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EVALUATION OF TOTAL DISSOLVED SOLIDS (TDS) IN GROUNDWATER AROUND A POULTRY FARM USING ELECTRICAL RESISTIVITY METHOD AND GEOCHEMICAL METHOD

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Abstract

Most hands dug wells and boreholes at Isundunrin (a town) in Ejigbo Local Government Area of Osun State, South-West Nigeria were completed without physicochemical analysis of the exploited water. This study aimed at validating the electrical resistivity technique as an alternative to the geochemical technique to identify potential aquifers based on total dissolved solids (TDS). Four Schlumberger Vertical Electrical Soundings (VES) were carried out very close to four different available hand-dug wells located within the premises of a poultry farm at Isundunrin on the longitude E04º 6′ 34″ - E04º 15′ 46″ and latitude N07º 51′ 52″ - N07º 51′ 56″. The apparent resistivity values obtained were later transformed to formation resistivity and layered thicknesses by curve matching and computer iteration. The formation resistivity was used to determine the TDS levels in the exploited groundwater. When the TDS of the geochemical analyses (GCA) was compared with the TDS from VES results, a strong correlation coefficient of R^2 = 0.875 was obtained, which indicated that the geoelectric sounding can be an alternative technique to geo chemical technique to estimate the TDS level in groundwater.

***Keywords*: Total Dissolved Solids, Electrical resistivity technique, geochemical technique

Introduction

Groundwater resource located in the aquifer is a major source of freshwater which is used by human beings on daily basis for domestic purposes. Other uses of this resource are found in the generation of electricity, construction of residential and industrial buildings, manufacturing industries, and commercial purposes [1]. The resource is polluted when organic and inorganic solids are dissolved or suspended in it [2]. Silt, stirred up bottom sediment and sewage treatment effluent are examples of suspended solids in water. Dissolved solids in groundwater samples include soluble salts which yield ions such as sodium (Na^{+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^{-}), sulphate (SO_4^{2-}) and chloride (Cl^{-}). Others are Ammonium (NH_4^{-}), Nitrate (NO_3^{-}), and phosphate (PO_4^{3-}) in fertilizer, hydrogen ion (H^{+}), nitrate (NO_3^{-}), and sulphite (SO_3^{2-}) in acid rainfall. The totality of these substances when present in water form total dissolved solids. TDS can come from organic sources such as decaying organisms (plants and animals). United States Environmental Protection Agency [3] defined total dissolved solid as all inorganic and organic substances contained in water that can pass through a 1.2 µ filter. According to the World Health Organization [4], the compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, silica, and nitrate. The high elevation of TDS in water affects the taste, and changes the color and odor of groundwater thereby makes it unfit to be used for drinking and other purposes [5] by consumers. United States Drinking Water Standard [6] recommends that the value of TDS in drinking water should not exceed 500mg/L. Beyond this value, human health is at risk with health challenges such

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as transient diarrhea, typhoid fever, etc. Obtaining useful information on the groundwater quality of an area is necessary for managing and sustaining the resource for various uses [7, 8, 9]. In Isundunrin where the study site was located, many groundwater resources have been developed and exploited with no attention paid to the geochemical characteristics of the groundwater. So, hand-dug wells and boreholes were completed without geochemical analysis. In such an instance, geo-electrical sounding may serve as a useful tool in estimating the TDS. A high level of TDS in groundwater makes it not fit for consideration as a practical source of portable water. Researchers such as [10, 11, 12] have used the Electrical Resistivity method to determine groundwater quality because measurement of resistivity can provide useful information about the fluid in the pore space, voids, joints, and weathered/fractured part within the rock matrix of an aquifer. This is based on the existing relationship between the resistivity of formation/formation water and the porosity of the formation. This study was carried out within the premises of a poultry farm in Isundunrin in Ejigbo Local Government Area of Osun State to compare and validate use of geoelectric techniques in the absence of geochemical technique to identify potentially useable aquifer based on the concentration of the total dissolved solids.

Study Site Description

An active poultry farm at Isundunrin (a town) in Ejigbo Local Government Area of Osun State, South-West Nigeria was used for this study (Fig. 1). The farm is located on the longitude E04° 6′34″ - E04°15′46″ and latitude N07°51′ 52″ - N07°51″ 56″. The farm covers twenty (20) acres of land. Isundunrin is accessible through tarred road from Ejigbo while the poultry farm is just 2.0 km from Isundunrin and accessible through untarred but motorable road. The climatic condition of this study site belongs to the tropical rainforest which is identical to that of the general climate of South-Western Nigeria with the rainy season between March and October and dry season between November and February. The lowest temperature of the study site was 20°C while the highest was 36°C. The highest temperature occurs between November and February. The vegetation is sparsely distributed with palm trees occurring in the direction of the flowing rivers and streams. The vegetation then causes highly fractured openings in rocks.

