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Full Length Research Paper

Hydro-chemical study of groundwater from North-eastern parts of Gombe, North-eastern Nigeria

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Twenty groundwater samples were collected from hand dug wells in North-eastern parts of Gombe town for the purpose of evaluating its quality for culinary and agricultural uses. The area studied is bounded by latitude 11° 09' - 11° 27' and longitude 10° 15' - 10° 27' covering an area of about 940 Km^2. Quantitative analysis of the water samples was carried out using Atomic Absorption Spectrometry (AAS) and Flame photometry while RockWare Aq•QA spreadsheet for water analysis was utilized in the evaluation. Three water types were identified, CaCl, Ca - HCO_3 and NaCl. Total carbonate ranges from 27.393 - 239.27 mg/L and salinity hazard ranges from low to medium. The low salinity type of water identified has no detrimental effects on crop while for medium salinity waters, detrimental effects are expected on crops that are sensitive to salinity. Dissolved solid ranges from <200 and 200 - 500 mg/L respectively, Sodium Absorption Ratio (SAR), Exchangeable Sodium Ratio (ESR) and Magnesium Hazard (MH) ranges from 0.832 - 4.13, 0.292 - 3.968 and 0.086 - 82 respectively. The variation in the chemical composition of groundwater in the study area may be due to leaching of terrestrial salts mostly within the Gombe formation, extensive use of fertilizers and ion exchange between soil minerals and water. The examined groundwater quality is suitable for domestic and agricultural uses except in some locations from Gombe formations where detrimental effect is expected on crops that are sensitive to salinity.

Key words: Hydrogeology, sodium adsorption ratio (SAR), detrimental effect (DE).

INTRODUCTION

Water is essential to life and the largest available source of fresh water lies underground. As a result of this, different techniques for investigating the occurrence and movement of groundwater resources have been developed. Even with the discovery of vast amount of groundwater today, there is a great concern about groundwater depletion and contamination. There is a need to understand, protect and manage the groundwater resources of the study area.

Nearly all dwellers in the study area (Figure 1) rely on groundwater resource for their domestic supplies. The presence, depth and quality of groundwater resources are often difficult to imagine or understand. Hydro-chemistry of the study area is of great interest, because of the extent of reliance by the people on groundwater, whose availability and quality are directly influenced by the properties of the geologic formations within which it occurs. The physical and chemical nature of the ground-water reservoir varies from one area to another thereby creating a wide range of properties for water yield and quality. The variation in quality could be as a result of hydrochemical anomaly between the rocks of the different area and the water flowing through them or as a result of anthropogenetic activities in the area which could pose health hazards to both consumer and plants that are cultivated in the study area.

The geologic sequence in the study area from youngest to the oldest comprises the Kerri-Kerri Formation, the

