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The Investigation Of The Hydraulic Connectivity, Origin, And Probable Uses of The Small Tropical Lakes In Nsukka, SE Of Anambra Basin Southeastern Nigeria - A Preliminary Approach To Water Resource Development

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ABSTRACT

The origin, probable uses and the investigation of the hydraulic connections of the small tropical lakes found in parts of Nsukka SE in Anambra River Basin of South-Eastern Nigeria was studied. The aim is to integrate the lake characteristics into the water resource development of the region. The study using various analytical apparatus include measurement of static water levels at different seasons of the year, Hydrogeochemistry of the lakes and emphasis laid on geochemical correlation of the waters of the various lakes. A total of six lake bodies were studied. The concentrations Ca^{2+}, Mg^{2+}, Na^{+}, Mn^{2+}, Cl^{-} Pb, Cd, K^{+}, Cu physical parameters, Fe^{2+}, Tds, Turbidity, HCO_3^{-} and SO_4^{2+} were measured. Water level variation of the lakes were also estimated at both the dry and rainy seasons. The result shows that All the lakes are magnesium rich and have Ca – Mg facies. The lakes are mildly acidic to acidic and have high iron content. Other chemical constituents are in conformity with the acceptable standard of world health organization 1984 for drinking water. The range of abundance of major cations and anions are in the following order. Mg > Ca > Na + K and Cl > SO_4 > HCO_3. This indicates that magnesium and Chloride are the major dissolved constituents. The lake waters are fresh dominated by magnesium and no dominant anion. The lakes are ideal for industrial, agricultural and domestic uses except that treatment to reduce iron content and elevate the ph is required. Finally, it was discovered that the lakes are Eutrophic, of tectonic origin and connected underground.

KEYWORDS: *small tropical lakes, water resources, development, Anambra drainage Basin, SE Nigeria Nsukka SE*

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I. INTRODUCTION

The area of study consists of Ekwegbe, Opi, EhaAlumona, Ehandiabu and Orba. The terrain is dotted by surface water bodies which are lakes. Effort has been made to examine the origin of the lakes and to examine the probale uses also if there is any underground hydraulic connections between the waters of the lakes. The aim is to integrate the lake study into the water resources development of the region. Investigations were also made to examine if the lakes have connections with the rivers / streams. The six major lakes selected for the study include, varavara lake, Iyiohe lake, Ijii, Ohere, Idodo and Ajoiyi, all of them are within the farm land lowlying areas of discharge environment. From literature the lakes are classified as Eutorophic (Winter, 2003).

Winter (2003) defined eutrophic lakes as those that are shallow, green to yellow to brownish green, have low transparency and are rich in calcium and dissolved oxygen though not often above 40%. The shape and size of a lake are largely dependent on the forces that produced them (Stephenson 2004). According to Winter 2003, individual lakes may be formed as a result of the combination of more than one of these factors - Glacial action, aqueous agencies (Karst Lakes) tectonic activity volcanic agencies. Stephenson (2004) proposed two views on the possible origin of the lakes in the area of study. These are paleocurrent and tectonic forces. Origin dependent on paleocurrent is based on the depositional cycle of the formations in the Anambra Basin. The lakes could be regarded as abandoned water bodies during the regression of the sea in the Maastritchian period (Reyment, 1965), as the sea was withdrawing, some of its waters were entrapped within small depressions within the deposited sediments. The entrapped water bodies remain without drying up because they are underlain by impermeable shale strata of Mamu Formation. They are recharged by underground water (Welch, 2000).The origin based on tectonism holds that the lakes were formed as a result of tectonism in the Benue Trough of which Anambra Basin is a part Ofoegbu (1985).

The result was the crumbling of the sediments, a situation that gave rise to small depressions/l valleys that hold water as lake bodies. Ofoegbu, 1985 noted that different sediments of Mamu Formation and Ajali Formation can react differently when acted upon by compressional forces because of variation in their lithologies. He noted that Mamu Formation will react differently due to inhomohenity of its lithologic unit. The shale unit can easily be disturbed whereas sandstone and silt stone cannot. The result was the crumbling of the sediments which led to the formation of small depressional features in which water was entrapped as lake bodies. Virtually, all the lakes are located within Mamu Formation rainwater, underground water and water from seepage probably recharge the lakes (Egboka, 2003). Based on the almost linear alignment of the lakes, the tectonic origin appears to be more acceptable. The history of regional and local structural geology of the area was also attributed to tectonic processes by Short and Stauble (1967) Murat (1980) Hogue and Ezepue (1977).

