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HYDROCHEMICAL CHARACTERISTICS AND QUALITY ASSESSMENT OF GROUNDWATER FROM SHALLOW WELLS IN GBOLOKO AREA, CENTRAL NIGERIA

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ABSTRACT

Physiochemical assessment of shallow groundwater in Gboloko area was carried out to determine its suitability for drinking and irrigation purposes. Eighteen (18) groundwater samples were collected from different rural communities' wells and subjected field measurements of physical parameters followed by chemical analyses using ICP-MS, ICP-ES, Calorimetry and Turbimetry methods. The results show that pH of the groundwater ranged from 5.1 to 8.6 (mean 6.6) which indicates the groundwater is slightly acidic and slightly alkaline. EC and TDS varied from 60 to1367mg/L (mean 277.4mg/L) and 53 to 995mg/L (mean 206.5mg/L) respectively. The concentration of major cations were in the order of Ca^{2+}>Na^{+}> Mg^{2+}> K^{+} while that of anion were in the order of HCO_3^->Cl^-> SO_4^-> NO_3^- .Five hydrochemical facies were delineated from Piper plot; they are $CaHCO_3$, $CaNaHCO_3$, CaMgCl, CaCl, and $NaHCO_3$ water type. $CaHCO_3$ water is the dominant facies which represents water of recharge zone while CaNaHCO3 and CaCl are the least. The presence of NaHCO3 CaNaHCO3, and CaMgCl water type shows hydrochemical processes such as ion exchange and linear mixing. The drinking water quality assessment indicates the values for all the hydrochemical parameters are within the maximum permissible standard by WHO, 2006 except for two locations where nitrate concentrations are above the guideline value. The nitrate contamination observed at those locations may be attributed to leachates from domestic wastes and agricultural activities. Although nitrate contamination was expected to be rampant in groundwater of the area Irrigation water quality indices showed that the groundwater is ranged from mostly suitable to unsuitable.

KEY WORDS: Groundwater quality, Gboloko, Hydrochemical Facies, Irrigation water

INTRODUCTION

Many rural communities in Nigeria, Africa and developing nations of the world depend largely on groundwater as source of water for domestic and agricultural needs. Unlike surface water, groundwater provides a reasonable constant supply that is not likely to dry up under natural conditions. Over the years, Gboloko and other communities around are known to be agricultural based and depend on groundwater mostly from shallow hand dug wells for their domestic water requirements as available surface water are being continuously contaminated by human activities through community waste discharge and grazing cattle, and some dry up during dry season. These communities access the groundwater through hand dug wells most of which are poorly completed and motorized boreholes provided by government agency, Rural Water Supply and Sanitation (RUWATSAN) and United Nation Children Education Fund (UNICEF).

Because of the shallow nature of the water wells and the increasing exploitation of groundwater in the area, groundwater in many places may have been contaminated by human wastes, and agricultural wastes as there are reports of water borne diseases such as typhoid fever, gastrointestinal diseases and guinea worm in the area. The need to evaluate the groundwater quality of the area for domestic and agricultural uses cannot be overemphasized. There are a number of works relating to hydrochemical characteristics and evaluation of shallow groundwater in a typical rural setting (Tijani and Abimbola 2003, Al-ahmadi and EL-Fiky 2009, Okogbue et al, 2012, Talabi and Tijani 2013, Ahamed et al 2013). This study, therefore is aimed at understanding the hydrochemical characteristics and evaluating the quality of the shallow groundwater system in Gboloko area.

DESCRIPTION OF THE STUDY AREA

The study area lies within latitude $6^0$45'N and $6^0$59'N and longitude $7^0$42'E and $7^0$50'E(Figure 1). Prominent towns and communities in the area are Gboloko, Shintaku, Emi-Atsumbe, Nyamkpo, Konu, Mozum, Kara and other smaller villages. The area has low to moderate relief with a few hills of elevation ranging from 100 to 900ft above

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sea level. The area is characterized by two distinct seasons namely, the rainy and dry seasons. The raining season commences in April and lasts till October, while the dry season is from November to March. The annual average rainfall ranges between 1000 to 1500mm while the mean annual humidity is about 70%. The annual average temperature is 27^0C with annual average sunshine hour of 6.7 per day. A high temperature of 30^0C to 34^0C is experienced in the area during the dry season of between November and February (Meteorological Department of Federal Ministry of Aviation, 2007).

