsions, coma and death in children.

Pair parameter correlation analysis was done and the quality parameter pair curves for arsenic vs. sulphate ion and copper vs chloride ion are plotted against well locations on Figures 5 and 6.

As	SO_4^{2-}
0.001	3.00
0.001	5.00
0.001	10.00
0.001	7.00
0.001	1.00
0.001	15.00
0.001	8.00
0.001	3.00
0.001	4.00
0.001	1.00

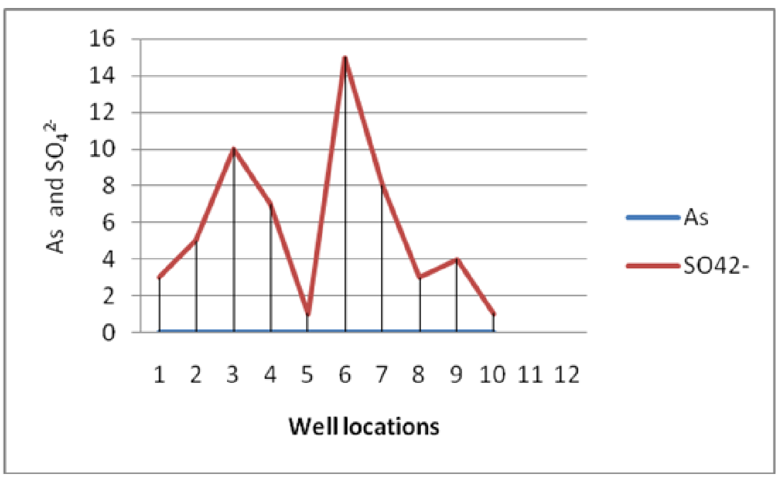

Figure 5: Graph of Arsenic and Sulphate Ions vs. Well Locations.

Cu^{2+}	Cr^{2+}
0.12	0.01
0.02	0.01
0.1	0.01
0.04	0.01
0.08	0.01
3.02	0.01
0.01	0.01
0.02	0.01
0.01	0.01
0.01	0.01

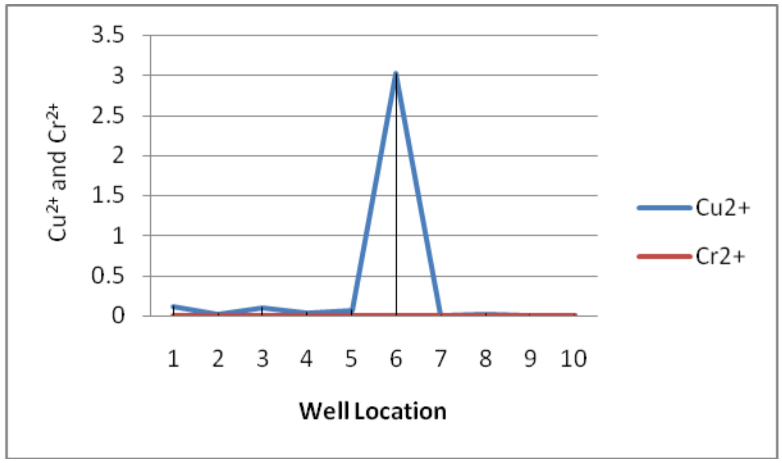

Figure 6: Graph of Copper and Chloride Ions vs. Well locations.

Table 3: Results of Metal Ion Analysis.

Groundwater Wells Location

Wells	A	B	C	D	E	F	G	H	I	J	K	WHO STD
Test Parameter												
Na^+ (mg/L)	2.10	3.26	2.08	1.25	1.22	4.08	2.55	2.16	2.12	1.10		200
Mg^{2+} (mg/L)	1.12	1.10	1.00	1.13	1.04	3.41	1.51	2.10	1.36	1.42		75
Ca^{2+} (mg/L)	2.35	3.32	3.32	2.45	4.28	15.11	2.88	4.15	2.05	2.15		200
K^+	0.5	2.2	1.3	1.4	0.8	3.8	0.3	0.4	0.1	0.1		75
Cu^{2+}	0.12	0.02	0.10	0.04	0.08	3.02	0.01	0.02	0.01	0.01		2.0
As	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		0.01
Pb^{2+}	10.0	5.0	4.0	10.0	2.02	20.0	3.0	9.0	10.0	5.0		0.01
$SO4^{2-}$	3.0	5.0	10.0	7.0	1.0	15.0	8.0	3.0	4.0	1.0		500
CL^-	0.1	<0.1	0.2	<0.1	<0.1	<2.1	<0.1	<0.1	<0.1	<0.1		250
NO^{3-}	1.3	1.7	0.6	0.4	0.3	2.4	0.2	1.1	1.0	0.9		50
$PO4^{3-}$	0.39	0.52	0.11	0.28	0.15	0.14	0.28	0.32	0.05	0.08		3.5
$T.Fe^{2+}$	0.21	0.05	0.15	0.12	0.16	2.34	0.02	0.14	0.11	0.10		1.0
Ph	4.71	5.09	6.90	6.81	5.27	6.94	4.98	4.98	5.04	6.27		6.5-9.2
Cr^{2+} (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		0.05

The locations A, B, C, D, E, F, G, H and I represent: A. (PG Hostel), B. (Chapel),C. (Engineering Block), D. (Male Hostel), E. (Admin. Block), F. (V.C. Lodge), G. (Zenith Bank), H. (Opp. Gate), I. (MPP6) and (Staff School).

CONCLUSION

A total of fourteen (14) vertical electrical soundings (VES) were carried out and interpreted. The field data were gotten from Schlumberger electrode configuration and the apparent resistivities were obtained. The lateral and vertical variations in the geoelectric columns which agree with the lithologic log indicate that VES profiles are useful method to investigate the lateral and vertical variation of subsurface lithology as well as subsurface hydrology. The hydrogeological studies have helped to delineate aquiferous zones and characterize the conditions of the groundwater in terms of the transmissivity, aquifer resistivities and kσ of the aquifer in the area. The sandy aquifer in the study area exhibits moderate to high transmissivity values, which reflects the geological setting of a typical sandy formation. Based on the above analysis, potential aquifer has been identified for sustainable groundwater development.

Hydrochemical assessment of groundwater was carried out based on some pollution indicators. The water quality parameters of concern were pH and turbidity because they had marked departure from WHO standard. The groundwater in the area is acidic and of high turbidity values. This is connected with the low pH range of the soil in the area, which has great influence on the groundwater quality. The low pH values of the boreholes water may also occur due to the agricultural activities in the area. These solutions diffuse through the sandy permeable layers of the formation to form weakly acidic solutions which are washed down into the aquifer containing the groundwater.

The waters have moderate to high values of total dissolved solids (100.00 to 1200.00 mg/L), total suspended solids (100.00 to 1200.00 mg/L) and conductivity (66.67 to 600.03 µs/cm). Recommendations include periodic groundwater monitoring and treatment.

The quality parameter pair curves for arsenic vs. sulphate ion and copper vs. chloride ion when plotted against well locations showed the highest peak at well number 6.

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