PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (3) 649-658 March 2024

Influence of Selected Soil Properties on Groundwater Flow around Ariaria Dumpsite, Aba, Southeast, Nigeria

***ALADIN, AE; OGUEH, DE**

Department of Geology, University of Benin, Benin City, Edo State, Nigeria

**Corresponding Author Email: anthonyoriginal26@gmail.com*
**Tel: +2348039237031*
Co-Author Email: desireeogueh@gmail.com

ABSTRACT: A study on the analysis of soil and groundwater characteristics due to municipal waste is indispensable to the sustenance of the environment and human health. This study is to evaluate the "Influence of selected Soil properties on groundwater flow around Ariaria dumpsite, Aba Southeast, Nigeria using Particle Size Analysis and Vertical Electrical Sounding (VES) configuration". The sieve analysis shows that the soil samples collected consist of 11.95% of Silt, 83.62% of Sand and 4.42% of little Gravel. The mean permeability of the study area ranges from 0.19 (cm/sec) to 0.49 (cm/sec), the mean infiltration rate ranges from 6840mm/hr to 31320mm/hr. The Longitudinal conductance and Transmissivity values range from 0.0060 to 0.0284Ω^{-1} and 3.8165 to 16.8589^2/day. The values of longitudinal conductance and transmissivity indicates that the aquifer has poor protection capacity rating and its classification of well is from very low potential to low potential. The soil samples of the study area are well sorted and the movement of leachate from the dumpsite into the subsurface is very fast because the Permeability (K) is good, Coefficient of uniformity (Cu) and Coefficient of curvature classified the soil samples collected from the area as well graded soil. From the geophysical survey (VES) results, the groundwater depths (upper and lower aquifers) within the study area ranges from 30m (98ft) to 60m (197ft) at average depth of 45m(147ft). The curve types are AHA, HKA and AKA. The SWL of the study area ranges from 12m to 19m deep. The recommend drill depth to groundwater of is 50m (164) for domestic and consumption purpose.

DOI: https://dx.doi.org/10.4314/jasem.v28i3.4

Cite this Article as: ALADIN, A. E; OGUEH, D. E. (2024). Influence of Selected Soil Properties on Groundwater Flow around Ariaria Dumpsite, Aba, Southeast, Nigeria. *J. Appl. Sci. Environ. Manage.* 28 (3) 649-658

Dates: Received: 18 January 2024; Revised: 24 February 2024; Accepted: 12 March 2024 Published: 29 March 2024

Keywords: Permeability; Soil properties; Aquifer; Infiltration; Transmissivity

According to (Akhionbare *et al.,* 2019) in "Soil and Leachate Quality Aspects of Ariaria Market Dumpsite Aba Southeast Nigeria" the result reveals that the subsoil (16–45cm) recorded the highest geo-accumulation index making it the most affected of the depths investigated; which is attributed to high precipitation in the area causing leaching. The high porous sand compositions, high heavy metal levels and microbial abundance, as well as low clay compositions recorded in the study could make groundwater aquifers of the study area susceptible to pollution from the dumpsite origin. Both Federal and state government should be committed to stipulated environmental standard as enshrined in our laws. According to Bernadette *et al*., (2019), Influence of Soil Particle Size Distribution on Groundwater Quality around Industrial Areas of Oshodi-Lagos Nigeria. The mean concentration of physicochemical parameters and heavy metals such as; total organic carbon, Zn, Cu, Cd, Fe, Pb, Ni and Cr in soil were higher in the control than that in-study samples. But the soil pH had mean value of 5.849 for the study sample and 5.445 for the control. All the physicochemical results from the soil samples meet up

**Corresponding Author Email: anthonyoriginal26@gmail.com*
**Tel: +2348039237031*

the standard set by Department of Petroleum Resources in Nigeria for metal concentration in the soil. The ecological risk of soil was very low. In contrast, the mean concentrations of the physicochemical parameters and heavy metals including; total dissolved solid TDS, biochemical oxygen demand BOD, Zn, Cu, Cd, Pb, Mn, Fe, Cr and Ni were higher in groundwater samples from the study area than in control except for the groundwater pH (5.57) which was lower than in control (5.89). Parameters like salinity, TDS, BOD, Zn and Cu were within the standard limit for drinking water in all the groundwater. The result showed that groundwater from well graded soil is of good quality where as those from poorly graded soil are of poor quality irrespective of the industrial activities. Also, in "Assessment of Heavy Metal Status of Groundwater in Parts of Aba, Southeastern Nigeria. The results showed that the indices which changed the water quality were due to anthropogenic factors from dumpsites and industrial wastes. Hydrogeological investigations showed that aquifer in the area were largely unconfined sands with intercalation of gravels, clay and shale. In order to detect further threat to groundwater quality in the area, routine monitoring of heavy metals and treatment are recommended. (Nwankwoala *et al*., 2016). The uncontrolled dumping and mismanagement of waste in Nigeria have raised significant environmental concerns (Iwuoha *et al.*, 2013). To address this issue, the current research aims to investigate the influence of certain soil properties on groundwater flow by employing Particle Size Analysis and Vertical Electrical Sounding (VES) configuration around the Ariaria dumpsite. The goal is to propose methods to mitigate the impact of leachate, generated from the waste, on subsurface soil, which may infiltrate deep into the ground, ultimately contaminating the groundwater. Groundwater flow and infiltration from precipitation typically occur in landfills or open dumpsites. Two key physical properties of soil that govern permeability are particle size and interconnectivity between soil particles. These properties are influenced by factors such as particle shape, density (degree of compaction), and particle size distribution (Bernadette *et al*., 2019). As the dumped waste releases interstitial water (leachate) and by-products that seep through the waste deposit, understanding the protective capacity of the aquifer and the soil particle size becomes crucial, especially as these dumpsites are transforming into residential areas. Hence, the objective of this work is to evaluate influence of selected soil properties on groundwater flow around Ariaria Dumpsite, Aba, Southeast, Nigeria.