II. METHODOLOGY

2.1.Description of study area:

The area is a part of Anambra Basin whose rocks are upper cretaceous in age (Reyment 1965). It lies within latitude 6° 42′ N and 6° 48′ N, longitude 7° 26′ E - 7° 36′ E and covers an area of about 160km^2 Fig 1

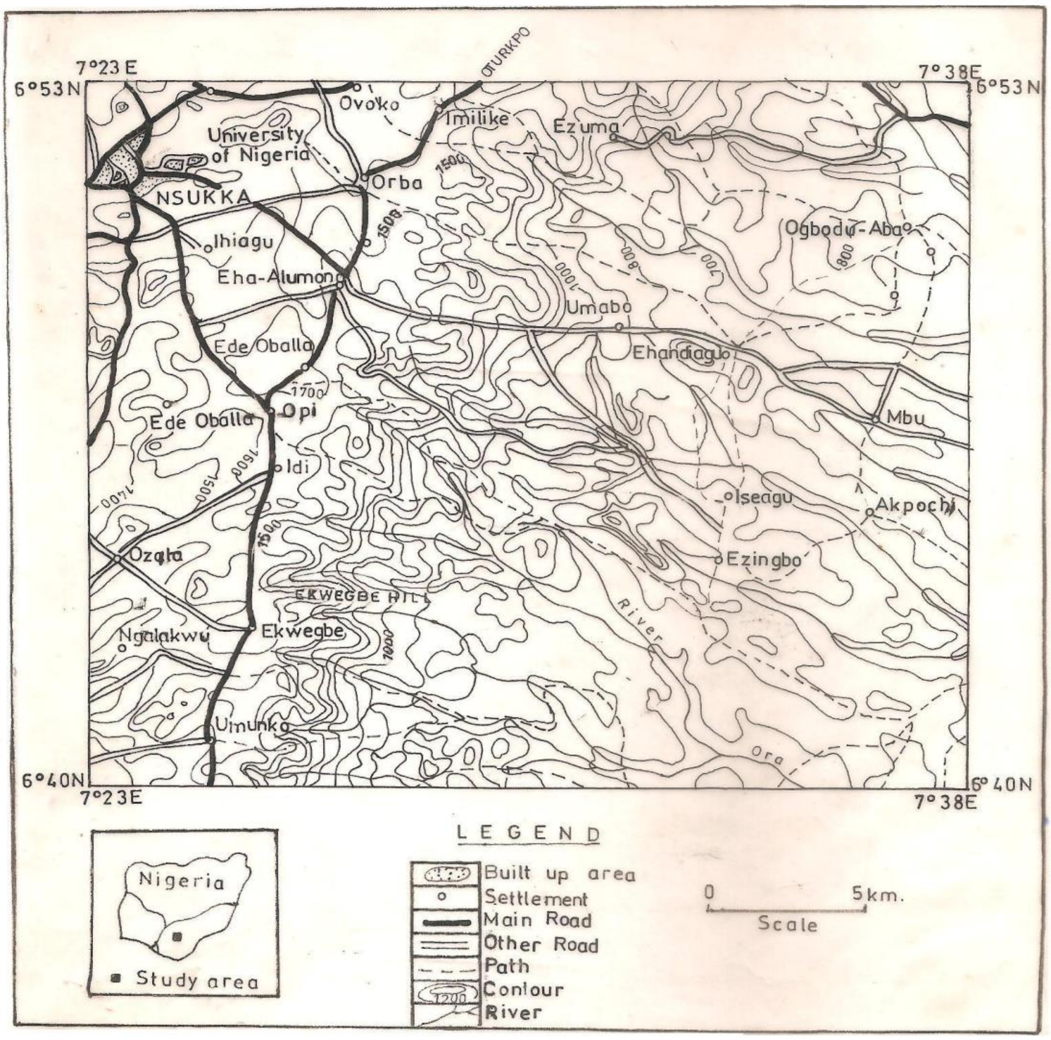

Fig. 1: Topographical Map of the study area

The stratigraphic succession in Anmabra Basin is given in Table 1. Three geological formations that outcrop in the area include Mamu Formation (lower Maastritchian Ajalli Sandstone (upper Maastritchian) and Nsukka Formation (Danian) Fig 2

