



Comparative analysis of the quality of the shallow and deep aquifer waters of Nsukka se, Nigeria – a preliminary approach to water resource development

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ABSTRACT

Comparative analysis of the shallow and deep aquifers of Nsukka SE, Nigeria was studied as a preliminary approach for the underground water resource development of the region. Method of approach involves the identification of rock formations and delineation of their stratigraphic relationships. Activities involved collection and analysis of water samples from boreholes and hand dug wells. A total of 14 water samples were collected (7 from shallow and deep aquifer each) and analyzed for inorganic and organic components. Ca²⁺, Na⁺, Mn²⁺, Cl⁻, Pb and Cd were analyzed using Atomic absorption spectroscopy. K⁺ was determined using flame photometer method. Copper Cu²⁺ was analyzed using spectrophotometer, pH was analyzed with the aid of pH meter, Fe²⁺ was determined calorimetrically using Spekker absorption meter; Tds was determined using glass fiber filter. Turbimetric method was used to assess turbidity. Anions like HCO₃⁻ were also estimated by titrimetric method. Coliform analysis was carried out by the most probable number technique (MPN). The result shows that average pH for deep and shallow aquifer gives 5.8 and 6.3, sulphate 14.2 and 10.97, Nitrate 2.5 and 2.2., Phosphate 1.48 and 1.68, iron 1.98 and 1.60 magnesium 11.4 and 11.8, Sodium 1.80 and 2.4, Chloride 8.4 and 9, Tds 33.51 and 62.17. The coliform count ranges from 3/100 to 7/100 ml only for shallow aquifer (pollution), magnesium is the major contributors of hardness in both cases. Deep aquifer water plots as magnesium cation and a no dominant anion and on the transition between fresh and salt water (brackish water). The shallow aquifer has magnesium sulphate and plots in the zone of sea water, and shows hard water. The SAR for deep aquifer is 0.58, while that of shallow aquifer is 0.32 both are excellent for irrigation. Both waters are ideal for use in industries and homes, while the aquifers are highly polluted by iron, the shallow aquifer is polluted by water borne diseases. Reference to these information is ideal for the water resource development of the region.

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Introduction

The primary objective of this study is to evaluate the comparison between the deep and shallow water aquifer systems of Nsukka SE, Nigeria as preliminary approach for water resources development of the region. This evaluation consisted of physical, chemical and biological reconstruction of the properties of the underground water systems, distribution of geochemical constituents and classification of water/ aquifer types. The areas affected by this study include Opi, Ekwegbe, Orba, Eha Alumona and Ehandiagu. The area covers about 160km² and lies within latitudes 6 42° N to 6.42°N and longitudes 7° 26' E to 7° 36' E (Iloje 1981). The 2006 population figure for the area is about 100,000 and this is likely to reach 1,000,000 by the year 2020. This calls for water resource development. Water table is very deep at the areas bordering the water divide (Opi Uno, Ekwegbe Uno and Eha Alumona) while it is shallow at Ekwegbe Agu, Opi Agu and EhandiAgu low lying areas. (Egboka , 1996).

Methodology:

Description of study area:

The area is a part of Anambra basin whose rocks are upper cretaceous in Age (Reyment, 1965). It lies within latitudes 6°

42' N and 6° 48' N, longitudes 7° 26' E – 7° 30' E and covers an area of about 160km² fig 1.



Fig. 1: Topographical Map of the study area

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The stratigraphic succession in Anmabra basin is given in table 1. The three geologic formations that outcrop in the area include Mamu Formation (lower Maastrichtian) Ajali sandstone (upper Maastrichtian) and Nsukka Formation (Danian) Fig 2.

