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# Evaluation of aquifer characteristics and groundwater quality using geoelectric method in Choba, Port Harcourt

**C. N. Ehirim and C. N. Nwankwo***

*Physics Department, University of Port Harcourt, Nigeria*

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**Abstract**

*A total of seven (7) vertical electrical sounding locations were occupied using the Schlumberger electrode configuration in the evaluation of the aquifer characteristics and ground water quality in Choba, Rivers State. The study was aimed at characterizing the aquifer in the area as well as assessing its potential risk to contaminant seepage in terms of the aquifer hydraulic properties and protective capacity of the overburden rock materials using Dar zarouk parameters. The results show a lithology that is dominated by sands of various grades with no significant delineable intercalating clay/shale impermeable bed. The study area is characterized by low values of the protective capacities* $P_c$, *of the overburden rock materials and high aquifer porosities and transmissivities. The low value of the protective capacities makes the aquifer system in the area highly vulnerable to surface contamination. A high porosity and transmissivity value of the aquifer materials implies highly permeable aquifers with significant storativity, which enhances the migration and circulation of contaminants within the ground water system over large areas. These revelations are indications that the ground water quality may have been impaired in the area and borehole water samples should be randomly sampled for contaminant loads based on this analysis.*

**Key words:** Dar Zarouk Parameters, Aquifer transmissivity, Protective capacity, Ground water quality.

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## INTRODUCTION

Groundwater as the main source of potable water supply for domestic, industrial and agricultural uses has been under intense pressure of degradation and contamination due to urbanization, industrial and agricultural related activities. The impact of this trio on soil and groundwater is alarming with years of devastating effects on humans and the ecosystem. Groundwater is said to be contaminated when it is unfit for the intended purpose and therefore constitute a nuisance to the user.

The study area lies in Choba community delineated by latitude $4^0 31^1$ to $5^0$ 00N and longitude $6^0 45^1$ to $7^0$00E (Fig. 1). The study area hosts the University of Port Harcourt and Ascon Nigeria Limited (an oil and gas servicing company). The high commercial and industrial activities in the area have increased environmental concern in relation to waste generation and management and ground water contamination. The uncontrolled and indiscriminate dumping of waste materials on the land surface, landfill and water bodies has placed the groundwater at the risk of being contaminated.

