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Determination of Contaminant Loads in the Water Supply Aquifer System of New Owerri Area, Southeastern Nigeria

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Abstract
Eight (8) vertical electrical soundings (VES) were conducted at predetermined points to assess the extent of contamination of the water supply aquifersystems in New Owerri area. Lithological cross sectional analysis using electrofacies packages from geoelectric logsrevealedthat the underlying lithofacies are predominantly gravels, sandstones, clays and silts. The analysis of the four profiles: AB, CD, EF and GH revealed a transient (perched) aquifer system within the depth of 20.0 to 38.5 m.Gravels and sandstones, which constitutethe major aquiferous units, readily yield copious water to boreholes and wells.The 3 to 4 Geo-electric layers obtained in the study area also showed that depth to water table (DWT) ranged between 22.0to 93.5m. This shows thatthe groundwater systemin the study area is comprised of both shallow and deep systems.The areas with the shallow aquifer system (22.0 to 38.5m)are heavily contaminated with iron. This condition is probably a consequence of the shallow water condition and nearness to pollution sources, culminating in the ease to which contaminants percolate to the groundwater system The areas that are classed weak and poor are most susceptible to contamination, while the good, very good and excellent classes indicated lithofacies with high pollution attenuation capacity.

Keywords: *Sounding, Contaminant, load, aquifer, attenuation, groundwater*

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I. Introduction

The advent of technology has made the quest for all purpose in life to drift from ordinary search for water to prospecting for steady and reliable subsurface or ground water from boreholes. In Nigeria presently, borehole has rescued the citizenry from acute shortage of water.

In as much as the borehole has been of immense help in water supply, it has been seen to face the challenges of water borne diseases such as cholera, typhoid etc., which are traced to have been caused by contaminants in the water system. This study is then set to assess the ground water constituents and the potentials of contaminants to leach from waste disposal and other similar sites to pollute the ground water.

Thus, it aims at achieving this by assessing the contaminant load in the ground water system as a result of human impacts. This contaminants exhibit larger uncertainty due to their limited number of observations and the natural heterogeneity of the underlying geologic formation as they vary from place to place which often tends to confer various levels of pollution vulnerability to the aquifer system.

The geo-electric method has been found to be very reliable for ground water studies. This study therefore, is centered at the use of Vertical Electric Sounding (VES) for underground water studies in a sedimentary environment to determine the contaminant load in the aquifer system in this study area.

In this work, the electrical resistivity (VES) is used to determine the contaminant load in the study areas and the venerability of these areas to the leaching contaminants. The concept of venerability is based on the assumption that the physical environment may provide some degree of protection to ground water against anthropogenic and natural impacts and that the degree of vulnerability is a function of the hydro-geologic conditions and the prevailing patterns of waste disposal system.

The degree of vulnerability is expressed by means of maps and analytical models that show the protection provided by the natural environment and how it varies at different locations.

New Owerri and its environs have witnessed a substantial industrial and population growth during the past decades. Waste generated in this area are disposed in open dumps, especially abandoned borrow and quarry pits, erosion sites, river banks, septic tanks and pit latrines. Other potential sources of pollution include oil and gas spills from numerous petrol stations in and around these areas, industrial effluents and waste from agricultural activities.

Open dumps in particular are located indiscriminately in New Owerri and environs without considerations to the protection of the underlying aquifer and sites. Thus, the aquifer which is basically confined now becomes semi-confined in some areas and unconfined in other areas.

Water table mounding and direct leachate infiltration would provide the major pathway for the entry of contaminants from pollution sources into the ground water system, which is comprised generally of an extensive confined sand aquifer and permeable/ porous overburden.

The unconfined nature of the aquifer, its strategic importance to the supply of portable water to the populace, and the fact that polluted aquifer is responsible for the water bore diseases; suggest the need for the development and implementation of appropriate protection strategy for the resource. Knowledge of the pollutants in this area forms the basis for developing such strategy.

Although the concept of ground water vulnerability has been introduced more than two decades ago, a generally recognized and accepted definition has not yet been developed. One of the earliest definitions found in literatures is that of Albinet and Margat (1970) who offered that acquired vulnerability is the possibility of percolation and diffusion of contaminations from the ground surface into the natural water table reservoir under natural conditions.Several works have been carried out on groundwater contamination vulnerability by a number of researchers and some of their findings that are in direct relationship with this study are summarized below:

Olmer and Rezee (1974) suggested that the vulnerability of ground water is the degree of endangering determinant by natural conditions and independent on present source of pollution. In their view, vulnerability depends on vertical permeability in the unsaturated zone, and on hydraulic gradient and flow velocity in the aquifer.

