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# Evaluation of Aquifer Protective Capacity in parts of Oru LGA Imo State, South-eastern Nigeria Using Resistivity Data

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***Abstract-*** *Geoelectrical Techniques involving Eighteen Vertical Electrical Soundings were carried out using the Schlumberger configuration in parts of Oru LGA Imo State of Nigeria to evaluate the Aquifer protective capacity of the overburden units in the Study Area to surface contaminants. The Dar Zarrouk parameter used for estimation of Aquifer protective capacity in the Study Area is Longitudinal conductance. The results show that the total longitudinal unit Conductance values range from 0.02135mhos at VES 15 (Akatta) to 0.5565mhos at VES 10 (Umuoji) with an average of 0.21859 mhos. The results also show that aquifer protective capacity values in the Area varied from 0.00541mhos at VES 11 (Mgbidi 1) to 0.53531 mhos at VES 2(Ubachima2) with an average value of 0.10340 mhos. Hence the aquifer protective capacity in the Study Area are classified as 16.67% moderate and 83.3% poor. This means that most part of the Study Area have aquifers that are highly or very susceptible to contamination from surface based contaminants*

***Keywords***; *Dar Zarrouk parameters; Longitudinal conductance; Aquifer; Aquifer protective capacity; contaminants.*

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## I. INTRODUCTION

Geophysical methods especially Vertical Electrical Sounding (VES) has been used successfully for investigating groundwater quality and aquifer protective capacity in different lithological settings (1). The VES survey data can be employed to develop spatial distribution maps of groundwater quality, layer thickness, aquifer protective capacity and to determine the water bearing formation potential (2). While it is good to sink boreholes for groundwater exploitation and development, it is equally necessary to assess the vulnerability of the aquifers to surface contamination. Aquifer protective capacity is the ability of the overburden unit to retard and filter percolating ground surface polluting fluid into the aquiferous unit. The Dar Zarrouk parameters are often used as a basis for the evaluation of aquifer properties such as aquifer transmissivity and protective capacity of groundwater resources (3). The Dar Zarrouk parameters consist of the transverse resistance ($R_T$) and longitudinal conductance ($L_c$). for a horizontal, homogenous and isotropic layer, the transverse resistance is defined as

$$R_T = \rho \quad (1)$$

And the longitudinal conductance ($L_C$) is defined as

$$L_C = \frac{h}{\rho} \quad (2)$$

h is layer thickness in metres, ρ is the electrical resistivity of the layer in ohm-metres. (3) described the protective capacity of an overburden overlying an aquifer as being proportional to its hydraulic conductivity on a purely empirical basis, the hydraulic conductivity of clayey sediment could be linked to electrical resistivity through the concept of clay content. High clay content generally corresponds with low resistivities and high hydraulic conductivity and vice versa. Hence the protective capacity of the overburden could be considered as being proportional to the ratio of thickness to resistivity or in other words to the longitudinal conductance. This means that equation 2 can be used to evaluate the aquifer vulnerability.

In this research work, we shall evaluate the aquifer protective capacity for the aquiferous zones in parts of Oru LGA Imo State, Southeastern Nigeria using resistivity data. (4) estimated aquifer characteristics in parts of Oru LGA of Imo State Nigeria using Resistivity data. A table of aquifer characteristics for the study area is drawn below;

**TABLE I.** Aquifer Hydraulic Parameters of the Study Area using data from Surface Electrical Soundings according to (4)