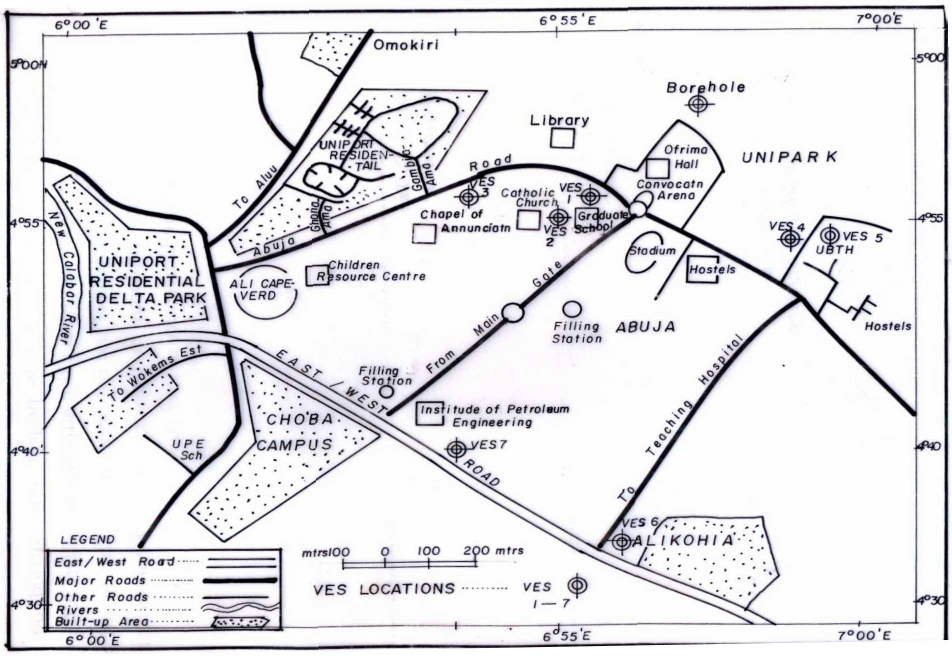


**Fig 1: Location map of the study area showing sounding points**

The water table and depth to the aquifer in the area varies from 3-15m and 25-76m, respectively, depending on the season and time of the year. The proximity of these to the surface makes them highly prone to contamination (5). Estimation of the impact of these waste materials on ground water quality requires the determination of the transmissivity of the aquifer materials and protective capacity of the overburden rocks.

Transmissivity is a major property of an aquifer and aids in the characterization of rocks as water conducting media/strata. The ability of the overburden to retard and filter percolating fluid is a measure of its protective capacity (3). Estimating these properties from pumping tests can be very expensive and time consuming. Surface geoelectrical methods offer an alternative, rapid and cost effective approach for aquifer evaluation and groundwater quality assessment using empirical relations between hydraulic and geoelectric parameters (10), (8).

The objective of the study is to evaluate the aquifer characteristics in terms of the Dar-Zarouk parameters and hence, the transmissivity of the aquifers and the protective capacities of the overburden rocks. The results of this investigation by inference will give clue to the probable impairment of groundwater quality in the area.

**Theoretical Basis**

The combination of the thickness and resistivity of the geoelectric layers into single variables; the Dar-Zarouk parameters of Transverse resistance ($R$) and Longitudinal conductance ($S$), can be used as a basis for the evaluation of aquifer properties such as transmissivity and protective capacity of the overburden rock materials (11), (14), (13), (6).

For a horizontal, homogenous and isotropic layer, the Dar-Zarouk parameters of transverse resistance $R$ and longitudinal conductance $S$ are obtained as:

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

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

where $\rho_i$ and $h_i$ are the layer resistivity and thickness of the ith layer. The aquifer transmissivity T is expressed as the product of the hydraulic conductivity ($k$) and layer thickness ($h$),

$$T = kh \qquad (3)$$

For clean saturated aquifers whose natural fluid characteristics are fairly constant (that is, no appreciable impact on the general ground water quality by surface contaminants loads), the hydraulic conductivity is proportional to the resistivity of the aquifer (10), (13). This implies that in the absence of a pumping test data, the aquifer hydraulic conductivity K can be approximated to the true resistivity of the aquifer derived from geoelectric investigation (Hubbard and Robin, 2002). Therefore,

$$T = kh = \rho h \qquad (4)$$

But the product of the resistivity to its thickness is the transverse resistance ($R$), which is numerically equal to the transmissivity $T$ (7), (16).

$$T = R \qquad (5)$$

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 ($P_c$) of the overburden layers is proportional to its longitudinal conductance $S$ (4).

$$P_c = S = \sum_{c=1}^{n} \frac{h_i}{\rho_c} \qquad (6)$$

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

$$f = \frac{1.0}{\phi^2} = \frac{\rho_b}{\rho_\omega} \qquad (7)$$

where Φ = aquifer porosity and $\rho_b$ and $\rho_\omega$ are respectively, the resistivity of the aquifer and ground water (2). The value of ground water resistivity in the area is 469 Ωm at 25°C (GSN, 1990).

**Geology and Hydrogeology of the Study Area**

The underlying sediments in Choba forms part of the stratigraphic sequence in the Niger Delta (Fig.2). They consist of unconsolidated fresh water bearing continental sands and gravels with occasional inter-bedded shales of the Benin Formation, deposited during the late Tertiary to early Quaternary period with an average thickness of about 2100m (15). The Benin Formation constitutes the main aquifer system of the study area and forms the main source of portable ground water supply. Structurally, the sediments in the area are deposited in the NW-SE trend and groundwater flow occurs inline with this trend. However, local variations occur in places due to the anisotropic behavior of the sediments.