Villumsem and Sonderstor (1982) proposed that ground water vulnerability is the risk of chemical substances used or disposed on or near the ground surface to influence ground water quality. According to these authors, ground water vulnerability depends on series of parameters. Theses parameters are grouped into dynamic (Land use population, density and static intrinsic parameters of the soil-rock ground water system. They emphasized that the chemical composition of the ground water system should be used as a preliminary indicator of vulnerability.

Johnston (1988), assessed aquifer vulnerability using three parameters: ground water flow system, the hydrogeological framework and climate. Legrand (1984) developed an empirical point count system that was based on five parameters for an unconfined aquifer. The factors include: depth to water table, aquifer permeability, distance from a pollution source (especially from a waste dump site) to a water well or stream.

Foster (1987) considered groundwater contamination risks as the interaction between natural vulnerability of the aquifer and the contaminant loading that is, or will be applied to its sub-surface environment as a result of human activity. He developed rating system based on three parameters: groundwater occurrence, overlying lithology and depth to ground table (GOD).

As far as we know, however, ground water pollution and management studies carried out in Owerri area including these of Ibe et al., 1992; Ezeigbo, 1989; and Uma, 1984 have focused purely on descriptive water quality of the aquifer systems. These studies did not provide a quantitative basis for developing pollution control and protection measures that will provide term solution to ground water quality management problems. But, Onyekuru, S.O (2003) carried out a qualitative vulnerability assessment using the GOD, Legrand, DRASTIC and Siga model in the Owerri area.

LOCATION AND CLIMATEOF THE STUDY AREA

The study area is within the Owerri Municipal and Owerri West axis of Imo State south- Eastern Nigeria. This is bounded by latitude 5°27´N – 5°29´N and longitude 6°58´E – 7°05´E.