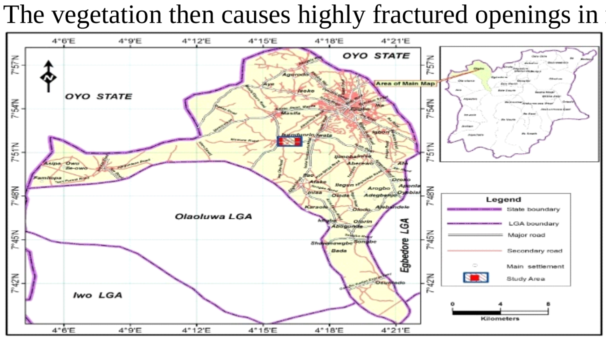

Figure1: Location map of the Study site

Geology of the Study Site

Fig. 2 showed the Geological map of the study site. Geologically, the study site belongs to the Precambrian basement complex rocks of South-Western Nigeria [13]. The study site is predominantly occupied by migmatite rocks. The main lithological units identified in the study area were the migmatite – gneiss and migmatite-gneiss undifferentiated. 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.

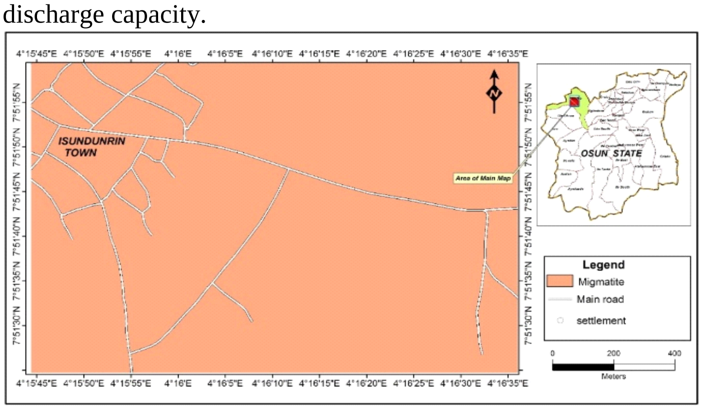

Figure 2: Geological map of the study site adapted from [14]

Materials and Methods

Field Procedure

VES data acquisition and processing

ABEM Signal Averaging System (SAS) 1000 - Tetrameter digital equipment was used to acquire four (4) Schlumberger Vertical Electrical Surroundings (VES) apparent resistivity data at different locations near and far away from the available hand-dug wells and the two dead bird disposal pits of the poultry farm (see table 1). The apparent resistivity data obtained were then plotted against current electrode spacing (AB/2) on a bi-logarithm paper. The results of this plotting produced layered resistivity values and layered thicknesses with the aid of partial curve matching and IP12WIN computer software for iteration [15].

Determination of TDS

TDS level was determined from the formation Resistivity Factor (F) because the conductivity (inverse of resistivity) of water is a measure of the amount (concentration) of charges (ions) it contains, so this can provide an estimate of the TDS levels in the water. In addition, the movement of ions that the electrolyte contains will account for its conductivity. Archie [16] (1942) established a direct relationship between the resistivity of full water-saturated rock (ρ_w) and rock resistivity (ρ_o) for a porous media as:

$$\rho_o \; \alpha \; \rho_w$$

$$\rho_o = \mathrm{F} \, \rho_w \qquad (1)$$

Where $F = \frac{\rho_o}{\rho_w}$ (2)

is the formation factor. Archie [16] also showed that the Formation Resistivity Factor (F) has an inverse relationship to porosity (∅) as

$$F = \frac{\rho_o}{\rho_w} = \phi^{-1} \qquad (3)$$

Therefore, the general form of Archie's law is

$$F = \mathrm{a} \times \phi^{-m} \qquad (4)$$

Where a is a constant whose value is in the range $0.5 \leq a \leq 2.5$, and m is a constant called cementation and its value ranged from $1.3 \leq m \leq 2.5$. In this work, a and m were 1.5 and 2.0 for soft deposits [17] respectively. Also, the porosity (∅) value was taken as 0.53 for the sand of the Precambrian deposit. Using equation (4), the value of the Formation Resistivity Factor is 5.4. The pore water formation resistivity is obtained from equation (2). Turcan [18] mathematical equation to estimate the TDS value present is

TDS = 0.64 x EC

$$= 0.64 \times \frac{1000}{\rho_w} \qquad (5)$$

E.C is the Electrical conductivity

Geochemical data acquisition and treatment

Four different groundwater samples were collected from the four available hand-dug wells in and around the poultry farm. The Total Dissolved Solids of the samples were determined using gravimetry according to the method of the American Public Health Association [19] water sample of 100 mL was filtered into a clean beaker. The solution was then quantitatively transferred into a previously ignited and weighed porcelain crucible and evaporated to dryness over a steam bath. The crucible was further dried in an oven at 105ºC for one hour. It was then transferred into a desiccator to cool and later weighed employing an analytical balance. The weight difference was expressed as mg/L. Table 2 showed the results of the groundwater analysis in and around the Poultry Farm of study. The levels of the TDS from both the Electrical Resistivity Soundings and those from the water analysis were plotted against each other for correlation purposes.

