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EVALUATION OF THE GROUNDWATER POTENTIAL IN NGOR-OKPALA, IMO STATE, NIGERIA

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ABSTRACT
Rapid urbanization being experienced in Ngor-Okpala has resulted in increased groundwater abstraction. As a result, accurate estimation and proper evaluation of the groundwater potential in the area becomes necessary for accurate utilization and management of the resources. The aquifer characteristics and groundwater occurrence in the area was evaluated using geophysical survey, borehole logs, sieve analysis and pumping test results. The area lies within the coastal plainsand aquifers of southeastern Nigeria which is composed of loosely consolidated sands, sandstones and gravels with minor intercalations of silt and clays. This study is an initial step towards providing information needed for effective management of the groundwater system in the area. The geophysical survey and borehole logs show that the area is sand dominated. The borehole logs and sieve analysis results indicate: coarse grained sand > medium grained sand > fine grained sand > gravel > (silt & clay). Pumping test gives transmissivity values ranging from $214m^2/d$ to $396m^2/d$ with a mean value of $306m^2/d$ while the storativity varies from 4.0×10^{-2} to 3.4×10^{-1} with an average value of 2.5×10^{-1}. The borehole yield is of the order of $2459m^3/d$ to $5622m^3/d$ and a mean value of $3207m^3/d$ while the hydraulic conductivity varies from 4.33m/d to 15.16m/d with an average value of 10.61m/d. These findings indicate that the area has high groundwater potentials.

Keywords: Aquifer characterization, Assessment, Ngor-Okpala

INTRODUCTION

Groundwater accounts for about 87% of thee world's fresh water and is fairly distributed throughout the world (Bourwer, 2002). Buchanan (1983) puts the groundwater reserves of the world at about 5.0×10^{24} litres, which is about 2000 times the volume of water in the entire world's ocean. Water, whether surface or groundwater is the elixir of life, meaning without it, life is not possible. It is a known adage that if you deny a man food, his body can sustain life for days, but denies him water and death must come within hours.

The present work focuses on the evaluation of the aquifers system and groundwater potential in Ngor-Okpala area using hydraulic parameters from pumping test, lithological logging of borehole, sieve analysis and geophysical survey results. The need for aquifer characterization arises from the need to have baseline information for groundwater management and optimum utilization. The study also provided information for the utilization, management and remediation processes of groundwater resources. The need for borehole to augment water supply from surface water makes it imperative to have a good knowledge of the aquifer potentials from which groundwater is sourced. The study of groundwater potentials in different parts of Nigeria has revealed that most boreholes are wrongly located due to inadequate predrilling geophysical and hydrogeological studies (Olasehinde and Amadi, 2008).

Study Area Materials and Methods

Ngor-Okpala hosts Imo International Airport and is located along Aba-Owerri expressway. It lies between latitude 5°15'N to 5°35'N and longitudes 6°55'E to 7°15'E covering a total area of about $1{,}345km^2$. It is a low lying terrain with a good road network and is drained by Otamiri and Oramiriukwa rivers, which flow in the north- south direction (Fig. 1).

The area lies within the coastal plainsand belonging to the Benin Formation of southeastern Nigeria which is composed of loosely consolidated sands, sandstones and gravels with minor intercalations of clay and shale (Onyeagocha, 1980). The stratigraphic succession of rocks (Table 1) in the study area consists of Nsukka formation, Imo- Shale, Ameki Formation, Ogwashi-Asaba Formation and Benin Formation with Nsukka and Benin Formations as the oldest and youngest formations respectively (Short and

Stauble, 1967). The coastal plainsand extends to a considerable depth in the area and is favorable for groundwater development. The formation consists predominantly of very thick coastal sand, sandstone, clays and sandy silt occurring in lenses. North of Owerri towards Orlu and Okigwe, the thickness of Benin Formation decreases drastically and starts to overlap the Ogwashi-Asaba formation which is mainly clayey sand with lignite seams and overlies the Ameki formation which is mainly sandstone. The Imo Shale unconformably underlies the Ameki formation while the Nsukka formation underlies all the formation (Uma and Egboka, 1986; Short and Stauble, 1967).

Groundwater occurs abundantly in the coastal plainsands (Benin formation) and the static water level (SWL) ranges from 8m to 65m depending on the location and the time of the year (Uma and Egboka, 1986). The Benin formation also overlies the petroleum bearing Agbada and Akata formation in the Niger Delta area (Figure 1 and Table 1). It is a good aquifer with an average annual replenishment of about 2.5 billion cubic meters per year (Onyegocha, 1980). In most areas, the sandy components forms more than 90% of the sequence of the layers therefore permeability, transmissivity and storativity are very high. Despite of these favourable conditions for groundwater accumulation, cases of borehole failures abound in the area and this is part of what led to the present study.