| VES NO | LOCATION | RESISTIVITY(ohm-m) | AQUIFER DEPTH (m) | AQUIFER THICKNESS (m) | AQUIFER CONDUCTIVITY (SIEMENS) | TRANSVERSE RESISTANCE (ohm-$m^2$) | LONGITUDINAL CONDUCTANCE(mhos) |
|---|---|---|---|---|---|---|---|
| 1 | Ubachima1 | 395 | 110 | 119 | 0.0025 | 47005 | 0.30126 |
| 2 | Ubachima 2 | 317 | 92.4 | 79.3 | 0.00315 | 251381 | 0.25016 |
| 3 | Umuokwe | 313 | 96.4 | 68.8 | 0.00319 | 21534.4 | 0.21981 |
| 4 | Oteru | 470 | 200 | 140 | 0.00213 | 65800 | 0.2979 |
| 5 | Umuowa | 636 | 86 | 103 | 0.00157 | 65508 | 0.1619 |
| 6 | Otulu 1 | 640 | 120 | 115 | 0.00156 | 73600 | 0.1796 |
| 7 | Ubahazu 1 | 642 | 125 | 115 | 0.00156 | 73830 | 0.1791 |
| 8 | Ubahazu2 | 645 | 117 | 109 | 0.00155 | 70305 | 0.1689 |
| 9 | Otulu 2 | 618 | 155 | 122 | 0.00162 | 75396 | 0.1974 |
| 10 | Umuoji | 221 | 164 | 123 | 0.00452 | 27183 | 0.55656 |
| 11 | Mgbidi1 | 196 | 205 | 90 | 0.0051 | 17640 | 0.4592 |
| 12 | Mgbidi 2 | 1831 | 87 | 67 | 0.00055 | 122677 | 0.03659 |
| 13 | Ibiasoegbe | 524 | 84 | 132 | 0.00191 | 69168 | 0.2519 |
| 14 | Nempi | 3934 | 81.6 | 63.5 | 0.00025 | 249809 | 0.1614 |
| 15 | Akatta | 3466 | 75 | 74 | 0.00029 | 256484 | 0.02135 |
| 16 | Aji | 557 | 27 | 24 | 0.00179 | 13368 | 0.04309 |
| 17 | Ubulu | 2915 | 36 | 69 | 0.00034 | 201135 | 0.02367 |
| 18 | Akuma | 96.5 | 39 | 41 | 0.01036 | 3956.5 | 0.42487 |

## II. LOCATION, GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The Study Area consists of some Communities located within the Oru Area of Imo State Nigeria. The communities are as listed in the Table 1 above. The Study area lies within longitude $6^0$50E and $7^0$00E and latitudes $5^0$50N and $5^0$37N as shown on the location Map below fig 1. It covers a land mass of about 315$km^2$ South east Nigeria.

