

Assessment of the Chemical Characteristics of a Spring Water Source at Ife-Owutu, Ezinihite-Mbaise, Southeastern Nigeria.

Ibeneme, S.I.¹, Ukiwe, L.N.², Essien, A.G.¹, Nwagbara, J.O.¹,
Nweze, C.A.², Chinemelu, E.S.¹ And Ivonye, C.A.¹

¹Department of Geosciences, Federal University of Technology, Owerri, Imo State, Nigeria.

²Department of Chemistry, Federal University of Technology, Owerri, Imo State, Nigeria.

Abstract: - The chemical characteristics of the Giri Giri Nwanjoku Spring in Owutu Ezinihite-Mbaise, South Eastern Nigeria was investigated to carefully determine some basic geochemical constituents of the water source with a view to identifying those constituents whose concentrations are unacceptably high, compared with the maximum permissible level of a regulatory body and as such determine its wholesome portability for diverse usage. The resultant data conform to the Nigerian Industrial Standard (2007) and the World Health Organization (2006) Standard. The water source is generally neutral with an average pH of 6.85. However, the samples gave an average Calcium and Magnesium ion concentrations of 3.205mg/l and 0.82mg/l respectively and an average hardness (as CaCO₃) of 11.375mg/l, indicating that the water is relatively soft. The Stiff and Schoeller plots show at a glance the spatial variations of the chemical constituents of the spring with Tri-oxo-carbonate and Calcium dominating. From the Box and Whisker plot, the greater amount of the cations and anions lie within the second quarter of the box ranging from 0.01meq/l to 0.05meq/l indicating similarity in origin. The Piper trilinear diagram reveals an alkaline earth and weak acid group predominantly the Tri-oxo-carbonate and as such classified as Ca-(Mg)-Na-HCO₃ water facies which indicates portability. The Sodium Absorption Ratio (SAR) and Percentage Sodium (%Na) values of 0.27 and 34.20% respectively show that the water is good for Agricultural use. The Pollution Index (PI) value of 0.6 (which is less than the critical value of unity) shows that the spring water is not polluted. For industrial use, the Saturation Index (SI) value of -3.41 reveals that the water may lead to moderate corrosion if not properly treated.

Key Words: - Eyelet, Hydrogeochemistry, Saturation Index, Spring, Water Facies.

I. INTRODUCTION

Water is the most abundant molecule on Earth's surface. It can also be the most abundant natural resource on earth. It constitutes about 75% of the Earth's surface. Water is a vital component of life for both plants and animals. It is available in forms of rain and snow thereby making rivers, oceans, streams, lakes, springs etc. A spring can be described as any natural occurrence where water flows on to the surface of the earth from below the surface. Some springs discharge where the water table intersects the land surface, but also they occur where water flows out from caverns or along fractures, fault or rock contacts that come to the surface. Spring may result from karst topography where surface water has infiltrated the earth's surface (recharge area), becoming part of the area's ground water that travels through a network of cracks and fissures/openings ranging from intergranular spaces to large caves. The water eventually emerges from below the surface, in the form of spring. The forcing of the spring to the surface can be the result of a confined aquifer in which the recharge area of the spring water table rests at a higher elevation than that of the outlet. The Giri Giri Nwanjoku spring occurs at the scarp face of the Umuosita-Awaka mini-escarpment. This spring serves as water source for the inhabitants of the area who utilize the water for their daily activities. Hence there arose the need to assess the quality of this spring to make recommendations where necessary.

II. AIMS AND OBJECTIVES OF THE STUDY

The principal aim of the study is to carefully determine some basic geochemical constituents of the water source within the study area with a view to identifying those constituents whose concentrations are unacceptably high and anomalous, compared with the maximum permissible level of a regulatory body and as such determine its wholesome portability for diverse usage.