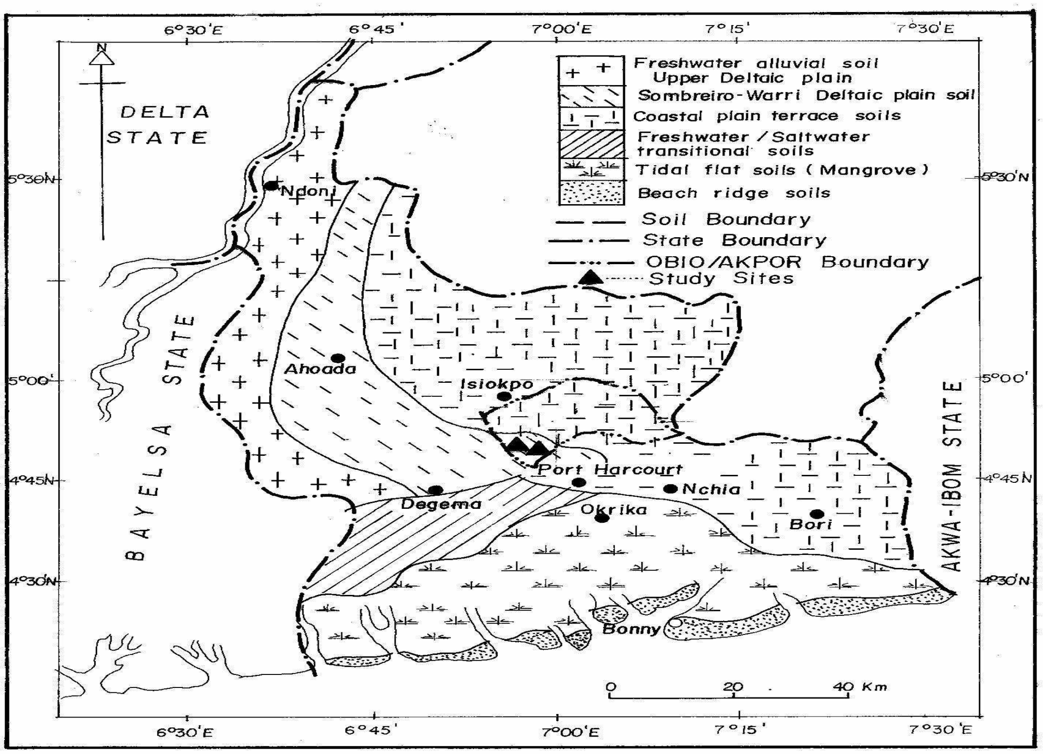


**Fig. 2: Geologic Map of the Study Area (Adapted from Ehirim et al, 2009)**

Choba lies in the rainforest belt and has an average temperature of 27°C with annual precipitation of about 1500mm (1). The climate is tropical with two regimes consisting of wet seasons followed by a shorter dry season.

**Methodology**

A total of seven (7) VES positions were occupied using the Schlumberger electrode array and the Abem Teremeter 1000C, aided with a 2000C booster for better penetration. The electrode spacing used has a maximum spread of AB/2 = 400m and MN/2 = 50m, with regard to target depth of between 67-150m. Only the current electrodes are moved more often during measurements until the measurable signal becomes very small. The potential electrodes are then expanded along the transverses, mostly along major roads. One (1) VES position was occupied close to an existing water borehole to constrain and minimize the ambiquity of interpretation. Resistance values R (Ω) at each VES point was recorded and apparent resistivity values $\rho_{a}$ (Ωm) were determined using the appropriate geomectric factor (K).

