GROUNDWATER QUALITY OF ZING AND ENVIRONS, TARABA STATE, NORTHEASTERN NIGERIA

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ABSTRACT

In Nigeria, groundwater is the most widely utilized source of freshwater for consumption and other domestic uses, as well as for irrigational purposes but its quality still remains a major issue. Seventeen (17) groundwater samples were collected and analyzed to determine its suitability for consumption and for irrigational purposes. Major cations and anions concentrations in the groundwater were recorded with average values for Ca^{2+}, Mg^{2+}, K^{+}, Na^{2+}, CO_3^{2-}, HCO_3^{-},Cl^{-}, NO_3^{-}, SO_4^{2-} as 20.76 mg/l, 7.10 mg/l, 1.80 mg/l, 41.00 mg/l, 0 mg/l, 3.4 mg/l, 0.75 mg/l, 0.01 mg/l, 1.20 mg/l respectively. Average TDS, pH, Conductivity and salinity values were 2282.66 mg/l, 7.52, 4.76 mS/cm and 2.4 respectively. Piper, Durov and Schoeller plots of the chemical constituents of the groundwater revealed that Na-HCO_3 is the most dominant water type within the study area. Based on Wilcox's classification, with respect to percent sodium (%Na), 11.8% of the groundwater samples were considered "good" for irrigation, 52.9% were permissible, 29.4% were doubtful while 5.9% were unsuitable for irrigation purposes. On a general note, the groundwater quality of Zing and Environs with regards to its chemical constituents can be considered safe for drinking, other domestic uses, also for irrigational and other agricultural purposes.

KEYWORDS: *Groundwater, irrigation, Quality, AAS, Zing, Environs, Taraba State*

1.0 INTRODUCTION

Freshwater quality and availability remain one of the most critical environmental and sustainability issues of the twenty-first century (UNEP, 2002). Of all sources of freshwater on the earth, groundwater constitutes over 90% of the world's readily available freshwater resources (Boswinkel, 2000). It plays a vital role as an important source of potable water in both rural and urban areas of Nigeria. Groundwater remains the largest available source of fresh water, thus it forms a very important part of the water supply chain (Olatunji, *et al.* 2015).

Groundwater is an economic resource and more than 85% of the public water for consumption is obtained from groundwater. This source of water is of great use for domestic, industrial, irrigation and agricultural purposes (Ufoegbune, *et al.* 2009). Ishaku (2011) mentioned that the assessment of groundwater quality status is important for socio-economic development of any region of the world. The determination of groundwater quality for human consumption is important for the well-being of the ever increasing population.

Poor environmental management creates havoc on the water supply, hygiene and exacerbating public health (Okoro, *et al.* 2009). Good quality water will ensure the sustainability of socio-economic development, as the government priority is shifted to other sectors of the economy, rather than channeling the resources towards combating outbreaks of water borne diseases due to consumption of contaminated groundwater (Ishaku, 2011).

Groundwater quality depends on the quality of recharge water, atmospheric precipitation, in-land surface water, and on sub-surface geochemical processes (Olatunji, *et al.* 2015). The physical and chemical parameters useful for water quality assessment are determined by the presence of both organic and inorganic compounds that are either suspended or dissolved in it. While some of the compounds are toxic to the ecosystem, some constitutes nutrients to aquatic organisms and others are responsible for aesthetics of the water body (Eletta and Adekola, 2005).

Zing town is the headquarters of Zing Local Government Area of Taraba State, Nigeria. With the recent relocation of the State-owned College of Education to Zing, the already-growing population of the town is almost doubled; hence, the need to continually monitor the groundwater (the major source of portable water in the area) quality of the town and environs cannot be over-emphasized.

1.1 THE STUDY AREA

The study area is part of Monkin Sheet 216 and part of Dong Sheet 195. This covers parts of Zing and Yorro Local Government Areas of Taraba State. It lies between latitudes 08°48' to 09°4'N and longitudes 11°30' to 11°48'E. It is located within the northern part of the Adamawa massif and covers an area of about 1004 km^2. It can be accessed through intra/interstate roads of Jalingo – Zing road and Mayo-Belwa – Zing road respectively. Footpaths and many rural road networks also link the study area from nearby communities (Fig. 1).