The study area lies within the tropical rainforest area of Nigeria and the climate has distinct wet (March to October) and dry (November to February) seasons. The average annual rainfall is approximately 2,250mm. The humidity is generally high throughout the year and the rate of evapo-transpiration far exceed that of precipitation during the dry season (Uma and Egboka,1986). The topography is characterized by gently undulating lowlands and plains, The soil type comprises of well-drained top lateritic-silty-clay with minor sand intercalation while downward horizon gives well-sorted sand and gravels (Etu-Efeotor and Akpokodje, 1990).

The present work focuses on the evaluation of the aquifers system and groundwater potential in Ngor-Okpala area using hydraulic parameters from pumping test, lithological logging of borehole, sieve analysis and geophysical survey results. The need for aquifer characterization arises from the need to have baseline information for groundwater management and optimum utilization. The study also provided information for the utilization, management and remediation processes of groundwater resources. The need for borehole to augment water supply from surface water makes it imperative to have a good knowledge of the aquifer potentials from which groundwater is sourced. The study of groundwater potentials in different parts of Nigeria has revealed that most boreholes are wrongly located due to inadequate predrilling geophysical and hydrogeological studies (Olasehinde and Amadi, 2008).

Experimentation

Detiled hydrogeological mapping of the area was undertaken and the major rock types in the area identified. The mapping exercise was complemented with pre-drilling geophysical survey, borehole logging at drilling sites and pumping tests while sieve analyses carried out in the laboratory. The field exercise lasted for a period of 18 weeks while the laboratory work was for 10 days. Due to large area involved (about 1,345km^2), the present study focuses on the southern part of the area (Fig. 3) while work on the northern portion will commence soon. The synergistic approach used in the characterization of the aquifer types in the area has addressed the demerit of aquifer characterization by a particular technique.

Geophysical Survey

Pre-drilling geophysical survey was carried out in the area. Resistivity method, using the Vertical Electrical sounding (VES) Schlumberger array technique was used.

RESULTS

The survey provides information about the nature of the subsurface geology and the viability of the drilling project at a chosen site. The lithostratigraphic information obtained from geo-electric section (Fig. 2) shows that sand and sandstone are the dominant rock type in the area.

Borehole- logs

The result of the lithologic-logs prepared from the samples collected at the settlement pit when borehole drilling was in progress shows that area is sand dominated (Fig. 3). Coarse grained sand occupies over 86% of the subsurface lithology and this agrees with the geo-electric section in FIG. 2.

Pumping Tests

Pumping test is one of the useful tools for assessing groundwater potential of an area. It test the response of groundwater in an aquifer to pumping. By carefully measuring and interpreting this response, it is possible to deduce the hydraulic information, which is useful in quantifying key aquifer parameters such as transmissivity and storativity. Aquifer pumping tests provides data used in evaluating and characterizing groundwater potential of an area. The tests were carried out in to obtain information on the aquifer yield, transmissivity and storativity in order to determine the size of the submersible pump to install in the respective boreholes.

Transmissibility

The aquifer transmissivity was determined by Bailer Test, which is a modified version of Thesis Formula. It indicates how easily groundwater flows through a rock into a borehole and is measured in m^2/d.

Bailer Test = T = $\frac{0.183Q}{\Delta S}$

Where: T = Transmissivity (m^2/day)

Q = Pumping rate (m^3/day)

ΔS = Slope/log cycle

The discharge values (Q) were determined in the field as pumping was in progress while the values of ΔS were determined from the graph in FIG. 4 while Table 2 contains the transmissivity result.

Storativity

Storativity is a measure of how much groundwater can be stored in a rock. It is dimensionless and known as specific yield in areas with unconfined aquifers. Storativity can only be analyzed from pumping test with observation well and therefore cannot be determined using data from pumping test alone. However, empirical formula for estimating Storativity was used in the study. The formula was postulated by Cooper and Jacob in 1946 and is stated below. The results of the storativity values are contained in Table 2.

Sieve Analysis

Sieve analysis was carried out on the borehole litho- samples. 85% of the grain size distribution curves fall within the sandy region in the order of: coarse sand > medium sand > fine sand > (silt & clay) > gravel (Fig. 5).

