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Hydro-geological surveys and evaluation in parts of Anambra state, Nigeria

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Abstract
Hydro geological surveys and evaluation were carried out in parts of Anambra State, Nigeria, A multi-objective, multi-technique; multidisciplinary and integrated approach was adopted in the area. The hydro-geological parameters (Water quality parameters tested fall within the WHO standard, desirable, permissible and acceptable limits, except for the high iron, nitrate contents of most surface waters and Nnewi ground-water for which appropriate treatments have been advised under discussion. The ground water, resources potentials are quite promising with high yield, high transmissivity, good specific capacity and minimal drawdown. Hydro geological environment depends on the aquifer of interest, and varies from formation to formation. The empirical hydro geological model shows that when the apparent resistivity for a 150m current electrode spread and below, comes to the average of 175, the ground water resources potential is promising. Imo shale formation, Nanka Sands formation, and Ogwashi-Asaba formation reveal the total depth of boreholes are at average of 62m to 550m, 150m and 550m, and 120.5m to 178.0m respectively. The Imo Formation has poor permeability but good storage. The Nanka Sands formation shows that the study area with a thickness of 120m to 440m in several places used for the study. The hydro geochemical study in Imo shale shows the average ph of the aquifier ground water is between 4.8 to 6.5 pH scales, with maximum permissible pH scale of 8.5, Nanka sand areas show the average ph of the aquifier ground water is between 5.0 to 6.6 pH scales, with maximum permissible pH scale of 8.5, while Ogwashi-Asaba formation also shows the average ph of the aquifier ground water is between 4.9 to 6.5 pH scales, with maximum permissible pH scale of 6.5. The Ogwashi-Asaba hydro geological data indicate good yield aquifers and its formation has equally good yields aquifer. The hydro geochemical study acquired along with derived and computed analyses of results of pumping tests of boreholes appraised in this study in parts of the study area, indicate the study area is hydro-geologically promising.

Keywords: Hydrogeology, Hydro geochemical, Water, High Yield, High Transmissivity, Good Specific Capacity, Survey, Electrode

1.0 Introduction

The provision of potable water boreholes are the most common solution to improving water supply in both rural and urban centres. Thus, groundwater development forms a major aspect of the water supply scheme programmes. The earth sub-surface is scarcely a homogenous entity, but made up of various rock materials of varying physical and/or chemical properties. This is caused by both the vertical and lateral variations in the distribution of the underlying rock masses. The age and metamorphism of these rocks are also contribution factors. With varying age and degree of metamorphism, comes the variation in the physical and chemical properties of these underlying rock masses. Thus, although the study area has abundant surface water and groundwater resources, these are not evenly distributed, while some areas have perennial surface waters, others are blessed with seasonal surface waters, and while some areas are underlain by thick aquifers that receive ample filtration from the abundant rainfall of this tropical rainforest region, others are underlain of aquitards and aquicludes.

To picture the groundwater situation of an area such as that of study area, requires mapping and classification of it's the water resources. The study of the geologic, hydro geologic/ hydro geochemical characteristics and the extent to which water is being taken from them in various places, and shows what is available and streamlines limitations in problem areas. Best results in the management of water resources are achieved when both surface waters and ground waters are conjunctively managed, knowing the input and output into and from a basin, enables the sustainable efforts to ensure that output does not exceed the input. A multi-objective, multi technique, multi-disciplinary and integrated approach, as indices for the design, planning, development and management of water resources in the area is therefore sine-qua-non. The extent, depth, thickness and geometry of aquifer in the study area, are yet to be fully established, as are the formation parameters and hydraulic values. The objectives of the study therefore are to establish the hydro geological environment of the study area, establish the empirical hydro geological models to describe the hydro geological system, pin-point limitations in the problem area and proffer solution.

2.0 Literature Review

Anambra State, Nigeria, faces significant water resource challenges due to factors like population growth, climate change, and agricultural practices. Hydro-geological surveys and evaluations are crucial for understanding the groundwater potential and ensuring sustainable water management in the region. This review explores relevant literature on hydro-geological studies conducted in various parts of Anambra State (Ekenta, Okoro, & Ezeabasili, 2015; Nweke et al., 2022). Studies have employed geophysical techniques (e.g., electrical resistivity surveys, seismic refraction) and hydrogeochemical analysis to map aquifers and assess their characteristics (hydraulic conductivity, transmissivity, yield potential) (Eze et al., 2019; Okonkwo et al., 2020).

Several studies have evaluated the physicochemical and microbiological quality of groundwater sources in Anambra, identifying concerns like nitrate contamination, iron content, and fecal coliform presence (Anyaegbunam et al., 2017; Egbuta et al., 2021). Research efforts have used numerical models to simulate groundwater flow and assess the impacts of pumping and climate change on aquifer sustainability (Okafor et al., 2018; Onyeagoro et al., 2022). Limited access to drilling data and historical water quality records hinders comprehensive understanding of aquifer systems (Atuanya, 2019). Further research is needed to quantify the effects of agricultural practices, urbanization, and waste disposal on groundwater quality (Obiora et al., 2020). Integrating local knowledge and collaborating with communities are crucial for sustainable water management strategies (Okonkwo & Ozor, 2022).