III. LOCATION, PHYSIOGRAPHY AND GEOLOGY OF THE STUDY AREA

The study area is bounded by longitudes $7^{\circ} 16' E$ to $7^{\circ} 23' E$ and latitudes $5^{\circ} 26' N$ to $5^{\circ} 32' N$ (Fig. 1). The area is located within the Anambra/Imo river basin. Ife-Owutu is located within Ezinihitte Mbaise Local Government Area of Imo state, south eastern Nigeria and is accessible through diverse road networks. The study area lies within the tropical rain forest region of Nigeria. The region has four dry months in which precipitation is less than 60mm, while the annual total rainfall ranges between 1800mm and 2600mm. The mean temperature of the area is about $80^{\circ} F$ [1]. The vegetative cover of the area is mainly shrub, rain forest and savannah vegetation. It is dominated by grass species. The drainage pattern is dendritic. Geologically, Ife-Owutu area is underlain by a sequence of sedimentary rocks belonging to the Benin Formation of Miocene to Recent age. It comprises of a thick sequence of poorly consolidated to unconsolidated sandstones that are friable with sorting ranging from poorly to fairly sorted [2]. Several grain sizes occur within the unit and the coarse and fine unit alternate along the vertical sequence. The thick sandy units are frequently separated by thin and discontinuous clay streaks and lenses. The clay beds are thin (less than 1m) and sometimes occur as lamination lining the bedding plane of the unconsolidated sandstone beds. The Formation starts as a thin edge at its contact with the Ogwashi/Asaba Formation in the north of the area and thickens southwards [3]. The Formation across the whole Niger Delta is about 90% sandstone with minor shale intercalations.

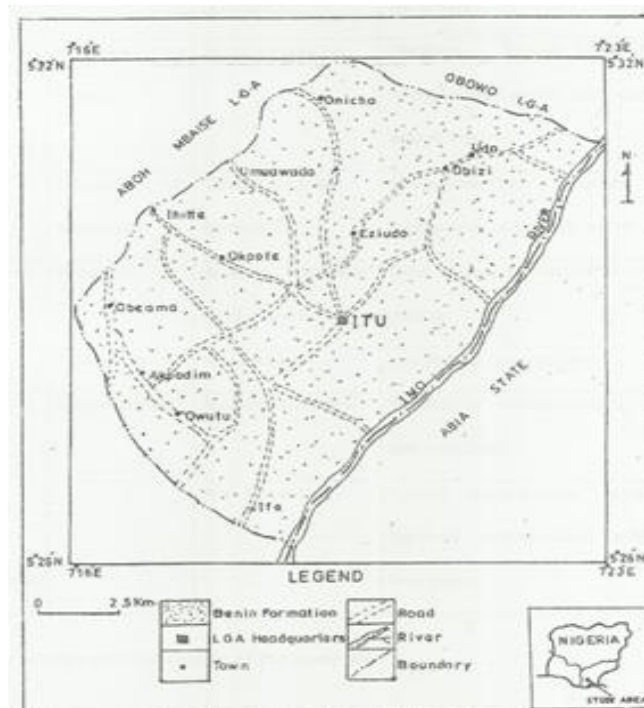


Figure 1. Geological map of the study area.

IV. METHODOLOGY

Water sampling was carried out from two different eyelets (hair-like openings from which water oozes out of a rock) of the spring and labeled GE I and GE II. The location of studied spring was taken with the help of GARMIN GPSmap76CSx. The water samples were collected into 1 L polyethylene bottles which were pre-cleaned with concentrated hydrochloric acid and distilled water. pH and temperature of the water samples were measured on-site with a Thermo electron Corporation Orion 3 Star pH Benchtop. This was also done to avoid unpredictable changes in characteristics as per the standard procedure [4]. Sampling protocols according to [5] and [6] were adopted. Total dissolved solids (TDS), electrical conductivity (EC) or specific conductance and resistivity of collected water samples were measured using Delta Ohm HD 2306.0 conductivity meter. All the water samples were preserved in a refrigerator to exclude microbial activity and unwanted chemical reaction until analysis was completed within 2 days. The determinations of other physico-chemical properties of the

water samples were performed within 2 days of sampling. HACH DR 2800 Spectrophotometer was used in the determination of different hydro geochemical properties such as Na, K, HCO₃, Cl, NO₃, and SO₄. Analytical water test tablets prescribed for HACH DR Spectrophotometer 2800 using procedures outlined in the HACH DR 2800 Spectrophotometer manual were used for the examination of the water quality. Other analyses such as the determination of Mg and Ca concentrations were done by complexometric titration method. The analytical data quality was evaluated by computing the sum of the equivalents of the cations with the sum of the equivalents of the anions [7]. A positive result means that both an excess cations or insufficient anion exists, and a negative result means the opposite. For freshwater, ionic balance is assumed to be good if it lies within the range of $\pm 10\%$ [8]. In this study, ionic balance values ranged from -0.92 to + 0.22%. Table 1 displays the result of the hydro geochemical analysis of the spring water sample, along with the Nigerian Industrial Standard [9] and World Health Organisation Standard [10]. Such drinking water standards are generally based on two main criteria [11]: (1) presence of objectionable taste, odour, and colour and; (2) presence of substances with adverse physiological (health-effect) characteristics.