MATERIALS AND METHODS

Description of the Study Area: This study was conducted at Ariaria waste dumpsite in Ariaria and environs, Aba South Local Government Area, Abia State, South-East Nigeria. It is situated between latitude 005°06'51" N to 005° 7′0″N and longitude 007°19'45" E to 007°20′0″E. It is accessible by the Port-Harcourt – Enugu Road, Aba-Owerri Road, Umuahia, Ikot Ekpene road.

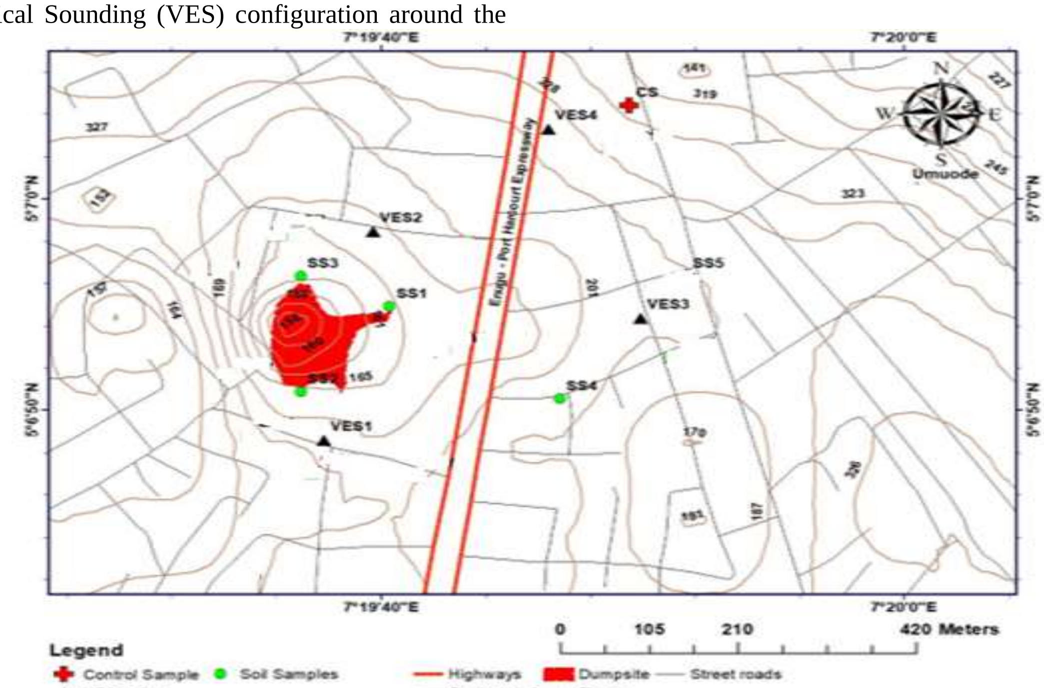

Fig 1: Base Map of the Study Area showing the Sampled Location

The area has two distinctive climatic conditions in a year - the dry season and rainy season. The dry season starts from November to March while the rainy season is from March to September annually although it varies due to seasonal changes and September is the month with abundant rainfall in Aba. Aba has a period of dusty winds cold and dry conditions known as Harmattan which starts from December to the month of February, thought it changes depending on the season. The average mean temperature of the city is between 24 to 34 with relative humidity of 70% in dry periods and 90% in rainy periods. Ariaria waste dumpsite is the major dumpsite used in Aba town. Aba town is a commercial center that has textiles, pharmaceuticals, plastics, timbers, cosmetics, shoe manufacturing industries and the Ariaria International market (Ukpong *et al.,* 2015). The projected population is about Two million, five hundred and thirty-four thousand, two hundred and sixty-five (2,534,265) (Nigeria Population Census 2016). According to Abia State Environmental Protection Agency (ASEPA), these activities generate much waste which makes it difficult for the agency to manage, coupled with the poor funding by the state government.

Geology Setting of the Study Area: Aba, geologically, is situated above the Benin Formation, which spans from the Miocene to the Recent period, as depicted in Figure 2. This formation primarily consists of friable fine to coarse-grained sand, occasionally interspersed with clay layers. The Benin Formation is mainly composed of highly resistant freshwater-bearing continental sand and gravel, with minor occurrences of clay and shale. Abia state has two principal geological formations: the Bende-Ameki Formation, dating from the Eocene to Oligocene era, comprises medium to coarse-grained white sandstones. The Benin Formation, which dates from the late Tertiary to Early Quaternary, is the dominant formation and entirely overlies the Bende-Ameki Formation, dipping southwestward. This Formation is approximately 200 meters thick (Ebilah-Salmon and Partners, 1993). The lithology of the Benin Formation consists of unconsolidated fine to medium to coarse-grained cross-bedded sands, with occasional pebbly sections and localized clay and shale (Igboekwe *et al*., 2006). Both of the principal geological formations exhibit comparable groundwater characteristics. They possess reliable groundwater sources that can sustain regional borehole production. However, the Bende-Ameki Formation contains less groundwater compared to the Benin Formation. The Bende-Ameki Formation comprises several discontinuous sand bodies with limited extent, forming minor aquifers with narrow zones of sub-artesian conditions. Their specific capacities typically range from 3 to 6 m3/hr. In contrast, the Benin Formation benefits from its high permeability, aided by the overlying lateritic earth and the weathered top of the Formation, as well as the underlying clay shale member of the Bende-Ameki series. These hydrogeological conditions are favorable for the development of aquifers in the area.