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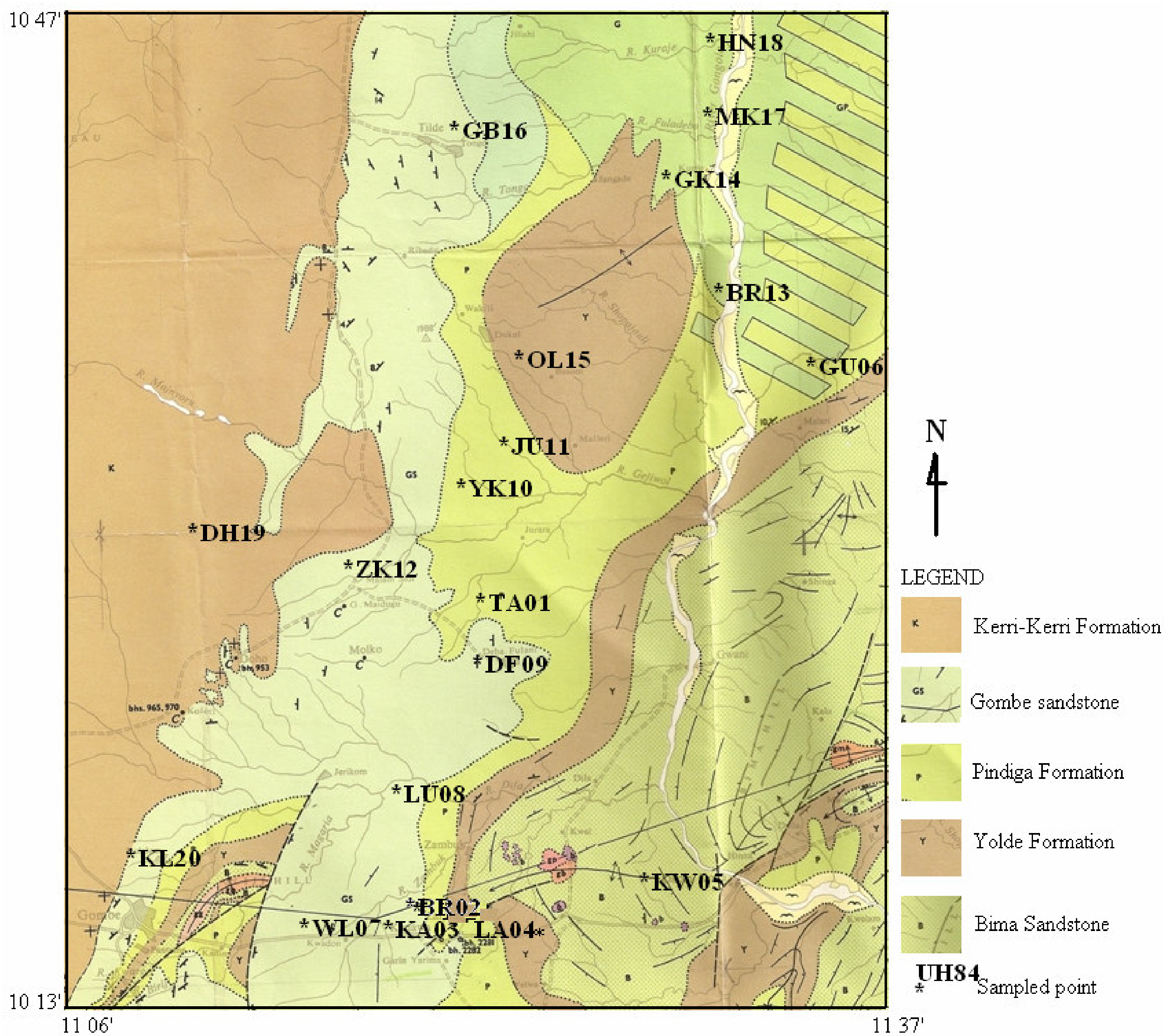

Figure 1. Geologic map of the study area (GSN, 1961).

Gombe sandstone, The Pindiga Formation, The Yolde Formation and the Bima sandstone.

KERRI-KERRI FORMATION

The Kerri-Kerri Formation was laid down in a continental environment ranging from lacustrine to deltaic, being derived from the weathering of the basement rocks as well as of Cretaceous Sedimentary Formations. It outcrops in the western part of the study area. The Kerri-Kerri Formation lies unconformably on the Gombe Formation. The contact between the two is being visible all along the eastern edge of the plateau. In the western part of the plateau, which coincides with the western edge of the study area, the Kerri-Kerri Formation overlies the basement complex, but the contact is almost completely masked by abundant alluvial deposits. The maximum thickness measured is about 200 m (Carter et al., 1963). The formation has not been subjected to folding and has the lowest fracture density of all the formations present in study area. This is probably dependent on the fact that is laid down after the main tectonic phase has occurred, and on the poorly cemented nature of the litho logical components of its upper part.

GOMBE SANDSTONE

The Gombe Sandstone outcrops in a narrow north south belt on the western part of the study area (Figure 1), it unconformably lies on shale and limestone of the Pindiga Formation and is unconformably covered by the Kerri-Kerri Formation. The Gombe sandstone is a continental sequence of sandstone, shale, siltstones and ironstones, having a maximum measured thickness of 300 m. The sequence can be divided into two parts: The Upper 223 m consists mainly of sandstones, the lower mainly of shale and contains ironstones layers up to 200 m thick (Carter, 1963).

PINDIGA FORMATION

The Pindiga Formation conformably overlies the Yolde Formation, while an unconformity separates it from the overlying Gombe Sandstone (Upper Maestrichtian). It outcrops and cuts across the study area in a north south direction, it is also in the southeast and the northeastern part. The Pindiga Formation consists of a series of marine, blue-black shale with interblended fossilferous limestone at the base.

