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Research Article

Analysis of Aquifer Porosity from granulometric data in Parts of Obio/Akpor Local Government Area, Rivers State

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ABSTRACT:
An analysis of aquifer porosity was conducted on aquifer sediment samples gotten from four boreholes at Obio/Akpor Local Government Area of Rivers State. The aquifer sediments were collected during the drilling process and were observed to exist at different depths. The aquifer sediments at Locations 1, 2 and 3 were observed to exist at 120 ft respectively while that of location 4 was at 70 ft. Sieve analysis was conducted on the samples in order to produce particle size distribution curves for the determination of coefficient of grain uniformity of the aquifer sediments and to further aid in the estimation of aquifer porosity of the four locations. The analysis of porosity values across the four aquifer locations revealed that Locations 2 and 3 have the highest aquifer porosity of 42%, followed closely by Location 1 with porosity of 40% and Location 4 with porosity of 36%.

Keywords: Aquifer, Porosity, Sieve analysis, Coefficient of uniformity, Particle size distribution.

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1.0 INTRODUCTION

Aquifers are vital sources of freshwater for, supplying drinking water, irrigation, and industrial needs (Fitts, 2002) and are of sedimentary composition. The occurrence, storage and movement of groundwater are controlled by the hydrogeological properties of aquifers, of which porosity is most fundamental. Aquifer sediments are composed of a wide range of grainsizes, from clay to gravel (Bloomfield *et al*., 2001), and the size distribution of the sediment grains can be studied using a laboratory technique known as sieve analysis. It is important to accurately compare the aquifer porosity of some locations within this study area for better understanding and monitoring of the aquifer system, as an improper study of aquifer properties may encourage challenges in the effective management of ground water resources, leading to several potential consequences (Smith, 2020).

Obio/Akpor Local Government Area (LGA) is one of the 23 LGAs in Rivers State, Nigeria, located within the metropolitan region of Port Harcourt, the state capital. Geographically, the LGA lies between latitudes 4°45′ N and 5°00′ N and longitudes 6°55′ E and 7°05′ E, covering an estimated land area of about 260km² (Ahiakwo, 2012). It is bounded by Port Harcourt City LGA to the south, Ikwerre LGA to the north, Emohua LGA to the west and Etche LGA to the east.

The LGA is situated within the Niger Delta sedimentary basin, which is dominated by consolidated sand, clay and silt deposits of Tertiary to Quarternary age. The subsurface geology is controlled by the Benin Formation, which is predominantly composed of coarse-grained sands and gravels interbedded with clay lenses. These lithologies constitute prolific aquifers that serve as the primary source of potable water for the population (Etu-Efeotor & Akpokodje, 1990; Offodile. 2002). Aquifers in Obio/Akpor are generally unconfined to semi-confined, with depths ranging shallow aquifers tapped by hand-dug wells (5-15 m) to deeper aquifers exploited by boreholes that extend to depths of 60-120 m (Amadi & Amadi, 2014). Equivalently, aquifers within the LGA are with depths ranging shallow aquifers (16-49 ft) to deeper aquifers (197-394 ft).

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The aim of this study is to compare the aquifer porosity of some locations in Obio/Akpor Local Government Area of Rivers State.

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A map showing Obio/Akpor as a local government area in Rivers State is presented in Fig. 1

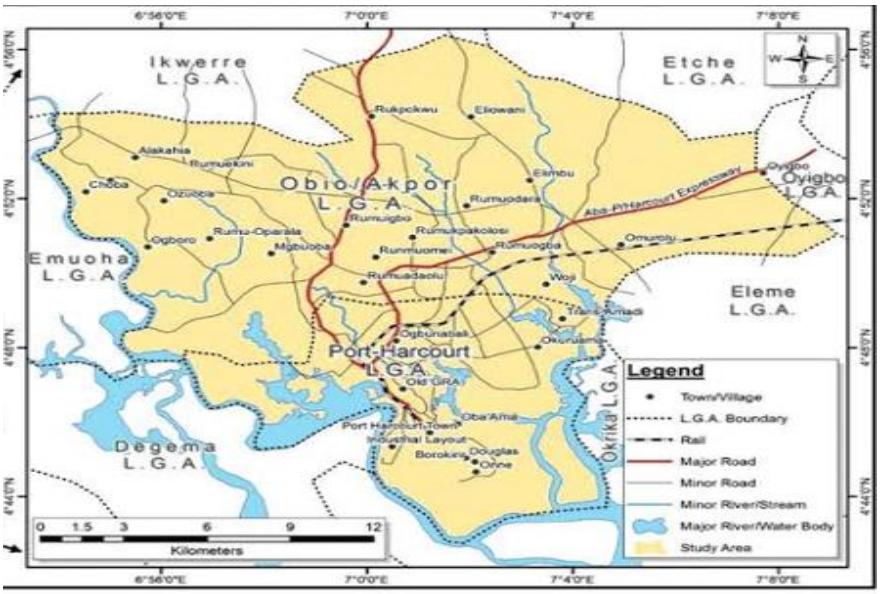


Fig. 1: Typical Map Showing Obio/Akpor in Rivers State of Nigeria (Abah, 2017)