Table 1. Result of the hydrogeochemical analysis of the spring water samples, compared with the Nigerian Industrial Standards (NIS 2007) and World Health Organization Standard (WHO 2006).

PARAMETER	GE I	GE II	GE MEAN	NIS 2007	WHO 2006	UNDESIRABLE EFFECTS AT HIGHER LEVELS
Temperature	26	24	25	Ambient	25	
pH	6.8	6.9	6.85	6.5-8.5	6.5-8.5	High pH-Corrosion; Low pH-Taste/Soapy feeling.
Colour (TCU)	5.0	5.5	5.25	15	15	Appearance.
Turbidity (NTU)	3.0	5.0	4.0	5	5	Appearance.
Conductivity	50.0	62.0	56.0	1000	100	-
T.D.S (mg/l)	25.5	20.4	22.95	500	500	Taste.
T.S.S(mg/l)	7.0	9.0	8.0	-	-	-
Calcium(mg/l)	3.6	2.81	3.21	100	75	Scale Formation.
Magnesium(mg/l)	0.89	0.75	0.82	0.2	<30	Hardness and Gastrointestinal Irritation.
Potassium(mg/l)	0.95	1.23	1.09	200	200	-
Sodium(mg/l)	2.17	1.98	2.08	200	200	Taste.
Sulphate(mg/l)	0.45	0.37	0.41	100	250	Taste and Corrosion.
Nitrate(mg/l)	0.10	0.08	0.09	50	10	Physiological problems.
Chloride(mg/l)	0.69	0.83	0.76	250	200	Taste and Corrosion.
Bicarbonate(mg/l)	18.74	25.6	22.17	500	500	-
Hardness as CaCO ₃ (mg/l)	12.65	10.10	11.37	150	200	High-Scale deposit and scum formation; Low-Possible corrosion.

Table 2. Concentration of the major Cations and Anions in (meq/l)

PARAMETER	Concentration (meq/l)
Calcium(mg/L)	0.1599
Magnesium(mg/L)	0.0675
Potassium(mg/L)	0.0279
Sodium(mg/L)	0.0903
TOTAL	0.3456
Sulphate(mg/L)	0.0085
Nitrate(mg/L)	0.0015
Chloride(mg/L)	0.0214
Bicarbonate(mg/L)	0.3633
TOTAL	0.3947

V. RESULTS AND INTERPRETATION

The major parameters measured in water samples collected from the study area include hardness, Total Dissolved Solids, Temperature, Colour, Concentration of the major cations and Concentration of the major anions. The mean values were compared against the Nigerian Industrial Standard for Drinking water Quality (2007) and the World Health Organization Standard for drinking water (2006) to determine its potability.

The pH is a parameter that indicates the acidity of a water sample. The operational guidelines [NIS (2007) and WHO (2006)] recommended that drinking water is to maintain pH between the values of 6.5 to 8.5.

The idea behind controlling the pH is to produce water that is neither acidic nor excessively basic. From the results of the analysis carried out, the mean pH value of the water sample is 6.9 which falls within the limit. The mean colour value of the water sample is 5.25 TCU which is within the range of the maximum permitted levels set by the regulatory bodies. Higher concentration affects the appearance of the water. The mean turbidity of the water samples is 4.00 NTU and conforms to the standards. Higher concentrations of turbidity also affect the appearance of water. Total Dissolved Solids (TDS) refers mainly to the inorganic substances dissolved in water. The mean TDS value of 22.95 mg/l lies within the allowable limit. The mean value of Calcium concentration obtained from the water sample is 3.205mg/l while the maximum concentration level set by the WHO 2006 is 75mg/l. This means that the calcium content is minimal though it has the highest concentration among the cations analyzed (Fig. 2). The problem with high concentration of Calcium in water is that it leads to scale formation and hardness. Magnesium has a mean value of 0.82mg/l and it falls within the range of the WHO 2006 standard which is less than 30mg/l. High concentrations of Magnesium leads to water hardness and gastrointestinal irritation. Potassium has a mean concentration value of 1.09mg/l and it falls within the range of 200mg/l set by the regulatory bodies (NIS 2007 and WHO 2006). The presence of Potassium in water may be due to agricultural activities. Sodium has a mean concentration value of 2.075mg/l which falls within the range of 200mg/l set by the NIS 2007. High levels of Sodium in water are noticeable in the taste of the water. The Sulphate content in the water sample gave a mean value of 0.41mg/l which meets the standard set by the NIS 2007 of 100 mg/l. High concentration of Sulphate lead to taste in water and corrosion. A major percentage of Nitrates in water originates from organic sources or from industrial and agricultural chemicals [12]. The Nitrate content in the water samples gave a mean value of 0.09 mg/l which falls within the range set by the regulatory bodies. High concentration of Nitrate leads to physiological problems. Chloride is a common non-toxic material present in small amounts in drinking water and possesses a detectable salty taste. The mean Chloride ion concentration of the water samples is 0.76 mg/l which is within the range set by the regulatory bodies. The Bicarbonate content concentration from the analysis gave a mean value of 22.17 mg/l. This is the most dominant anion in the spring (Fig. 3).