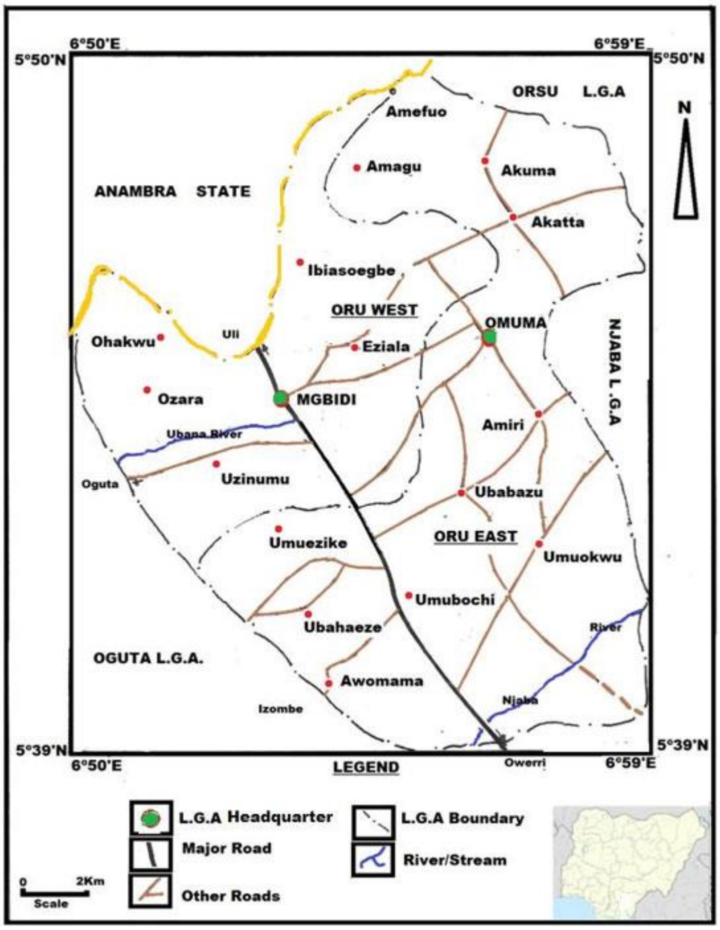


Fig 1. Location map of Study Area

A study of geology of Nigeria shows that the Oru Area is made up of two geological formations, the Ogwashi-Asaba and the Benin formation which was formerly known as coastal plain sands (5). According to (6), Ogwashi –Asaba formation is characterized by alternation of clays and sands, Grits and Lignites. (5) suggested Oligocene-Miocene age for this formation. For the Benin formation, the sands and sandstones are coarse to fine grained and commonly of granular texture. The formation consists of friable sand with intercalations of shale and clay lenses occurring occasionally at some depths (7). The formation is partly estuarine, partly lagoon, partly deltaic and fluid, lacustrine in origin Reyment (1965). The sands and sandstones in this formation are coarse grained, very granular, pebbly to very finegrained. They are either white in colour or yellowish brown. Hematite grains and feldspars are also obtained. The shale are grayish brown, sandy to silty and contains some plant remains and dispersed lignites (5). The formation has an average thickness of 6 00ft(196.85m) (8).

Surface waters are not a major feature of the Oru Area. The Njaba and Obana rivers seem to be the only surface waters in the area (9). The two formations are known to have reliable groundwater that could sustain borehole production. The high permeability of coastal plain sands, the overlying lateritic earth and the weathered top of this formation provide the hydraulic conditions favouring aquifer formation in the study area. The copious rainfall that prevails in the area makes the aquifer prolific and continuously provides the groundwater recharge. The geological map of the study area is shown in figure 2.

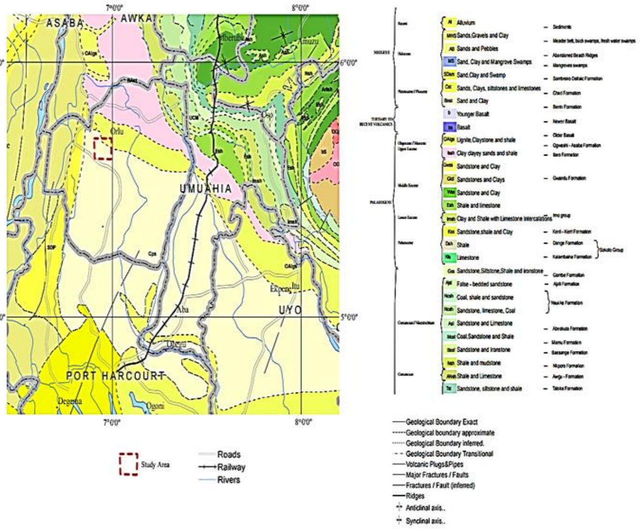


Fig 2. Geological map of study Area

## III. DATA ACQUISITION AND INTERPRETATION

Eighteen Vertical Electrical Soundings were made in the Study Area using a maximum current electrode separation of 1.0km. The ABEM Terrameter SAS 3000B was used in acquiring data while four metal stakes were used as electrodes. The Schlumberger electrode configuration was adopted in this survey. In this array the Current and potential electrode pairs have a common midpoint but the distances between adjacent electrodes differ significantly. For a Schlumberger Spread, the apparent resistivity computed from the measurement of Voltage, and the current is given by the equation.

$$\rho_a = \pi \left(\frac{a^2}{b} - \frac{b}{4}\right) \frac{\Delta V}{I} \qquad (3)$$