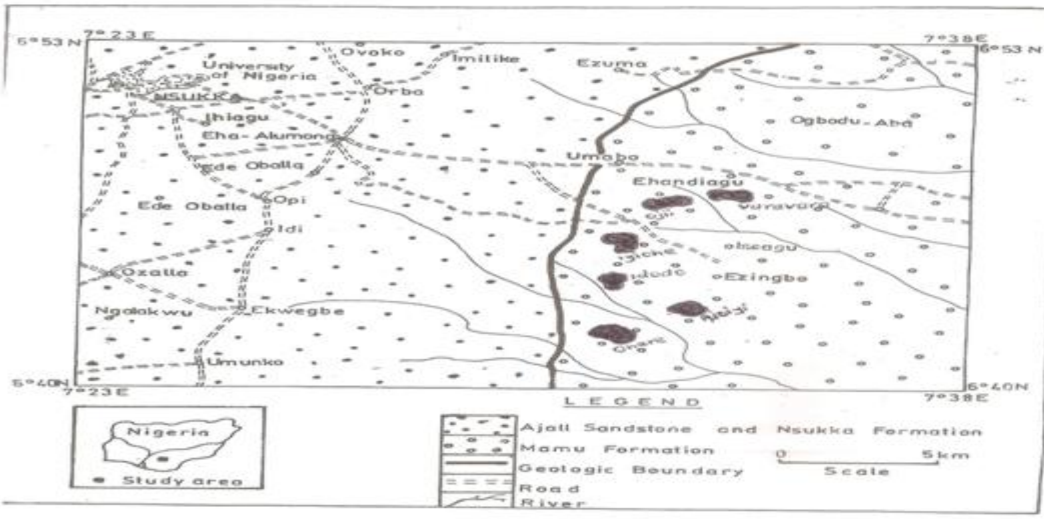

Fig. 2: Geological map of the study area

The Nsukka Formation is described as cap rock previously known as the upper coal measures (Simpson 1954, Reyment 1965). The Mamu Formation consists of mudstone, sandy Shales and fresh water sandstone Reyment (1964) noted the presence of ammoniferous Shales in some parts of the Formation. Coal seams have also been described at Enugu. The measured value of average dip of the area gives 4° to 8° in the western direction (Onunkwo-Akunne, 2000). The sandstone unit of the formation is fine grained . The Mamu Formation provides the Shaley impermeable base on which the waters of Ajali Aquifer are trapped. The Mamu Formation is comformably overlain by Ajali sandstone. The Ajali Sandstone (upper Maastritchian is about 451m thick Agagu et al (1985). Lithologically the Ajali sandstone consists mainly of medium to coarse grained, poorly consolidated white sands with characteristic cross bedding (Hoque and Ezepue, 1997). Outcrops of Ajali sandstone is very thin within the farm land discharge areas of the low lying environment that habours the lakes (Agagu et.al. 1965). Agagu et al (1965) have reported presence of such Ostracods as cytherella , ovocytherides and a few foraminifera such as Hyplophragmoids and a few foraminifera such as Hypophragmoids and Ammobaculites in the Ajali sequence. The Nsukka Formation is related to Mamu Formation in many aspects except that Nsukka Formation has no coal seam in the study area. Outliers of Nsukka Formation dot the area with Ajali sandstone providing the base (Hogue and Ezepue, 2004).

Table 1 Stratigraphic Succession in Anambra Basin (Reyment 1965)

Age Epoch	Age	Formation	Lithology
Tertiary	**Miocene-recent**	**Benin Formation**	**Medium-coarse grained, poorly consolidated sands with clay lenses and stringers.**
	Oligocene-miocene	**Ogwashi Asaba Formation**	**Unconsolidated sands with lignite seams.**
	Eocene	**Ameki Formation**	**Grey clayey sandstone and sandy clay stones.**
	Paleocene	**Imo Shale**	**Laminated clayey shales**
Upper Cretaceous	**Upper Maaastritchian**	**Nsukka Fm**	**Sandstones intercalating with shales**
		Ajali Sandstone	**Poorly consolidated sandstone, typically cross beded with minor clay layers.**
Lower Cretaceous	**Lower Maastritchian**	**Mamu Formation**	**Shales, sandstones, mudstones and coal seams.**
	Campanian	**Nkporo/Enugu Shale**	**Dark grey shale, clayey shale with clay lenses**
	Santonian	**Awgu Formation**	**Bluish grey shale with clay lenses.**
	Turonian	**Ezeaku Formation**	**Black shale with clay and limestone lenses.**