2.0 LITERATURE REVIEW

Sieve analysis is the process of measuring the particle size distribution of unbound sediments (Amakiri *et al*., 2023), it is a technique that has been widely used in the study of porosity and size distribution of sediments. Weber and Daukoru (1975) used granulometric analysis to study the petroleum geology of the Niger Delta by carrying out sieve analysis and visual examination to describe the sedimentology of the Niger Delta and the results showed that granulometric characteristics of the sediments had a significant impact on their hydraulic properties. Bloomfield *et al*. (2001) used dry sieving and sedimentation technique to determine grain size distribution of sediments. Also, Barker (2004) used sieve analysis and pipette analysis to determine grain size distribution of sediments.

Porosity refers to the measure of void spaces or pores within a material, such as soil, rock, or sediment (Fetter, 2001; Freeze & Cherry, 1979), it is defined as the ratio of the volume of voids to the total volume of the material. The factors that affect porosity include; grain size and shape, cementation and compaction, that is, larger grains and irregular shapes can increase porosity (Fetter, 2001) while the presence of cementing agents, such as minerals or inorganic matter and increased pressure can reduce porosity (Tucker, 2001). Porosity values can be estimated from the empirical relation between porosity and coefficient of grain uniformity, where η is the coefficient of grain uniformity given by Urish (1981) and Salem (2001) as in Amakiri *et al*. (2023). Oladunjoye *et al*. (2022) used granulometric analysis to investigate the grain size and porosity in aquifer sediments in the Niger Delta (Bayelsa State to be precise) using machine learning algorithms and the results showed that the porosity of the sediments decreased with increasing grain size.

3.0 METHODOLOGY

3.1 Method of Sample collection and Analysis

The methods used for sample collection and analysis in this research were the manual rotary drilling method and sieve analysis technique respectively. Samples were collected from four borehole locations in parts of Obio/Akpor and subjected to sieve analysis using American Standard for Testing and Materials (ASTM) D6913 set of sieves for the realization of the aim of the research at the Civil Engineering Laboratory, Rivers State University, Port Harcourt. All the experimental procedures were

well observed for the realization of reliable results at the laboratory. A typical table showing the soil classification system for clastic sediments is presented in Table 1, the sample locations and geo-references are presented in Table 2 and the collected aquifer samples are presented in Fig 2.

Table 1: Typical Soil Classification system for Clastic sediments (Schon, 2011)

Basic Soil Type	Sub-type	Grain size range (mm)
Sandy	Fine sand	0.063-0.2
	Medium sand	0.2-0.63
	Coarse sand	0.5-2.0

Table 2: Geo-Reference Coordinates for Sampling Points

S/N	Location	Landmark	Longitude (DMS)	Latitude (DMS)	Aquifer Depth (ft)
1	Rumuesara, Eneka	Queen Esther Hotel	7°1′38.753″ E	4°54′36.487″ N	120
2	Progress Estate, Rumuapu, Rukpokwu	POVMA Hotel	7°0′54.015″ E	4°54′40.382″ N	120
3	Amadi Street, Psychiatric Road, Rumuomoi	St. Philomena Catholic Church	6°59′58.617″ E	4°50′23.911″ N	120
4	Corner Stone Street, Ozuoba, NTA Road	African Independent Television	6°57′9.2245″ E	4°52′26.162″ N	70



Fig. 2: Aquifer Samples from Locations 1-4

3.2 Generation of Cumulative Particle Size Distribution Curve

The samples after being sieved, weighed and recorded, were used as primary inputs for the generation of particle size distribution curve for each sample location using Microsoft excel software. Also, the values of D_{10} and D_{60} for each location were determined from the respective curves.

3.3 Estimation of Coefficient of Grain Uniformity

From the particle size distribution curves, the coefficient of grain uniformity (η) for all the sample locations were estimated following Awad and Al-Bassam (2001).

$$\eta = \frac{D_{60}}{D_{10}}$$

Where η is the coefficient of grain Uniformity, D_{10} is the effective grain size and D_{60} is the grain size at which 60% of the sample is finer.

3.4 Porosity Determination

The porosity (Ø) for all sample locations was estimated from the particle size distribution curves following Vukovic and Soro (1992) as in Amakiri *et al.* (2023),

$$\emptyset = 0.255\,(1 + 0.83^{\eta}) \quad (3.1)$$

Where $\emptyset$ is the porosity, η is the coefficient of grain uniformity and the coefficients are empirical parameters.