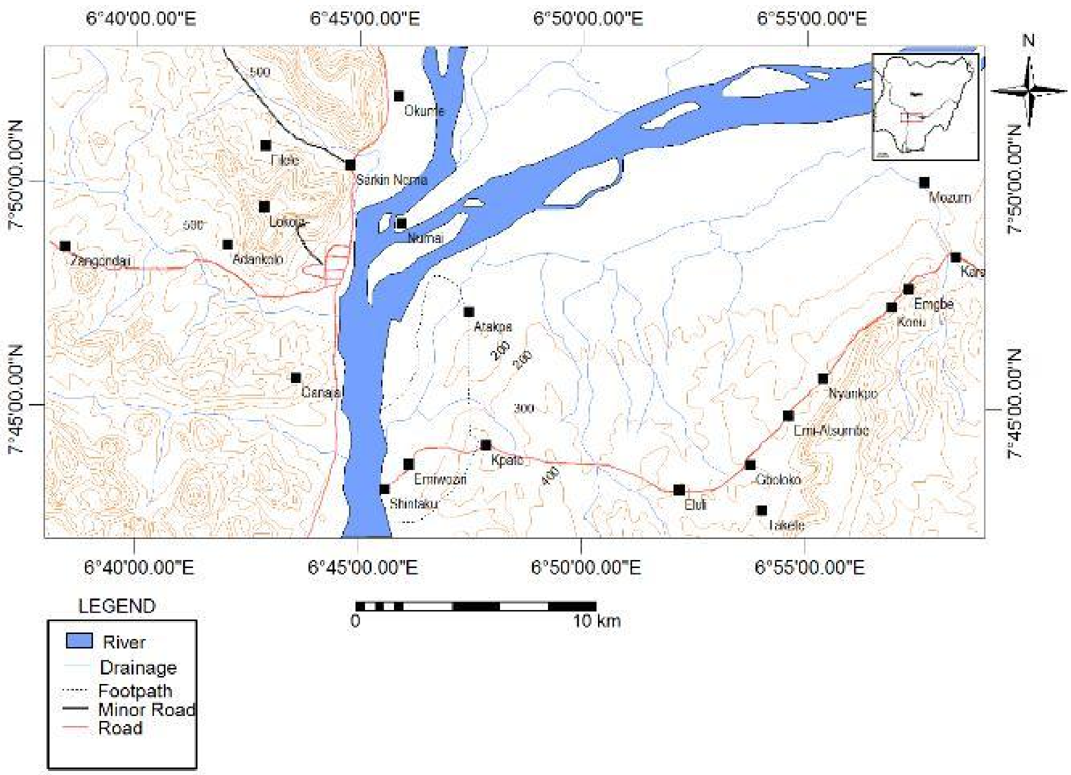

Figure 1: Topographic map of the study area showing the sample locations

Geographically, the study area falls within Guinea Savannah vegetation belt with denser (gallery) forest fringing some of the rivers and open savanna grass. The study area is poorly drained by River Nyatsu and its tributaries forming a dendritic pattern which flows eastward out of the study area. The tributaries of this river are flowing southward perpendicular to its flow direction.

GEOLOGY OF THE STUDY AREA

The study area is the Basement complex – Sedimentary transition zone where both crystalline and Sedimentary rocks are represented (Figure 2). The sedimentary portion consists