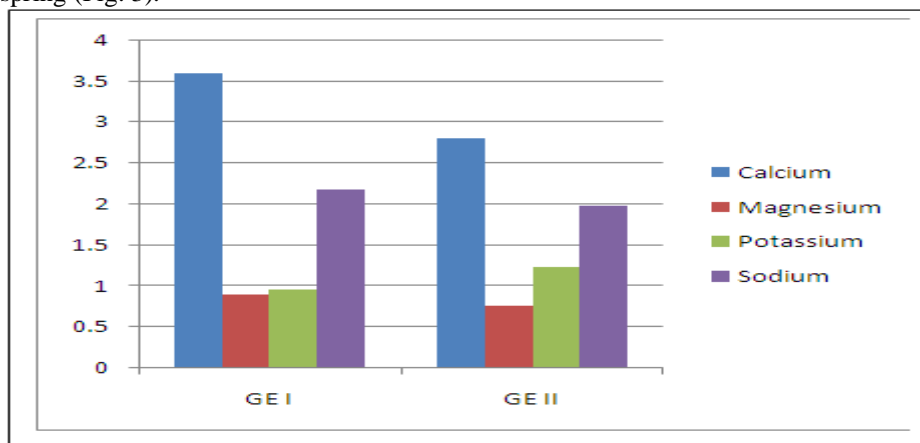


Figure 2. Cation concentration (in Mg/l) of the spring water.

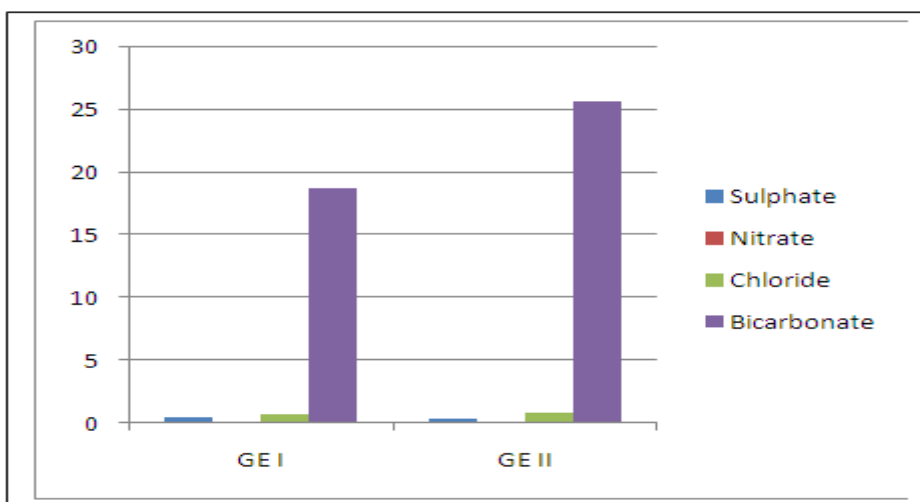


Figure 3. Anion concentration (in Mg/l) of the spring water.

The classification of water for agricultural purposes is based on specific conductance expressed as Total Dissolved Solids (TDS), Sodium content and Boron concentration [13]. The Sodium content can be said to be the most important element used to determine water quality for the basis of agriculture because it is the reaction of sodium with soil that determines soil's permeability.

To determine the Sodium content, a formula called the Sodium Absorption Ration (SAR) is used:

$$SAR = \frac{[Na^+]}{[Ca^{2+} + Mg^{2+}]^{1/2}} \dots\dots\dots(1)$$

After determining the SAR, a table adapted from [13] (Table 3) was used to classify the SAR value so as to determine the water class for agricultural purposes.

Table 3. Water Classification for Agricultural purposes (Adapted from [13]).