According to Fetter (2018), porosity in unconsolidated sediments typically ranges from 25-50%, depending on grain size, sorting and compaction.

A typical table showing the values of porosity given by Fitts (2002) are presented in Table 3.

Table 3: Typical Values of porosity (Fitts, 2002)

Material	n (%)
Narrowly graded silt, sand, gravel	30-50
Widely graded silt, sand, gravel	20-35
Clay-clay-silt	35-60
Sandstone	5-30
Limestone, dolomite	0-40
Shale	0-10
Crystalline rock	0-10

3.5 Comparative Analysis of the Porosity Values of Sample Locations

The aquifer porosity of Locations 1-4 were compared based on the findings made by Fitts (2002) and Fetter (2018). According to Fitts (2002), all narrowly graded sands fall within 30%-50%. According to Fetter (2018), well-sorted, coarse sediments generally exhibit higher porosity than poorly sorted or compacted sediments.

4. RESULTS AND DISCUSSION

4.1 Granulometric Analysis

The sieve analysis result gotten in the cause of this research show no sediment retained in the pan indicating that the aquifers consist mostly of coarse particles and limited fines. Table 4 below shows the sieve analysis result for Locations 1-4.

Table 4: Sieve Analysis for Samples in Locations 1-4

Sieve Size (mm)	% Passing for Location 1	% Passing for Location 2	% Passing for Location 3	% Passing for Location 4
4.75	98.28	98.31	99.17	98.45
2.36	79.03	93.78	91.83	77.47
1.18	31.28	81.05	74.34	28.90
0.6	9.17	65.54	59.33	7.87
0.3	1.33	15.96	19.21	0.31
0.15	0.94	3.03	3.53	0.00
0.075	0.12	0.75	0.94	0.00
Pan	0.00	0.00	0.00	0.00

4.2 Cumulative Particle Size Distribution Curve

The resultant particle size distribution curves for Locations 1-4 lie within medium to coarse sands indicating uniformly graded soils having most particles of the same size.

A cumulative particle size distribution curve for Locations 1-4 is presented in Fig. 3, also, the resultant values of D_{10} and D_{60} for the four locations are presented in Table 5.

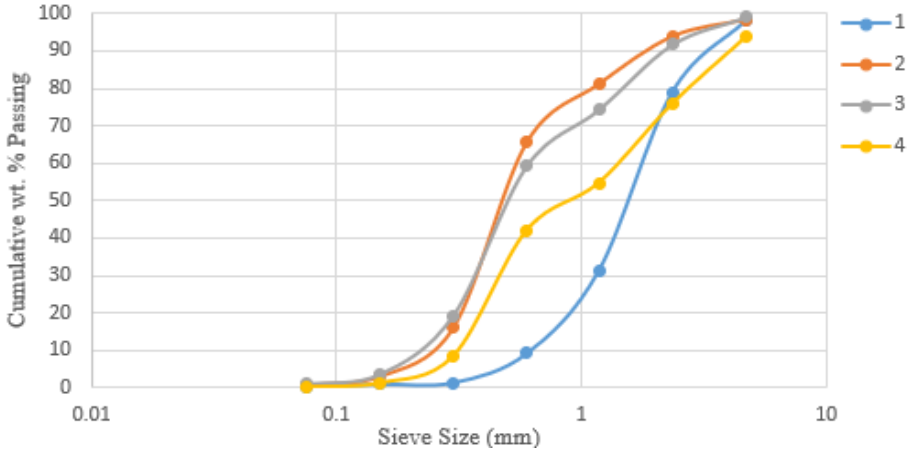


Fig. 3: Cumulative Particle Size Distribution Curve

Table 5: D_{10}, D_{30} and D_{60} Values for Locations 1-4

Location	D_{10}	D_{60}
1	0.60	1.80
2	0.25	0.55
3	0.24	0.60
4	0.30	1.50

4.3 Estimated Coefficient of Grain Uniformity

The coefficient of grain uniformity (η) for the four locations is presented in Table 6.

Table 6: Coefficient of Uniformity Values for Locations 1-4

Location	η
1	3.00
2	2.20
3	2.50
4	5.00

4.4 Aquifer Porosity Values of Locations 1-4

Table 7 and Fig. 4 represent a comparative analysis of aquifer porosity of the four sample locations in Obio/Akpor, Rivers State.