YOLDE FORMATION

The Yolde Formation conformably overlies the massive coarse sandstones of the Bima Formation (Albian - Cenomanian) and is conformably bounded at the top by the marine shale of the Pindiga formation. The Yolde Formation is present in the study around the south east on the central area and in the Northern area, it constitutes the transition facieses between continental and marine sedimentation.

BIMA FORMATION

The Bima formation is the oldest, most extensive and thickest of the cretaceous sedimentary formations in the North East Nigeria, it outcrops in the Northwest and south of the study area (Figure 1).

The Bima formation rests directly on the Precambrian basement complex and is covered without any break by the Yolde Formation in the Zambuk ridge area. According to Carter, at Zambuk, the Bima formation consists of Yellow-brown, massive cross-bedded feldspathic sand stones, with some white saccharoid sandstones, ferruginous sandstones and pebble bands. The age of Bima formation is uncertain. However, various pointers indicate that it runs from Upper Albian to Lower Turonian.

According to Arabi (2009), the general information and data available and the result of hydrogeological reconnaissance, the Stratigraphic succession of the study area could be defined from the hydrogeological point of view as follows: (from top to the bottom).

(a) Recent deposits; generally permeable but do not provide sufficient ground water supply and are mainly dry except along river channels.
(b) Kerri-Kerri Formation: within are some aquifers, probably under both water table and confined condition at great depth.
(c) Gombe Formation: It presents some aquifers under both water table and confined condition.
(d) Pindiga Formation: generalized as aquiclude.
(e) Yolde Formation: This occurs as aquiclude with scattered water bearing horizons mostly in its lower part.
(f) Bima Formation: This occurs as aquifers under both water table and confined conditions.

For This study, twenty groundwater samples were analyzed using flame photometer and Atomic absorption spectrometry in order to determine its suitability for human usage in homes and agricultural purposes. The study will also save as an avenue to upgrade the knowledge of the Hydrogeochemistry of northeastern parts of Gombe, so that a better and well informed decision can be made about groundwater protection, management and utilization in the area.

MATERIALS AND METHODS

Twenty groundwater samples were collected from hand dug wells in the study area during the peak of dry season (April, 2009) for analysis of major, minor and trace elements. Prior to sample collection, a protocol was established and was strictly followed. This involves obtaining appropriate containers, and utilizing the appropriate methods of preservation in order to reduce the effect of adsorption or biodegradation. Sample were collected and transported in plastic containers and preserved by addition of acid to reduce adsorption of sample constituent to the container wall. The analysis of Na, K and Ca was carried out using CORNING FLAME PHOTOMETER 410, while the remaining major and minor elements listed in Table 1 were carried out using BUCK SCIENTIFIC 210VGP Atomic Absorption Spectrometer and the evaluation was carried out using RockWare Aq•QA spreadsheet for water analysis. Electrical conductivity, dissolved solid and pH were determined in the field using Sension platinum series portable pH meter by HACH.

RESULTS

The result of analysis of some of the Anions and cations obtained from samples analyzed is presented in Table 1. Also presented in this table are parameters measured in-situ, this include conductivity, Total Dissolved Solid (TDS), Electrical conductivity (EC), Temperature and pH. The Total Dissolved Solid varies from 127 - 200.99 mg/kg, pH ranges from 5.9 - 6.74, conductivity varies

Table 1. Major cations and Anions, aquifer and water types of groundwater samples from the study area.