Results and Discussion

The results of the position of the various wells to the two disposal pits are shown in Table1 while Table 2 shows the curves types, thickness, depth, and lithology obtained at the study site. The results of the iterative curves of the four VES and the concentration of TDS of groundwater respectively are presented in Figs. 3 (a – d) and Table 3. It depicted that the study site comprises four geoelectric layers. The first layer is the topsoil (clayey) whose resistivity and thickness values ranged from 119.0 to 814.0 Ω m and 0.641 to 6.830 m respectively. The weathered layer, which was the second layer, had has resistivity which ranged from 14.4 to 31.5 Ω m, and thickness values of this layer varied from 0.762 m to 3.870 m. The resistivity values of the third layer, a fractured layer, ranged from 47.8 to 35.0 Ω m. This layer's thickness values varied from 5.84 to

7.63 m. The last layer was the basement and had resistivity values which ranged from 893 Ω m to 75038 Ω m. Fig. 5 shows the geoelectric sections of the four layers while Table 4 showed the result of the levels of the TDS in groundwater around the poultry farm when electrical resistivity sounding was performed. The concentration of the TDS varied from 1097.77 to 2397 mg/L. These values were beyond the maximum acceptable level of 500 mg/L recommended by [20], [21] and [22]. This indicated that the groundwater in the study site is not fit for drinking and other domestic uses. According to Drever [23], freshwater is defined as water containing TDS of less than 1000 mg/L. For comparison purposes, Table 3 also showed the TDS level obtained from the geochemical analyses of the water samples from the four hand–dug wells in and around the poultry farm. The results of the plotting of the TDS values of both the Electrical Resistivity Soundings and that from the water analysis showed a strong positive correlation (R^2> 0.88). The slope of this graph is approximately 1 (Fig. 4). This is an indication that the results of the two methods are similar. Salifu et al., [24] had earlier reported this identical result for the two methods ($R^2 = 0.9922$). Figure 5 is the geoelectric section.

Table 1: Location of the well and their distance to the pit

Well, No and VES No	Longitude (°)	Latitude (°)	Distance to Pit 1 (m)	Distance to Pit 2 (m)	Depth of well (m)
Well 1 VES 1	4.1546	7.5152	39.00	61.30	7.50
Well 2 VES 2	4.1569	7.5156	191.30	91.30	7.44
Well 3 VES 3	4.1542	7.5152	196.40	96.40	8.04
Well 4 VES 4	4.1546	7.5153	189.50	89.50	7.40

Table 2: Iterative Curves Types, thickness/Depths, and lithology obtained at the study site

S/N	Type of VES curve	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
VES 1		119.0	6.83	6.83	Clayed Topsoil
	HA	19.8	3.87	10.70	Weathered layer
		51183.0	-	-	Basement
VES 2		211.0	1.11	1.11	Clayed topsoil
	HKHA	27.5	0.935	2.04	Weathered layer
		2234.0	1.14	3.18	Basement
		47.8	7.63	10.80	Fracture / Weathered layer
		893.0	-	-	Basement
VES 3		209.0	1.91	1.91	Clayed topsoil
	KHA	14.4	2.06	3.97	Weathered layer
		75038.0	_	_	Basement
VES 4		814.0	0.641	0.641	Lateritic topsoil
		31.5	0.762	1.40	Weathered layer
	HKHA	2595.0	2.86	4.27	Basement
		35.0	5.84	10.10	Fracture
		47169.0	-	-	Basement

Table 3: Concentration of TDS in Groundwater from Sounding and Geochemical Method

Location	Formation Resistivity (Ω m)	Water Resistivity (Ω m)	$TDS_{(sounding)}$ (mg/L)	$TDS_{(Geochemical)}$ (mg/L)
1	27.5	5.09	1257.37	3650
2	14.4	2.67	2397.00	5770
3	31.5	5.83	1097.77	1960
4	19.8	3.67	1743.87	3890