Two climatic seasons characterize the study area – the dry and wet seasons. According to Udo (1978), the dry season generally begins about the middle of October and ends around March , while the rainy season sets in April and ends in early October (Iloeje , 1995). According to the author, the mean annual rainfall is 1304mm, while the mean monthly maximum temperature is 28,73°C, also the mean annual relative humidity is 58.28%, mean vapour pressure is 21.68, pitche evaporation is 4.32 and mean monthly minimum temperature is 21.26 °C. According to Ogbukagu (1976), hills that are laterite capped, are the outliers of Nsukka Formation (Tattam 1981). The conical hills are often separated by low lands and broad valleys. The surface runoff on these valleys is virtually nil due to the high permeability of the red earth mantle and soil as well as the thick underlying Ajali sandstone. The most prominent topographical features in the study area are the North-South trending Cuesta over Ajali Sanndstone. The dip slope of the Cuesta is generally south-east wards (Edokwe, 2005).

The vegetation and soil types are related. The study area lies within the tropical rain forest / guinea savannah belt of Nigeria (Iloeje, 1995). The author classified the soil as rainforest and lateritic soils. The rainforest soils are rich in humus derived from rainfall in the forest, unfortunately, the soils are highly leached by heavy rainfall. Soils underlying savanna type of vegetation have low organic matter content and low cation exchanges capacity. Their pH values are low (3.3 to 4.3), and this may be due to excessive leaching (Edokwe, 2005). The major characteristic of the vegetation of this area is the abundant combination of varied plant groups whose branches interwine to form a continuous canopy of leaves. The major plant and grass species include iroko, palmtree, obeche , Eupatorium odoratumm and imperatasylindrica.

III. METHOD OF STUDY

The method of study includes literature review and reconnaissance work. Topographic and geologic maps of the area were employed in the identification of the various lakes of the area. Activities involved measurement of static water levels in the lakes at different periods of the year with emphasis on the peak of the rainy season (September) and dry season (January) as to ascertain the nature of recharge. The hydrogeochemistry of the lakes were studied and emphasis laid on geochemical correlation of the waters of the various lakes, also water samples were collected from lakes springs and streams of the area. The final phase was used for laboratory studies in which chemical analysis of water samples were carried out.

3.1.Data Acquisition: A total of 6 lake bodies were studied and include varavara lake, Ojii lake, Idodo lake, Iyioha lake Ohere lake and Ajoiyi lake. All the lakes are located within the discharge lowlying areas of the study environment (see fig. 2). The water levels in the lakes were measures by a meter rule fixed at the middle of the lakes. Initial readings were then recorded. Other readings were taken at the peak of the rainy and dry seasons. Water samples were collected from the various lakes for geochemical analysis and correlation. Atomic absorption spectroscopy was employed for the measurement of Ca^{2+}, Na^{+}, Mn^{2+}, Cl^{-}, Pb and Cd. Potassium (K^{+}) was determined using flame photometer, while copper was analysed with spectrophotometer while concentrations of total iron (Fe^{2+}) were determined calorimetrically using Spekker absorption meter. Total dissolved Solids (Tds) was determined using glass fiber filter. The concentrations of Ca^{2+}, Mg^{2+} and Na^{+} in milliequivalent per litre were used to obtain sodium absorption ratio (SAR). Turbi metric method was used to assess turbidity. Physical parameters like pH and dissolved oxygen were measured insitu in the field with appropriate standard meters, while anions like $HCO3^{-}$ were estimated by titrimetric method. Clean plastic container were used to contain the water samples, they were rinsed several times with the same water samples to be analysed, then covered with air tight-cork, carefully labelled and sent to the laboratory for chemical analysis within 24 hours of collection. All details of analytical procedures are reported in Omidiran, (2005).

IV. RESULT AND DISCUSSION

The results of the study are displayed in tables 2, 3 and 4 respectively.

Table 2: Water level variations of the lakes (in meters)

	AVERAGE READINGS IN METERS							
	Date water Levels	**Vara vara Lake**	**Iyiohe Lake**	**Ojii Lake**	**Ohere Lake**	**Idodo Lake**	**Ajoiyi Lake**	**Remarks**
DRY SEASON READINGS	15-11-90 Initial WL	20	15	10	20	30	50	Initial Water level

	20-12-90 New WL	-10	-5	+15	+25	-25	+62	Effluent and influent lakes
	20-1-91 New WL	-5	-2	+30	-30	-20	+70	Effluent and influent lakes
	28-2-91 New WL	-3	-1	+38	-36	-14	+75	Effluent and influent lakes
DRY SEASON READINGS	3-5-91 New WL	+80	+90	+55	+45	+50	+95	General rise in WL
	20-6-91 New WL	+100	+100	+60	-70	-67	+100	General rise in WL
	30-7-91 New WL	+117	+114.6	+70	+105	+80	+125	General rise in WL

Note: Negative values indicate a drop from the initial water level (WL). Positive values indicate an increase from the initial water levels (the instrument is a measuring rule in meters fixed in the Lakes and projected above the lake WL).