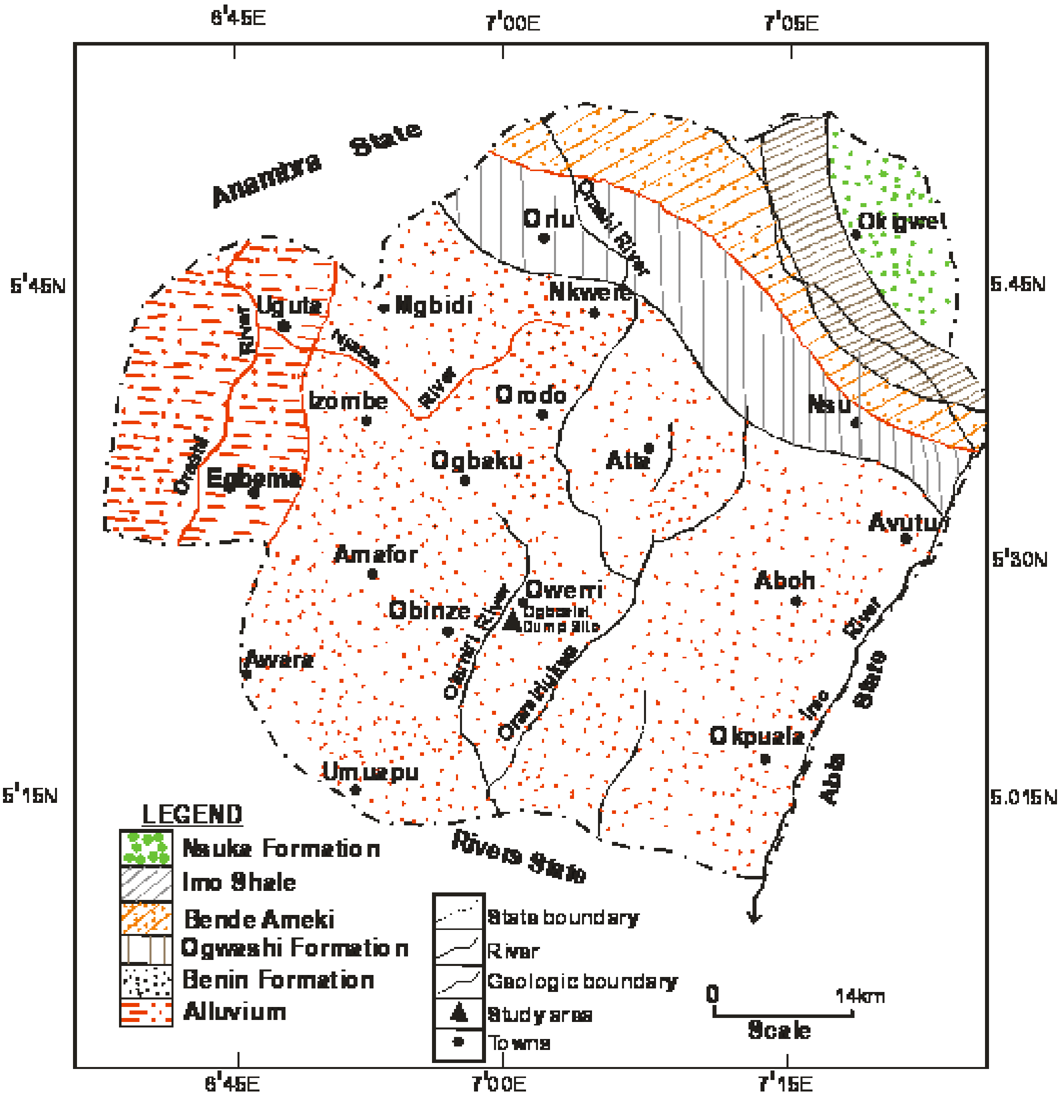


Fig. 1: the geological map of the study area.

The prevalent climatic conditions is marked by two main regimes, the wet season lasts from April to October while the dry continental North-Eastern wind blows from the Mediterranean sea, across the Sahara Desert and down the Southern part of Nigeria. The wet season is a season characterized by the double maxima of rainfall. The first peak occurs in July, and the second occurred in September with mean annual rainfall of about 2152mm (Monanu and Inyang, 1975).

PHYSIOGRAPHY OF THE STUDY AREA

Two types of land forms made up of undulating lowlands and near- level plains characterize the area. The landforms are dissected by rivers most of which originated from the Awka Orlu escarpment. The Owerri area occupies a relatively low elevation and is drained by Otamiri and Nworie River.

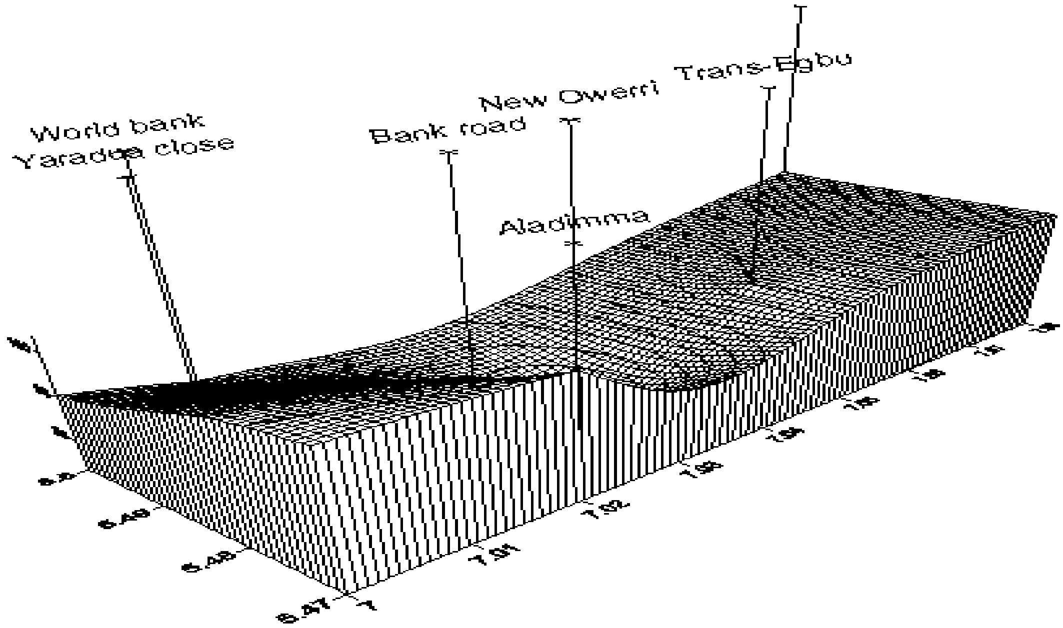


Fig. 2 the elevation of the study area

The study area lies within the tropical rain forest belt of Nigeria. The natural vegetation in the greater part derived Savannah grassland interspersed with oil palm trees. Generally, the area is underlain by intensely weathered and leach uniform sand, loamy sands and clay.