2.1 Location

The study area is bounded by latitudes 50 401N to 60 451N and longitudes 60 401E to 70 231E. In the north it is bounded by Anambra alluvial plains and marshy landmarks in the west by River Niger, while the southern boundary is marked by 5O 40' parallel, the area is accessible by roads through Enugu-Awka road and Asab-Onitsha road, the Owerri-Onitsha road and Aba-Ekwulobia road in the north-south direction. Numerous secondary and rural feeder roads linking the densely populated area also exist, providing means of communication of personnel and transportation of agricultural products from rural to urban centres.

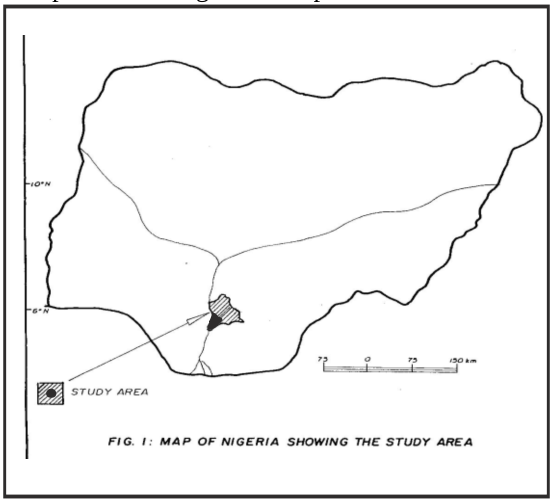

Figure 1: Area of Study

2.1.1 Climate, physiography, drainage and vegetation

2.1.1a Climate

The study area lies within the humid tropical rain forest belt of Nigeria, with rainfall amounting to 2500m perannum. Two climate seasons exist. These are the rainy season (March to October) and the dry season (October to March). These seasons have their variable regimes. The dry season has the coldest, direst windy period known as the harmattan between November and February. The rainy season has peaks in July and September with a dip in August known as the August break. Much rainfall occurs as violent downpours, accompanied by lightning and thunderstorms, heavy flooding, soil leaching, sheet outwash and groundwater infiltration and percolation. Minimum temperature is 230C maximum temperature is 340C while the average temperature is 280C. Relative humidity is 80% during the raining season and 65% during the dry season (Egboka & Okpoko 1988; Atuanya, 2019).

2.2. Physiography

The study area has undulating topography, topographic highs include the North-South trending Awka-Orlu uplands. The crest of the uplands stands at about 350m above mean seal level (AMSL), sloping down on both east and west to form the low lying Manu River plains and the Niger plains respectively.

2.3. Drainage

The area is drained by River Niger through the Anambra and Idemili River Systems. These two river systems are separated by North - South trending belt of dry zone which is over 50km in length, passing through Ekwulobia, Agulu and Awka. This stretch of land is known as the Idemili-Anambra water divide. The major rivers include Niger and its tributaries of the River Anambra and River Idemili. Other rivers are the Nkissi, Obizi, Obibia, Odo and Ezu. Lakes include Agulu, Odo and Itolo lakes.

A hydraulic connectivity exists between the surface water and groundwater. During heavy precipitation, accompanied by surface runoff, groundwater infiltration and percolation, there is resultant increase in water level, enhanced flow rates and spillage of the river banks. But during the dry season, the hydroregime events are reversed.

2.4 Vegetation

This is characteristic of the humid tropical rainforest belt type of Nigeria, trees with evergreen leaves and thick undergrowth. The vegetation cover has greatly reduced the savannah type. It is characterized by open vegetative lowland interspersed with tall oil palm trees and deciduous trees. Agricultural practices are intense, particularly along the hills, slopes, dry river valley and low-lying planes, further reducing the vegetation to the aforesaid savanna type. In some places, the vegetation has been cleared for agriculture, road construction, industrial sites and urban development (Daniel, 2016c).

3.0. Geology

The Time-Stratigraphic scale shows the occurrence in the area of the following main geologic units. The Imo Shale of the Paleocene is the oldest. Overlying the Imo Shale is the Nanka, Sands of the Eocane age. In the Quartenary is the Ogwashi-Asaba Formation.

3.1. The Imo Shale

This formation covers the Awka area, stretching towards Umunze in the North and Orumba area in the South. It consists of well laminated shale with occasional intercalations of calereous sandstone, siltstone and limestone lenses. The Ebenebe sandstone unit member of this formation is poorly sorted poorly consolidated, friable, very porous and permeable and it is prolifically aquiferous (Daniel, 2016).