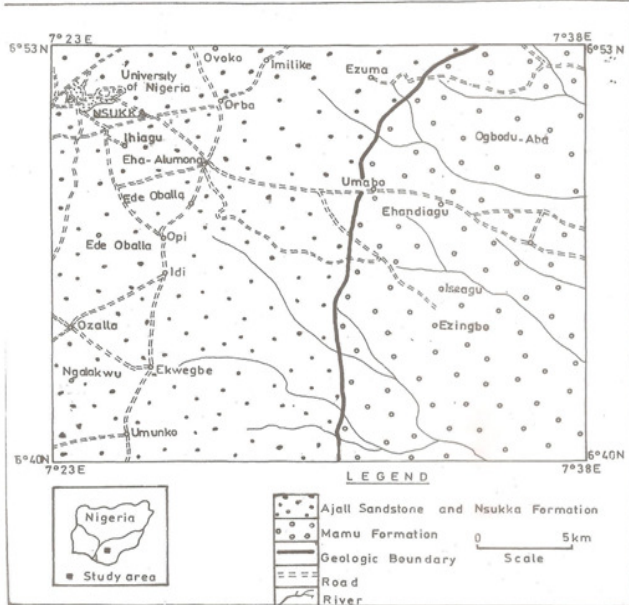


Fig 2: Geological Map of the study area

The Nsukka Formation is described as caprock previously known as the upper coal measures (Simpson 1954, Reymont 1965). The Mamu Formation consists of mud stone, sandy and fresh water sandstones.

Reymont (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 is 4° to 8° in the western direction. The sandstone unit of the formation is fine grained (Egboka, 1983). The Mamu Formation provides the shalley impermeable base on which the waters of Ajali aquifer are trapped. The Mamu Formation is conformably overlain by the Ajali sandstone. The Ajali sandstone (upper Maastrichtian) 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 (Edokwe, 1976). Outcrops of Ajali sandstone make up considerable percentage of the total rock out crop in the area.

Agagu et al (1985) have reported presence of such ostracods as cytherella, ovocytherides, and a few foraminifera such as Hyplophragmoids and Ammobaculites in the Ajali sequence. The Nsukka Formation is related to Mamu Formation in many aspects only that Nsukka Formation has no coal seams in the study area. Outliers of Nsukka Formation dot the area with Ajali sandstone providing the base (Agagu et al . 1985).

Climate:

Two climatic seasons characterize the study area – the dry and wet seasons. According to Udo (1998), 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 1304.2mm, 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 Ogbuaku (1976), the physiography is dotted by numerous coneshaped hills that are laterite capped and are the outliers of

Nsukka Formation (Tattan 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 feature, in the study area are the North-South trending Cuesta over Ajali sandstone. The dip slope of the Cuesta is generally South-eastwards (Edokwe, 1976).

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 rain forest soils are rich in humus derived from rainfall in the forest, unfortunately the soils, are highly leached by heavy rainfall. Soils underlying savannah type of vegetation have low organic matter content and low cation exchange capacity. Their pH values are low (3.3 to 4.3), and this may be due to excessive leaching (Edokwe, 1976). The major characteristic of the vegetation of this area is the abundant combination of varied plant groups whose branches intertwine to form a continuous canopy of leaves. The major plant and grass species include Iroko, palmtree, obeche, Eupatorium odoratum and imperata cylindrica (Iloeje, 1985).

Method of Study:

The method of study includes literature review and reconnaissance work. Topographic and geologic maps were employed in the identification of rock formations and in establishing their stratigraphic relationships. Activities involved collection of water samples from springs, hand dug wells and bore holes. The final phase was used for laboratory studies in which chemical analysis of water sample were carried out.

Data acquisition:

A total of 14 water samples – 7 from shallow and 7 from deep aquifer were collected for organic and inorganic analysis using Atomic absorption spectroscopy for Ca^{2+} , Na^{2+} , Mn^{2+} , Cl^{-} , Pb and Cd . Potassium K^{+} was determined using flame photometer method while Copper (Cu) was analyzed with the aid of 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^{2+} in milliequivalent per litre were used to obtain sodium absorption ratio (SAR). Turbimetric 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 HCO_3^{-} were estimated by titrimetric method. Coliform analysis was carried out by the most probable number technique (MPN). Clean plastic containers were used to contain the water samples, they were rinsed several times with the same water samples to be analyzed, 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 procedure are reported in Omidiran (2000).

Results:

The result of chemical analysis of both the deep aquifer waters and shallow ones are shown in tables 2 and 3.

The result of biochemical examination of the shallow aquifer is shown in table 4. From analysis the deep aquifer show no pathogenic presence (Ezigbo and Ozoko, 1987). The shallow aquifer has bacterial presence (Table 4).

Sawyer and MC Carty (1967) indicated that pathogenic micro organisms survival can be expected to be greater when normal biological activity is the least such as under low temperature and anaerobic conditions. The coliform count in table 4 ranged from 4/100ml to 7/100ml.