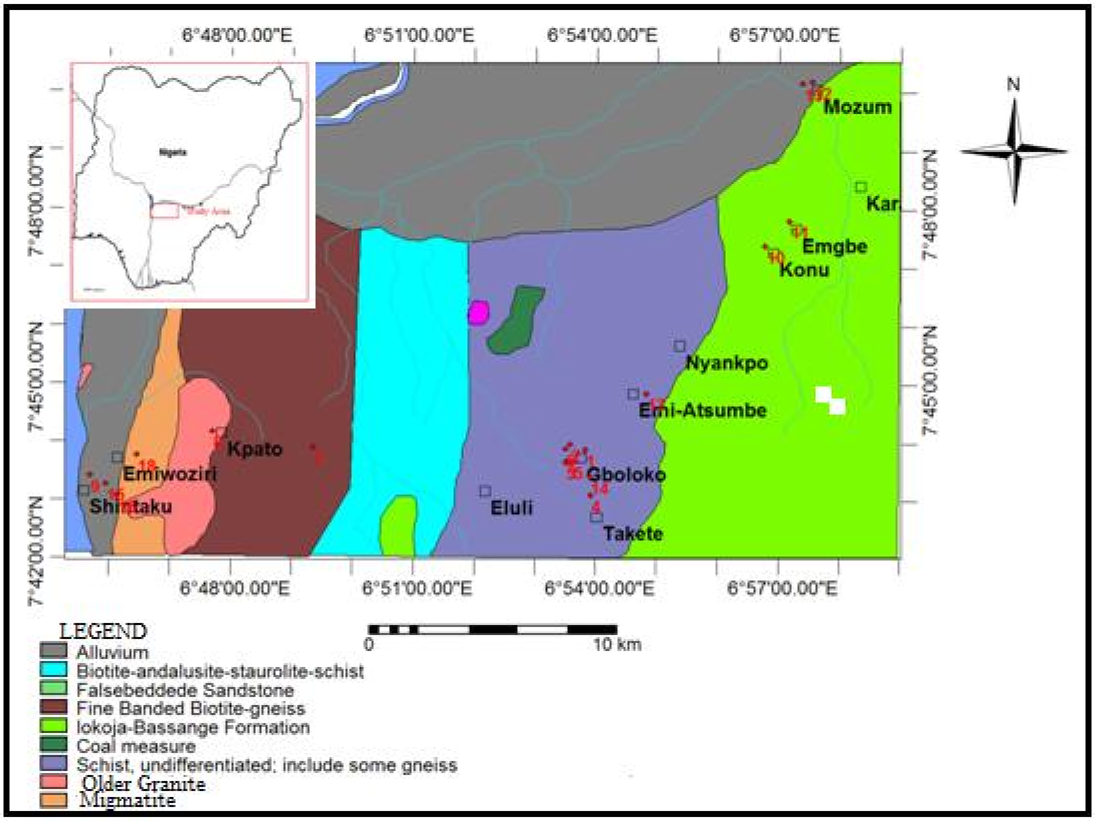

Figure 2: Geological map of the study area

of Quaternary - Recent River Alluvium and Cretaceous False-Bedded Sandstone. The False-Bedded Sandstone Formation consists of medium to fine grained poorly sorted invariably pebbly, white to yellow-brown conspicuously planner tubular cross bedded sandstone (Hockey and Sachi, 1986). The sandstones are poorly exposed but their morphology is conspicuous as they form gently sloping red sandy soil. To the east of the study area is the Lokoja-Bassange Formation. This formation is thought to be the equivalent of the Asata Nkporo Shale as defined along the eastern border of the Anambra basin, as both are overlain by the Lower Coal Measures. In the topmost part, the Lokoja-Bassange Formation contains carbonaceous materials and plant remains which make it difficult to distinguish this formation from the overlying Lower Coal Measures. The occurrence of glauconite and waxy clays has been taken as a diagnostic characteristic for the upper part of the Lokoja-Bassange Formation.

The basement complex portion of the area comprises mainly granite, gneisses and schists. The granite is coarsely porphyritic with biotite and hornblende usually forming the main ferromagnesian mineral content. The gneisses are characterized with fairly regular banding resulting from mineral segregation, in which predominantly light bands alternate with predominantly dark bands. Individual bands vary in thickness from a few millimeters to several centimeters. The schists include mica-schists, quartz-schists, and quartz-muscovite schist, in which the quartz is usually dominant over the muscovite. The quartz-muscovite schists are comparatively well exposed and form rounded hills or ridges due to resistant intercalated quartzite bands. Hockey and Sachi (1986) noted from field observation that the mineral contents of these rocks are biotite, quartz and feldspar. The rocks are broadly oriented in the north- south direction and marked by a sub-parallel alignment of elongated and closely packed feldspar phenocrysts, mainly microcline and a corresponding preferred orientation of biotite mica and iron

METHODOLOGY

In order to evaluate the hydrochemical properties of the shallow groundwater in the study area, a sampling survey was carried out. Eighteen (18) representative groundwater samples were collected from boreholes and hand dug wells. The plastic containers used for the collection of the water samples were rinsed with the sample to be collected prior to use. Temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH were determined in-situ using EC meter model 3084. Measuring these parameters in situ during sampling operation is to obtain physiochemical values which may not be accurately determined in the laboratory due to possible changes transportation (Tijani and Abimbola, 2003). The concentration of major Cations such as Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Iron (Fe), Barium (Ba) and Strontium (Sr) were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and while Inductively Coupled Plasma Emission Spectrometer (ICP-ES) was used to confirm higher concentrations. Solutions containing a high amount of total dissolve solids were diluted 10X prior to analysis with a corresponding increase in detection limits. While the concentration of major Anions such as Chloride (Cl), Nitrate (NO_3) and Bicarbonate (HNO_3) were analyzed by Calorimetric method, and Sulphate (SO_4) was analyzed by turbimetric. The analyses were carried out at ACME Analytical laboratory, Vancouver, Canada.

RESULTS AND DISCUSSION

Physicochemical characteristics

Results of the physicochemical field measurements and hydrochemical laboratory analyses of groundwater in the study area are presented in Table 1. From the table, temperature ranged from 25.1 to 31.2^{0}C with a mean value of 29.1^{0}C. The pH of ranged from 5.1 to 8.6 with a mean of 6.6 which indicates that the groundwater varied between weak acid and weak alkaline. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) varied from 60 to 1367mg/L with a mean value of 277.4mg/L and 53 to 995mg/L with a mean value of 206.5mg/L respectively. The TDS is generally low in the study area, that is, all the values are <500mg/L except location L10 which has the value of 995mg/L. The high value of TDS observed in this location can be attributed to the influence of poor hygienic practices within the location. Groundwater from the area generally are freshwater type as all the sampled water have TDS values below 1000mg/l. Total Hardness (TH) of groundwater samples of the study area is varied between 20.2 and 404mg/L with a mean value of 90.6mg/L. TH in the area is generally <150mg/L except for locations L9 and L10 with values of 264mg/L and 404mg/L respectively. The high values in these locations can be attributed to the influence of bedrock geology and anthropogenic activities in these areas. Hardness of water is the amount of calcium and magnesium, and iron to a lesser extent in water commonly expressed as milligram of calcium carbonate equivalent per liter. According to Sawyer and McCarty (1967) water containing calcium carbonate <75mg/L is considered as soft, 75-150mg/L as moderately hard, 150-300mg/L as hard and >300mg/L as very hard. The classification of groundwater based on TH reveals that 13 groundwater samples (L2, L3, L4, L5, L6, L7, L11, L12, L13,L14, L15, L16, and L18) fall within the soft water class, samples L1 and L8 fall in the moderately hard class, samples L9 and L17 fall in the hard class and sample L10 falls in the very hard class. The concentration of major cations were in the order of Ca> Na > Mg > K with mean values of 1.572meq/l, 1.201meq/l, 0.872meq/l, and 0.404meq/l respectively while those of anion were HCO_3>Cl>SO_4> NO_3 with mean values of 1.178meq/l, 0.694meq/l, 0.282meq/l, and 0.205meq/l respectively.