Hydraulic conductivity (K) of the area was calculated from the grain size distribution curve using **Hazen's formula**. The Hazen's formula is given as:

$$\mathbf{K = c[d_{10}]^2}$$

Where K = hydraulic conductivity (cm/sec)

d_{10} = the effective grain size (cm)

c = a coefficient factor

The hydrogeological properties of rocks in the area have been examined through pre- drilling geophysical survey, strata- logs from drilled boreholes in the area. Pumping tests and sieve analyses. The borehole logs and sieve analysis results indicate: coarse grained sand > medium grained sand > fine grained sand > gravel > (silt & clay). Pumping tests indicates that the transmissivity ranging from $214m^2/d$ to $396m^2/d$ with a mean value of 306 m^2/d while the storativity varies from 4.0×10^{-3} to 3.4×10^{-2} with an average value of 2.5×10^{-2}. The well discharge ranges from 2459 m^3/d to 5622 m^3/d and a mean average value of 10.61 m/d. These results show that the area has a good groundwater potential to sustain domestic, agricultural and industrial purposes. The main aquiferous unit in the area is sand with high porosity and permeability due to the absence of cementing materials.

CONCLUSION.

The area has a good groundwater potential as revealed by the transmissivity, storativity and hydraulic conductivity and sieve analyses result. The unsaturated zone materials are mainly sandy and gravelly facies with high permeability rates. The highly permeable formation coupled with the shallow water table is indication that contaminant would migrate easily into the groundwater. The permeability and porosity of the aquifer materials could enhance both vertical and horizontal movement of contaminant into the groundwater system, therefore techniques aimed at protecting the aquifer should be incorporated in future design and construction of boreholes in the area. Groundwater quality management through education of the public is encouraged.

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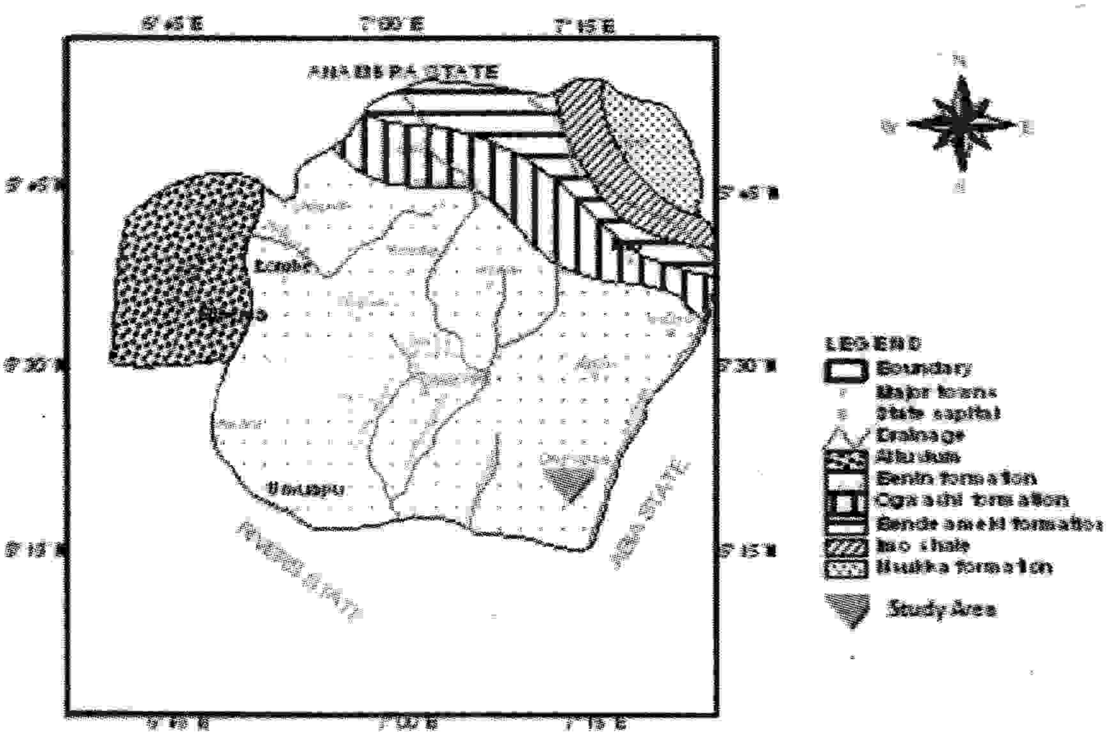