3.2. The Nanka Sand

Overlying the Imo Shale is the Nanka Sands. This is extensive, covering Nanka - Oko, Agulu - Nnobi and Njikoka – Oyi –Otuocha areas of the study area with a thickness of 350m in places. It is a sequence of poorly consolidated, poorly sorted, friable, medium - coarse sands of Eocene age. The formation contains thin bands of claystones, siltstones and shale. These occasion the occurrence of aquitards and aquicides. The sandstone unit is very prolifically aquiferous. (Daniel, 2016a)

3.3 The Ogwashi - Asaba Formation

Overlying the Nanka Sands is the Ogwashi-Asaba formation of the Quaternary. This consists of alternation of lignites and clays. Good exposures occur around Ihiala, Oraifite, Onitsha and Oba as well as Ozubulu and Nnewi. The formation is Oligocene - Miocene in age. The sandstone unit of the formation is prolifically aquiferous. The formation is a new name for the lignite series which are of potential economic usefulness (Daniel, 2016b). Deposition was continuous and the division of strata is made on a facies change and not marked by a major break in sedimentation. Hazel (1961) observed that the formation is a coal measure type sequence (lenticular siltstone. clay and shales with subordinate sandstone lignites) in the southwest of Onitsha, grading laterally southwest wards into a belt of shales, some 244m thick in the upper Orashi valley.

3.3.3 Groundwater Resources

The geologic units in the area comprise aquifers and aquiferous units and gives high yields to wells and boreholes; the Ogwashi-Asaba Formation has equally good yields. Hand dug wells tap water from shallow depths at +/-20meters in the sand member of the Imo-shale. Deeper aquifers occur in the Nanka sands around Aguata Local Government Area of Anambra State at between 150m and 400m. Hydro geological data indicate good yield aquifers. The Imo Formation has poor permeability but good storage. The literature has generally reviewed the hydro-geology of several areas including some study areas. This literature study finds out that there is no hydro-geological survey and hydro-geological evaluation the selected parts or areas in Anambra state. The study therefore aims to achieve the hydro-geological survey and hydro-geological evaluation of the selected geopolitical locations in Anambra state.

4.0 methods

A multi-objective, multi-technique, multi-disciplinary and integrated approach, as indicate for the water resources field design, planning, development and management in the area was adopted.

Tools used included

a. Hydro-geological/formation parameters
b. Water quality characteristics data
c. Geologic/physiographic maps
d. Electric resistivity with the empirical hydro-geological models.

4.1 Hydraulic/Hydrogeolocal Parameters

Pumping tests of boreholes in parts of the study are in Cooper – Jacob's method, involving step-draw down, continuous and recovery test. Water levels were measured with electronic water level indicator while discharges were determined with 100 litre container and electronic watch. All measurements were done in the pumping boreholes as there were no observation walls in the vicinity. step – drawdown measurement involved the measurement of pumping of water of levels at various discharge rates and time intervals. Aquifer parameters and well loss coefficients were computed from step-drawdown tests and, therefore, the draw - down within the pumping wells at maximum and critical discharge were computed from the equation.

SW = BQ +CQn where N = numbers of the studies

The observed data are as shown in table No. 1

While Transmissivity (T) was estimated by means of Jacob's (1946) Straight line method from the formular

Q being the constant discharge rate in M3/Sec.

Storalitive (s) was calculated from its relationship with the aquifer thickness as

S=3x10b.

Table 1: Summary of the Geological Parameters in Parts of the Study Areas

BOREHOLE LOCATION			BOREHOLE GEOMETRY									AQUIFER CHARACTERISTICS				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
S/N	Name of Location	Coordinates Lat Long.	TD m	ϕC mm	TC	LOC m	ϕS mm	TS	SS mm	PS m	SWL m	Q m^3/s	S m	q $m^3/s/m$	T m^2/s	S
1	Ibolo Oraifite		168	153	steel	153	100	Steel	0.51	153.163	12					
2	Azia		126.2	153	Steel	111	100	Steel	0.51	112.124	87					
3	Osumogbu		178	153	Steel	128	100	Steel	0.51	128.134	115					
4	Amorka		120.5	153	Steel	96	100	Steel	0.51	96.125	84.5	0.011	1.31	0.0086		

COLUMN 4 TD= Total Depth of the Borehole 5 ϕC= Casting Diameter 6 TC = Casting Type 7 LOC= Casting Length 8 ϕS= Screen Diameter 9 TS= Screen Type 10 SS= Screen Slot 11 PS= Screen Position 12 SWL= Static Water Level 13 Q = Yield 14 s= Drawdown 15 q = Specific Capacity 16 T = Transmissivity 17 S=Storativity

Figure 2 shows the summary of the geological parameters of the boreholes geometry and the aquifer characteristics in Anambra State. The figure shows the summary of the ground water characteristics in the selected zones in Anambra State. The graph shows that the total depth of the Ibolo Oraifite borehole is always deeper than other selected zones with 178m depth, while Amorka zone has the lowest total depth of borehole with 120m depth. The cast length of the Ibolo Oraifite borehole is higher than other selected zones with 153m depth, while Amorka zone has the lowest cast length of borehole with 96m depth. The screen position of the Ibolo Oraifite borehole is higher than other selected zones with 153.163 m depth, while Amorka zone has the lowest cast length of borehole with 96.125m depth. The static water level of the Osumogbu borehole is higher than other selected zones with 115 m, while Ibolo Oraifite zone has the lowest static water level of borehole with 96.125m.