Statistical analysis (correlation matrix) was employed to understand spatial control of the major ions concentrations and the relationship between TDS (a useful indicator of anthropogenic contamination) and major ions (Table 2). The concentrations of the major ions analyzed tend to increase with increasing TDS except with few anomalous locations. This suggests the impact of

Table 1: Overall physiochemical parameters of the Study Area

Sample ID	T^0C	pH	EC	TDS	TH	Ca	Mg	Na	K	Ba	Sr	HCO3	NO3	SO4	CL
L1	29.1	5.4	290	210	124	28.27	12.97	4.75	4.89	0.038	0.466	86	23.6	1.62	27
L2	29.3	5.1	130	101	47.9	10.78	5.11	2.4	7.76	0.027	0.168	116.2	10.9	0.62	9.3
L3	28	5.6	150	116	53.1	12.57	5.28	2.39	6.19	0.023	0.207	67.3	10.7	0.89	11
L4	29	6.7	190	143	44.2	12.3	3.28	21.71	4.87	0.031	0.256	45	7.3	4.9	21
L5	26.5	5.3	170	128	50	12.09	4.83	7.09	6.77	0.021	0.188	37.9	11	0.81	17
L6	28.8	6.3	90	68	33.7	10.25	1.98	5.82	6.85	0.013	0.111	110.5	5.2	1.18	5.2
L7	31.2	8.1	279	208	46.7	14.17	2.75	55.9	2.47	0.023	0.519	83.6	2	3.84	2.1
L8	25.1	8.6	210	156	83.8	19.12	8.77	14.61	3.84	0.009	0.086	68.9	2	1.84	4.5
L9	28.8	6.9	650	466	264	21.8	6.4	9.6	7.27	0.05	0.361	46	45.8	12.9	4.9
L10	29.7	7	1360	995	404	66.77	23.69	47.64	8.46	0.049	0.408	88.4	4.8	59.8	43
L11	30	8.6	116	86	20.2	5.6	1.51	57.33	2.56	0.046	0.242	57	2	6.01	7.3
L12	31.1	5.5	86	65	29.4	7.41	2.65	23.33	5.58	0.018	0.127	71.9	2	35.7	1.7
L13	26.8	6.4	240	174	20.2	83.7	26.9	50.8	5.05	0.065	0.129	30.6	71	8.2	78
L14	29	7	260	194	46.7	108.67	32.27	77.1	99.06	0.161	0.813	94.4	51.3	60.5	160
L15	28.8	5.8	60	53	27.4	27.3	12	46	85.22	0.012	0.214	60	13.8	8	17.4
L16	30.5	6.6	150	115	29.4	43	16.1	47	16.33	0.017	0.169	61.6	16	32.6	24
L17	31.1	7.9	520	386	278	76	21.4	18.9	8.9	0.036	0.126	86	3.12	6.6	5.2
L18	30.9	5.3	79	53	27.4	6.42	2.77	4.81	2.84	0.014	0.107	84.5	2	4.93	4.9
WHO	-	6.5-8.5	-	500	150	-	-	200	-	-	-	-	50	200	250
MIN	25.1	5.1	60	53	20.2	5.6	1.51	2.39	2.47	0.009	0.086	30.6	2	0.62	1.7
MAX	31.2	8.6	1360	995	404	108.67	32.27	77.1	99.06	0.161	0.813	116.2	71	60.5	160
MEAN	29.1	6.6	279.4	206.5	90.6	31.5	10.6	27.6	15.8	0.03	0.30	71.9	15.8	13.9	24.6

Table 2: Correlation matrix of physicochemical parameters in the study area

	Ba	Ca	Cl	HCO3	K	Mg	Na	NO3	pH	SO4	Sr	TDS
Ba		0.757	0.920	0.06	0.579	0.698	0.587	0.661	0.173	0.604	0.761	0.222
Ca	0.757		0.810	0.02	0.495	0.980	0.579	0.614	0.218	0.610	0.454	0.425
Cl	0.920	0.810		0.01	0.659	0.794	0.616	0.693	0.022	0.626	0.661	0.130
HCO3	0.063	0.028	0.019		0.104	0.011	-0.130	-0.344	-0.084	0.158	0.196	0.082
K	0.579	0.495	0.659	0.10		0.502	0.536	0.338	-0.052	0.453	0.517	-0.099
Mg	0.698	0.980	0.794	0.01	0.502		0.550	0.610	0.147	0.615	0.424	0.443
Na	0.587	0.579	0.616	-0.1	0.536	0.550		0.317	0.485	0.595	0.536	0.161
NO3	0.661	0.614	0.693	-0.3	0.338	0.610	0.317		-0.098	0.219	0.358	0.061
pH	0.173	0.218	0.022	-0.0	-0.052	0.147	0.485	-0.098		0.087	0.171	0.261
SO4	0.604	0.610	0.626	0.15	0.453	0.615	0.595	0.219	0.087		0.527	0.521
Sr	0.761	0.454	0.661	0.19	0.517	0.424	0.536	0.358	0.171	0.527		0.314
TDS	0.222	0.425	0.130	0.08	-0.099	0.443	0.161	0.061	0.261	0.521	0.314	