GEOLOGY OF THE STUDY AREA

The study area is underlain by the Benin formation (coastal plain sands), which is an extensive stratigraphic unit in the south-eastern Nigeria sedimentary basin. The formation is of Miocene (recent age) and consists of very friable sands with intercalations of shale and clay lenses (Short and Stubble, 1967). The formation also contains small isolated units of gravel, conglomerates, very coarse-grained sands and sandstones in Owerri area (Ananaba et al., 1991). The environment of deposition is lagoonal and fluvial-lacustrine/deltaic, and starts as a thin bed at its contact with the OgwushiAsaba formation in the north of the area and thickens southwards to about 1000m in Owerri area (Regment, 1965; Avboubo, 1978).

Mineralogically, the sandy unit which constitutes over 90% of the rock is composed of over 95% quartz (Oneacha, 1980), a marked banding of coarse and fine layers with large scale cross bedding are the major structures of the formation (Ofiegbu, 1988).

Reyment, (1965) studied the stratigraphy and paleontology characteristics of different basins, in which can be employed with the method of surface geological field sampling and concluded that the stratigraphic units of Imo River are as tabulated in Table 1.

Table 1: The stratigraphic units of the study area.

Age	Formation	Lithology
Miocene	Benin Formation	Medium coarse grained poorly consolidated sand with clay lenses and stringers
Oligocene Miocene	OgwuashiAsaba Formation	Unconsolidated sand with ligmite seam at various layers.
Eocene	Ameki Formation Nanka Shale	Grey clayey sandstones and sandy clay
Paleocene	Nsukka/Imo Shale	Laminated clay shale while Nsukka has sandstone intercalated with shale and coal body.
Maastrichtian	Ajali Sandstone	Poorly consolidated sandstone typically cross bedded with minor clay layers.

II. Hydrogeology

This is the study of water flow in aquifer and the characterization of the aquifer. The area is drained by Otamiri and Nworie Rivers. The regional flow trend is in the south west direction. Stream discharge is mainly from surface runoffs and ground water base flow with peak stream discharge occurring between September and October (Akpodje et al, 1991).

The bacteriological quality of most of the stream water is poor mainly due to contamination from widespread and indiscriminate human and animal defecation and very poor waste disposal practices (Ezeigbo, 1989). Chemical quality of the surface water bodies is also impaired mainly due to industrial effluents and other anthropogenic activities (Ezeigbo, 1989; Ibe et al., 1992).

Three distinct aquifer units have been recognized in the lower Imo River basin of which the study area is part (Uma and Egboka, 1986). They are: the upper water table aquifer, a middle semi confined and lower confined aquifer unit. The lower confined aquifer unit is at a depth of about 100m, the middle semi-confined aquifer has an average thickness of over 600m. Aquifer parameters indicate high storage and transmissive properties. Well yields range from 54.24m3/hr to 231.50m^3/hour (Uma and Egboka, 1986).

III. Materials And Methods

Materials used in the field operation include: Geophysical Positioning System (GPS); power source (dry cell battery pack); 2 measuring tapes; wo pairs of metallic electrodes; Abem Terrameter (SAS 4000) resistivity meter; 2 potential wires of about 100 meters length each wound on a metallic rod; 2 current wires of about 600 meters length each on a metallic red; 4 hammers, machetes, field umbrella and a meter for the measurement of continuity of the wire.

Resistivity Sounding (known as Vertical Electric Sounding) using Schlumberger ABEM TARAMETER SYSTEM (SAS) for the investigation in the study area (New Owerri and environs) and the resulting sounding curves were interpreted using computer iteration techniques the to determine the ground water location and the contaminant load in this study area.

A total of 8 VES data sets were obtained using Schlumberger electrode configuration. All necessary precautions required in geo-electric measurement were duly observed. A maximum of 250 meters (L/2) current electrode spacing were used for each transverse, using the Schlumberger electrode configuration shown in Fig 3, the midpoint O, being the center of observation.