4.2 Water sample Data

Water samples were taken from boreholes in parts of the study areas and analyzed in the laboratory for physical, bacteriological and chemical properties. Samples for bacteriological analyses were collected in 250ml sterile plastic bottles, directly from boreholes after pumping out water for about 3 minutes. They were then stored in cold box and transported to the laboratories for analyses. Samples for chemical and physical analyses were collected in half (½) gallon plastic jerry cans previously thoroughly washed with the borehole water, stored in cold box and transported to the laboratory, allowed to stand to attain room temperature before tests and analysis. Media and indicators used for faecal coliform enumeration were prepared according to manufactures specifications Membrane Enriched Tiepool Broth; containing 0.1% Dodeoryl sulphate was used. For all bacteriological samples, enumeration of faecal coliforms was done by the membrane filtration (M.F) technique using milipore items. These include milipore sterile unit (xx 1104700), absorbent pads (AP 10047SI) and petri dishes (PD 1004700). The procedures followed were as specified in the standard methods for the examination of water and wastes. For the chemical analyses, the Direct Reading Engineering Lab (DR. EE-Model) (4HACH – KIT) was used. This HACH Kit uses the usual spectrophotometric principle. All tests were performed as specified in the HACH unit Standard Manual. For physical analyses, all parameters were obtained by Direct Reading. For pH for instance, the pH paper was dipped into the sample and the emerging colour was matched against the standard pH colour specifications to read off the pH of the water sample. The water analyses data base are as shown in the following tables. 2 to 3.