agricultural activities on groundwater chemistry through leaching of readily soluble salts from soil zone. TDS correlates positively with NO_3 (0.544) which indicates the influence of leachates of nitrate fertilizer use in agriculture and wastewater linkages. SO_4 is positively correlated with Cl (0.626) indicating that the two anions which are sewage pollution indicators where derived from the same source. In addition, Na^{2+} is correlated positively with Cl^-, Ca^{2+}, K^+ and Mg^{2+}. This positive correlation is an indication that the ions are controlled by the same geochemical factors or processes.

Hydrochemical facies

Piper Trilinear Diagram (1944) is used to infer hydrochemical facies. The diagram is made up of two triangles, one for plotting cations and the other for plotting anions. The cation and anion field are combined to show a single point in a diamond-shaped field, from which inferences is drawn on the basis of hydrochemical facies concept (Back and Henshaw, 1965). Five hydrochemical facies were delineated from the Piper trilinear plot of groundwater samples from the area (Figure 3), they are $CaHCO_3$, mixed $CaNaHCO_3$, mixed CaMgCl, CaCl and $NaHCO_3$ water type. The Piper diagram showed that there is no NaCl water type (III). Linear mixing process gives birth to water of non-dominant ion water type called mixed water types $CaMgHCO_3$ and $NaCaHCO_3$ that is, water types V and VI respectively. Ion exchange processes gives birth to the $NaHCO_3$ (Water Type II) which results from $CaHCO_3$ (Water Type I), that is, exchange of Na with Ca.

Durov Diagram which define the hydrological processes affecting the groundwater chemistry was also employed. From the Durov diagram (Figure 4), only two hydrochemical processes out of the three defined by the plot were observed to affect the chemistry of the groundwater of the area and these include, ion exchange processes and linear mixing. No reversed ion process and the reason being that for reversed ion exchange to take place, there must be saline water or salty water which is absent and this is also indicated by the Piper plot. Fields 1, 4, and 7 define ion exchange process while Fields 1, 5 and 9 define linear mixing Fields 3, 6, and 9 define reversed ion exchange process.

Domestic Quality Assessment

The drinking water quality is assessed by comparing the results of the physiochemical analysis of groundwater in the area with the standard guidelines recommended by the World Health Organization (WHO, 2006) as presented in Table 3.According to the WHO, 2006, no standard have been proposed for EC, calcium, magnesium, potassium and bicarbonate as their concentration in groundwater have no effect on health. However, the only standards that have been proposed for these parameters are based on taste. From table 3, it is observed that ten out of the eighteen samples