Table 7: Porosity Values for Locations 1-4

Location	Porosity (%)
1	40
2	42
3	42
4	36

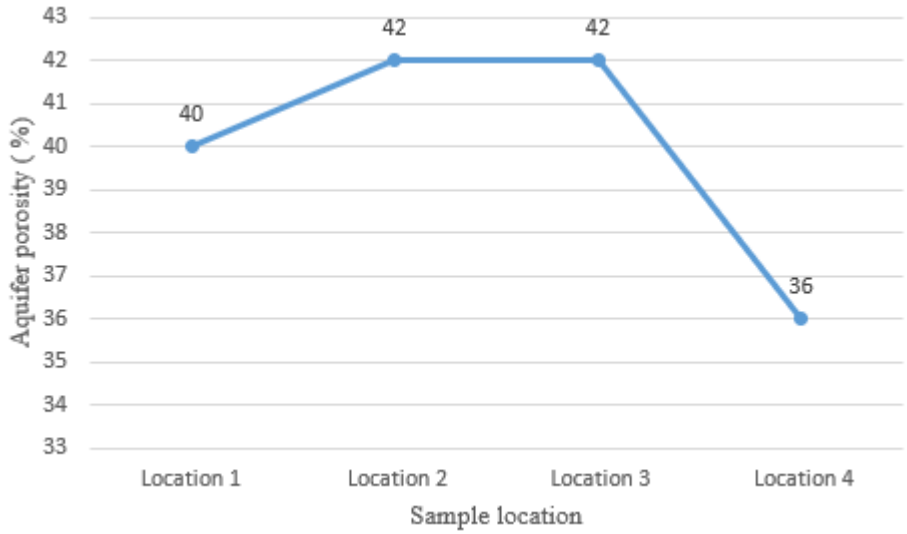


Fig. 4: Graph Comparing Aquifer Porosity of Locations 1-4

The mean porosity = $\frac{40\% + 42\% + 42\% + 36\%}{4}$

The mean porosity = 40%

The porosity values obtained across the four sampled locations in Obio/Akpor LGA reveal notable spatial variations that provide insight into the hydrogeological behavior of the aquifers in the area. Locations 2 and 3 recorded the highest porosity values (42%), followed closely by Location 1 (40%), while Location 4 showed the lowest porosity (36%). These differences can be attributed primarily to variations in grain size distribution and degree of sorting, as reflected in the sieve analysis results and the calculated coefficients of grain uniformity.

Sediments at Locations 2 and 3 exhibited relatively better sorting and lower grain uniformity coefficients (η = 2.20 and 2.50), indicating a narrower particle size range. Well sorted sediments typically have higher porosity because similarly sized grains pack less efficiently, creating larger void spaces. This relationship explains the elevated porosity values observed at these sites and suggests that the aquifers underlying these locations are likely to possess enhanced groundwater storage and potential for rapid recharge.

Location 1, although characterized by moderately well-sorted sediments (η = 3.00), exhibited a slightly lower porosity compared to Locations 2 and 3. This suggests minor variations in grain distribution that affect the packing arrangement of the sediment. Nonetheless, the porosity value of 40% still indicates a highly productive aquifer typical of unconsolidated sand formations.

In contrast, Location 4 exhibited the highest grain uniformity coefficient (η = 5.00), implying poorer sorting with a wider variety of grain sizes. The coexistence of fine and coarse particles allows smaller grains to fill voids between larger grains, reducing overall pore space. This explains the comparatively lower porosity value (36%). Additionally, the shallower sampling depth at this location (70 ft compared to 120 ft for other locations) may mean greater influence of compaction, clay interlayers, or anthropogenic disturbance from surface activities.

Overall, the porosity values across all locations fall within the expected range for aquifers within the Benin Formation, known for its predominantly sandy and highly permeable sediments. This reinforces the area's reputation for reliable groundwater yield. However, the difference among locations demonstrates the importance of site-specific characterization when planning borehole construction, groundwater extraction, or aquifer management practices. The observed variation also highlights the need for continuous hydrogeological assessment, especially in rapidly urbanizing regions like Obio/Akpor where land-use changes can influence recharge conditions, compaction, and sediment structure over time. Understanding

porosity distribution is critical for sustainable groundwater development, contamination risk assessment, and modelling of groundwater flow patterns.

5.0 CONCLUSION

The comparative evaluation of porosity values across the four aquifer locations reveals a generally high porosity level within the studied area. The porosity values for the four locations fall within the upper range for unconsolidated aquifer materials (25-50%), suggesting that the aquifers are of high porosity. Locations 2 and 3 stand out as having similar porosity, followed closely by Location 1. Location 4 has the least porosity amongst them but, it is also within the high-porosity range. The reduced porosity value in Location 4 may have resulted from poorer sorting and greater compaction.The mean porosity of 40% across all locations confirms the general abundance of void spaces within the aquifer materials.

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Conflict of Interest

The authors declare that there are no conflicts of interest in the execution of this study.

Data Availability

Data availability is not applicable.

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