Table 1. Stratigraphic Succession in Anambra basin (Kogbe, 1979)

Age Epoch	Age	Formation	Lithology
Tertiary	Miocene-recent	Benin Formation	Medium-coarse grained, poorly consolidated sands with clay lenses and stringers.
	Oligocene-miocene	Ogwashi Formation Asaba	Unconsolidated sands with lignite seams.
	Eocene	Ameki Formation	Grey clayey sandstone and sandy clay stones.
	Paleocene	Imo Shale	Laminated clayey shales
Upper Cretaceous	Upper Maastrichtian	Nsukka Fm	Sandstones intercalating with shales
		Ajali Sandstone	Poorly consolidated sandstone, typically cross bedded with minor clay layers.
	Lower Maastrichtian	Mamu Formation	Shales, sandstones, mudstones and coal seams.
Lower Cretaceous	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.

Table 2: Chemical Constituents of water samples from deep aquifer (water shade / Recharge)

Location	pH	Hardness	Colour	Alkalinity	SO ₄ ²⁻	Nitrate	Phosphates	Iron	Magnesium	Ca ²⁺ /Mg ²⁺	Sodium	Chloride	Tds	K ⁺	Calcium
EhaAlumona	6.6	12	5	25	-	-	-	.38	12	.33	97	15	-	0	4
Opi I	5.6	12	5	10	15.2	2.7	2.2	1.68	9.7	.41	.4	17	56	0	4
Ekwegbe (I)	6.7	20	5	10	11.6	3.7	.92	1.68	14.6	.32	0	4	60	0	4.7
Orba (I)	5.4	20	10	10	16	3.6	1.84	.68	9.7	0.86	.80	12	4.8	6	7.8
Ekwegbe (II)	5.5	8	8	10	11.6	3.2	1.84	1.68	9.7	.22	.8	6	24	0	3.2
Opi (II)	6	16	4	8	15.2	1.5	1.8	2.7	14.6	.22	0.1	1.5	0.24	4	3.2
Orba (II)	5.4	12	4	10	15.2	2.7	1.5	2.1	9.7	.32	.5	4	56	0	3.3
Average	5.8	17.3	7.37	8.53	14.2	2.5	1.68	1.60	11.4	0.32	1.8	9.9	33.51	3.0	4.31
WHO 1984	6.5-8.5	250	-	8.53	250	45	10	0.3	50	-	200	250	500	200	75

Table 3: Chemical Constituents of water samples from shallow aquifer (discharge farm land settlement)

Location	pH	Hardness	Colour	Alkalinity	SO ₄ ²⁻	Nitrate	Phosphate	Iron	Calcium	Magnesium	Ca ²⁺ /Mg ²⁺	Sodium	Chloride	Tds	K ⁺
Ehakumona	6.9	20	4	10	11	2.7	.76	1.7	4.7	14.6	.3	0	4	92	0
Orba	6.8	20	3.2	3.2	8	2.7	.8	2.1	4.7	14	.3	.1	4	76	0
Opi	6.3	20	10	10	8	2.7	.8	2.1	6.3	14.6	.4	1.2	7	44	10
Opi Agu	7.2	20	5	10	8	1.1	2	2.2	1.2	9	.5	.4	4	68	0
Orba Agu	4.7	12	10	8	15.2	-	2.3	2.7	6.3	9.7	.2	2.7	4	40	8
Ekwegbe	6.1	12	12	10	15	-	2.2	1.1	4	9.0	.2	.2	5.7	53	0
Average	6.3	17.3	7.37	8.53	10.97	2.3	1.48	1.98	4.53	11.8	.32	0.92	6.67	62.17	3
WHO 1984	6.5 -8.5	250		8.53	250	45	10	0.3	75	50	-	200	250	500	200

Table 4: Coliform analysis of selected shallow aquifer of the area

Location	Total Coliform Count				Remarks	
EhandiAgu	1/3	0/3	0/3	MPN	4/100ml	Coliform Presence
Opi Agu	0/3	1/3	0/3	MPN	3/100ml	Coliform Presence
Ekwegbe Agu	1/3	0/3	1/3	MPN	7/100ml	Coliform Presence

Table 5: Cations and anions computations in milliequivalent per litre for deep aquifer waters