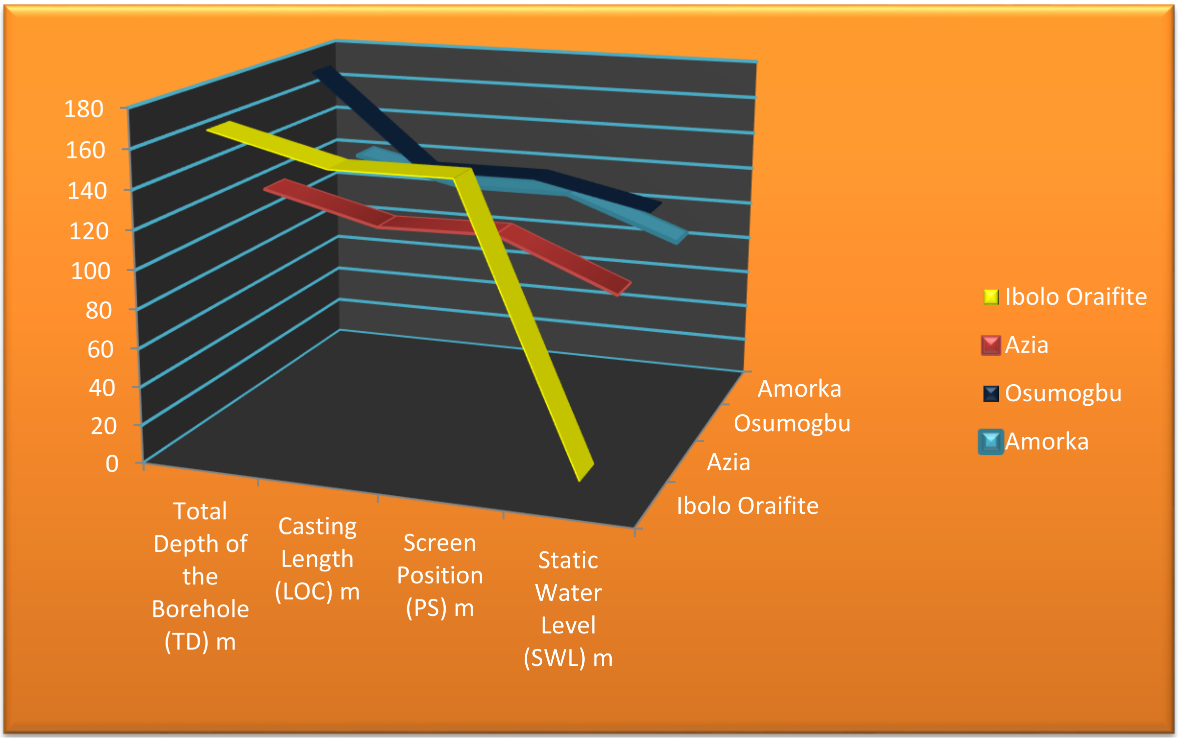

Figure 2: Summary of Geological Parameters

Figure 3 above shows the hydro-geochemical data of some selected surface and ground water in some selected parts of Onitsha metropolis. From the table, Idemili river at Ideani has the highest pH Scale of 6.6 (which is within pH standard), while Nnewi ground water and Nideni River at Umunya for surface water have the lowest pH scale of 4.8 each. The total water hardness in Idemili River (surface water) at Ideani is highest with 904 mg/L, while the water hardness is lowest at Nnewi, ground water at 4.0 mg/L. The water calcium content in the water is highest at Oraifite ground water with 28.8 mg/L, while the water calcium content is lowest at Nnewi with 2.3 mg/L. The magnesium content in the water is highest at Idemili River, at Obosi surface water with 108 mg/L, while the magnesium content is lowest at Nideni River, at Umunya and in Idemili river Oraukwu with 0.96 mg/L respectively. The total solid content in the water is highest at Nkiesi River at Nkissi surface water with 1000 mg/L, while the total solid content is lowest at Oraifite, Nnewi and Onitsha ground water with 0 mg/L each. The Nkiesi River at Nkissi has the highest total dissolved substances of 500 mg/L, while Nnewi and Onitsha ground water has the lowest total dissolved substances of 3.0 mg/L of water. The total suspended solid content in the water is highest at Nkiesi River at Nkissi surface water with 500mg/L, while the total suspended solid content is lowest at Oraifite, Nnewi and Onitsha ground water with 0 mg/L. The Nkisi River Onitsha has the highest total iron contents of 6.61 mg/L, while in Oraifite ground water, the has the lowest total iron contents of 0.30 mg/L of water.

Figure 4 above shows the hydro-geochemical data of some selected surface water and ground water in some selected parts of Awka metropolis. From the table, Obibia stream at Nibo has the highest pH Scale of 6.8 (which is within pH standard), while Agulu Lake2 and Ogba spring at Awka has the lowest pH scale of 5.0 for surface water. The total water hardness of the water is highest at Ogaba Sping in Awka with 68 mg/L, while the water hardness is lowest at Obibia stream, in Assika with 16 mg/L. The water calcium content in the water is highest at Awka surface water with 11.5 mg/L, while the water calcium content is lowest at Agulu Lake 1 with 0.00 mg/L. The magnesium content in the water is highest at Ezira ground water with 10 mg/L, while the magnesium content is lowest at Obibia stream water at Assika with 0.48 mg/L. The total solid content in the water is highest at Obibia stream at Nibo surface water with 800 mg/L, while the total solid content is lowest at Amenyi stream Unizik permanent site with 305 mg/L. The Obibia stream at Nibo has the highest total dissolved substances of 550 mg/L, while Ezira ground water the lowest total dissolved substances of 95 mg/L of water. The total suspended solid content in the water is highest at Agulu lake 2 surface water with 360mg/L, while the total suspended solid content is lowest at Amenyi stream Unizik permanent site with 105 mg/L. The Obibia stream at Nibo has the highest total iron contents of 4.00 mg/L, while in Ezira ground water, the has the lowest total iron contents of 0.00 mg/L of water.

Table 2: Hydrogeochemical Data of Some Surface and Ground Waters in Parts of the Onitsha Study Area

Parameters	Surface Water							Ground Water			Standard	
	Nkisi River (Onitsha)	Idemili River (Obosi)	Nkiesi River (Nkissi)	Nideni River (Umunya)	Idemili River (Ideani)	Awada Village Stream Nnobi	Idemili River Oraukwu	Oraifite	Nnewi	Onitsha	Highest Desirable	Maximum Permissible
pH	6.3	6	5.4	4.8	6.6	6	6.3	6.3	4.8	6.0	6.5	8.5
Total Hardness (mg/L)	32	900	20	24	904	900	902	463	4.0	6.8	100	500
Calcium (Ca^{2+}) (mg/L)	4.5	12	3.2	6.4	12.8	11.8	12	28.8	2.3	5	75	200
Magnesium (Mg^{2+}) (mg/L)	2.4	108	1.44	0.96	104.64	100.64	0.96	17.5	1.7	2.0	50	250
Total Solid (mg/L)	1005	5	1000	500	250	5.3	500	_	_	_	_	_
Total Suspended Solid (mg/L)	700	305	500	350	430	4.0	400	_	_	_	_	_
Total Dissolved (mg/L)	305	105	500	150	100	130	100	16	3.0	3.0	500	1500
Total Iron (mg/L)	6.61	1.84	8	3	1.8	1.0	1.8	0.3	2.0	0.5	0.1	1.0
Nitrate NO_3 (mg/L)	60	62	37.5	15.3	61.8	60	50	0	0	2.6	0	10
Chloride Cl (mg/L)	48.7	380	35.5	63.9	383.4	380.4	349	0.9	6.2	6.0	200	600
SO_2 (mg/L)	180	109	150	90	110	110	120	-	-	-	-	-
Total Alkalinity	32	38	30	25	35	32.5	35	-	-	-	-	-
HCO_3 (mg/L)	36	46	36	20.5	47.2	47	47	29.4	-	-	500	-
CO_2 (mg/L)	31	30	33.44	24.64	29.92		-	-	-	-	-	-
CO_3	-	-	-	-	-	29	30	12.9	-	-	500	-
Appearnace	-	-	-	-	-	-	-	-	-	-	-	-
Temp °C	-	-	-	-	-	-	-	24	24	24	35	25
Colour (AP-cOstd)	-	-	-	-	-	-	-	5	5	5	5	50
Turbidity	-	-	-	-	-	-	-	10	0	5	5	25
Odour	-	-	-	-	-	-	-	0	0	0	0	0
Conductivity (mg/L)	-	-	-	-	-	-	-	31.6		6.2	500	1500