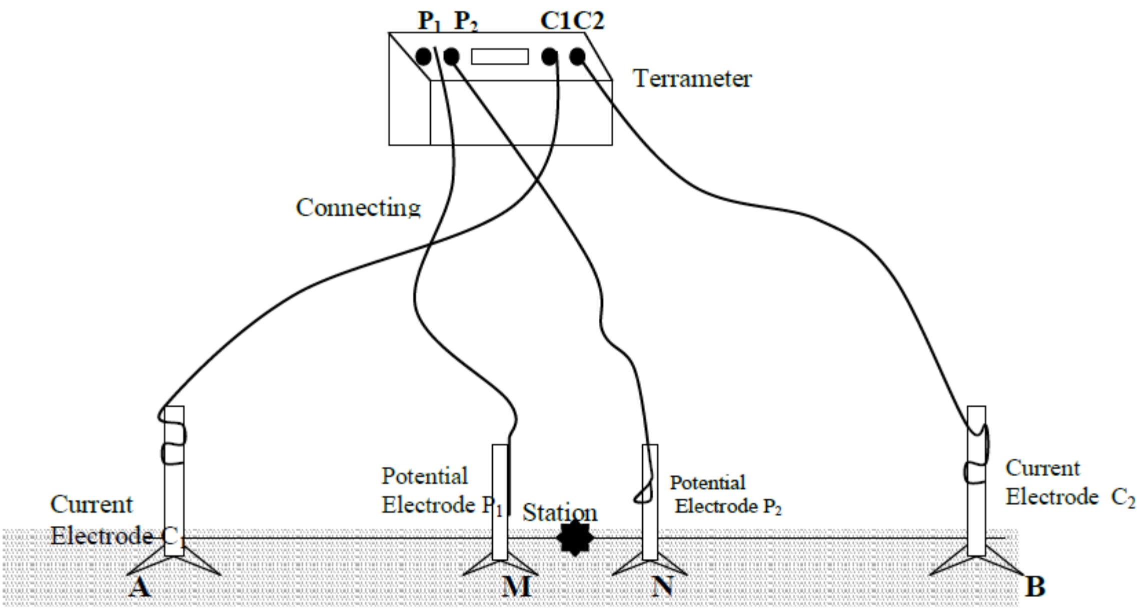


Fig. 3 The Schlumberger electrode arrangement for resistivity sounding (VES)

C_1 and C_2 = current electrodes
P_1 and P_2 = Potential electrodes
L = Total current spread
MN = Total potential electrode spread
I and V = Current and Voltage readings respectively.

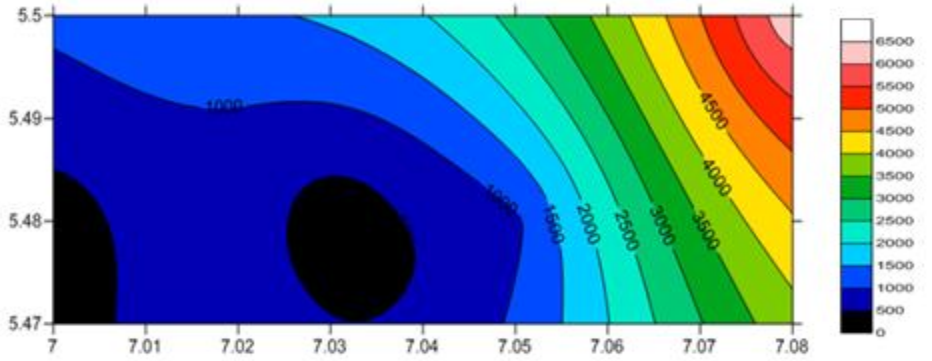
In the Schlumberger arrangement (Fig 3), the current electrodes C_1 and C_2 are moved outward after each reading. In practice, however, this is the measurement of accurate potential electrode separation. The operator expands the electrode spacing by increasing the distance current electrodes or that between the potential electrodes only one at a time, during the course of measurement. The potential P_1 and P_2 are kept constant and were only moved to obtain a satisfactory reading of the potential drop. This array is widely employed in measuring the earth resistivity and it is designed as well as to measure current electrode spacing up to 250 meters.

Precautionary measures taken include:
(a) Checking continuity of cables as well as protecting any opening one by cello tape.
(b) Proper positioning of electrodes on consolidated surface along the transverse and not on filled surface or recent alluvial deposits. Electrode must be lowered perfectly down to have a firm grips with the earth.
(c) Avoidance of high tension and other energized electric wires.
(d) Avoidance of obstacle such as busy roads, market square, and wire fence etc.