**Presentation of Results**

The apparent resistivity data $\rho_a$ (Ωm) from field measurements were inverted using IPI2WIN resistivity sounding interpretation software version 3.0 (2003), to determine the true resistivity and depths of subsurface formations. The resulting model curves have RMS errors of <5% and exhibit HK, KH and QH type curves with 5-7 interpretable geoelectric layers (Fig 3).

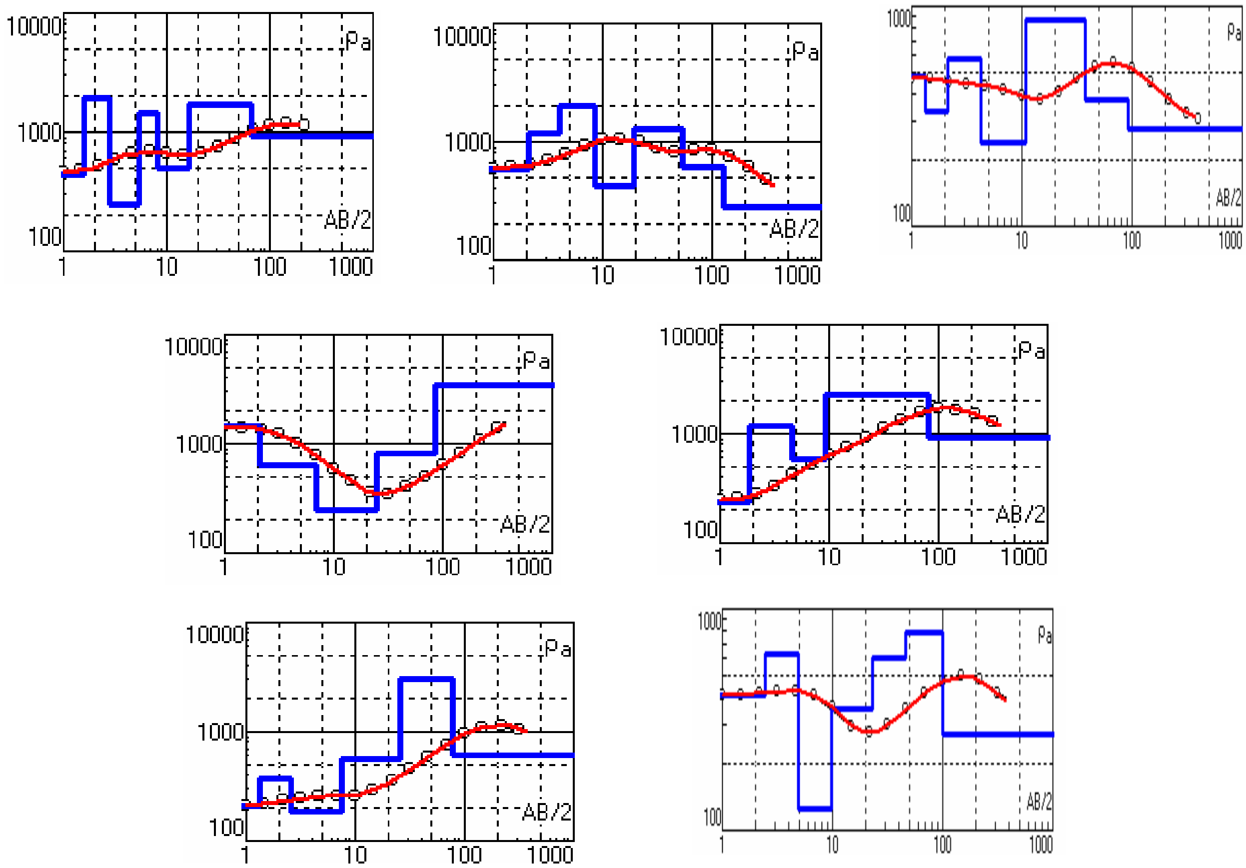


**Fig. 3: Interpreted Geoelectric model curves**

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 60m (Fig. 4).