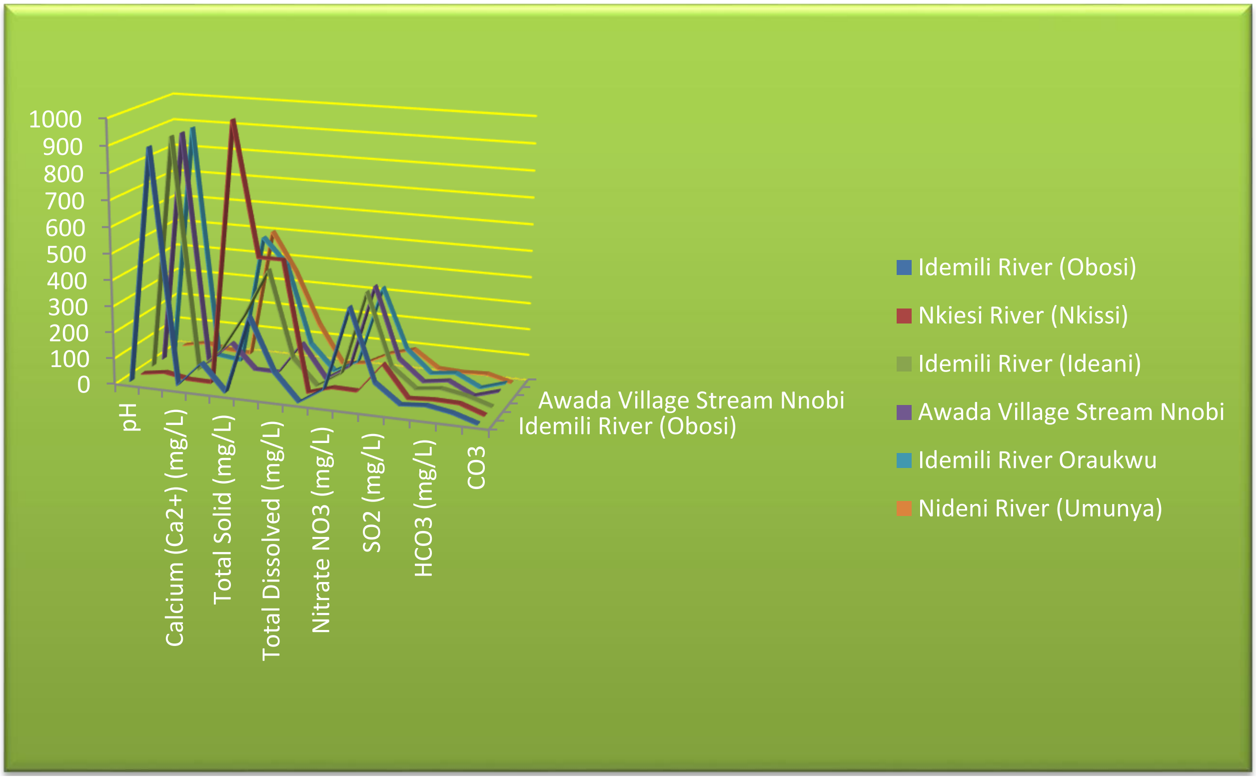

Figure 3: Hydrogeochemical Data of Some Surface and Ground Waters in Parts of the Onitsha

Table 3: Hydrogeochemical Data of Some Surface and Ground Water in Parts of the Awka Study Area

Parameters	Surface Water							Ground Water		Standard	
	Awka	Agulu Lake 1	Agulu Lake 2	Obibia Stream (Assika)	Ogba Spring (Awka)	Obibia Stream (Nibo)	Amaenyi Stream Unizik Perm Site	Awka	Ezira	Highest Desirable	Maximum Permissible
pH	5.8	6.2	5.0	5.6	5.00	6.8	5.2	6.4	6.4	6.5	8.5
Total Hardness (mg/L)	28.5	50	20	16	68	32	32	52.3	40	100	500
Calcium(Ca) (mg/L)	11.5	0.0	6.4	4.8	9.6	4.8	6.4	7.5	10	75	200
Magnesium (Mg^{2+}) (mg/L)	1	3.84	0.98	0.48	5.28	2.4	0.96		10	50	250
Total Solid (mg/L)	398	325	510	320	500	800	305				
Total Suspended Solid (mg/L)	295	200	360	200	300	250	105				
Total Dissolved (mg/L)	103	125	150	120	200	550	200	168	95	500	1500
Total Iron (mg/L)	1.40	3.40	3.10	2	0.5	4.00	1.80	0.0	0.11	0.1	1.0
Nitrate NO_3 (mg/L)	69.0	75.0	18	32.5	48	34	52.00	0	0	0	10.0
Chloride Cl (mg/L)	21.0	45.0	63	56	71	42.60	49.70	148	23	200	600
SO_2 (mg/L)	150	140	90	90	100	100	110	160			
Total Alkalinity	52	25	24	35	30	20					
HCO_3 (mg/L)	60	38	21	47.2	36.6	24.4	30.50		35	500	
CO_2 (mg/L)	32	86.28	24								
CO_3						22.88	29.92		10	500	
Appearnace								Clear	Clear		