FIG. 1: GEOLOGICAL MAP OF THE IMO STATE SHOWING THE STUDY AREA

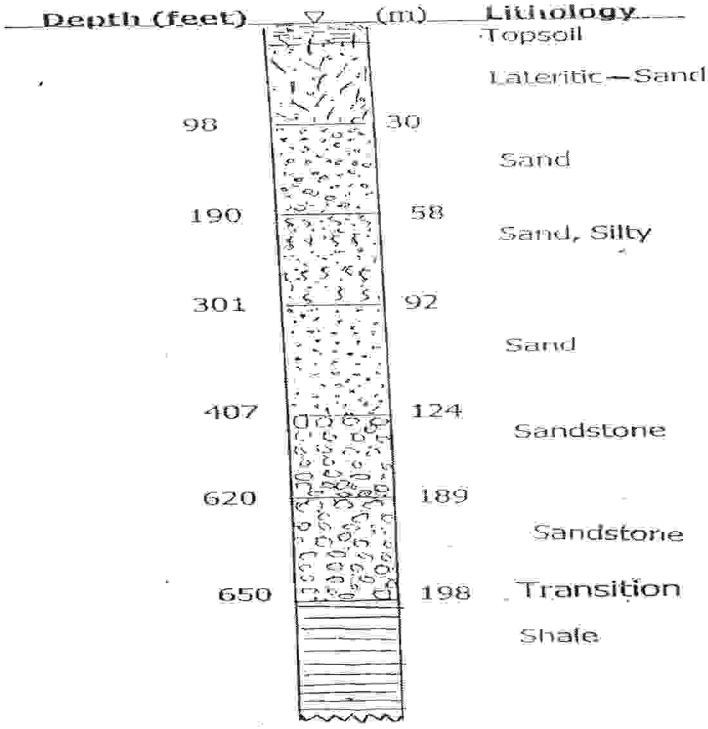

FIG. 2: GEO-ELECTRIC SECTION FROM THE AREA

LITHOLOG	DEPTH(M)	FORMATION	COLOUR
	0-3	Laterite	Reddish
	3-6	Laterite	Reddish
	6-9	Laterite	Reddish
	9-12	Laterite	Reddish
	12-15	Laterite	Reddish
	15-18	Sandy-gravel	White
	18-21	Coarse grained sand	White
	21-27	Coarse grained sand	White
	27-30	Coarse grained sand	White
	30-33	Coarse grained sand	White
	33-36	Coarse grained sand	White
	39-42	Coarse grained sand	White
	42-45	Coarse grained sand	White
	45-48	Coarse grained sand	White
	48-51	Coarse grained sand	White
	51-54	Coarse grained sand	White
	54-57	Coarse grained sand	White
	57-60	Coarse grained sand	White
	60-63	Coarse grained sand	White
	63-66	Coarse grained sand	White
	66-69	Coarse grained sand	White
	69-72	Coarse grained sand	White
	72-75	Coarse grained sand	White
	75-78	Coarse grained sand	White
	78-81	Coarse grained sand	White
	81-84	Coarse grained sand	White
	84-87	Coarse grained sand	White
	87-90	Coarse grained sand	White
	90-93	Coarse grained sand	White

FIG. 3: A TYPICAL BOREHOLE-LOG FOR THE AREA.