The general model interpretation show that the geoelectric section consists essentially of laterite, clayey sands, and fine to coarse sands. These compares favorably well with lithologic log of the borehole. The aquifer and Dar-Zarouk parameters of the seven (7) interpretable geoelectric sections are presented in Table I.

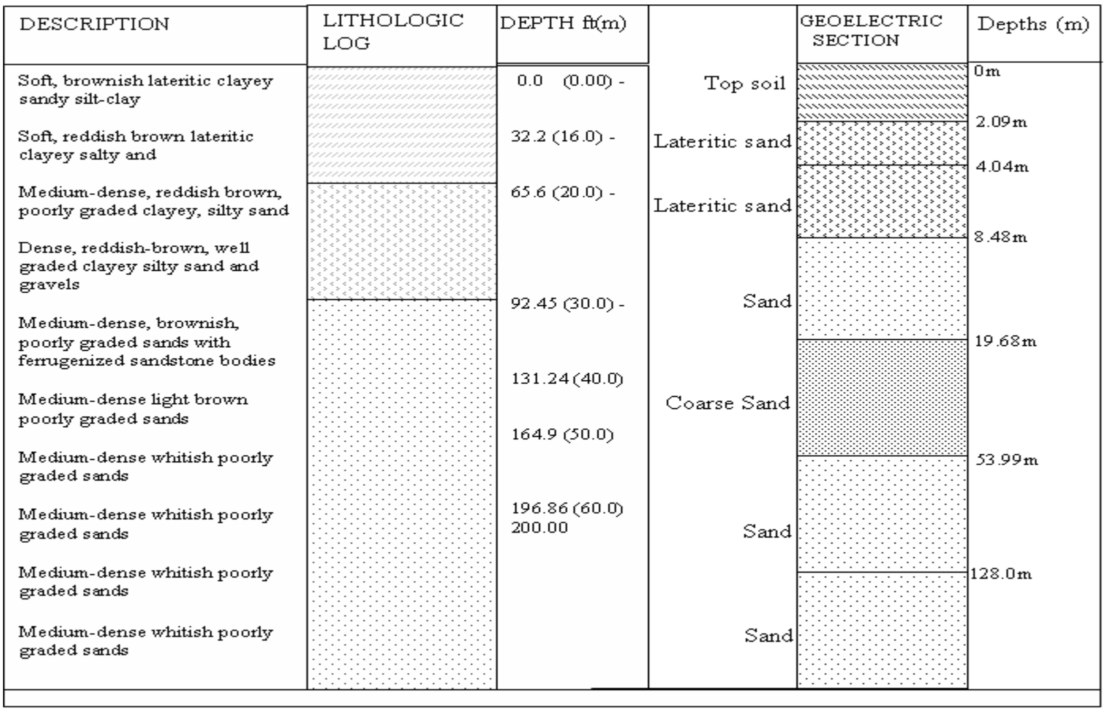


**Fig. 4: Lithologic Log and Interpreted Geoelectric sections**

**Table I: Computed aquifer and Dar-Zarouk parameters of the geoelectric sections**

| **VES No** | $\rho_a$ **(Ωm)** | **Aquifer depth (m)** | **Aquifer thickness (m)** | **Protective capacity $P_c$ (Siemens)** | **Transmissivity T (Ωm²)** | **Porosity Φ (%)** |
|---|---|---|---|---|---|---|
| 1 | 814.2 | 84.84 | 60.13 | $1.06x10^{-2}$ | $4.89x10^{4}$ | 75.5 |
| 2 | 1280.0 | 53.97 | 34.29 | $4.68x10^{-3}$ | $4.39x10^{4}$ | 60.6 |
| 3 | 1707.0 | 66.29 | 49.91 | $3.59x10^{-3}$ | $8.51x10^{4}$ | 52.5 |
| 4 | 600.9 | 46.10 | 23.04 | $1.52x10^{-2}$ | $1.34x10^{4}$ | 88.4 |
| 5 | 578.8 | 92.18 | 54.58 | $1.50x10^{-2}$ | $2.07x10^{4}$ | 90.2 |
| 6 | 3035.0 | 78.18 | 52.39 | $1.93x10^{-2}$ | $1.59x10^{5}$ | 39.3 |
| 7 | 2276.0 | 81.57 | 72.36 | $4.60x10^{-3}$ | $1.64x10^{5}$ | 45.4 |