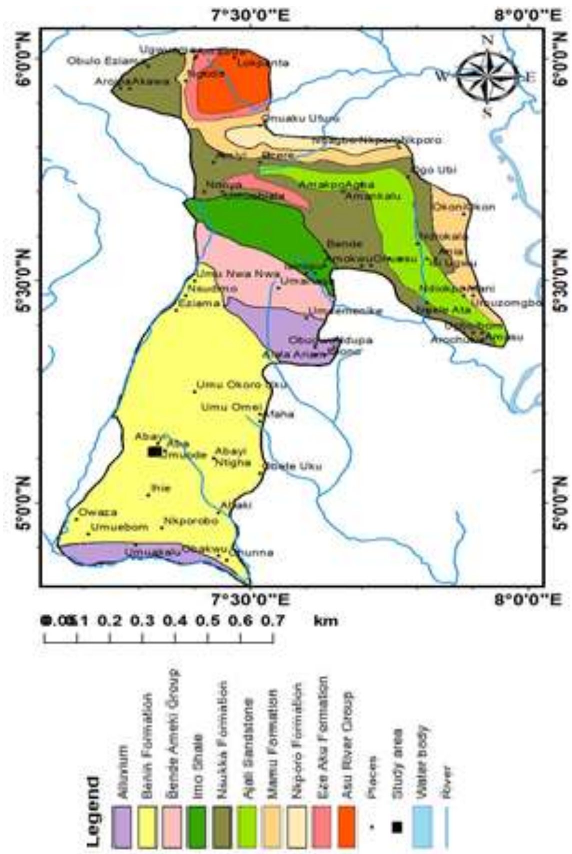

Fig 2: Remodify Geological Map of Abia State showing the Study Area (Source: Geological Survey Agents 2006).

Sample Collection: Eighteen (18) soil samples were collected by method of random sampling. Each of the sampling point had three (3) soil samples collected at the depth of 0 – 10cm, 10 – 20cm and 20 – 30cm. Soil samples of sampling points 1, 2 and 3 were collected around the Ariaria dumpsite area while soil samples of sampling points 4 ,5 and control sample were collected opposite the dumpsite area as shown in Figure 1. PETROZENITH Terrameter was used for the acquisition of data. According to (Olawuyi and Abolarin, 2013), in the Schlumberger array, the spacing between the potential electrode (MN) was recommended for reliable readings, not to exceed 40% of half the distance of the spacing (AB) of the current electrodes. The Schlumberger array was deployed with a maximum current electrode separation (AB/2) of 200m. The current survey comprises of four (4) VES stations (Figure 2).

Schlumberger array: The Schlumberger array is more complex when spacing between the current electrodes is not equal to the spacing between the potential electrodes. The vertical electrical sounding with Schlumberger array as a low-cost technique and veritable tool in groundwater exploration is more suitable for hydrological survey of sedimentary basin. The method is regularly used to solve a wide variety of groundwater problems. Resistivity influenced by temperature. DC Resistivity Survey (Schlumberger Array). The Schlumberger array is a type of electrode configuration for a DC resistivity survey and is defined by its electrode array geometry. The distance between the current electrodes was represented by AB and each current electrode is placed at AB/2 from the center point and MN/2 from the point for the potential electrode. For the first reading, the potential electrodes were at 0.2m from the center point while the current electrodes were at 1.5m. The maximum electrode spread was AB/2 = 200m. The data was acquired under favourable weather conditions. The electrode movement on the current electrode C1-C2 are moved outward symmetrically, keeping P1-P2 fixed at the Centre. For VES data obtained from the field was plotted on a graph manually, a graph of apparent resistivity against half electrode spacing. Parameters such as apparent resistivity and thickness obtained from the curve matching were used as input data for computer iterative modeling. The data of VES were analyzed using the geophysical software IX1Dv3 and the geoelectric layers, depth was generated, as well as the resistivity spread. The analyzed data was interpreted to reflect the geology of the investigated area. Formula for Geometric factor (*G*) and Apparent Resistivity (ρ_a) for Schlumberger array is given as:

$$G = \pi \frac{b(b+a)}{a}, \qquad \rho a = \frac{V}{I} \pi \frac{b(b+a)}{a} \qquad (1)$$

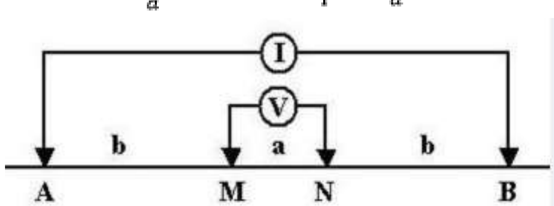

Fig 3: Schlumberger array

RESULTS AND DISCUSSIONS

From the summary of grain size distribution (Table 1) it reveals that the soil is made of three type of soil particle which are: sand, silt and little of gravel. The coefficient of uniformity (Cu) and coefficient of curvature ranges from 4.00 to 10.25 and 1 to 1.8 respectively, which classified the soil to be well graded soil. This indicates that the soil particles are well sorted and the movement of soil water, soil solute and the infiltration of leachate from the dumpsite into the soil might be very fast and easy around the dumpsite area and it might be slow at the area far off the dumpsite. It is observed that the soil samples collected from study area from a depth of 0cm to 30cm is pre-dominantly Sand and Silt with little of Gravel particle in percentage.

From (Table 1), the average standard deviation of the soil samples collected from the various sampling points varies from very well sorted to poorly sorted grain size. The soil samples collected around the dumpsite vary from very well sorted to moderately sorted grain size, which indicated that the passage for heavy metals contaminant will be easy and fast because the permeability of the grains is very good. While soil samples collected far away from the dumpsite varies from moderately sorted to poorly sorted grain size. Permeability of the area was calculated based on the data (D_{10}) obtained from the grain size distribution curve. Allen Hazen's method (1892). The permeability of the area is classified as medium or good. This suggests that the movement of soil water and solutes will be fast.

$$K=100^{\times}(D_{10})^2 \qquad (2)$$

From (Table 3), the mean permeability of the study area ranges from 0.19 (cm/sec) to 0.49 (cm/sec), the mean rate of infiltration ranges from 6840mm/hr to 31320mm/hr. This indicates that inflow of leachate into the soil and groundwater will be fast and timely. The depth to groundwater data was obtained from VES 1-4 resistivity model that was carried out around the Ariaria dumpsite area.