Table 3: Hydrogeochemical Constituents of the lakes

Location	**Alkalinity**	**Temp °C**	**Conducti**	**ph**	**Dissolved Oxygen**	**Nitrate**	**Hardness**	**Calcium**	**Sulphate**	**Magnesiu**	**Iron**	**Sodium**	**TDS**	**Phosphat**	**HCO_3**	**K^+**	**Remarks**
Varavara Lake	**10**	**28.2**	**14.4**	**5.45**	**3.1**	**2.7**	**12**	**1.6**	**11.6**	**9.7**	**1.6**	**8**	**28**	**1.4**	**8.2**	**.73**	
Ojii Lake	**10**	**30.3**	**17.8**	**5.18**	**3.2**	**3.2**	**8**	**6.3**	**11.6**	**14.6**	**1.2**	**.2**	**24**	**1.8**	**6.4**	**.12**	
Ohere Lake	**10**	**31.8**	**11.8**	**6.16**	**3.7**	**2.4**	**15**	**4.7**	**11.6**	**9.7**	**1.7**	**.5**	**46**	**1.9**	**12.4**	**.35**	
Idodo Lake	**10**	**30**	**13.4**	**5.3**	**3.4**	**3.0**	**1.8**	**1.8**	**11.6**	**9.7**	**2.5**	**.7**	**25**	**1.8**	**6.4**	**.62**	**Acidity and**
Ajoiyi Lake	**10**	**29.5**	**14**	**5.8**	**3.5**	**2.6**	**1.6**	**1.6**	**11.6**	**9.7**	**1.2**	**.6**	**43**	**1.8**	**9.2**	**.45**	**Iron Content is high**
Average	**10.0**	**29.82**	**14.17**	**5.48**	**3.38**	**2.67**	**9.73**	**3.45**	**11.6**	**10.52**	**1.62**	**.1.77**	**.35**	**1.45**	**10.17**	**0.45**	

WHO, 1984		**<40° C**		**6.50 TO 8.50**	**5ppm**	**45**	**250**	**50**	**250**	**30**	**.3**	**200**	**500**	**10**	**250**	**50**	

Table 4: Cations and anions computations for the lakes in Milliequivalents per litre

Lakes	Cations	Conc (mg/L)	Atomic Wt	Charge	Conversion Factor	Equivalent Mass	Milliequivalent per litre	% total of Meq/L
Varavara 1	Ca^{2+}	1.6	40.08	2	.04990	20.04	.08	5.71
	Mg^{2+}	9.7	24.31	2	.08226	12.155	0.78	55.71
	Na^{+}	8	22.98	1	.04350	22.98	.35	25
	K^{+}	7.3	39.10	1	.02557	39.10	.19	13.57
Iyiohe 2	Ca^{2+}	6.3	40.08	2	.04990	20.04	.31	20.40
	Mg^{2+}	14.6	24.31	2	.08226	12.155	1.20	78.95
	Na^{+}	.2	22.98	1	.04350	22.98	0.009	0.59
	K^{+}	.12	39.10	1	.02557	39.10	0.003	0.20
Ijii 3	Ca^{2+}	4.7	40.08	2	.04990	20.04	0.23	21.50
	Mg^{2+}	9.7	24.31	2	.08226	12.155	0.80	74.77
	Na^{+}	.6	22.98	1	.04350	22.98	0.03	2.80
	K^{+}	.43	39.10	1	.02557	39.10	0.01	0.93
Ohere 4	Ca^{2+}	4.7	40.08	2	.04990	20.04	0.23	21.70
	Mg^{2+}	9.7	24.31	2	.08226	12.155	0.80	75.47
	Na^{+}	.5	22.98	1	.04350	22.98	0.02	1.89
	K^{+}	.35	39.10	1	.02557	39.10	.009	0.85
Idodo 5	Ca^{2+}	1.8	40.08	2	.04990	20.04	0.09	9.57
	Mg^{2+}	9.7	24.31	2	.08226	12.155	0.80	85.12
	Na^{+}	.7	22.98	1	.04350	22.98	0.03	3.19
	K^{+}	.62	39.10	1	.02557	39.10	0.02	2.13
Ajoiyi 6	Ca^{2+}	1.6	40.08	2	.04990	20.04	0.08	8.70
	Mg^{2+}	9.7	24.31	2	.08226	12.155	0.80	86.96
	Na^{+}	.6	22.98	1	.04350	22.98	0.03	3.26
	K^{+}	.45	39.10	1	.02557	39.10	0.01	1.09
Total							0.92	100
Lake	**Anions**	**Conc (mg/L)**	**Atomic Wt**	**Charge**	**Conversion Factor**	**Equivalent Mass**	**Milliequivalent per litre**	**% total of Meq/L**
Varavara 1	HCO_3	8.2	61.02	1	0.01639	61.02	0.02	2.17
	NO_3	2.7	62.0	1	0.01613	62.0	0.04	4.35
	SO_4	11.6	96.06	2	0.02082	48.03	0.24	26.09
	CL	2.2	35.45	1	0.02821	35.45	0.62	67.39
Iyiohe 2	HCO_3	6.4	61.02	1	0.01639	61.02	0.10	8.26
	NO_3	1.2	62.0	1	0.01613	62.0	0.02	1.65
	SO_4	11.6	96.06	2	0.02082	48.03	0.24	19.83
	CL	30	35.45	1	0.02821	35.45	0.85	70.24
Ijii 3	HCO_3	18.4	61.02	1	0.01639	61.02	0.03	3.33
	NO_3	.48	62.0	1	0.01613	62.0	.007	0.78
	SO_4	11.6	96.06	2	0.02082	48.03	0.24	26.67
	CL	22	35.45	1	0.02821	35.45	0.62	68.89
Ohere 4	HCO_3	12.4	61.02	1	0.01639	61.02	0.20	18.69
	NO_3	.4	62.0	1	0.01613	62.0	.006	0.56
	SO_4	11.6	96.06	2	0.02082	48.03	0.24	22.43
	CL	2.2	35.45	1	0.02821	35.45	0.62	57.94