Theoretically, the resistivity of a material is directly proportional to the potential difference and inversely proportional to the induced current.

$$\alpha \frac{V}{I} \qquad (4)$$

$$\rho = \frac{KV}{I} \qquad (5)$$

$$R = \frac{V}{I} \qquad (6)$$

$$\rho = KR] \qquad (7)$$

Where k is the geometric factor, R is the resistance. The geometric factor k depends on the electrode separation. R is the resistance of the volume of ground between the potential electrodes. If V and I are measured in milli-volts and milli-amperes respectively and the distance of separations in meter, then the resistivity is expressed in Ohm—meter. The apparent resistivity values obtained from the field were plotted against half the current electrode spacing (AB/2) on a bi-logarithmic graph for all the VES stations. The computer modelling delineated 6-7 geoelectric layers for the 18 places where the vertical electrical sounding were done.

## IV. THEORY OF AQUIFER PROTECTIVE CAPACITY

The values of the total longitudinal conductance of the overburden layers of the aquifers were used in the evaluation of the protective capacity of an aquifer.

$$P_C = \sum\left[{h_i}/{\rho_i}\right] \qquad (8)$$

Where $P_C$ is protective capacity, $h_i$ is the thickness of the Ith layer. $\rho_i$ is the resistivity of the Ith layer.

While high longitudinal conductance values are associated with excellent and good aquifer protective capacity, low longitudinal conductance values correspond to poor and weak aquifer protective capacity.

The rating of aquifer protective capacity was described by (10) as expressed in the table 2 below

TABLE 2. Rating of Aquifer protective capacity (10)

| S/N | PROTECTIVE CAPACITY (MHOS) | RATING |
|---|---|---|
| 1 | 10 | Excellent |
| 2 | 5 ---10 | Very good |
| 3 | 0.7—4.9 | Good |
| 4 | 0.2 –0.69 | Moderate |
| 5 | 0.1—0.19 | Weak |
| 6 | <0.1 | Poor |

According to (9) the following tables display the number of layers, layer thickness, layer resistivity and depth for each of the eighteen vertical electrical soundings whose aquifer characteristics have been summarised in table 1. These tables are to enable us calculate the aquifer protective capacity for each sounding point or location. We shall make illustration for VES 1, VES2 and VES 3 and subsequently draw up a table of aquifer protective capacity for the entire eighteen locations.

**TABLE 3.** Number of layers, layer thickness, resistivity and depth for ves1( ubachima1)(9)

| NUMBER OF LAYERS | RESISTIVITY(OHM-M) | THICKNESS(m) | DEPTH FROM TOP(m) |
|---|---|---|---|
| FIRST LAYER | 3406 | 0.6 | 0.6 |
| SECOND LAYER | 227 | 1.3 | 1.9 |
| THIRD LAYER | 1172 | 4.2 | 6.1 |
| FOURTH LAYER | 3322 | 28.6 | 34.8 |
| FIFTH LAYER | 10255 | 75.3 | 110.1 |
| SIXTH LAYER | 395 | 119.2 | 229.3 |
| SEVENTH LAYER | 480 | ----- | ---- |
| | | | |

**TABLE 4;** Number of layers, layer thickness, resistivity and depth for ves 2 (ubachima 2) (9)

| NUMBER OF LAYERS | RESISTIVITY(ohm-m) | THICKNESS(m) | DEPTH FROM TOP(m) |
|---|---|---|---|
| FIRST LAYER | 113 | 0.5 | 0.5 |
| SECOND LAYER | 11 | 1.2 | 1.8 |
| THIRD LAYER | 29 | 8.4 | 10.1 |
| FOURTH LAYER | 196 | 25.9 | 36.0 |
| FIFTH LAYER | 315 | 56.4 | 92.4 |
| SIXTH LAYER | 317 | 79.3 | 171.7 |
| SEVENTH LAYER | 193 | ---- | ---- |