According to Unified Soil Classification System (USCS), adopted by Casagrande (1948), when Coefficient of Uniformity (Cu), Cu > 4 indicates a well-graded soil, Cu < 2 indicates a uniform soil and Cu < 4 indicates poorly graded soil. The formula is given by:

$$Cu = \frac{D_{60}}{D_{10}} \qquad (3)$$

And Coefficient of Curvature (Cc), when Cc is between 1 and 3 indicates a well-graded soil Cc < 0.1 indicates a possible gap-graded soil.

$$Cc = \frac{(D_{30})^2}{D_{60} * D_{10}} \qquad (4)$$

VES 1-4 Data Interpretation: From (Table 4), the Modelling of VES 1 reveals seven (7) Geoelectric layers. The Resistivity ranges from 110.67Ωm to 12401Ωm, overburden has a thickness range from

0.8994m to 0.5219m and depth ranges from 0.8994m to 1.4214m. VES 1 reveal that the third and fourth geoelectric layer are medium Sand with thickness ranges from 6.4783m to 11.042m and the depth ranges from 7.8996m to 18.941m with apparent resistivity ranges from 842.73Ωm to 1392.8Ωm.

The fifth and sixth geoelectric layer are fine-medium Sand and medium to coarse Sand with thickness ranges from 28.639m to 24.768m at a depth range of 47.580m to 72.348m with apparent resistivity ranges from 783.56Ωm to 2228.5Ωm. The seventh geoelectric layer has apparent resistivity of 12401Ωm with undetermined thickness and depth. The recommended drill depth for VES 1 ranges from 47m (154ft) to 57m (187ft) and average depth of 52m (171ft). The VES 1 curve type is AHA curve. The depth of the boreholes drilled varies from 21.02m - 250m, around Aba South (Abija *et al.*, 2018). The Modelling of VES 2 reveals six (6) Geoelectric layers. The Resistivity ranges from 85.905Ωm to 10433Ωm, overburden has a thickness range from 1.0978m to 3.8162m and depth ranges from 1.09786m to 4.9140m. VES 2 reveal that the third geoelectric layer is Clay with thickness of 6.9966m at a depth of 11.911m with apparent resistivity of 319.15Ωm.

The fourth and fifth is medium Sand and very coarse Sand + little gravel with thickness ranges from 7.7935m to 27.262m at a depth range of 19.704m to 46.966m with apparent resistivity range of 1136.7Ωm to 5604.4Ωm. The sixth geoelectric layer has apparent resistivity of 1043Ωm with undetermined thickness and depth. The recommended drill depth for VES 2 ranges from 47m (154ft) to 55m (180ft) at average depth of 51m (167ft).

Table 1: Grain Particle Distribution of Soil samples collected from the study area

Sample Name	Profile layers	Silt *(%)*	Sand *(%)*	Gravel *(%)*	D10	D30	D60
Sample 1	10cm	2	88	10	0.18	0.4	0.75
	20cm	17	76	7	0.02	0.15	0.40
	30cm	28	67	5	0.01	0.08	0.35
Sample 2	10cm	7	86	7	0.1	0.2	0.40
	20cm	3	93	4	0.17	0.28	0.50
	30cm	3	92	5	0.01	0.3	0.50
Sample 3	10cm	13	87	0	0.04	0.16	0.35
	20cm	16	84	0	0.03	0.17	0.30
	30cm	18	82	0	0.18	0.15	0.30
Sample 4	10cm	15	81	4	0.04	0.18	0.38
	20cm	11	84	5	0.06	0.2	0.42
	30cm	17	75	8	0.03	0.13	0.40
Sample 5	10cm	17	82	1	0.045	0.1	0.30
	20cm	9	87	4	0.06	0.13	0.35
	30cm	16	78	6	0.04	0.2	0.40
Sample 6	10cm	10	90	0	0.06	0.19	0.36
	20cm	9	91	0	0.06	0.18	0.36
	30cm	13	87	0	0.04	0.18	0.36

Table 2: Showing the relationship between Standard deviation and Sorting of Soil samples grain size.

Soil profile		ϕ_5	ϕ_{16}	ϕ_{25}	ϕ_{50}	ϕ_{84}	ϕ_{95}	Mean	Std. Dev.	SD range values	Connotation
SS1	10cm	-2.5	-0.5	-0.1	0.75	2.15	3.2	0.8	1.44	<0.50	Well Sorted
	20cm	0	0.2	0.75	1.8	0	0	0.67	-0.05	<0.35	Very Well Sorted
	30cm	-1.25	0.5	1.05	2.1	0	0	0.87	0.064	<0.35	Very Well Sorted
SS2	10cm	-1.25	0.2	0.7	1.55	2.9	4.3	1.55	1.51	<2.00	Poorly Sorted
	20cm	-0.65	0.35	0.65	1.35	2.5	3.7	1.4	1	≤1.00	Moderated Sorted
	30cm	-0.85	0.4	0.7	1.3	2.4	3.6	1.37	1.17	<2.00	Poorly Sorted
SS3	10cm	0.15	0.85	1.15	1.95	3.85	0	2.22	0.77	<1.00	Moderated Sorted
	20cm	0.35	0.95	1.25	1.95	4	0	2.3	0.81	<1.00	Moderated Sorted
	30cm	0.4	0.95	1.15	2	4.35	0	2.43	0.91	<1.00	Moderated Sorted
SS4	10cm	-0.75	0.5	1	-1.75	4.2	5.7	2.15	1.9	<2.00	Poorly Sorted
	20cm	-0.75	0.2	0.75	1.5	3.5	5.6	1.73	1.79	<2.00	Poorly Sorted
	30cm	-1.5	0.05	0.75	1.75	4.3	0	2.03	1.29	<2.00	Poorly Sorted
SS5	10cm	-0.25	0.7	1.2	2.4	4.1	4.9	2.4	1.63	<2.00	Poorly Sorted
	20cm	-0.9	0.2	0.75	2.3	3.75	4.45	2.08	1.7	<2.00	Poorly Sorted
	30cm	-1.1	0.1	0.65	1.8	3.95	4.45	1.95	1.8	<2.00	Poorly Sorted
CS	10cm	0.35	0.85	1.2	1.8	3.4	4.25	2.02	1.23	<2.00	Poorly Sorted
	20cm	0.3	0.9	1.2	1.9	3.4	4.35	2.07	1.23	<2.00	Poorly Sorted
	30cm	0.25	0.8	1.15	1.95	3.75	0	2.17	0.7	<1.00	Moderated Sorted

Table 3: Showing the relationship between Permeability, Rate of Infiltration, Grading and Sorting.