Idodo 5	**HCO_3**	**6.4**	**61.02**	**1**	**0.01639**	**61.02**	**0.10**	**9.62**
	NO_3	**3.0**	**62.0**	**1**	**0.01613**	**62.0**	**0.05**	**4.81**
	SO_4	**11.6**	**96.06**	**2**	**0.02082**	**48.03**	**0.24**	**23.08**
	CL	**23**	**35.45**	**1**	**0.02821**	**35.45**	**0.65**	**62.50**
Ajoiyi 6	**HCO_3**	**9.2**	**61.02**	**1**	**0.01639**	**61.02**	**0.15**	**13.51**
	NO_3	**2.6**	**62.0**	**1**	**0.01613**	**62.0**	**0.04**	**3.60**
	SO_4	**11.6**	**96.06**	**2**	**0.02082**	**48.03**	**0.24**	**21.62**
	CL	**24**	**35.45**	**1**	**0.02821**	**35.45**	**0.68**	**61.26**

Fig. 3: Piper Trilinear plot representing the chemical characteristic of the lakes of the study area

Legend:
1. Varavara Lake
2. Iyiohe Lake
3. Ijii Lake
4. Ohere Lake
5. Idodo Lake
6. Ajoiyi Lake

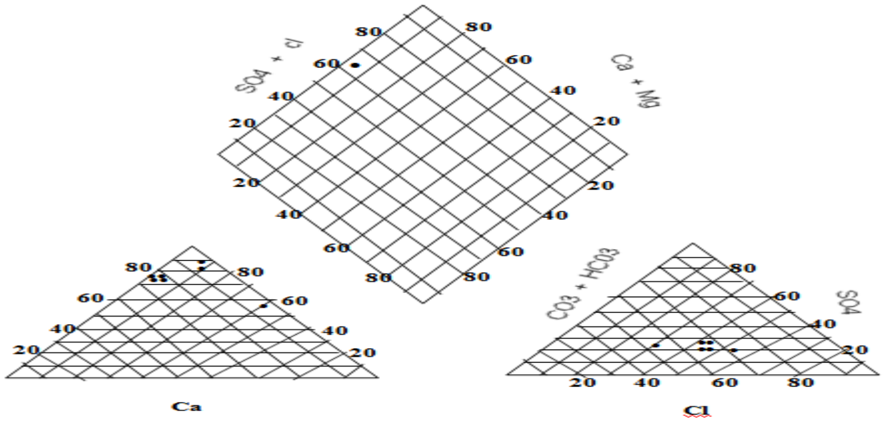

Fig. 3: Piper Trilinear plot representing the chemical characteristics of the lakes - Varavara lake, Iyiohe lake, Ijii lake, Ohere lake, Idodo lake, Ajoiyi