**TABLE 5;** Number of layers, layer thickness, resistivity and depth for ves 3 (umuokwe)(9)

| NUMBER OF LAYERS | RESISTIVITY(ohm-m) | THICKNESS (m) | DEPTH FROM TOP(m) |
|---|---|---|---|
| FIRST LAYER | 123 | 0.5 | 0.5 |
| SECOND LAYER | 13 | 1.5 | 2.0 |
| THIRD LAYER | 32 | 9.4 | 11.5 |
| FOURTH LAYER | 253 | 27.8 | 39.3 |
| FIFTH LAYER | 287 | 57.1 | 96.4 |
| SIXTH LAYER | 313 | 68.8 | 165.2 |
| SEVENTH LAYER | 182 | ---- | ---- |

For the first VES location, the aquifer protective capacity is calculated as follows; we note that the aquiferous layer is the sixth layer, even the seventh layer is also an aquiferous layer. So in our calculation, we obtain the longitudinal conductance for the first to the fifth layers and obtain their summation which gives the aquifer protective capacity (11)

Applying equation 8 to layers one to five we have;

$0.6/3406 + 1.3/227 + 4.2/1172 + 28.6/3322 + 75.3/10255 = 0.0254386809$ approximately 0.02544 mhos

Similarly for VES 2 the aquiferous layers are the fifth and sixth layers, so applying equation 3 we have;

$0.5/113 + 1.2/11 + 8.4/29 + 25.9/196 = 0.5353137174 = 0.53531$mhos

For VES 3 we have as follows;

$0.5/123 + 1.5/13 + 9.4/32 + 27.8/253 = 0.523081079 = 0.52308$ mhos.

Following this method the table 6 below presents the computed aquifer protective capacity for the various locations in the study area where vertical electrical sounding was done.

**TABLE 6;** Aquifer protective capacity for the eighteen VES locations in the Study Area.

| VES NUMBER | LOCATION | AQUIFER PROTECTIVE CAPACITY(mhos) | RATING |
|---|---|---|---|
| One | Ubachima1 | 0.02544 | Poor |
| Two | Ubachima2 | 0.53531 | Moderate |
| Three | Umuokwe | 0.52308 | Moderate |
| Four | Oteru | 0.43699 | Moderate |
| Five | Umuowa | 0.02749 | Poor |
| Six | Otulu1 | 0.02170 | Poor |
| Seven | Ubahazu 1 | 0.02135 | Poor |
| Eight | Ubahazu 2 | 0.02062 | Poor |
| Nine | Otulu 2 | 0.03910 | Poor |
| TEN | Umuoji | 0.05139 | Poor |
| Eleven | Mgbidi 1 | 0.00541 | Poor |
| Twelve | Mgbidi 2 | 0.00628 | Poor |
| Thirteen | Ibiasoegbe | 0.01744 | Poor |

| | | | |
|---|---|---|---|
| Fourteen | Nempi | 0.03510 | Poor |
| Fifteen | Akatta | 0.03558 | Poor |
| Sixteen | Aji | 0.01874 | Poor |
| Seventeen | Ubulu | 0.02355 | Poor |
| Eighteen, | Akuma | 0.01665 | poor |

## V. RESULTS AND DISCUSSIONS;

The total Longitudinal unit conductance values obtained from the Study Area range from 0.02135mhos at VES 15(Akatta) to 0.55656mhos at VES 10 (Umuoji) with an average of 0.21859mhos. The results of assessment of Aquifer vulnerability Table 6 show that aquifer protective capacity values in the study area varied from 0.00541 mhos at VES eleven (Mgbidi 1) to 0.53531mhos at VES 2 (Ubachima 2) with an average value of 0.10340 mhos. According to table 2 the aquifer protective capacity in the study area are classified 16.67% moderate and 83.3% poor. This means that most part of the study area have aquifers that are susceptible to contamination.

## VI. CONCLUSION

The Aquifer vulnerability assessment of the Study Area show that most parts of the Area are susceptible to contamination.

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