S/N	Location Name	Sample ID	pH	TDS (mg/kg)	Conductivity μ(Ω/cm)	SAR	$Na^+ + K^+$	Ca^{2+}	Mg^{2+}	NO_3	HCo_3^{2-}	Cl^-	$S04^{2-}$	Aquifer	Water type
1	Tabra	TA01	6.01	127	289.18	$126X10^{-3}$	4.50	95.00	0.50	4.2	51.00	4.20	14.80	Pindiga Formation	Cacl
2	Baure	BA02	6.1	200	343.09	$566X10^{-3}$	18.60	81	0.40	6.1	65.20	30.30	4.50	Gombe Sand stone	Ca-HCo_3
3	Kanawa	KA03	6.5	200.52	362.9	1.21	35.40	64.30	0.30	3.7	42.62	56.20	1.70	Gombe Sandstone	Cacl
4	Lakau	LA04	6.3	170	292.21	4.94	89.60	9.50	0.90	8.9	29.60	61.70	8.70	Yolde Formation	Nacl
5	Kwali	KW05	6.7	200	366.7	1.34	38.30	61.60	0.10	14.3	37.58	61.80	0.62	Bima Sandstone	Cacl
6	Gurajawa	GU06	6.5	199.97	368.28	3.03	65.18	34.50	0.32	25.0	21.20	69.70	9.10	Pindiga Formation	Nacl
7	Wuro lande	WL07	6.21	200	361.31	1.11	33.17	66.63	0.20	8.0	44.67	55.12	0.21	Gombe Sandstone	Cacl
8	Lubo	LU08	6.02	200	369.95	1.99	51.78	43.79	4.43	6.9	32.58	66.80	0.62	Gombe Sandstone	Nacl
9	Daban fulani	DF09	6.5	200	357.99	1.52	42.85	52.67	4.48	8.2	45	50	5	Gombe Sandstone	Cacl
10	Yerima Kalo	YK10	6.0	199.98	367.71	1.44	40.55	58.95	0.50	24.1	35.90	63.10	100	Pindiga Formation	Cacl
11	Jurara	JU11	5.9	200.28	371.76	1.95	51.03	44.87	4.10	26	27.30	61.58	11.12	Pindiga Formation	Cacl
12	Z-Kyari	ZK12	6.74	190.03	354.71	1.61	44.74	50.75	4.51	25	33.77	65.70	0.53	Gombe Sandstone	Cacl
13	Bure	BR13	6.1	191.9	342.85	1.1	33.11	63.86	3.03	13	50.10	40.10	1.80	Gombe Sandstone	Cacl
14	Gerkwame	GK14	6.0	200	360.16	1.14	34.40	60.80	4.80	21	47.17	48.40	3.90	Gombe Sandstone	Cacl
15	Old Jili	OL15	6.51	199.94	374.22	3.12	68.00	25.95	6.05	13	23,.30	76.60	0.10	Yolde Formation	Nacl
16	Gambomi	GB16	6.32	200.99	367.87	1.24	36.59	61.91	2.50	21	40.46	56.54	3.00	Gombe Sandstone	Cacl
17	Madukellum	MK17	6.22	157.82	293.17	$258X10^{-3}$	46.89	52.03	1.08	20.8	35.32	61.10	3.40	Gombe Sandstone	Cacl
18	Yelwa	HN18	6.0	199.92	371.95	1.93	50.77	44.45	4.78	17	28.29	62.71	9.00	Gombe Sandstone	Cacl
19	Doho	DH19	6.0	200.02	364.44	1.2	35.84	58.56	5.60	19	44.27	52.13	3.60	Kerri-Kerri Form.	Cacl
20	Kundulum	KL20	6.12	200	345.52	7.69	92.60	1.90	5.50	26	34.35	61.35	4.30	Gombe Sandstone	Nacl

between 289.2 - 374.22 uS/cm and Sodium Adsorption Ratio (SAR) ranges from 0.126 - 7.64. Water types vary from NaCl, CaCl and Ca-HCo_3. Sources of Ca in groundwater from the study area are mainly from calcite, gypsum and anhydrides which constitute most of the clay units of the aquifers. Mg and Na are from dolomite and Halite, plagioclase varieties respectively. Major Anions and Cations, aquifer from which the different water samples are drawn are also presented, this include the Kerri-Kerri, Gombe, Pindiga, Yolde and Bima aquifers.

DISCUSSION

Salinity distribution

This parameter is determined by using measured conductivity or measured dissolved solids according to Table 2.

Forty percent (40%) of the water samples analyzed are of medium salinity status, this means that this group of water can have detrimental effects on crops that are sensitive to salinity, while sixty percent are of low salinity and so, has no detrimental effects on crops. Waters that may have detrimental effects on sensitive crops are mostly from the Gombe formation, which is prone to leaching from the overlaying Kerri-Kerri formation.