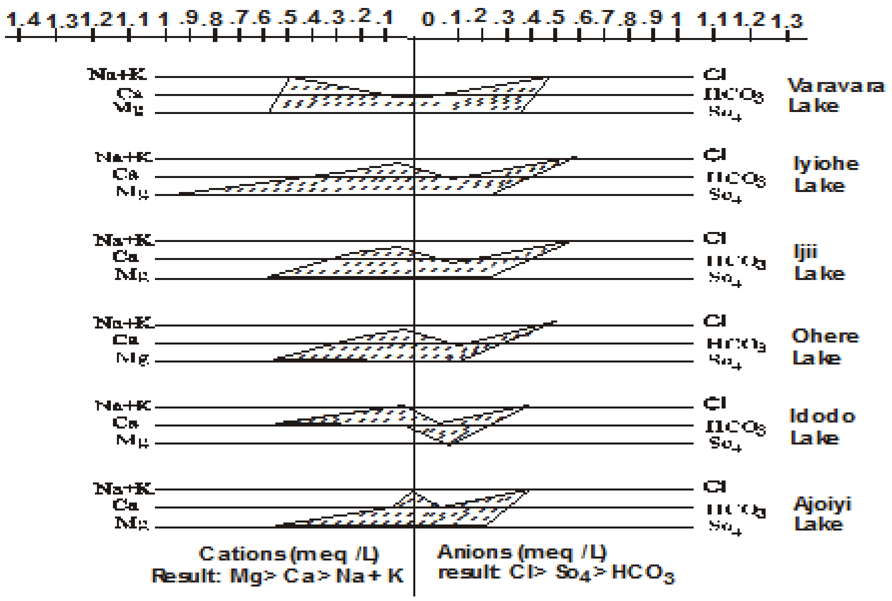

Fig 4 Stiff diagrams for the selected lakes

Sodium content was used to classify the water quality of the lakes for irrigation purpose because of its reaction with soil to reduce permeability (Etuefeotor 1981). Thus the relation sodium absorption ratio (SAR)

SAR $\quad Na^{+}$…………………………..(2)
$(Ca^{2+} + Mg^{2+})^{½}$ Meq/L

Equation (2) was used to determine the suitability of the lake waters for irrigation purposes. According to EtuEfeotor 1981, water class based on SAR is classed as 0-10 excellent, 10-18 good, 18-26 fair while > 26 is poor. Using equation 2 and the average components derived from table 4, the average SAR for the lakes are Varavara = 0.38, Iyiohe 0.007, Ijii 0.0297, Ohere 0.0198, Idodo 0.032 and Ajoiyi 0.32 giving an average of 0.083. The lakes are excellent for irrigation purposes (EtuEfeotor 1981).

The waters of the lakes were also compared with the American water works association (AWWA, 1991) to assess their suitabilities in industries.

Table 5: Average lake water analysis result compared with American Water Works Association (AWWA) For Industrial uses.

Parameters	Average value of samples analysed (Mg/L)	AWWA 1991 Accepted Standard	Remarks
Tds	35.0	50-500	Poor
Total hardness	12.50	0-250	Good
Iron	1.82	0.1-10	Good
pH	4.83	6.5-8.3	Poor
Chloride	23.83	20-250	Good
Manganese	-	0-0.50	-

Some of the lakes did not meet the specification of America Water Works Association 1991 for industrial water. Problem of inadequacy of total dissolved solids and pH are in shortfall and need to be upgraded to AWWA, 1991 status except Ohere lake whose pH is 6.16.

The pollution index of Horton 1995 was also applied to ascertain the pollution index of the lakes as to assess the extent of their pollution (Horton, 1995). The Horton scale is shown in fig 5

SAR $\quad Na^{+}$……………………………(2)
$(Ca^{2+} + Mg^{2+})^{½}$ Meq/L

Unit value (1) indicates tolerable standard, but above this value (1) the water is polluted and below this value the water is not polluted (Horton, 1995). The pollution index (piji) of the lakes was calculated employing equation (1) Where Ai is the measured parameter and wij is the universal standard . From equation (1) and employing the results of table 6 the average pollution index of the lakes give 4.3 indicating pollution, probably due to high iron and acidic content.