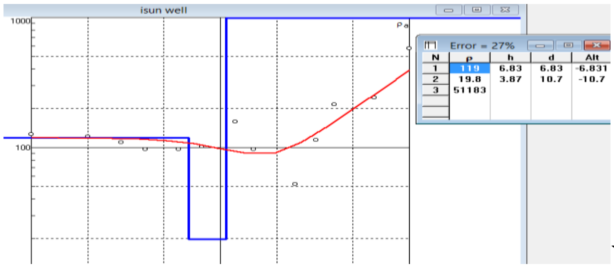

Figure 3a: Iterative curve of VES 1 at well 1

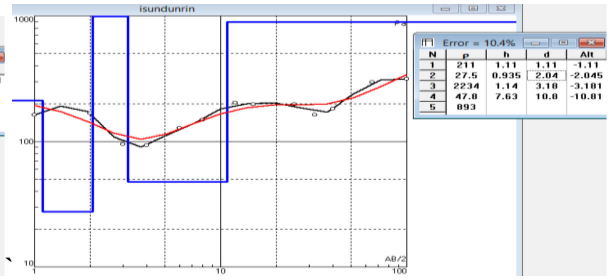

Figure3**b:** Iterative curve of VES 2 at well 2

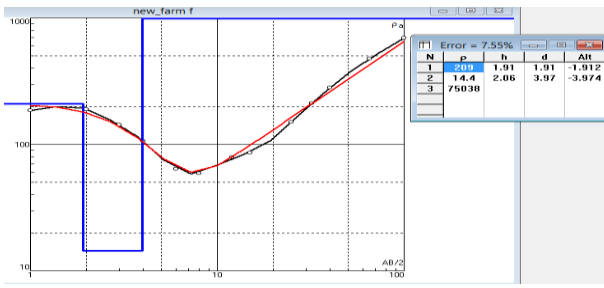

Figure 3c: Iterative curve of VES 3 at well 3

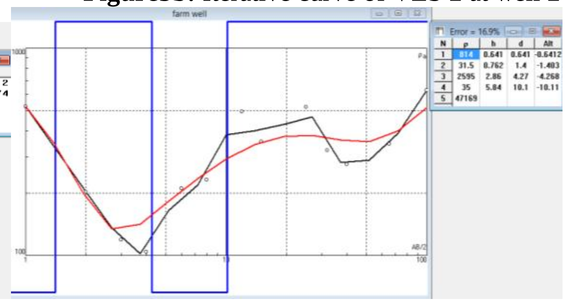

Figure 3d: Iterative Curve for VES 4 at well 4

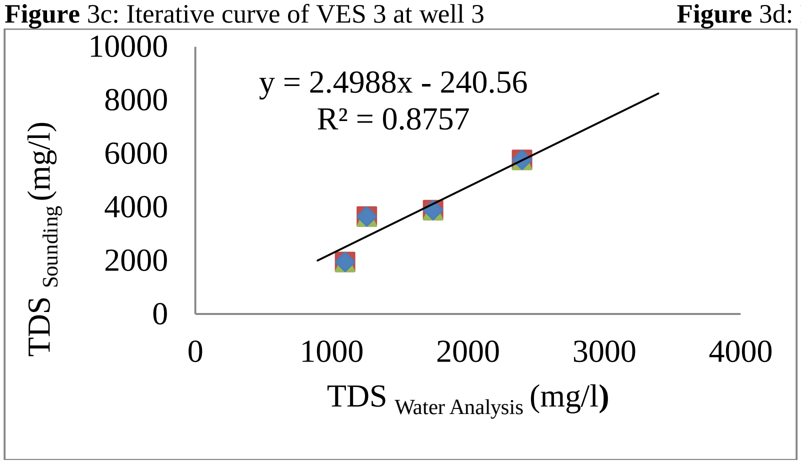

Figure 4: Correlation of the estimated TDS from sounding with water analyses

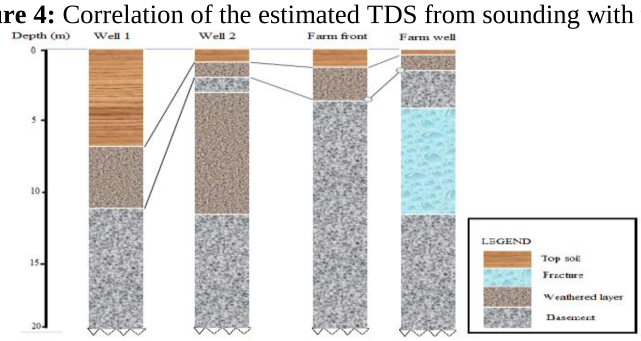

Fig. 5: Geo electrical section

Conclusion

In this study, the Total Dissolved Solids (TDS) values obtained were greater than the recommended permissible by US EPA, WHO, and SON. This makes the water unsuitable for drinking. The study also established the positive correlation between Electrical Resistivity and geochemical methods. The validation that was performed showed that there was a perfect agreement between the levels of TDS obtained from the two methods. This agreement makes the electrical resistivity soundings a useful tool in estimating the TDS level which helped to determine the water quality of the study site without chemical analysis.

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