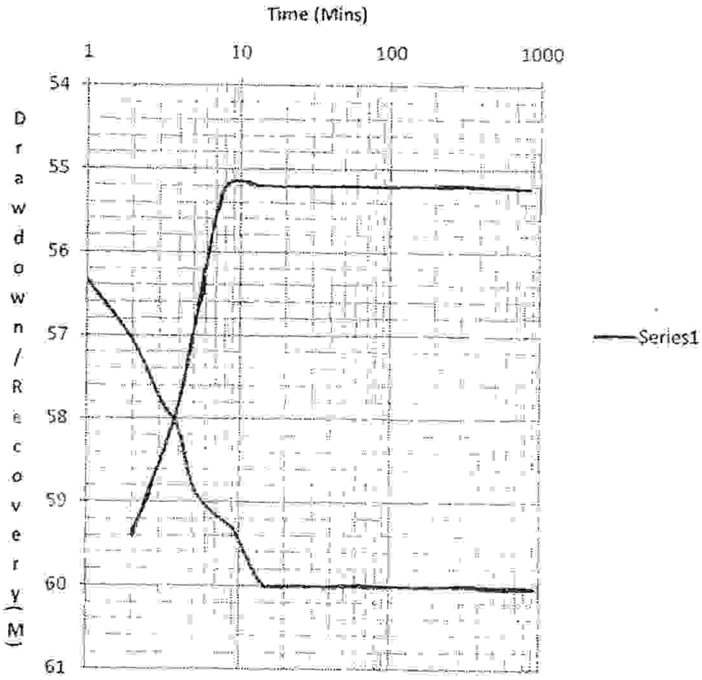

FIG. 4: A GRAPH OF DRAWDOWN/RECOVERY VERSUS TIME FOR THE AREA

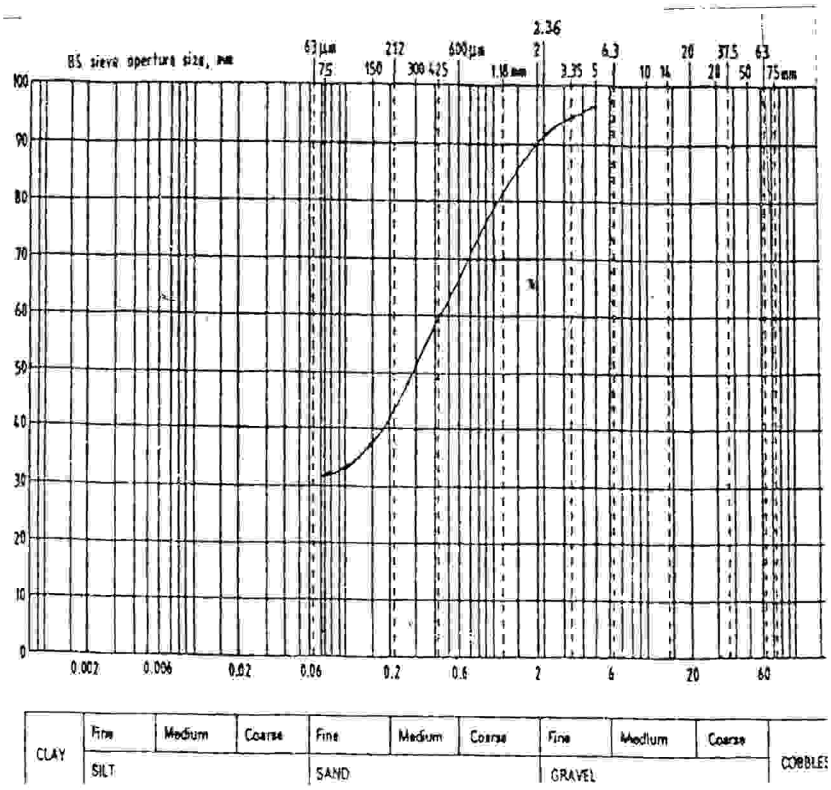

FIG 5: PARTICLE SIZE DISTRIBUTION CURVE OF NGOR-OKPALA, IMO STATE

TABLE 1: STRATIGRAPHIC SUCCESSION OF ROCKS IN OWERRI AREA (AFTER, UMA AND EGBOKA, 1986).

	Age	Formation	Lithology
T E R T I A R Y	Miocene-Recent	Benin Formation (Afam Member)	Medium to coarse grained, poorly consolidated Sand with clay lenses and stringers
	Oligocene-Miocene	Ogwashi- Asaba Formation	Unconsolidated Sand with Lignite seams at various layers
	Eocene	Ameki Formation Nanka Sand	Grey Clayey Sandstone and Sandy Claystone
	Paleocene	Imo Shale	Laminated Clayey Shale
Upper Cretaceous	Maastrichian	Nsukka Formation	Sandstone intercalated with Shale and Coal beds

TABLE 2: SUMMARY OF RESULTS OF DISCHARGE (Q); TRANSMISSIVITY (T); STORATIVITY (S); HYDRAULIC CONDUCTIVITY (K), SLOPE (ÄS) AND RADIUS OF THE WELL (R)

S/N	Borehole Locations	Discharge (Q) m^3/d	Slope	Transmissivity (T) m^2/d	Storativity (S) (Dimensionless)	Well-radius (r) (Inches)	Hydraulic Conductivity (K)m/d
1	Okpala	3258	2.4	248	$3.4 X 10^{-2}$	6	4.33
2	Umuneke	4330	3.0	264	$1.2 X 10^{-2}$	6	9.80
3	Eziama	2459	2.1	214	$1.5 X 10^{-2}$	6	12.13
4	Obokwe	4015	2.3	319	$2.1 X 10^{-2}$	6	8.53
5	Nguru	2764	1.5	337	$4.8 X 10^{-2}$	6	14.34
6	Obike	5622	2.5	396	$2.6 X 10^{-2}$	6	15.16
7	Umuekwune	3571	1.8	363	$1.7 X 10^{-2}$	6	10.17
Mean		3207	2.2	306	$2.5 X 10^{-2.5}$	6	10.61
Range		2459- 5622	1.5- 3.0	214- 396	$4.8 X 10^{-3}$ -$3.4 X 10^{-2}$	-	4.33- 15.16