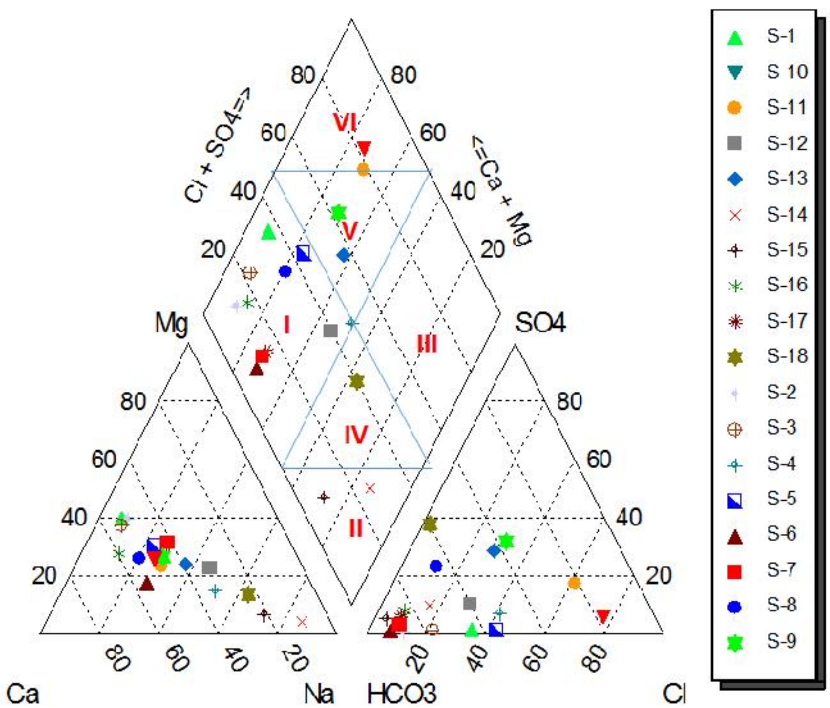

Figure 3: Piper diagram of the studied groundwater samples

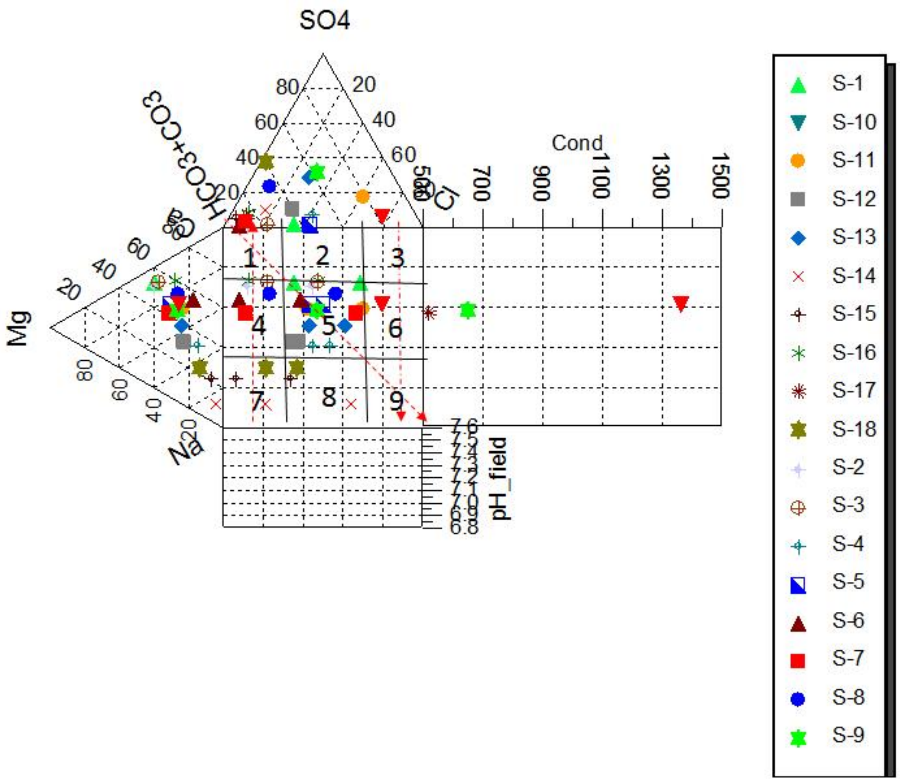

Figure 4: Durov diagram of the studied groundwater samples

have shown values outside the range proposed by WHO, 2006. Eight out ten samples with values outside the permissible range are slightly acidic while the other two samples are slightly alkaline water. For hardness and nitrate, two samples each have values above maximum permissible limit. All values for other parameters are all within the maximum permissible limit. Barring few locations, groundwater in the study area is generally suitable for drinking purposes.

Irrigation Quality Assessment

The suitability of groundwater quality for irrigation purpose depend on the effects of the composition of water on the plant and as well as the soil. The important chemical constituents that affect the suitability of water for irrigation are the total concentration of dissolved salts, relative proportion of Sodium, magnesium and relative proportion of sodium to calcium. Irrigation water quality indices were determined using different relationships with the anions and cations measured in milliequivalent per litre (meq/l) in order to evaluate the suitability of the groundwater of the area for irrigation purposes (Brindha and Elango 2011; Ayuba et al,

Table 3: Groundwater Quality of the Study Area.

Parameters	Range of values (mg/L)	Average(mg/L)	WHO, 2006 guideline (mg/L)	No. of sample with values more than WHO, 2006 maximum permissible limit
pH	5.1-8.6	6.6	6.5-8.5	10
EC	60-1360	279.4	-	-
TDS	53-995	206.5	100	0
TH	20.2-404	206.5	150	2
Ca^{2+}	5.6-108.67	31.5	-	-
Mg^{2+}	1.51-32.27	10.6	-	-
Na^{+}	2.39-77.1	27.6	200	0
K^{+}	2.47-99.06	15.8	-	-
HCO_3	30.6-116.2	71.9	-	-
NO_3	2-71	15.8	50	2
SO_4	0.62-60.5	13.9	200	0
Cl	1.7-160	24.6	250	0

2013). The overall summary of irrigation water quality indices in the study area is presented in Table 4.