SAR	WATER CLASS (for agricultural purposes)
0 - 10	Excellent
10 - 18	Good
18 - 26	Fair
> 26	Poor

The SAR is 0.27; so from Table 3, the water falls within the excellent range (0-10), indicating that the water is very good for agricultural purposes. The Stiff (Fig. 4) and Schoeller (Fig. 5) plots are generated using the milli equivalents per litre (meq/l) values of the parameters of the samples collected (Table 2). These values are plotted against their various corresponding parameters and show at a glance the distributions of these parameters. A Box and Whisker plot is equally done using the milli equivalent per liter (meq/l) values of the major cations and anions present in the water samples (Fig. 6). It shows the degree of clustering of the dominant species. The parameters of the spring are observed to concentrate within the second quarter of the box ranging from 0.01meq/l to 0.05meq/l indicating similarity in origin. From the Piper's trilinear diagram, the spring water sample falls within the region that indicates the dominance of alkaline earth and weak acids and the water facies classified as Ca-(Mg)-Na-HCO₃ water (Fig. 7). Water of this facies is generally portable for domestic use.

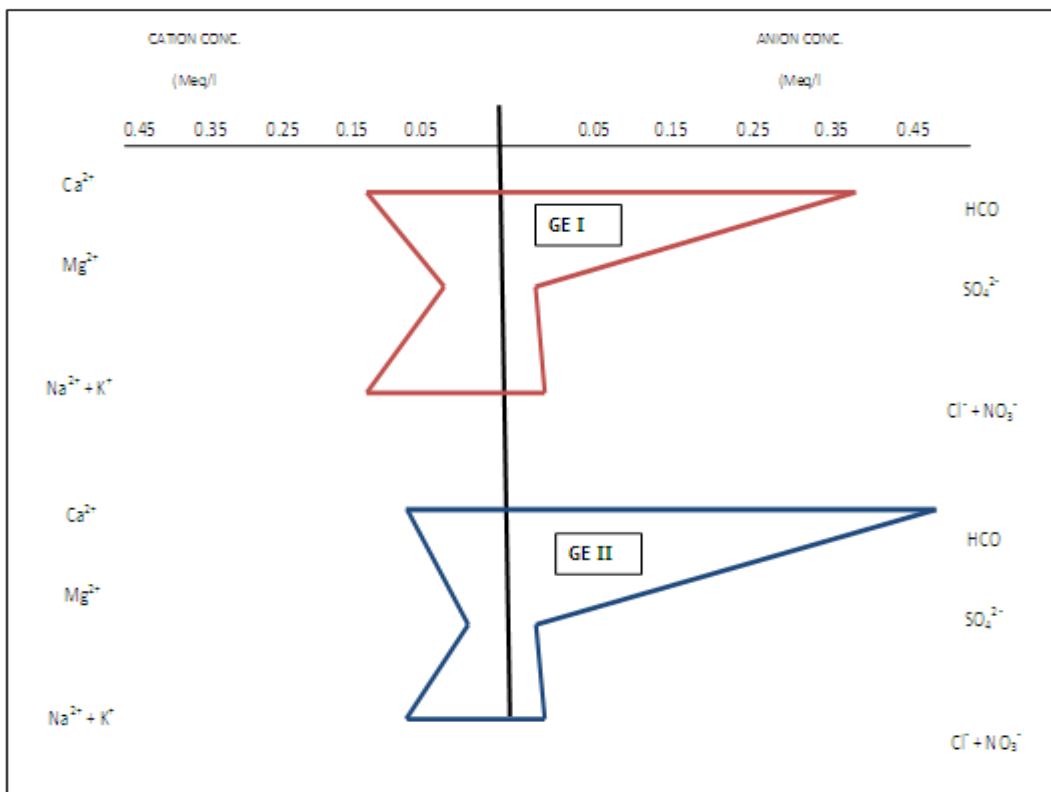


Figure 4. Stiff Diagram displaying the relative concentrations of the Cations and Anions.