The main aquiferous zones occur between the 4th and 6th geoelectric layers with a resistivity range of 814 to 3035Ωm, depths varying from 46.10m to 92.18m, and layer thickness in excess of 23m. The longitudinal conductance (S) and hence, the protective capacity ($P_c$) of the overburden rock materials range from $4.68x10^{-3}$ to $1.52x10^{-2}$ Siemens. The low values of the protective capacities <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 rates of surface contaminants into the aquifer. This is interpreted as overburden layers with smaller capacity of protection to contaminants and probable risk to soil and groundwater contamination.
The transverse resistance R and hence, the transmissivity of this aquiferous zones vary from $1.34x10^4$ to $1.64x10^5$ $\Omega m^2$. These values are >400 $\Omega m^2$ and correspond to zones where the thicknesses and resistivities of the aquifer are large. The high transmissivities suggest that the aquifer materials are highly permeable to fluid movement within the aquifer, which possibly may enhance the migration and circulation of contaminants in the groundwater aquifer system.

The computed porosities of the groundwater aquifers vary from 39.31 to 90.2%. The high porosity 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.

## RESULTS AND DISCUSSION

The geoelectric survey gave interpreted resistivity model sections with aquiferous zones occurring generally between the 4th and 6th geoelectric layers at the depth range of 46.10m to 92.18m. The relative proximity of these aquiferous layers to the surface has serious implications on the ground water quality in relation to the aquifer transmissivities and protective capacity of the overburden rock materials in the area. The protective capacity of the overburden rock materials in the area is very low. The low values of the protective capacity is due to the absence of significant overburden impermeable rock material (clay /shale), which can impede contaminant infiltration. The implication of this is that any surface contaminant travels down at a faster rate and goes into storage into the aquifer with relative ease and with unprecedented impact on the general ground water quality over time.

The aquiferous zones exhibit high transverse resistance (R) values. The high R values are associated with zones of high transmissivity and, hence highly permeable to fluid movement. The fact that the aquiferous materials in the study area are highly permeable and relatively shallow, suggests that the groundwater has a high propensity of being contaminated over large area once the aquifer receives a load of contaminant dose from any surface source. The estimated aquifer porosities are very high in the study area. This is due to the unconsolidated and friable nature of the aquifer materials with little or no clay materials. High porosities are associated with aquifers of relatively low resistivity, fine to medium grained sands and high water content. The high porosities implies high storativity of the aquifers in the area. The low protective capacities of the overburden rock materials, and the high aquifer transmissivities and porosities will aid the seepage of contaminant loads and migration within the groundwater aquifer system at a relatively shorter time. Groundwater potential in the area is high due to the high transmissivities and thicknesses of the aquifer, which is suitable for the development of boreholes for portable water supply.

## CONCLUSION

The geoelectric studies has helped to delineate aquiferous zones and characterized the conditions of the underground flow in terms of the transmissivities and porosities of the aquifers and the protective capacities of the overburden rock materials. The general lithology is mainly sands of various grades with no delineable intercalating clay/shale impermeable bed.

The study area is characterized by low values of the protective capacities of the overburden rock materials which make the aquifer system in the area highly vulnerable to contamination. A high transmissivity value of the aquifer materials imply highly permeable aquifers which enhances the migration of contaminants within the groundwater system over large areas, while the high aquifer porosities imply aquifers of high storativity and better yeild. These revelations are indications that the ground water quality may have been impaired in the area and borehole water samples should be randomly sampled for contaminant loads based on this analysis.

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