Soil Sampling points	Mean D10 (mm)	Mean D30 (mm)	Mean D60 (mm)	K (cm/sec)	Av. Depth to GW (m)	Velocity (m/sec)	Times (sec)	Infiltration rate	Cu	Cc
S1	0.07	0.21	0.52	0.49	40	0.0049	8163.3	17640mm/hr	7.43 >5	1.21
S2	0.093	0.26	0.48	0.87	40	0.0087	4597.7	31320mm/hr	5.16>5	1.51
S3	0.08	0.16	0.32	0.69	40	0.0069	5797.1	24840mm/hr	4<5	1
S4	0.04	0.13	0.41	0.19	40	0.0019	21052.6	6840mm/hr	10.25>5	1.76
S5	0.048	0.14	0.32	0.23	40	0.0023	17391.3	8280mm/hr	6.67>5	1.28
CS	0.05	0.18	0.36	0.28	40	0.0028	14285.7	10080mm/hr	7.2>5	1.8

K means permeability, Cu means Coefficient of Uniformity and Cc means Coefficient of Curvature

Table 4: Summary of Geo-Electric Section Resistivity Model

VES 1				
S/NO	Specific Layer Resistivity(Ωm)	Thickness(m)	Depth(m)	Inferred Lithology
1	110.67	0.89943	0.89943	Topsoil
2	289.46	0.52192	1.4214	Lateritic Clay
3	842.73	6.4783	7.8996	Medium Sand
4	1392.8	11.042	18.941	Medium Sand
5	783.56	28.639	47.580	Fine-Medium Sand
6	2228.5	24.768	72.348	Medium-Coarse Sand
7	12401	Undetermined	Undetermined	Compacted Sandstone
VES 2				
S/NO	Specific Layer Resistivity(Ωm)	Thickness(m)	Depth(m)	Inferred Lithology
1	85.905	1.0978	1.0978	Topsoil
2	645.20	3.8162	4.9140	Lateritic Sand
3	319.15	6.9966	11.911	Clay
4	1136.7	7.7935	19.704	Medium Sand
5	5604.4	27.262	46.966	Very Coarse Sand + little Gravel
6	10433	Undetermined	Undetermined	Compacted Sandstone
VES 3				
S/NO	Specific Layer Resistivity(Ωm)	Thickness(m)	Depth(m)	Inferred Lithology
1	264.77	1.3182	1.3182	Topsoil
2	156.54	0.97515	2.2934	Lateritic Silt
3	605.68	2.6561	4.9494	Fine Sand
4	850.86	7.5650	12.514	Medium Sand
5	758.21	18.471	30.986	Fine - Medium Sand
6	910.85	69.825	100.81	Medium Sand
7	3348.4	Undetermined	Undetermined	Medium-Coarse Sand + little Gravel
VES 4				
S/NO	Specific Layer Resistivity(Ωm)	Thickness(m)	Depth(m)	Inferred Lithology
1	185.90	0.93228	0.93228	Topsoil
2	409.58	4.2620	5.1943	Lateritic Clay
3	1407.7	11.245	16.439	Medium Sand
4	979.40	23.703	40.142	Medium Sand
5	3594.8	30.294	70.436	Medium-Coarse Sand + little Gravel
6	7404.2	Undetermined	Undetermined	Compacted Sandstone

The VES 2 curve type is AHA curve. The Modelling of VES 3 reveals seven (7) Geoelectric layers. The Resistivity ranges from 264.77Ωm to 3348.4Ωm, overburden has a thickness range from 1.3182m to 0.9751m and depth ranges from 1.3182m to 2.2934m. VES 3 reveal that the third and fourth geoelectric layer is fine Sand with thickness ranges from 2.6561m to 7.5650m and the depth ranges from 4.9494m to 12.514m with apparent resistivity range of 605.68Ωm to 850.80Ωm. The fifth and sixth geoelectric layer is fine-medium Sand and medium Sand with thickness ranges from 18.471m to 69.825m at a depth range of 30.986m to 100.81m with apparent resistivity range of 758.21Ωm to 910.85Ωm. The seventh geoelectric layer has apparent resistivity of 3348.4Ωm with undetermined thickness and depth. The recommended drill depth for VES 3 ranges from 30m (98ft) to 60m (197ft) and average depth of 45m (148ft). The VES 3 curve type is HKA curve. The aquifer in Abia State is the prolific Coastal Plain Sands and depth to boreholes range from 40 m to 100 m in Aba (Magnus *et al*., 2011). The Modelling of VES 4 reveals six (6) Geoelectric layers. The Resistivity ranges from 185.90Ωm to 7404.2Ωm, overburden has a thickness range from 0.93228m to 4.2620m and depth ranges from 0.93228m to 5.1943m. The VES 4 reveal that the third and fourth geoelectric layer is medium Sand with thickness ranges from 4.2620m to 23.703m at a depth range of 16.439m to 40.142m with apparent resistivity ranges from 1407.7Ωm to 979.40Ωm. The sixth geoelectric layer has apparent resistivity of 7404.2Ωm with undetermined thickness and depth as shown in Figure 1-4. The recommended drill depth for VES 4 ranges from 40m (131ft) to 60m (197ft) at average depth of 50m (164ft). The VES 4 curve type is AKA curve. The SWL of the study area ranges from 12m to 19m deep as shown in Figure 1-4. The recommended drill depth of groundwater is 50m (164) for domestic and consumption purpose. Figure 7 shows the contour map of the apparent resistivity of the study area.