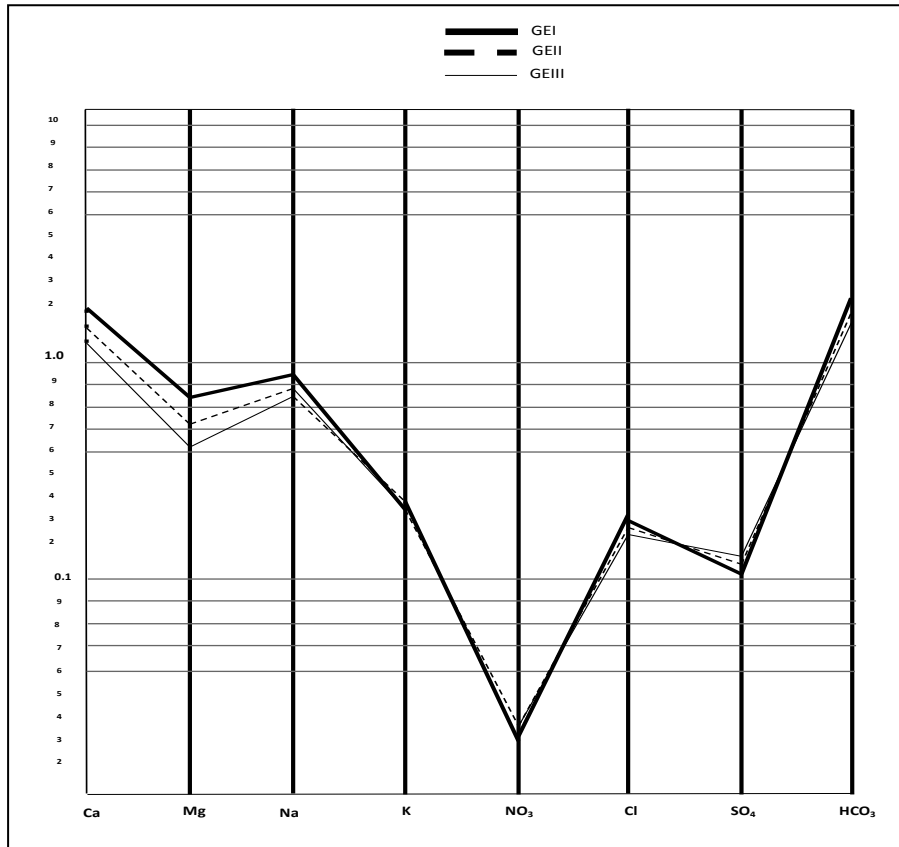


Figure 5. Schoeller Plot showing the relative concentrations of the Cations and Anions.

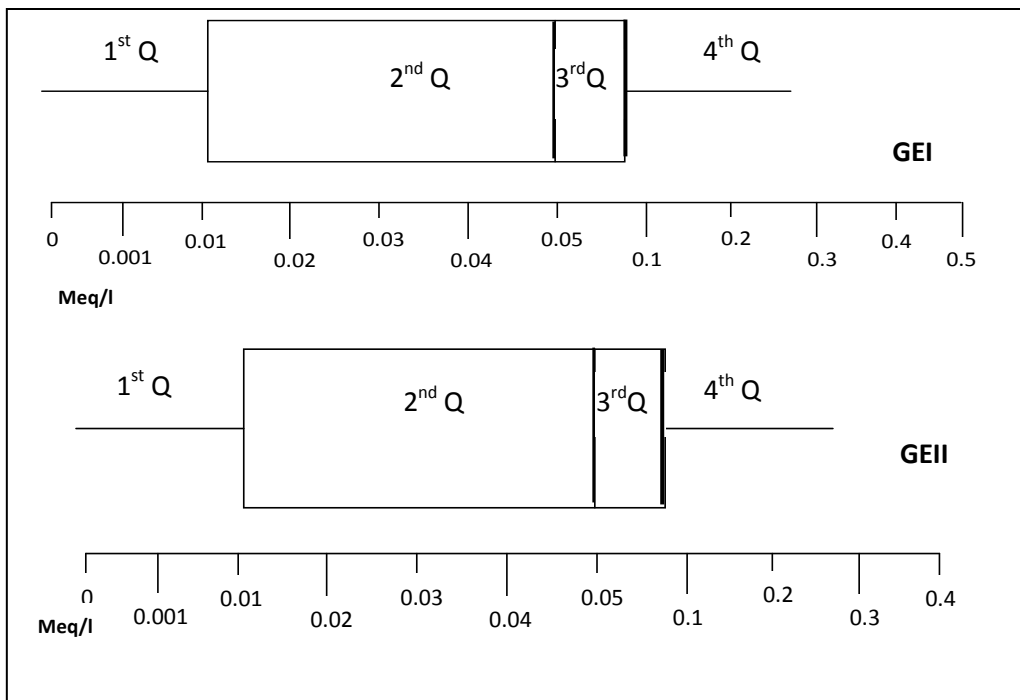


Figure 6. Box and Whisker plot of the spring water parameters.