Temp °C	25	24	25	25
Colour (AP-cOstd)	0	0	5	50
Turbidity	0.5	0	5	25
Odour	0	0	0	0
Conductivity (mg/L)		110	500	1500

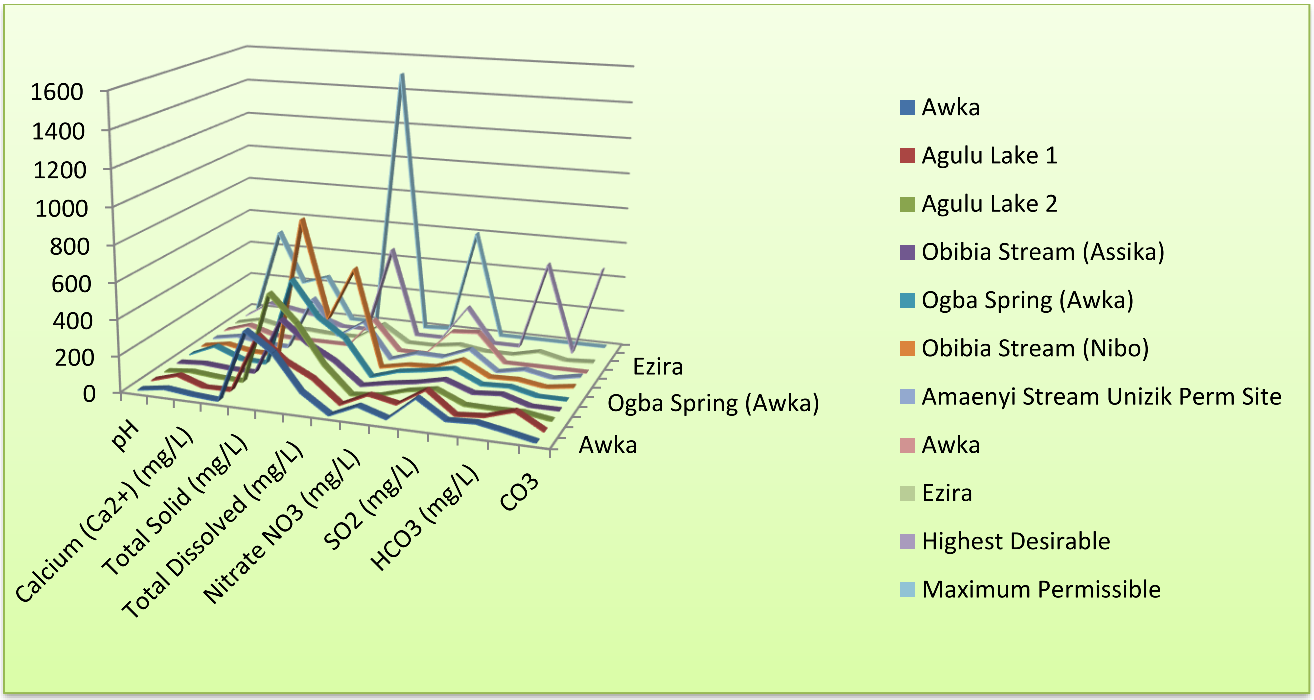

Figure 4: Hydrogeochemical Data of Some Surface and Ground Water in Parts of the Awka

5.0. Conclusion

Hydro-geological survey and evaluation were carried out in parts of Anambra state, Nigeria, to establish the hydro-geological environment, develop empirical, hydro-geological models describing the system, pinpoint limitations in the problem area and proffer solutions. The climate of the study area is typical of the rainforest belt type of Nigeria, with two climatic seasons of rainfall (March to October) and dry season (October to March) dominating. Rainfall is terrestrial and amounts to about 2,500mm per annum, with violent down pours, accompanied with thunderstorms, lightening, heavy flooding, soil leaching, sheet-outwash, and ground water infiltration and percolation. The lithological sandstone units of the three stratigraphic units are poorly sorted poorly consolidated, friable and medium to coarse sand grains. Therefore groundwater infiltration/percolation and recharge potentials are heavy and ground water movement free. Temperature is about 28^0C on the average. Humidity is about 30% and evaporation minimal, guaranteeing good ground water storage. From the Time-Stratigraphic Scale, 3 major stratigraphic units of Imo Shale of Paleocane, Nanka Sands of Eocane and Ogwashi-Asaba formation of the Quaritenary are easily identifiable.