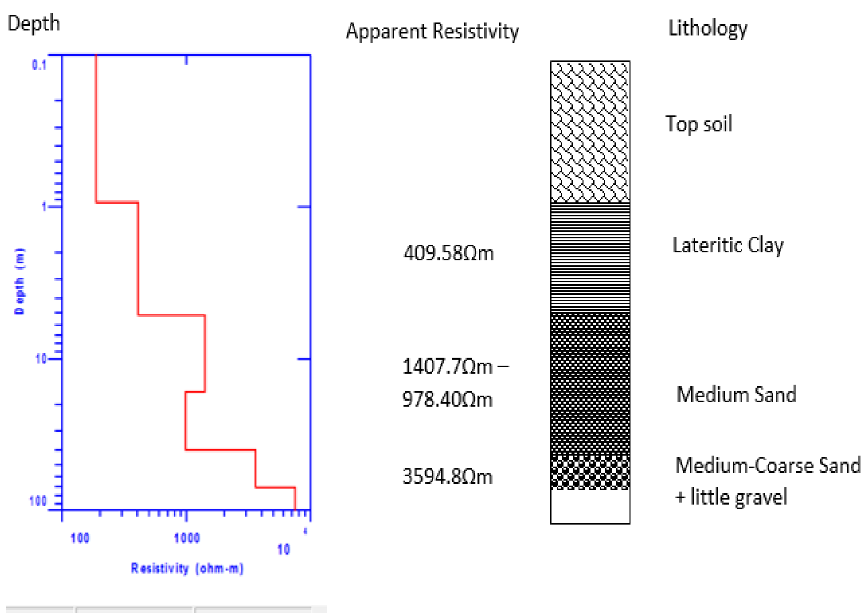

Fig 3: Layered Inversion Model and Geoelectric column of VES 1

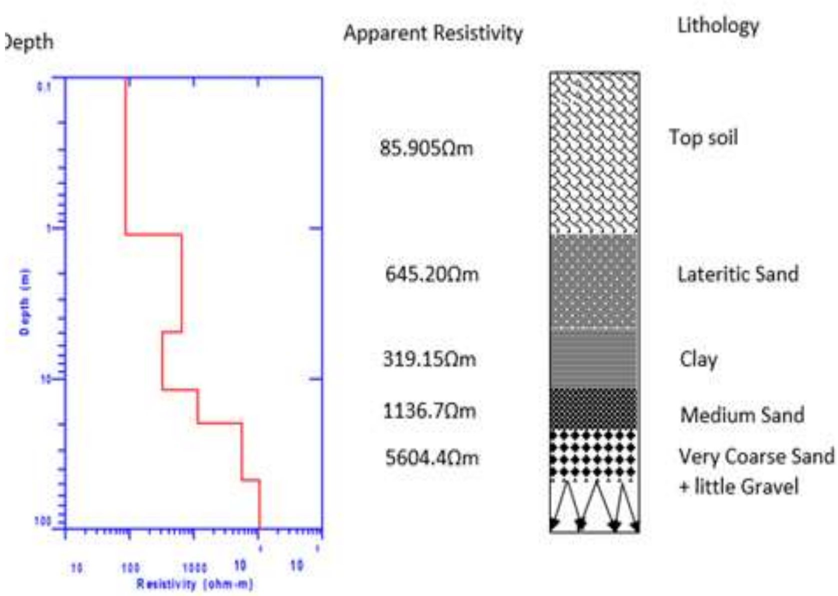

Fig 4: Layered Inversion Model and Geoelectric column of VES 2

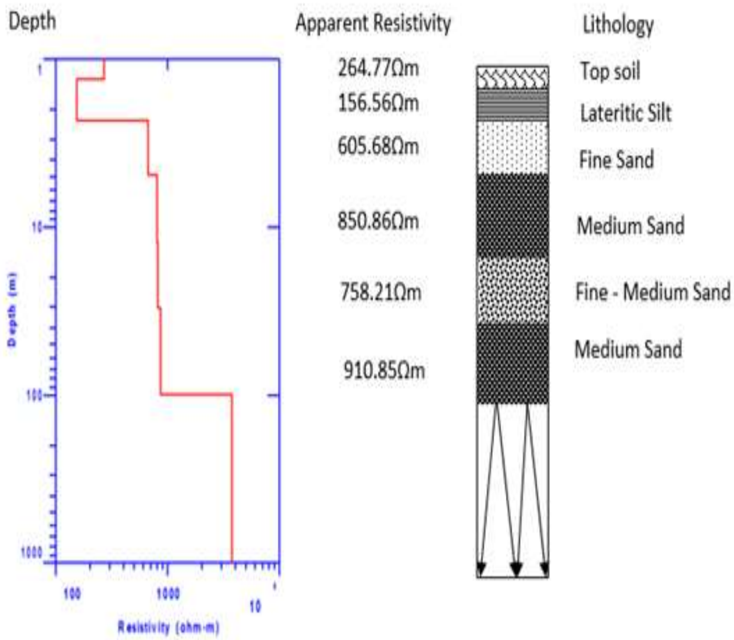

Fig 5: Layered Inversion Model and Geoelectric column of VES 3

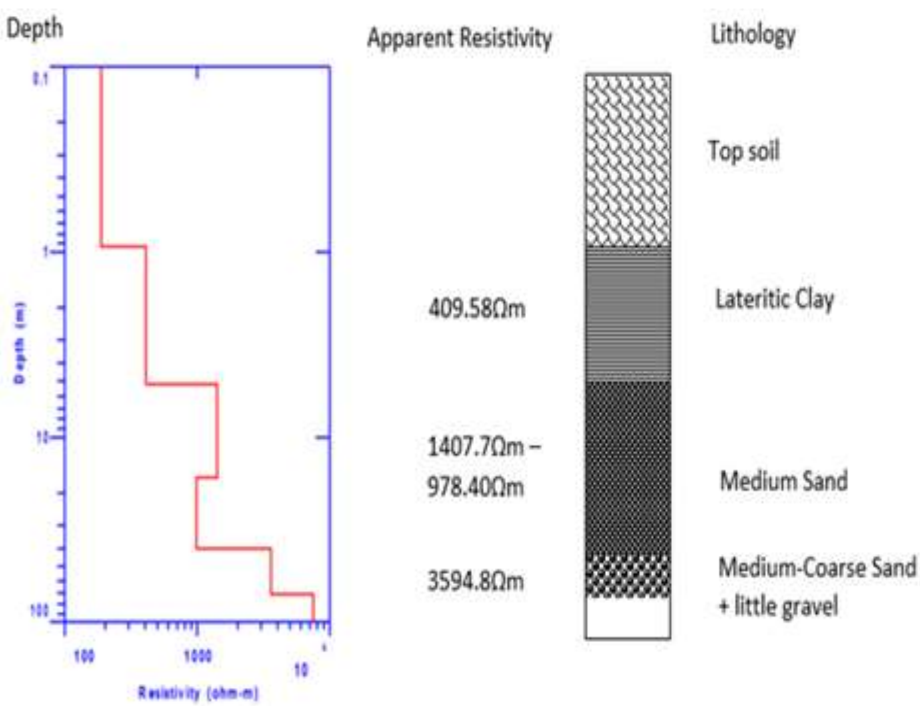

Fig 6: Layered Inversion Model and Geoelectric column of VES 4

Table 5: Hydraulic parameters

Points	Resistivity (**ρ**, Ωm)	Thickness (m)	Conductivity (**δ**, Ωm^{-1})	Longitudinal Conductance (**S**, Ω^{-1})	Transverse Resistance (**TR**, Ωm^2)	Hydraulic Conductivity (**K**)	Transmissivity (Tr, m^2/day)	Curve type
VES 1	941.2867	12.05811	0.001062	0.01281	11350.14	0.6502	7.840182	AHA
VES 2	1558.271	9.39322	0.000642	0.006028	14637.18	0.4063	3.816465	AHA
VES 3	591.1517	16.80174	0.001692	0.028422	9932.378	1.0034	16.85887	HKA
VES 4	1315.476	14.08726	0.00076	0.010709	18531.45	0.4758	6.70328	AKA

*Hydraulic Parameters***:** Longitudinal conductance (S) is a measure of the impermeability of a rock layer (Billing, 1972) and Transverse Resistance is shows the relationship between aquifer transmissivity, and longitudinal conductance as proposed by Todd (1980).

The formular for longitudinal conductance and Transverse Resistance is given as

$$Si = \frac{h1}{\rho 1} \qquad (5)$$

$$Ti = \rho 1 \times h1 \qquad (6)$$

For a sequence of horizontal, homogeneous and isotropic layers of resistivity $\rho 1$ and thickness h1. Eqn. (5) and (6) defined the Dar Zarrouk parameters (Maillet, 1947), (Longitudinal conductance S and Transverse resistance TR) as follows:

$$S = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} + \frac{h3}{\rho 3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \sum_{i=o}^{n} \left(\frac{hi}{\rho i}\right)$$

$$R = h1\rho 1 + h2\rho 2 + h3\rho 3 \ldots\ldots\ldots \sum_{i=o}^{n} (\mathrm{hi}\rho\mathrm{i})$$

For Transverse Resistance (TR)

$$Tr = K\delta TR = Kh \qquad (7)$$

Where Tr: Aquifer Transmissivity, K: Hydraulic Conductivity, σ: Electrical Conductivity (reciprocal of resistivity), TR: Traverse Resistance, S: Longitudinal Conductance and h: Aquifer Thickness.

The Hydraulic conductivity K was determined using the equation given by Heigold *et al*., (1979).

$$K = 386.40Rrw^{-0.93283} \qquad (8)$$

Where, K is the hydraulic conductivity and R_{rw} is the aquifer resistivity (Resistivity of the inferred aquiferous layer from the interpreted curves).

From Table 4 and 5, the longitudinal conductance and Transmissivity values ranges from 0.006028 to $0.028422\Omega^{-1}$ and 3.81646 to $16.85887 m^2/day$.

The longitudinal conductance (mhos) ratings were modified by (Oladapo *et al.*, 2004) as follows :> 10, excellent; 5 to 10, very good; 0.7 to 4.9, good; 0.2–0.69, moderate; 0.1 to 0.19, weak ;< 0.1, poor and were used for the interpretation of the protective capacity of the layers.

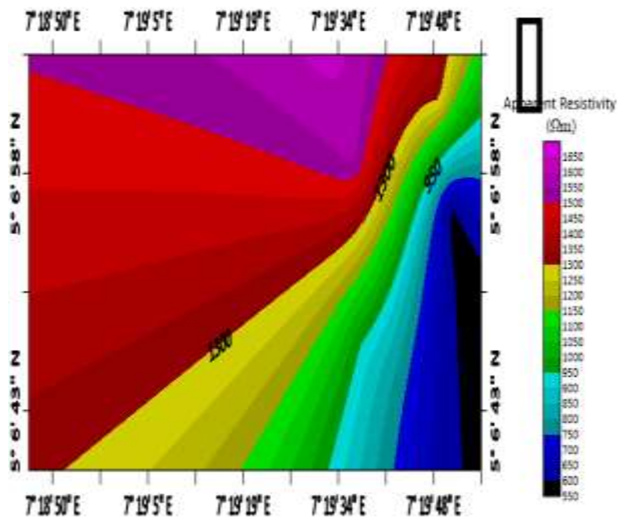

Fig 7: Contour map of Apparent Resistivity (Ωm) of the study area.

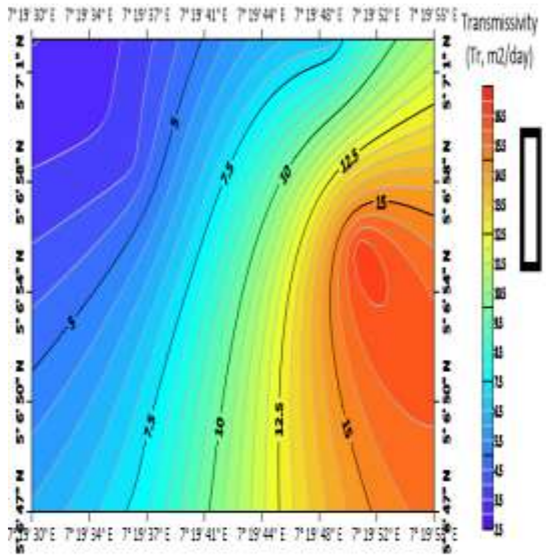

Fig 8: Contour map of Transmissivity of the study area.