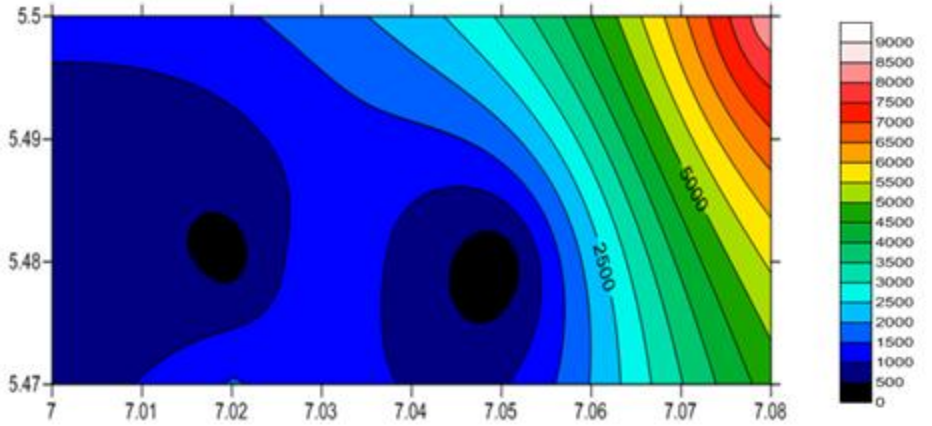
IV. Result Presentation,Discussion And Interpretation

The VES of the 8 different locations under this study area were taken at points of equal elevation. The soundings were carried out using an ABEM terrameter SAS 4000 model with digital readout. The values of resistance read from the terrameter were converted to resistivity values by multiplying some with a geometric factor already established as a function of electrode separations.
These resistivity data were keyed in alongside their corresponding AB/2 to the computer for analysis. The Schlumberger O'Neil software was used to model the data and the modeled curves presented in terms of depth probes. These modeled curves were used in the generation of the Geo-electric sections as shown in fig 4. below.
The parameters of the aquifer layers in the 8 VES locations of the study area and their respective resistivity are as shown in the Table 2 below:

The following steps were taken in obtaining the results of these 8 VES locations.
1. Development of the Iso-Resistivity map of the study area.
The iso-resistivity map was obtained by plotting the resistivity values as obtained from the sounding curves at a given electrode spacing common to all the sounding points and points of equal resistivity contoured. This type of map shows variation in resistivity with depth at a given area. The iso-resistivity modeling data information of the study area were used to plot the iso-Resistivity maps for the various locations as shown in fig.4



AB/2=2.0m(DEPTH=1.33m)



AB/2=400.0m(DEPTH = 266.67m)

Fig. 4 A representation Iso-Resistivity Modeling Map at AB/2 = 2.0m and AB/2 = 400.0m

2. Computer modeling

Computer Iteration method was used to model the obtained data and the resistivity graph of the 8 different locations were plotted against the depth of the ground water table in the locations using a computer software program (Schlumberger O'Neil program). The graphs of the Vertical Electrical Sounding conducted in the New Owerri and environs (the 8 VES locations for this work) are shown in fig 1

The geo-electric sections obtained from VES which was accurately evaluated and modeled by the ABEM computer program for geo-electric measurements of Schlumberger automatic analysis version 0.92 by Hemker (1985), enable the determination of prospective aquifer units at various points which will help in the setting the standard water borehole.

In the area of study, sand poor aquifer units consisting mainly of sandstone with clay intercalations were noted. Table 2 shows the depth to prospective aquifer units in each of the 8 VES locations.

Table 2: The depth to prospective aquifer units in each of the 8 VES locations:

VES Number	Locations	Number of Layers	Depth to Prospective Aquifer Units (m)	Prospective Aquifer Material
1	Holy Ghost College	4	23.5	Sand
2	Musa Yar'dua Close	4	22.0	Sand
3	Area-A World Bank	3	24.0	Gravely Sand
4	AchikeUdenwa Estate	3	22.5	Sand
5	Area-C New Owerri	4	31.4	Sand
6	Trans-Egbu	4	25.4	Sand
7	Ikenegbu/Aladinma	3	25.7	Sand
8	Egbu (AGC H/Q)	4	38.5	Sand

Using the results obtained from the VES of these 8 locations as presented in Table 3, the following deductions could be made on the location of prospective zone or depth for drilling of productive borehole in this study area. The VES carried out in the study area shows that a total drilling depth (TDD) of more than 24, 22, 24, 23, 32, 26. 26 and 39 meters must be reached for standard borehole water in the locations of VES 1-8 respectively, with VES 5 (Area-C New Owerri) been the deepest and VES 2 (Musa Yar'dua Close) been the shallowest of the 8 VES locations.