Cations	Conc (mg/L)	Atom Wt (g)	Charge	Conversion factor	Equivalent Mass	Meq/L	Meq./L Percentage total (%)
Ca ²⁺	4.3	40.08	2	.04990	20.04	0.21	16.67
Mg ²⁺	11.43	24.31	2	.08226	12.16	.94	74.60
Na ⁺	1.7	22.98	1	.04350	22.98	.07	5.56
K ⁺	1.43	39.10	1	.02557	39.10	.04	3.17
Total						1.26	100
Anions					Eq.Mass	Meq./L	% Total
HCO ₃ ⁻	0.32	61.02	1	0.01639	61.02	.005	0.900
No ₃ ⁻	2.73	62.0	1	0.01613	62.0	.04	7.21
SO ₄ ²⁻	13.18	96.06	2	1.02082	48.03	.27	48.65
Cl ⁻	8.5	35.45	1	0.02821	35.45	.24	43.24
TOTAL						0.555	100.00

Table 6: Cations and anions computations in milliequivalent per litre for shallow aquifer waters

Cations	Conc (mg/L)	Atom Wt (g)	Charge	Conversion factor	Equivalent Mass(g)	Meq/L	Meq./L Percentage total (%)
Ca ²⁺	4.53	40.08	2	0.0499	20.04	0.23	17.42
Mg ²⁺	11.80	24.31	2	0.08226	12.16	0.97	73.48
Na ⁺	0.92	22.98	1	0.04350	22.98	0.04	3.03
K ⁺	3.0	39.10	1	0.02557	39.10	0.08	6.06
Total						1.32	99.99
Anions	Conc (mg/L)	Atom Wt (g)	Charge	Conversion factor	Eq.Mass(g)	Meq./L	% Total
HCO ₃ ³⁻	0.25	61.02	1	0.01639	61.02	0.004	0.72
No ³⁻	2.3	62.0	1	0.01613	62.0	0.04	7.22
SO ₄ ²⁻	15.17	96.06	2	0.02082	48.03	0.32	57.76
Cl ⁻	6.67	35.45	1	0.02821	35.45	0.19	34.30
TOTAL						0.554	100

From table of drinking water standard, water with more than 1 per 100 ml bacterial content is not good for drinking (Who, 1984). Therefore these sections of the study area have, excessive quantity of coliform bacteria. Freeze and Cherry (1979) indicated that coliform presence is due to wastes of humans and farm animals.

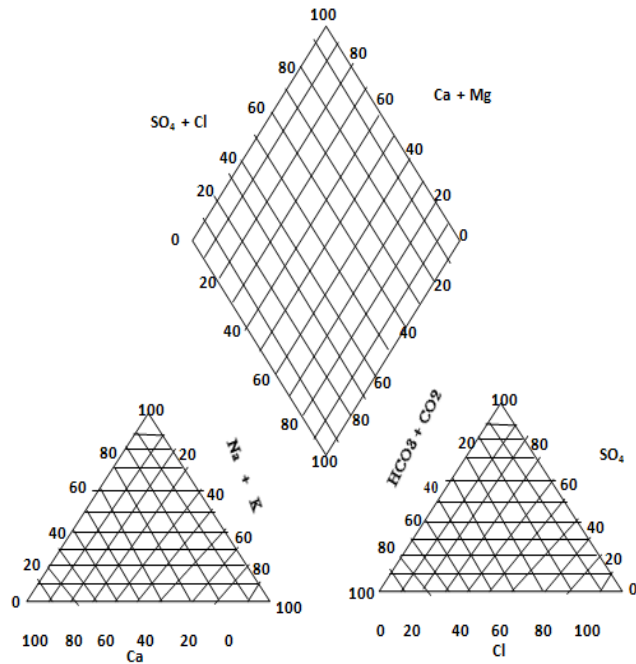


Fig 3: Piper's Diagram for deep aquifer

The water chemistry of the area for both the shallow and deep aquifer was classified using Pipers' diagram as shown in fig 3 and 4.

Tables 5 and 6 were used to classify the deep and shallow aquifers using Pipers' diagram Figs 3 and 4.

From the plots, the deep aquifer classification shows that the water contains Magnesium cation and a no dominant anion type and plotted within the transition in the diamond plot indicating water between fresh and salt water (brackish), while the shallow aquifer classification shows Magnesium Sulphate water and plots on the right side of the diamond shape of the Piper plot indicating Sea water (Pipers 1944). The shallow ground water belongs to hard water (Edward, 1978). The Stiff diagrams Figs 5 and 6 shows that the deep aquifer waters have more dissolved constituents.