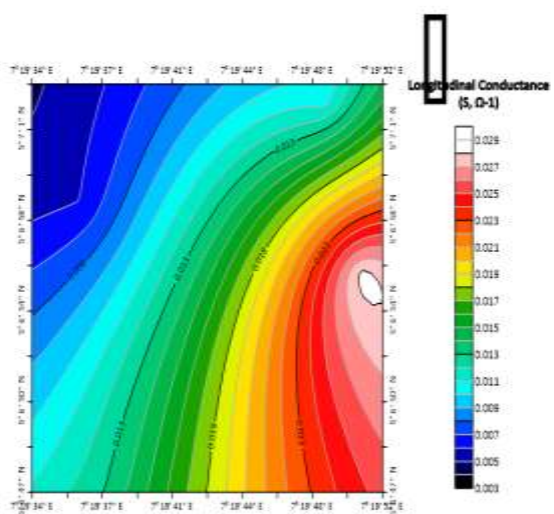

Fig 9: Contour map of longitudinal conductance of the study.

The values of longitudinal conductance and transmissivity indicates that the aquifer has poor protection capacity rating and its classification of well is from very low potential to low potential, which indicates that the soil and groundwater can be easily be contaminated in the study area because of the porous nature of the soil as shown in Figure 8 and 9. According to Aladin *et al*., 2022; from the physiochemical analysis of the heavy metals from groundwater samples collected from the study area reveals that the direction movement of the heavy metal from the dumpsite is from Southwest direction to Northeast direction.

Conclusion: The research reveals that the soil in the study area has variable soil properties, with well-graded soil, high permeability, high infiltration rate and varying groundwater quality. Proper consideration of drilling depths is crucial to avoid groundwater contamination, and in some areas, additional water treatment may be necessary to ensure safe drinking water.

REFERENCES

Abija, FA; Nwankwoala, HO (2018). Characterization of Aquifers Using Geo-electrical Methods in parts of Abia State, Southeastern Nigeria. *Sumerianz J. Sci. Res. Website: https://www.sumerianz.com*. 1(1): 1-7.

Akhionbare, SM; Okoro, II (2019). Soil and Leachate Quality Aspects of Ariaria Market Dumpsite Aba Southeast Nigeria. *World J. Inn. Res*. 7(5): 11-18.

Aladin, AE; Imariabe, DO; Odia-Oseghale, JO (2022). Impact of Heavy Metals on the Soil and Groundwater of Ariaria Waste Dumpsite, Aba, South-Eastern Nigeria. *Int. J. E. Sci. K. Appl.* 4(3): 365-374.

Bernadette, UU; Ogbonnaya, I; Oyem, EU (2019). Influence of Soil Particle Size Distribution on Groundwater Quality around Industrial Areas of Oshodi-Lagos Nigeria. *J. Soil. Water. Sci.* 3(1): 102-111.

Billing, MP; Eaglewood, CN. (1972). Structural Geology. Third ed. Prentice-Hall.

Casagrande, A (1948). Classification and identification of soils. *Trans Am. Soc. Civil. Eng.* 113: 901-930.

Ebilah-Salmon and Partners (1993). Abia State Rural Water Supply Project: Feasibility report and preliminary engineering design report.

Heigold, CP; Robert, HG; Kreos, C; Philip, CR (1979). Aquifer Transmissivity from Surficial Electrical Methods. *Groundwater*. 17: 330-345.

Igboekwe, MU; Okwueze, EE; Okereke, CS (2006). Delineation of Potential Aquifer Zones from geoelectric sounding in Kwa-Ibo River watershed, Southeastern Nigeria. *J. Eng. Appl. Sci*. 1: 410-421.

Iwuoha, GN; Osuji, LC; Onwuachu, UI (2013). Impact of waste dump on the sediment and surface water quality of otamiri river, Nigeria. *J. Appl. Sci. Environ Manage.* 17(4): 573-575.

Geological Survey Agency of Nigeria (2016). Republic of Nigeria

Magnus, UI; Cyril, NN (2011). Geostatistical Correlation of Aquifer Potentials in Abia State, South-Eastern Nigeria. *Int. J. Geosci.* 2: 541-54.

Maillet, R. (1947). The Fundamental Equations of Electrical Prospecting, *Geophysics.* 12: 529-556.

National Population Commission [*Internet*] (2016). PHC priority Table. c2016. Available from: *http://population.gov.ng/core-activities/surveys/dataset/2016-phc-priority-tables*.

Nwankwoala, HO; Nwowo, KN; Udom, GJ (2016). Assessment of Heavy Metal Status of Groundwater in Parts of Aba, Southeastern Nigeria. *Int. J Emerg. Eng. Res Tech.* 4(11): 27-36.

Olawuyi, KA; Abolarin, S (2013). Evaluation of Vertical Electrical Sounding Method for Groundwater Development in Basement Complex Terrain of West-Central Nigeria. *Nig. J. Tech. Develop.* 10(2): 22-28.

Oladapo, ML; Mohammed, MZ; Adeoye, OO; Adetola, BA (2004). Geo-electrical investigation at Ondo State housing corporation estate, Ijapo, Akure, southwestern Nigeria. *J. Min. Geo.* 40(1): 41–48.

Todd, DK. (2004). Groundwater Hydrology, 2nd Edition, John Wiley & Sons, New York.

Ukpong, EC; Udo, EA; Umoh, IC (2015). Characterization of materials from Aba waste dumpsites. *Int. J. of Eng. and Appl. Sci.* 6(3): 1-4