In this area, the hydro-geological environment is quite promising. The depth to an area of hydro-geological interest varies from formation to formation and depends on the aquifer of interest. In Awka area the Ebenebe Sandstone unit aquifer of Imo Shale is tapped to the depth of 60m from the surface. From Awka towards Agulu in South-east Nigeria, the depth increases to 150m to 300m, tapping the Nanka sands. Still further East towards Ozubulu, Nnewi and Oraifite and Ihiala areas, the Lignite series of Ogwashi-Asaba formation replaces the Nanka sands, depths to the aquifer varying between 150m and 200m. Northwest of Awka towards Amanuke and Ukwulu areas, the depth to the aquifer varies from 15m to 45m for Amanuke, while the water table stands at 6m at Ukwulu. South of Awka towards Umunze, aquifer occurs between 130m and 180m. Thus in Imo shale the aquifer thins down away Northwards at a gradient of 1/3. In Abagana-Ukpo areas, aquifer occurs between 80m and 200m. Northwest ward, the aquifer occurs at between 15m and 31m at Aguleri and between 30m and 45m at Igboknyi. In Ogbaru area, penetration should go to 95m to tap the closely spaced aquifers between 62m and 92m. in Onitsha area aquifer generally occurs between 95m and 135m.

The field acquired as well as derived and computed analyses of results of pumping tests of boreholes appraised in this study in parts of the study area, indicate the study area is hydro-geologically promising. The aquifer setting is inferred as very highly productive generally, with very low and minimal draw down and high transmissivity. However, since the sand is fine to medium grained, the screen slot of 0.15mm is advised to discourage the slipping of silts fines into the well. The hydro-geological parameters (water quality parameters) tested for, fall within WHO standards, desirable, permissible and acceptable limits, except for high contents at Nnewi. The hydrogeochemistry of the groundwater resources is, therefore, described as good. The empirical hydro-geological model shows that when the apparent resistivity for a 150m current electrode spread and below, comes to the average of 175, the ground water resources potential is promising. Thus, establishing the hydro-geological regime of the study area, the following inferences are made. The thickness of various aquifer systems in the various parts of the study area is quite promising. The aquifers are of good hydro-geological characters and quite promising. They are within reach and groundwater potentials good and capable of yielding enough quantity of potable water to serve the study area, when proper water resources field design and management are in place. The ground water quality criteria are within WHO acceptable standards. The water can, therefore be tapped for domestic, agricultural and industrial uses.

However, the high iron contents of most surface waters in the study area and the Nnewi ground water systems are noted and are attributable to the presence of clays in the regions where found. The water is, therefore prone to staining the laundry and giving unpleasant taste to the mouth. For potability, the water should be subjected to treatment plant where the water is aired in an open overhead tank to encourage the oxidation and precipitation of excess dissolved ferrous to iron to ferric state (usually brown in colour), which then sediments to the bottom layer in the tank. The clear water layer above is then pumped into another overhead tank and thus piped through the filtration unit (to filter off the remains of sediments) into the chlorine dosing unit to take care of bacterial effects before it is jetted out for consumption. Hardness of surface water at Nsugbe/Otuocha is expensive to laundry services.

The high nitrate values of most surface waters appraised in this work are attributed to excessive fertilizer application to the farm lands. The major components of fertilizer are nitrogen, phosphate and potassium. Nitrogen in the soil exists as unassimilable organic matter, transformed by Oxidation bacteria into the assimilable forms of ammonia and nitrates. Excess nitrates in water are harmful to both human and animal health. The ingested nitrate water-under the requisite pH condition in the alimentary system is reduced to nitrites to readily form the nitrosamine which could be carcinogenous and deleterious/poisonous in the blodd stream. Other associated diseases include abortion in cattle, hay poisoning, plant tetany and reduction in haemoglobin contents of the red blood corpusles. In stabilized waters, excess supplies of nitrates lead to hyper growth of aquatic plants which use up all the available oxygen in the water, resulting in the mass death of aquatic life by eutrophication. To mitigate/reduce this ugly trend, crop rotational system of farming, in which crops that have to do with nitrates are avoided for some years, and revisited after some years is advised. Also advised in shifting cultivation- a bush fallow system in which the farmer returns to the same land after a number of years of non-cultivation.

5.1 Recommendation

The following are the recommendation of the study:

i. The hydro geochemical study at Nanka sand ground water areas have the best average pH scales of the aquifer ground water which is between 5.0 to 6.6units;
ii. The hydro-geological areas revealed that the lowest and the highest total depth of the boreholes to the aquifer are 62m and 550m respectively;
iii. There is high mineral contents at Obibia Stream, Nibo surface water when compared with other hydro geochemical in Awka hydro geological areas under investigation;
iv. There is high mineral contents at Idemili River in Ideani surface water when compared with other hydro geochemical in Onitsha hydro geological areas under study;
v. The studied areas are hydro-geologically promising.

Nomenclature

TD= Total Depth of the Borehole;
ϕC= Casting Diameter;
TC = Casting Type;
LOC= Casting Length;
ϕS= Screen Diameter;
TS= Screen Type;
SS= Screen Slot;
PS= Screen Position;
SWL= Static Water Level;
Q = Yield;
s= Drawdown;
q = Specific Capacity;
T = Transmissivity;
S=Storativity

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