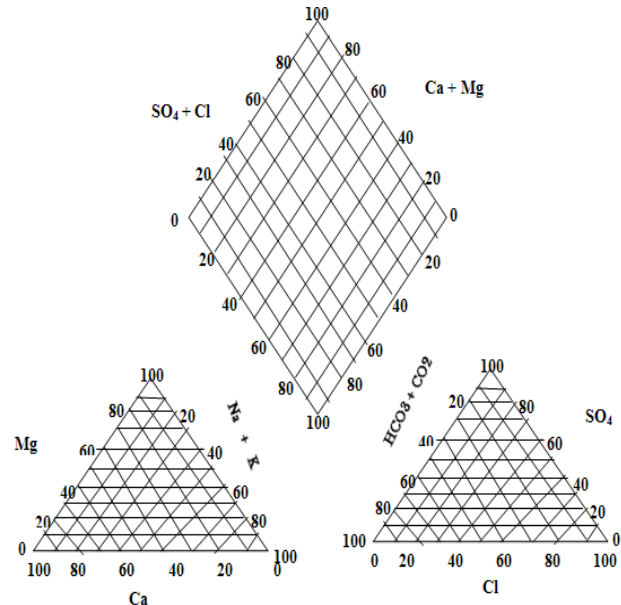


Fig. 4: Piper's Diagram for shallow aquifer

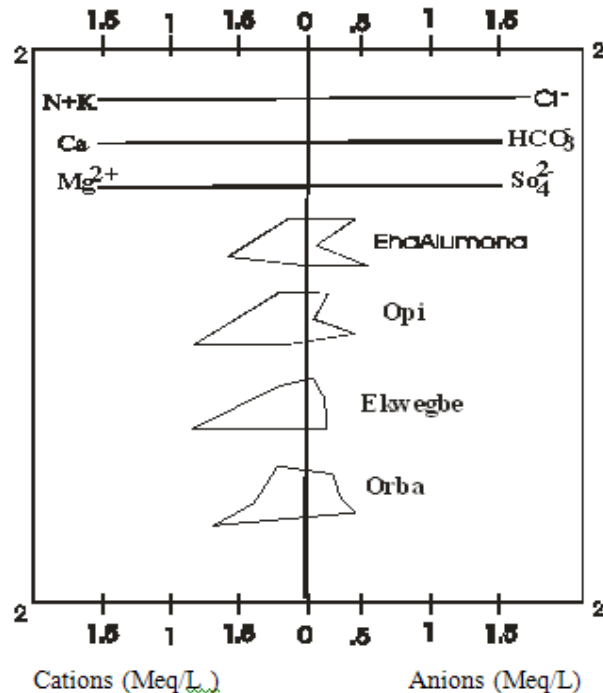


Fig. 5: Stiff diagram for deep aquifer in Meq/L

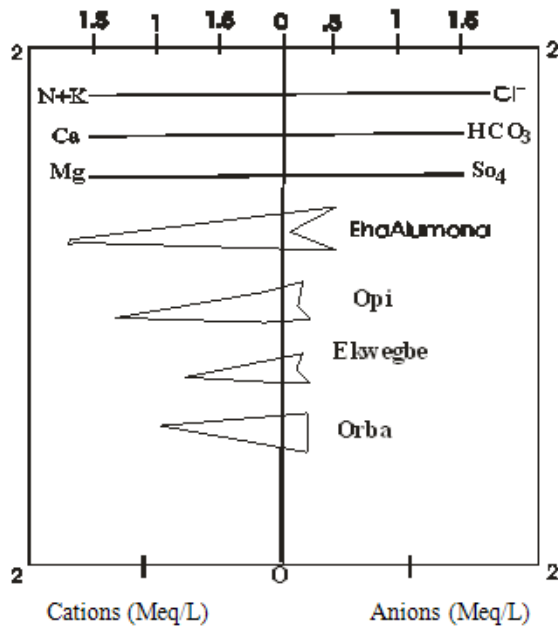


Fig. 6: Stiff diagram for shallow aquifer in Meq/L

Sodium content was used to classify water quality of the area for irrigation purposes because of its reaction with soil to reduce permeability (Etu Efeotor, 1981). Thus, the relation Sodium Absorption Ratio (SAR) gives:

$$\frac{Na^+}{(Ca^{2+} + Mg^{2+})^{1/2}} \text{ Meq/L} \dots\dots\dots(1)$$

Equation (1) was used to determine the suitability of the water 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 (1) the average SAR for components derived from tables 5 and 6 yields 0.58 for deep aquifer and 0.32 for shallow aquifer indicating water excellent for irrigation (EtuEfeotor 1991). The groundwater resources of the area was compared with American Water Works Association (AWWA) as to assess the usability in industries. This shown in tables 7 and 8