It can be seen that the VES conducted in this 8 locations is as follows:

VES 1: No access road or track, the VES terminated at AB/2 = 215m. The extrapolation from the VES resistivity graph for VES 1 (Holy ghosts college) gives that the apparent resistivity values started increasing from AB/2 = 370m. The true penetration at this spread is about 123m, so the actual increase started from between AB/2 = 215m. Due to these limitations, the fresh water zones between 7.7m and 23.5m at the shallow and the deepen level respectively can only be inferred while the mineralized zone starts from 23.5m at VES 1. Also, the depth curve indicates a contaminant which is mostly to be iron.

VES 2: The aquifer starts from 22.0m. The thickness could not be ascertained, but the depth curve shows that the aquifer in this location (Musa Yar'Adua close) is infected with iron as a contaminant.

VES 3: The aquifer starts from 24.0m. The slope shows that the aquifer of this location (Area A World Bank housing Estate) is not affected with iron.

VES 4: The aquifer starts from 22.5m. The depth curve shows that the aquifer of this location (AchikeUdenwa Estate) is not affected with iron.

VES 5: The first aquifer starts from 12.1m to 31.4m, and the second aquifer could only be inferred to start from about 72m. While the first aquifer in this location (Area C New Owerri) is contaminated with iron, the second is not thus, making the second portable water for drinking.

VES 6: The fresh water zone is between 9m and 25.4m. The second fresh water zone can be inferred from the apparent resistivity reading which started increasing from AB/2 = 370m with a true depth of 280/3 = 93.3m. This simply means that in this location (Trans Egbu), the first aquifer is contaminated with iron while the second is not hence, safe for drinking.

VES 7: The saturation zone starts from 25.7m and the depth curve of this location (Ikenegbu/Aladinma) shows that the aquifer is not contaminated by iron.

VES 8: The saturation zone starts from 38.5m and the depth curve this location (Egbu) shows that the aquifer is not contaminated by iron. The fact that the slope is indented suggests another possible contaminant though not iron.

From the data available, VES 7 and VES 8 are located in the eastern part of the study area. The variation of their saturation points are noted above and their apparent resistivity values show that at AB/2 = 500m, Egbu (VES 8) is 8090.3Ωm while at Aladinma (VES 7), it is 990.2Ωm. They both have lowest values at that point indicating the end of the aquifer. Inferring from this; AB/2 = 500, one-third of 500 gives 166m, so the aquifer terminated around 167m.

In VES 1, 2, 5 and 6, lying in the northwestern part to the central part of the study area, two fresh water zones were deduced in these areas. The iron mineralization occupies about 63m of the aquiferous zones of these areas, so between 30m and 93m are invaded by/with iron infiltration.

It can be generally said that the eastern part of the study area are free from iron water while the central to the northwestern part are attacked by it.

The Geo-electric section of the Vertical Electric Sounding conducted on different locations of the study area is shown in Fig 5 below.