Sodium Percentage (Na %): Sodium content of groundwater is an important factor in classifying irrigation water as sodium react with soil to reduce its permeability. Sodium ion tend to be absorbed by clay particles when the concentration of sodium in irrigation water is high, thereby displacing Ca^{2+} and Mg^{2+} ions. This exchange process of sodium in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage. Na % is determined by;

$$Na\% = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} Na^{+} + K^{+}} \times 100$$

Sodium percentage in the study area ranges from 18.9% to 89.4% with a mean of 49.5%. Based on Na% only one sample location has Na% less than 20% and it is classified excellent water type. Seven (7) samples representing 38.9% of the total samples have Na% of between 20 and 40% and

Table 4: Overall irrigation water quality for the study area

Location	Na%	SAR	RSC	PI	MH	KR
1	18.94654	1.479327	127.24	30.49276	31.45005	0.115179
2	39.00192	1.204146	132.09	72.05911	32.15859	0.151038
3	32.46311	1.131381	85.15	52.34021	29.57983	0.133894
4	63.04554	11.00034	60.58	76.20865	21.05263	1.393453
5	45.02924	3.447276	54.82	55.16992	28.5461	0.419031
6	50.88353	3.328432	122.73	90.48143	16.1897	0.475879
7	77.5269	27.17951	100.52	89.32066	16.25296	3.303783
8	39.81442	5.53294	96.79	53.9073	31.44496	0.523844
9	37.43066	3.615569	74.2	43.3395	22.69504	0.340426
10	38.27784	10.01783	178.86	41.30494	26.18837	0.526642
11	89.38806	43.00086	64.11	100.6825	21.23769	8.063291
12	74.18527	14.71112	81.96	95.26621	26.34195	2.319085
13	33.55362	9.660868	141.2	34.90194	24.32188	0.459313
14	55.55345	12.98875	235.34	39.81653	22.89627	0.547041
15	76.95285	14.67545	99.3	63.00817	30.53435	1.170483
16	51.72752	12.2274	120.7	51.69516	27.24196	0.795262
17	22.20447	3.830119	183.4	24.22495	21.97125	0.194045
18	45.42755	3.173345	93.69	100.0171	30.14146	0.523395

they are classified good water type. Five (5) samples representing 27.8% fall within 40 and 60% and four (4) samples representing 22.2% fall within 60 and 80% are classified as permissible and doubtful water type respectively. One sample location has Na% greater than 80% and it is classified as unsuitable water type (Table 5).

Table 5: Classification of Gboloko groundwater based on Na%

Range (%)	Class	Sample number	%
<20	Excellent	1	5.6
20-40	Good	7	38.9
40-60	Permissible	5	27.8
60-80	Doubtful	4	22.2
>80	Unsuitable	1	5.6

Sodium Absorption Ratio (SAR): SAR is important in assessing groundwater quality for irrigation purpose as high sodium content in irrigation water may increase soil hardness and reduces permeability (Tijani, 1994) thus inhibits the supply of water needed for crop growth. It is defined mathematically as;

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

SAR calculated for groundwater samples of the area varied from 1.1 to 43.0 with an average value of 10.0. SAR value greater than 10 is classified as unsuitable for irrigation purposes (Mandel and Shiftan, 1991). Ten (10) of the groundwater samples are suitable for irrigation purposes as their values are <10 while eight samples are unsuitable for irrigation purposes as their values are >10.

Classification based on US salinity laboratory (1954) showed that the groundwater samples from the area plotted in low (C1), medium (C2), and high (C3) salinity hazard while all the groundwater samples are plotted in low (S1) sodium hazard (Figure 5). Twelve (12) samples plotted in C1-S1 field indicating low salinity hazard and low sodium hazard. These ground waters can be used safely for irrigation in all types of soil. Five (5) samples plotted in C2-S1 field indicating medium salinity and low sodium hazard and a sample was plotted in C3-S1 field indicating high salinity and low sodium hazard. Samples in these two fields can be used on clay