Table 6: Computation of pollution Index of the lakes

Parameter	Ai	Wij	Ai / wij	Result
Phat 29°C	**4.83**	**6.50 _0 8.50**	**0.64**	**Max Ai / Wij = 6.07**
Turbidity (NTU)	**-**	**5.0**	**-**	
Conductivity (ms)	**14.17**	**100**	**.14**	
Tds	**35**	**500**	**.07**	
Iron (Fe^{2+})	**1.82**	**0.3**	**6.07**	
Calcium (Ca^{2+})	**3.45**	**50**	**.07**	**Mean Ai / wij = 0.17**
Magnesium (Mg^{2+})	**10.52**	**30**	**.68**	
Potassium (K^{+})	**.45**	**50**	**.009**	
Sulphate (SO_4^{2-})	**11.6**	**250**	**.05**	
Phosphate (PO_4^{2-})	**1.75**	**10**	**.8**	
Nitrate (NO_3^{-})	**4.4**	**4.5**	**.10**	
Chloride (Cl^{-})				
Carbonate (CO_3^{-})	**10.17**	**250**	**.04**	
Mean	**-**		**0.17**	

Discussion: It was observed that lakes Ojii, Ohere and Ajoiyi are probably recharged by groundwater and other lakes at higher elevations, giving rise to influent and effluent lakes since their levels rose at the peak of dry season (Winter, 2001). A schematic illustration of this situation was shown by Winter (2001). Fig 6. this anomalous trend is known as effluent lake. Varavara, Iyiohe and Idodo were recharging Ojii, Ohere and Ajoiyi lakes. It is evident that during the periods of intense rains, the influent lakes can become effluent and vice versa.

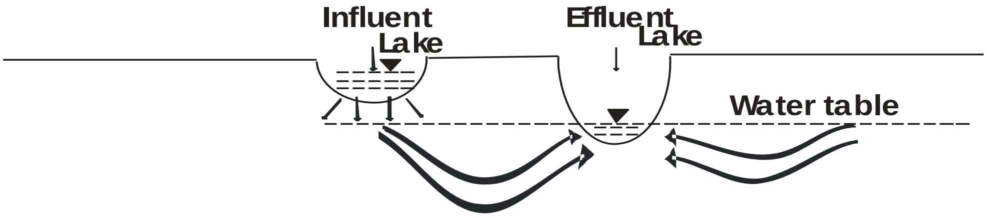

Fig 6: Schematic illustration of influent and effluent lakes (After Winter, 2001).

Sieve analysis of the Ajali sandstone taken from the areas around the lakes indicate high permeabilities. From the works of Egboka and Uma (1983), the conductivity values of Ajali sandstone Formation is high in the area. Thus, there is probably hydraulic connection between the lakes. The lakes that loose water are at higher elevation than those that gain water. Stiff diagram indicate that Mg^{2+} and Cl^{-} are the major dissolved species and also show uniformity in anion and cation plots which is another evidence of underground hydraulic connection. Pipers trilinear diagram shows that the lakes are magnesium type with no dominant anion and have Ca-Mg facies. The lakes are acidic to mildly acidic, above all, the highly permeable nature of Ajali sandstone in the sub layers of the lakes provide other evidence suggesting possible connections underground. The chemical constituents of the lakes are in conformity with world health organization standard guide lines for drinking water (Who, 1984). The range of abundance of the major cation anions are in the following order: $Mg^{2+} > Ca^{2+} > Na^{+} > K^{+}$ for Cations and $Cl^{-} > So_4^{2-} > HCO_3^{-}$ for anions. This indicates that Magnesium and Chloride are the major dissolved constituents. The lake waters plot within the zone of fresh water, though anion plot is undefined, but it is probable that Mg^{2+} and Cl^{-} water is recommended. Acidity and iron content is high with low dissolved solids.

Comparism of the lakes with American Water Works Association for industrial uses, shows that the lakes are ideal for industrial applications except that iron and acidity are out of range and therefore needs treatment. The Sodium absorption ratio of the lakes ranges from 0.007 to 0.38 indicating water excellent for irrigation Etuefeotor (1981). The waters of the lakes were also compared with the pollution indices of Horton (1995), and it shows that the average value for the lakes gives 4.3 indicating pollution, probably due to high iron content and acidic level of the lakes.

V. CONCLUSION AND RECOMMENDATION

The lakes found within Nsukka South East are Eutropic and the origin is due to tectonism. The lakes are hydraulically connected underground. It is also likely that fractures due to tectonic activity occurs underground. The lake waters are of magnesium type and are ideal for human consumption, agricultural and industrial purpose though iron and acid treatment are required. Alkaline fertilizer is recommended for formers as this will correct the acidic water. These informations should be integrated into the formulation of the water resource development of the region.

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