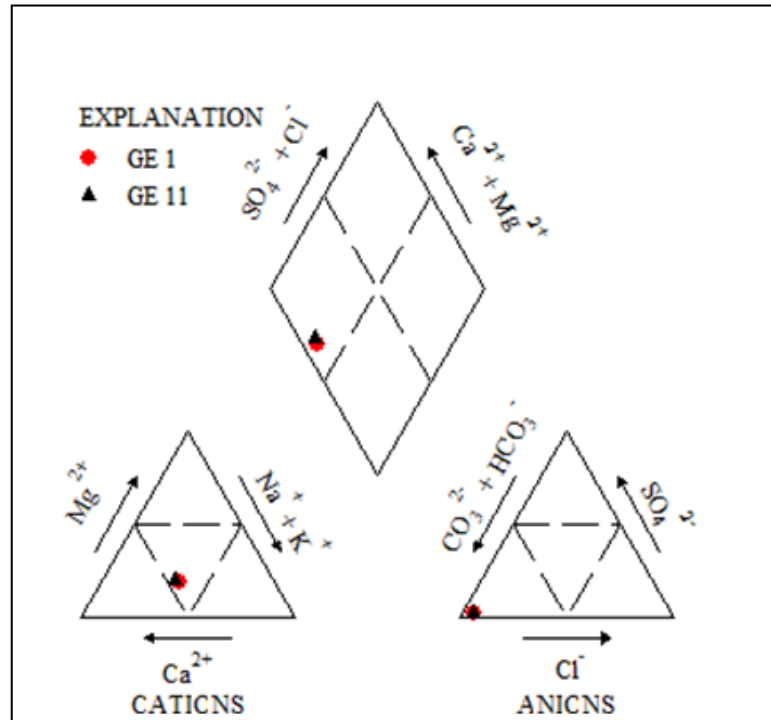


Figure 7. Piper Trilinear Diagram of the spring water samples.

To further assess the portability of the spring water source, the pollution index was determined using the relation proposed by [18]:

$$PI = \frac{\sqrt{I \text{Max}(G_{ij}/W_{ij})^2 + [\text{Mean}(G_{ij}/W_{ij})]^2}}{2} \dots\dots\dots (2)$$

Table 4. Data for calculating the Pollution Index of the Spring water.

PARAMETER	MEAN VALUE (G _{ij})	WHO 2006 (W _{ij})	(G _{ij} /W _{ij})
P ^H	6.58	6.5-8.5	0.810
Turbidity	4.00	5	0.800
Conductivity	56.00	100	0.560
T.D.S	22.95	1000	0.023
Calcium	3.21	75	0.043
Magnesium	0.82	<30	0.027
Potassium	1.09	200	0.005
Sulphate	0.41	400	0.001
Nitrate	0.09	10	0.009
Chloride	0.76	200	0.004
TOTAL			2.282
MEAN		2.28/10	0.228

The Pollution Index (PI) calculated using (2) above gave a value of 0.6. This value, which is less than the critical value of unity, shows that the spring water is not polluted.

The Langelier Saturation Index (SI) is a means of evaluating water quality data to determine its tendency to form a chemical scale [19].

The Saturation Index is;

$$SI = P^H - P^H_s \dots\dots\dots (3)$$

Where;

P^H = the actual P^H measured in the water sample

P^H_s = the P^H at saturation in Calcite or Calcium Carbonate and is defined as:

$$P^H_s = (9.3 + A + B) - (C + D) \dots\dots\dots (4)$$

Where;

$$A = (\text{Log}_{10} [\text{TDS}] - 1) / 10 \dots\dots\dots (5)$$

$$B = -13.12 \times \text{Log}_{10} (\text{Temperature} + 273) + 34.55 \dots\dots\dots (6)$$

$$C = \text{Log}_{10} [\text{Ca}^{2+} \text{ as Calcium Carbonate}] - 0.4 \quad \dots\dots\dots (7)$$

$$D = \text{Lo}_{10} [\text{Alkalinity as Calcium Carbonate}] \quad \dots\dots\dots (8)$$

With these relations, and combining (3)-(8), the Saturation Index (SI) was obtained as -3.41. This value is compared against table 5 below.