Chemical water type

Major ions and water type distribution in the study area are presented in Table 1. Water type was determined by finding the predominant inorganic

Table 2. Salinity determinant parameter (Lloyd, 1985).

	Conductivity (μΩ/cm)	Dissolved solid (mg/L)
Low salinity, no detrimental effects expected	< 250	< 200
Medium salinity, detrimental effects to sensitive crops	250 – 750	00 - 500
High salinity, adverse effects on many crops	750 – 2250	500 - 1500
Very high salinity, suitable only for salt tolerant plants	2250 – 5000	1500 - 3000

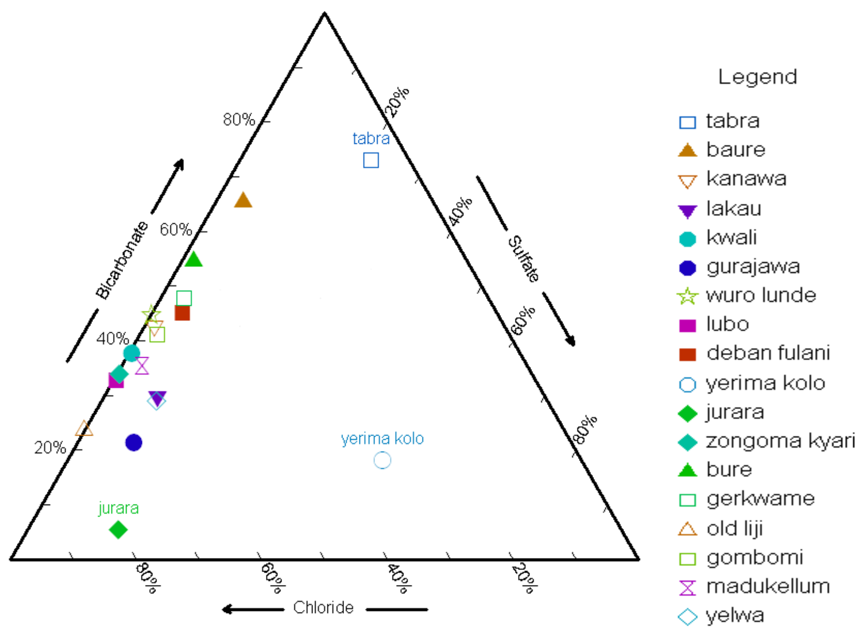

Figure 2. Ternary diagram of bicarbonate, sulphate and chloride in water sample from the study area.

cations and anions, figured on the basis of electrical equivalents. In determining water type, the software accounts whenever possible for the carbonate speciation in solution, using the sum in electrical equivalents of the CO_3^{2-} and HCO_3^- concentrations to represent carbonate. If carbonate is the dominant anion by this criterion, the software states the water type in terms of whichever of the two species is present in larger equivalent concentration (e.g., Ca-HCO_3 or Na-CO_3). It also calculates, where pH is given, the free ion concentrations of H^+ and OH^-, and accounts for these species when assigning a water type. Figures 2 and 3 present a piper and trilinear diagrams for HCO_3^-, Cl and SO_4 with plots of all the water samples analyzed.

The types of water obtained in the study area are:

1. CaCl, and such is noticed to constitute 70% of the samples evaluated, that is, samples TA01, KA03, KW05, WL07, DF09, YK10, JU11, ZK12, BR13, GK14, GB16, MK17, YW18 and DH19
2. Ca – HCO_3 constitutes only 5% of the samples, that is, sample BA02
3. NaCl is 25% of the samples and these include samples LA04, GU06, LU08, OL15 and KL20 with total carbonate ranging from 27.393 - 239.27 mg/L. The waters analyzed are made of about 80 - 90% Cl^-, 7 - 68% HCO_3^- and 20 - 65% SO_4^{2-}.

Exchange of ions alters a physical characteristic of geologic material, e.g. the permeability of clay material is controlled by the percentage of Ca^{2+}, Mg^{2+} and Na^+ (Lloyd, 1985). Therefore, all the samples analyzed are classified as fairly good for irrigation.