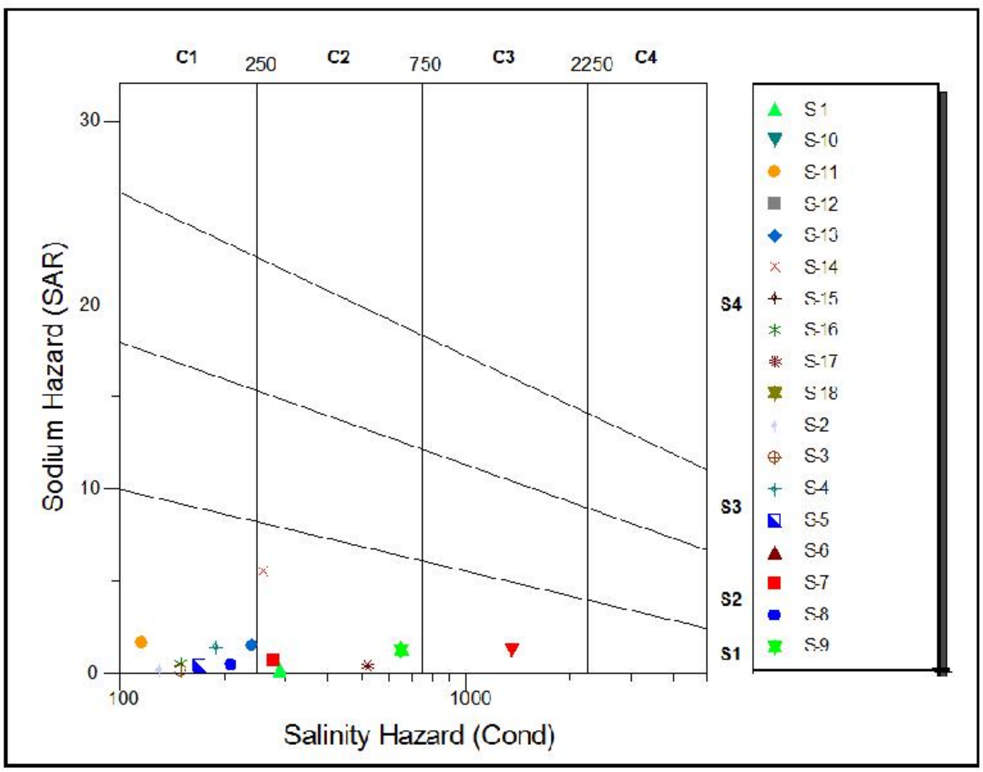

Figure 5: Wilcox diagram of the studied groundwater samples

soil but selection of the crop type depends on the salt tolerance which should be carried out prior to cultivation (EL-Alhamdi and EL-Fiky, 2009).

Magnesium Hazard (MH): Magnesium hazard defines the relationship between magnesium and calcium concentration in groundwater. Calcium and magnesium are essential for plant growth but they may be associated with soil aggregation and friability sometimes by destroying soil structure. Magnesium hazard is determined using the formula:

$$MH = \frac{Mg^{2+}}{(Ca^{2+} + Mg^{2+})} \times 100$$

Magnesium hazard ranged from 16.1 to 32.2% with a mean of 25.6%. The magnesium hazard calculated for groundwater sample of the study area revealed that the values are all below the guideline of 50% and thus, are considered to be safe and suitable for irrigation purposes (Kacmaz and Nakoman, 2010).

Residual Sodium Carbonate (RSC) equals the sum of the bicarbonate and carbonate ion concentrations minus the sum of the calcium and magnesium concentrations.

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

A negative RSC indicates that sodium build up is unlikely since sufficient calcium and magnesium are in excess of what can be precipitated as carbonates. A positive RSC shows that sodium build up in the soil is possible. In the study area, RSC ranged from 54.82 to 235.34. All the 18 groundwater samples are >2.50 (Table 6) indicating high RSC with most calcium and magnesium removed causing sodium to accumulate. The groundwater in the study area is unsuitable for irrigation purposes based on RSC.

Table 6: Groundwater quality based on RSC

Range (meq/l)	Water class	Sample number	%
<1.25	Safe	0	0
1.25-2.5	Moderate	0	0
>2.5	Unsuitable	18	100

Permeability Index (PI): Permeability of the soil is affected by high sodium as well as carbonate and bicarbonate contents in water. A part of CO_3^{-} and HCO_3 is precipitated as $CaCO_3$ or $MgCO_3$ removing Ca^{2+} and Mg^{2+} from irrigation water and leads to increased proportion of solution. Permeability hazard is determined by:

$$PI = \frac{(Na^{+} + (\sqrt{HCO_3^{-}})}{(Ca^{2+} + Mg^{2+} + Na^{+}} \times 100$$

Permeability index in the study area ranged from 24.22 to 100.68%. 7 groundwater samples representing 38.9% of the total samples have PI values of >75% permeability, 10 groundwater samples (55.6%) have >25% but <75% permeability and 1 groundwater sample has <25% permeability (Table 7).

Table 7: Groundwater quality based on PI

Range (%)	Class	Sample number	%
>75	I (>75% permeability)	7	38.9
25-75	II (>25% but <75% permeability)	10	55.6
<25	III (<25% permeability)	1	5.6

CONCLUSIONS

The physiochemical composition of groundwater system in Gboloko area was used to assess its suitability for drinking and irrigation purposes. The concentration of major cations were in the order of Ca^{2+}> Na^{+}>Mg^{2+}> K^{+} while that of anion were HCO_3^{-}>Cl^{-}> SO_4^{-}> NO_3^{-} .The drinking water quality assessment shows that ten (10) samples have pH values outside the range values recommended by WHO, 2006. This indicates that the groundwater is slightly acidic in eight samples and slightly alkaline in two samples. All values for hardness are within the maximum permissible except for two locations and nitrate also has all values except for two locations within the maximum permissible limit while values for all other parameters are within the limit. US Laboratory salinity diagram revealed that most samples were plotted in C1-S1 field indicating low sodium hazard and the groundwater is suitable for irrigation on all soils and few were plotted in C2-S1 and C3-S1 indicating that the groundwater is only suitable on clay soil and salt tolerant crop. The groundwater is generally ranged from good to doubtful based on sodium percentage, unsuitable based on residual sodium carbonate and suitable based on magnesium hazard. Five hydrochemical facies were delineated from Piper plot; they are $CaHCO_3$, mixed $CaNaHCO_3$, mixed CaMgCl, CaCl and $NaHCO_3$ water type. $CaHCO_3$ water is the dominant facies which results ion exchange processes. From the Durov diagram, only two processes affect the chemistry of the study area and these include, ion exchange processes and linear mixing. No reversed ion process and the reason being that for reversed ion exchange to take place, there must be saline water or salty water.

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