Table 5. Quality Classification of water for industrial purposes

SATURATION INDEX	DESCRIPTION	GENERAL RECOMMENDATION
-5	Severe Corrosion	Treatment Recommended
-4	Severe Corrosion	Treatment Recommended
-3	Moderate Corrosion	Treatment Recommended
-2	Moderate Corrosion	Treatment may be Needed
-1	Mild Corrosion	Treatment may be Needed
-0.5	None-Mild Corrosion	Probably no Treatment
0	Near Balance	No Treatment
0.5	Some Faint Coating	Probably no Treatment
1	Mild Scale Coating	Treatment may be Needed
2	Mild to Moderate Coating	Treatment may be Needed
3	Moderate Scale Forming	Treatment Advisable
4	Severe Scale Forming	Treatment Advisable

From table 5, the ideal range for the saturation index is -0.5 to 0.5, values below -0.5 are considered corrosive while values higher than +0.5 indicate the formation of scales.

VI. CONCLUSION

From the results obtained, it indicates that the concentrations of the constituents are within the recommended range as provided by the Nigerian Industrial Standard (2007) and WHO (2006) and as such good for domestication. The spring water is excellent for agricultural purposes sequel to the Sodium Absorption Ratio (SAR) value of 0.27 and the Percentage Sodium value of 34.20%. The spring water is not polluted because the pollution index value of 0.6 is less than the critical value of unity (1). The Piper plot indicates that the water samples in the study area belonged to Alkaline Earth group and classified as Ca-(mg)-Na-HCO₃ facies. The Saturation Index of - 3.41 revealed that the spring water needs some sort of treatment before put into industrial use to avoid moderate to severe corrosion.

REFERENCES

- [1] P. E. S. Inyang, Climatic Region in Ofomata G.E.K. (ed), *Nigeria in maps, Eastern States* (Benin Nigeria Ethiope 1975) 22-29
- [2] A.C. Onyeagocha, Petrography and Depositional Environments of the Benin Formation, *Journal of Mining Geology 17 (2)*, 1980, 147-150.
- [3] A. A. Avobovbo, Tertiary Lithostratigraphy of Niger Delta, *Bull. Am. Assoc. Pet. Geol 62*, 1978, 295-306.
- [4] APPHA, Standard methods for the examination of water and waste water. *American Water Works Association, Water Environment Federation*, 1995.
- [5] M. Barcelona, J.P.Gibb, J.A. Helfrich, E.E. Garske, Practical guide for groundwater sampling. Champaign: *Illinois State Water Survey ISWS Contract Report 374*, 1985.
- [6] H. C. Classen, Guidelines and techniques for obtaining water samples that accurately represents the quality of an aquifer, *Lakewood: US Geological survey open file report 82-1024*, 1982, 49.
- [7] A.W.Hounslow, *Water Quality data analysis and interpretation* (New York: Lewis, 1995).
- [8] L. Celesceri, A.E. Greenberg, A.D. Eaten, Standard method for the examination of water and waste water, *American Public Health Association, Washington*, 1998, 134.
- [9] Nigerian Industrial Standard (NIS 554:2007), Nigeria Standard for Drinking water Quality, *ICS 13.060.20*, 2007, 15-19.
- [10] WHO, Guide line for Drinking Water Quality. World Health Organization, Geneva, *2nd Edition (2)* 2006, 281-308.
- [11] S. N. Davis and R.J.A. Dewiest, *Hydrology* (New York: John Wiley and sons, 1966).
- [12] R. Sugisaki, Water supply treatment and distribution (Englewood Cliffs, New Jersey: Prentice-Hall, 1978).

- [13] J.O. Etu-Efeotor, Preliminary Hydro geochemical investigation of subsurface waters in parts of the Niger Delta, *Jour. Min. Geol.* 18, (1), 1981, 103-106.
- [14] J.R. Stiff, L. E. Davis, A method for predicting the tendency of oil field water to calcium carbonate, *Pet. Trans. AIME* 195, 213, 1951.
- [15] H. Schoeller, Utility of the notion of the basic exchanges for the comparison of the water sources, *Fr. Soc. Geo. Journal* 5th Edition, 1953, 651-657.
- [16] G. E Box, D. R Cox, An Analysis of Transformation. *JRSS*, B26, 1964, 221-243
- [17] A.M. Piper, A Graphic Procedure in the Geochemical Interpretation of water Analysis. *Washington D.C, US Geol. Survey. ISBN ASIN: B0007H2Z36*, 1953.
- [18] R.K. Horton, An Index Number Rating system for rating Water quality, *J. Water pollution control federation* 37, 1965, 300-306.
- [19] W. F. Langelier, The Analytical Control of Anticorrosion water Treatment, *Journal of the American water works Association (AWWA)* 28 (10) 1936, 1500-1521.