Nitrate

The distribution of nitrate in the water samples studied is given in Table 1 and it shows that nitrate concentration in the samples ranges from 3.7 – 27 mg/l, and this falls within the 44 mg/L (WHO, 2006) recommended value.

Sodium adsorption ratio (SAR)

The Sodium Adsorption Ratio (SAR) of water is used to

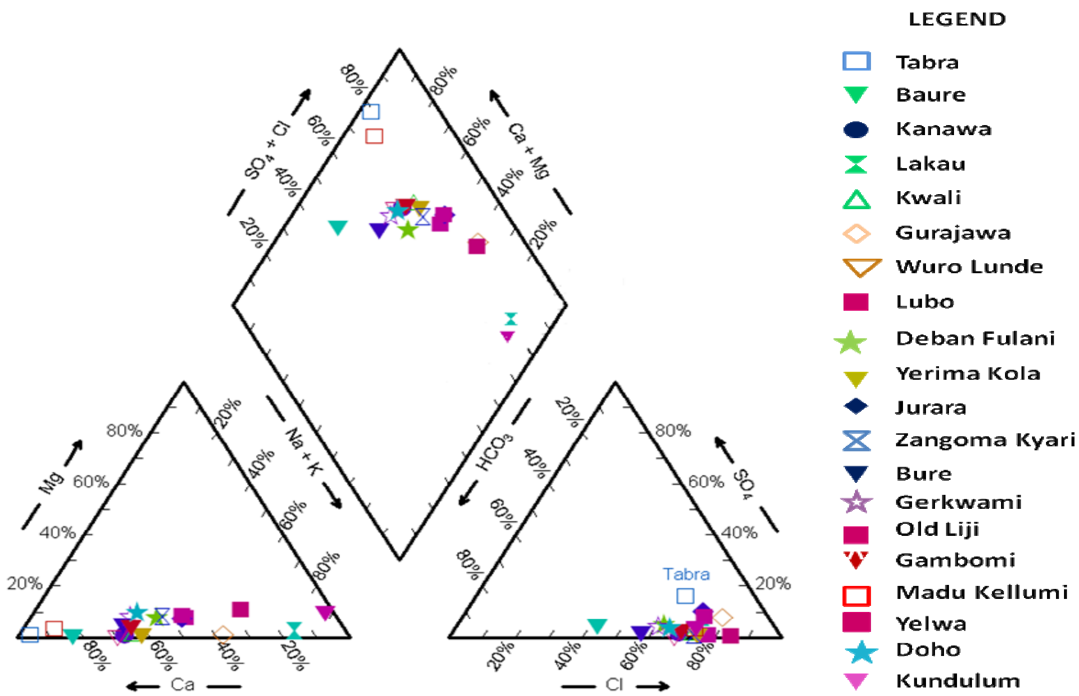

Figure 3. Piper diagram of water samples from the study area.

evaluate the suitability of water for irrigation. It estimates the degree to which sodium will be adsorbed by the soil. High SAR implies that sodium in the irrigation water may replace calcium and magnesium ions in the soil potentially causing damage to the soil structure (Lloyd, 1985).

The SAR value is defined as follows (Lloyd, 1985):

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

This concentration is expressed in ppm.

The sodium hazard is a function of both SAR and salinity which can result to low to very high salinity and sodium (Table 2) most of the water samples analyzed is of medium salinity and sodium waters indicating that water sample have no effect on both crops and human.

Total dissolved solid (TDS)

The increase in dissolved solids in irrigation water affects soil efficiency, growth and yield of crops. For long term irrigation, TDS is not supposed to exceed 2000 mg/l (Lloyd, 1985). So, based on Wilcox (1955) as quoted in (Fournier, 1981) on classification of water using TDS, all the water samples analyzed are classified as best quality water for irrigation because all TDS values are below 500 mg/l.

Conclusion

Results obtained indicate that the water can be used for irrigation purposes except at some few points that indicate medium salinity (TA01, BA02, LA04, GU06, YK10, ZK12, OL15, MK17 and HN18) where detrimental effects is likely to occur on crops that are sensitive to salinity. The Sodium Absorption Ratio (SAR), Exchangeable Sodium Ratio (ESR) and Magnesium Hazard (MH) show a fair to moderate suitability for permanent supply, while generally the water is fairly good for domestic activities.

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