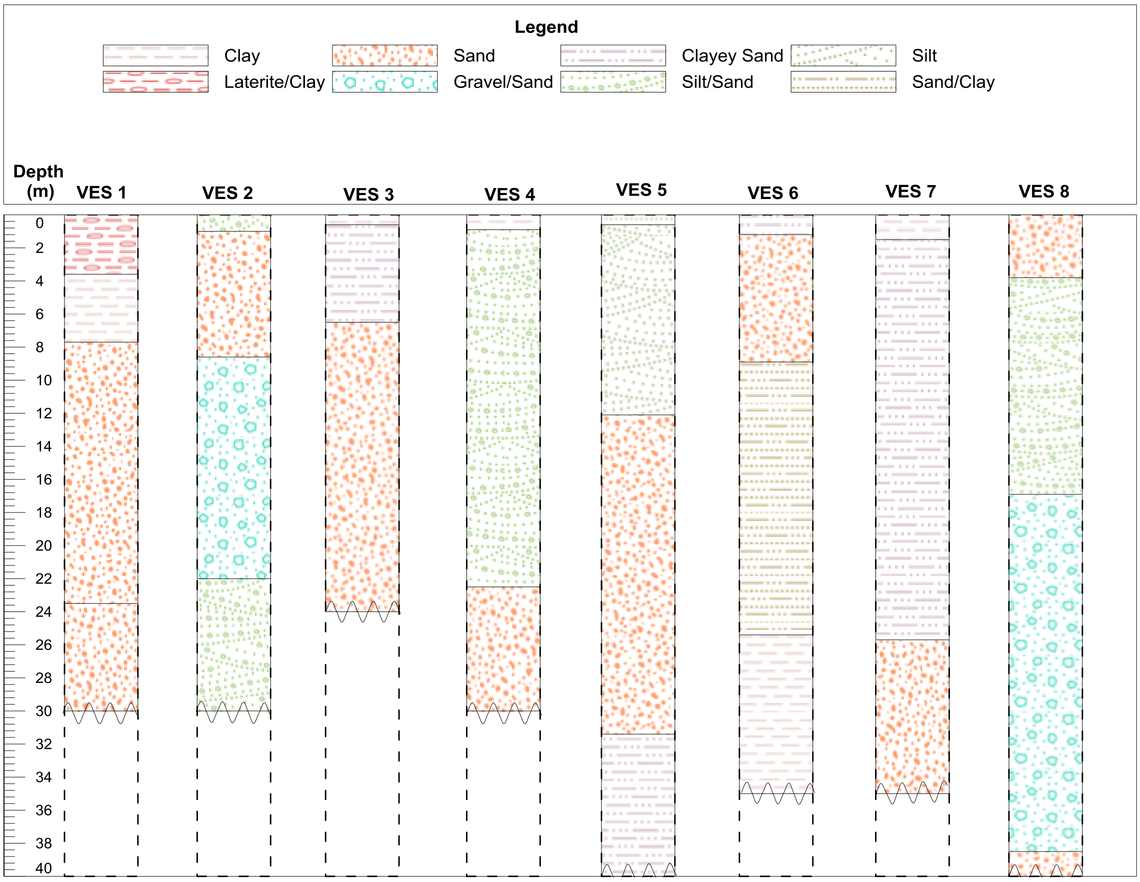


Fig 5. The geo-electric section of the 8 VES locations of the study area.

The aquifer system in this area could be grouped into two- shallow and deep on the basis of Depth to Water Table (DWT) of 63m. Four VES points were classified as having shallow aquifer units while four have deeper aquifer system. The overall survey carried out in this study area interpreted lithology units ranging in number from 3 to 4 as shown in the Geo-Electric Sections are as (a) Top soil, (b) Silt, (c) Sand, (d) Sand stone, and (e)Clay.

V. Conclusion

1. This study revealed that New Owerri and environs is underlain by sand and clay lenses which possesses good aquifer system. 3 to 4 Geo-electric layers were obtained with depth for water table (DWT) ranging from 22.0m to 93.5m. This shows that the area is underlain by both shallow and deep unconfined aquifer system.
2. The locations with the shallow aquifer (VES 1, 2, 5 and 6) ranging from 22.0m to 38.5m are seen to have iron contaminants. This is because of the nearness of the water table to the top surface hence the contaminants would migrate down to the water table with relative ease.The locations with the deep aquifer system (VES 3, 4, and 7) ranging from 30.5m to 93.0m are seen to have no iron contaminants. This is because of the further nature of the aquifer in these locations from the top surface of the soil.
3. The VES 8 location was seen not to be contaminated by iron but the curve shows possibility of other contaminants. Because aquifer materials are highly permeable which enhances lateral spreading of contaminants in the ground water system, this could be as a result of the indiscriminate dumping of refuse along Egbu road which has the ability to leach from the top soil into the water table within that locality

hence contaminating the aquifer system of that locality.Moreover, the observed hydraulic gradients are directed toward streams and rivers, which suggest considerable ground water in flow into them, and hence, indicating that the surface water bodies also are in great risk in the event of pollution of the ground water system.

4. It is recommended that indiscriminate dumping of waste along the road sides, riverbanks, and unplanned areas should be discontinued so as to forestall the contamination of ground water.Boreholes in this area should be properly grouted (at least 10cm) down hole to stop the infiltration of contaminants into the underlying aquifer. Also, pit latrines and septic tanks should be well planned and properly built to reduce the risk of ground water contamination.Industries should be advised to treat their waste before dumping or channeling it into the surrounding water bodies.

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