Table 7: Ground water analysis result compared with American Water Works Association (AWWA) for deep aquifer

Parameters	Average Value of sample analysed mg/L	AWWA (1991) Accepted Standard Mg/L
Tds	37.46	50-500
Total Hardness	14.29	0.250
Iron (Fe2+)	2.27	0.1-10
pH	5.09	6.5-8.3
Chloride (Cl-)	8.5	20- 250
Manganese	-	0-0.5

Table 8: Groundwater analysis result compared with American Water Works Association (AWWA, 1991) for shallow aquifer

Parameters	Average Value of sample analysed mg/L	AWWA (1991) Accepted Standard Mg/L
Tds	62.17	50-500
Total Hardness	17.30	0.250
Iron (Fe2+)	1.98	0.1-10mg/L
pH	7.5	6.5-8.3
Chloride (Cl-)	6.67	20- 250
Manganese	-	0-0.5

In both cases, the water resources of the area is ideal for industrial applications (AWWA, 1991). The pollution Index of Horton (1995) was employed to calculate the pollution index of the deep and shallow aquifer as to assess their extent of pollution. The Horton scale is shown in fig 7.

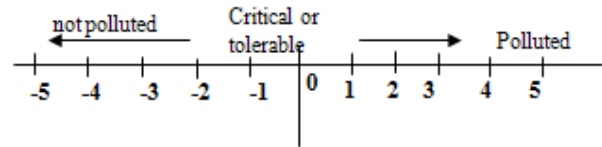


Fig. 7: The Hortons Scale (Horton, 1995)

Where unit value (i) 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) was calculated using equation 2. as shown below.

$$\sqrt{\frac{(\max Ai / wij)^2 + (\text{mean } Ai / wij)^2}{2}} \dots\dots\dots(2)$$

Where Ai is the measured parameter and wij is the universal standard.

Table 9: Deep Aquifer pollution Index Computation

Parameter	Ai	Wij	Ai / wij	Result
Phat 29°C	5.09	6.50-8.50	0.78	Mean $\frac{Ai}{Wij}$
Turbidity (NTU)	21.50	5.0	5.70	
Conductivity (ms)	30.24	100	0.30	
Tds	37.46	500	0.75	
Iron (Fe ²⁺)	2.27	0.3	7.57	
Calcium (Ca ²⁺)	4.30	50	0.38	Max $\frac{Ai}{wij}$
Magnesium (Mg ²⁺)	11.43	30	0.38	
Potassium (K ⁺)	1.43	50	0.03	
Sulphate (SO ₄ ²⁻)	13.18	250	0.05	
Phosphate (PO ₄ ²⁻)	1.68	10	0.17	
Nitrate (NO ₃)	2.73	45	0.06	= 1.29
Chloride (Cl ⁻)	8.5	250	0.04	
Carbonate (CO ₃ ⁻)	14.29	250	0.06	
Manganese (Mn)	-	0.5	-	
Mean	10.39		1.29	

From equation 2 and applying parameters in table 9 and referencing fig 7, the pollution Index of deep aquifer is 7.67 in the same way that of shallow aquifer is 6.63. This indicates pollution in both cases. The higher value of deep aquifer is probably due to high iron content of Nsukka Formation which harbours ferruginized sand stones Simpson (1954) and Tattan (1981).

Discussion of Results

The physical quality of waters from perched aquifers show that pH of the water range from 4.68-7.24 indicating that shallow water is slightly acidic to acidic. This may be due to carbonaceous nature of Mamu Formation. Mamu Formation is known to host coal seams which is being mined in Enugu area. The oxidation of sulphide to sulphate lower the pH of water bodies. The area also has much soil organic matter whose decomposition most probably produces fluvic and humic acids that lower the pH (Raymond, 2000) most perched water samples of the area contain much soluble cations, because most metallic element are soluble in acid ground water. The problem to this effect is that Back and Henshaw (1995) has noted that when pH concentration in water is above 9 or below 5, the hydrogen ion concentration can reactivate some poisons found in sediments. Water hardness of the shallow aquifers range from 12 to 4mg/L. Sulphate concentration ranges 8-15.2 Mg/L giving an average 8.89mg/L of sulphate. The maximum recommended concentration limit for sulphate is 250mg/L. From this the sulphate concentration in the area poses no danger

to the portability of the waters (Who 1984). Some hand dug wells and springs (Shallow aquifer) recorded very high concentration, this is probably due to the presence of pyrite or gypsum in the underlying shales in the area (Reyment, 1965). The oxidation of sulphides present in the rocks is the alternative source of sulphate. Again it may be due to fertilizer and sewage contamination (Raymond 2008). The problem of sulphate is its combination with calcium to form an adherent heat retarding scale, also water containing about 500mg/L of sulphates tastes bitter and may be cathartic (Raymond 2000). The range of nitrate concentration is between 2.1 to 3.2 respectively. If nitrate increases in water in the range greater than 45mg/L, the water tastes bitter and may lead to physiological disorders in humans and livestock if consumed on regular basis (Camp 1963). He further noted that water up to 45mg/L of nitrate can cause methemoglobinemia in infants. The probable source of Nitrate are runoff from fertilizers and contribution from sewage, these may be the origin of Nitrate in the area.

The average concentration of calcium is 4.75 mg/L and range is from 1.6 -6.3mg/L. It is clear that calcium concentration is marginally lower than magnesium. The low concentration of calcium results in low $\text{Ca}^{2+}/\text{Mg}^{2+}$ for the shallow aquifer waters. From the above, it is evident that Magnesium is the major contributor of water hardness sodium concentration ranges from 0.4 to 4.2 mg/L.

Sawyer and Ma Carty (1967) indicated the importance of sodium in irrigation water. Sodium reacts with the soil to reduce its permeability and restricts water entry into the soil. Very low concentration of chloride was recorded in the entire area (4 to 7mg/L) the recommended maximum limit by WHO, 1984 is 250mg/L.

Mark (1981) noted that most excess chloride concentration may be due to contamination from excretion products (livestock and human defaecation). The total dissolved solids signify the mineral constituents dissolved in water. The major dissolved solids in the area arise due to calcium and magnesium ions. The range for the area is between 40 to 92 mg/L. The iron content is high in the whole area under study.

Iron forms rust (Ironoxide) deposits causing staining of plumbing fixtures, laundered clothes and manufactured products as well as imparting a metallic taste to water (WHO, 1984), Raymond (2000) noted that humic substances are products of natural vegetative decay and can retard the oxidation of ferrous iron. The high water table in the discharge low lying area promotes intensive vegetative cover which leads to the stabilization of iron two compounds. While magnesium is the dominant cation in the whole system, sulphates are the dominant anion in the shallow aquifer waters.

Comparison of the shallow and deep groundwater of the area

As has been noted earlier, pH range for the shallow water is 4.68-6.90, showing that the water is acidic to mildly acidic. The pH range for the deep water is 5.4 to 6.70 indicating that the deep groundwater is slightly less acidic than the shallow ones. While magnesium concentration is the same in both waters, sulphate dominates the shallow aquifer. The $\text{Ca}^{2+}/\text{Mg}^{2+}$ ratio for both the shallow and deep groundwater is the same yielding an average of 0.32 mg/L. Ca^{2+} and Mg^{2+} constitute a dominant facies in deep ground water, while $\text{Ca} - \text{Na}$ is the dominant facies in shallow waters. The shallow aquifer waters show a no magnesium anion concentration, while the deep groundwater is dominated by a no dominant type. The general trend shows that for deep aquifer waters, $\text{Mg}^{2+} > \text{Na}^+ > \text{Ca}^{2+} > \text{K}^+$ while the shallow aquifer shows that $\text{Mg}^{2+} > \text{Ca}^{2+} > \text{Na}^+ > \text{K}^+$. From the

above observations and comparing the two types of water based on domestic agricultural and industrial uses as well as their pollution indices, the water is ideal for agriculture, industry and domestic purposes, but requires treatment to reduce acidity, coliform presence and high iron content.

Conclusion and Recommendation

Comparism with WHO, 1984 for water quality standard indicates minor similarities and major differences in the two underground water systems. Areas. The high water table of the discharge low lying area facilitates contamination of the water resource by coliforms which is an indication of pollution by water pathogens. The area is a typical case of chebotarev sequence of ground water evolution. Deeper water boreholes should be encouraged in the discharge lowlying areas and modern water system of toilet facility should replace pit latrines used by the inhabitants of the area. The problem of high iron, acidity and coliform should be addressed.

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