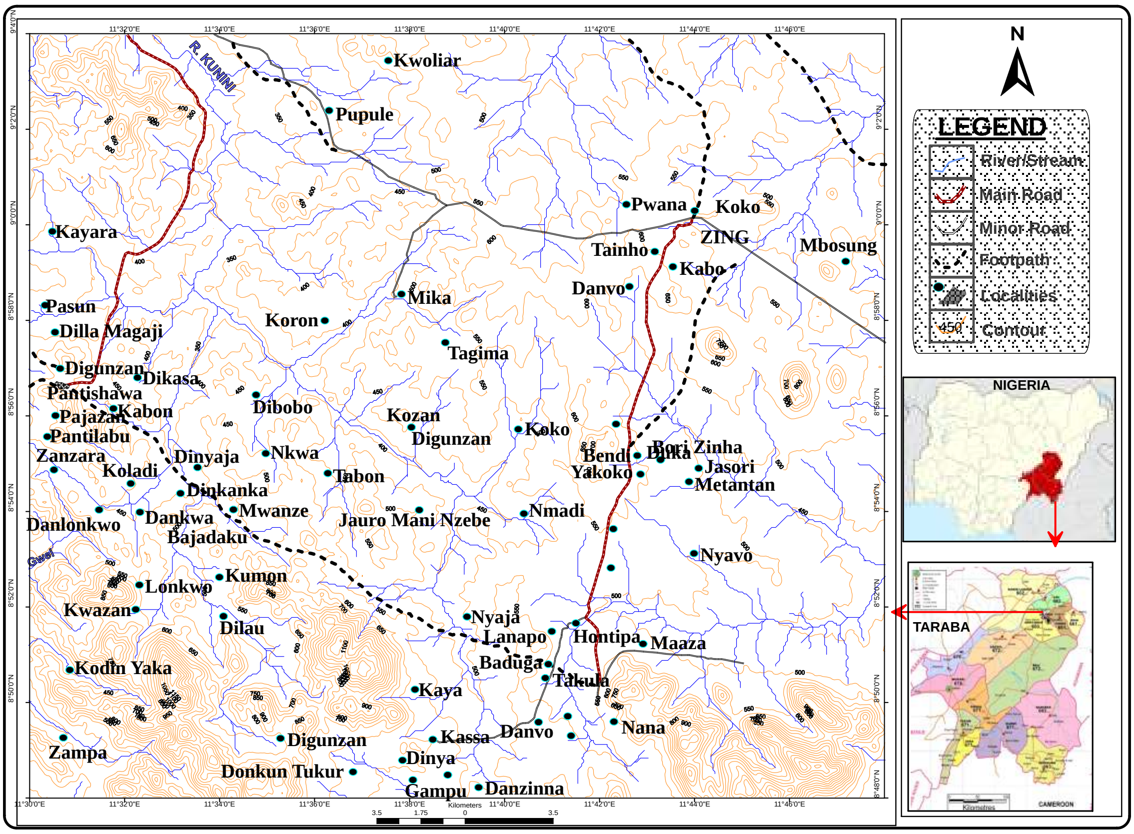

Fig. 1: Topographic map of the study area showing drainage system of the area.

1.2 MATERIALS AND METHODS

Groundwater samples were collected from 15 boreholes equipped with hand pumps and 2 hand-dug wells. The sampling was carried-out based on two (2) factors considered; the availability of samples and ensuring uniform spread, so that results may be a fair representation of the study area. Sampling and preservation of water samples were carried-out in accordance to a detailed standard procedure on water sampling described in (EPA, 2010). Sampling containers (a 1 litre sampling container used) were washed with distilled water and rinsed with the sample before it was collected and sealed to ensure airtightness. Physi-chemical parameters were measured in-situ using "HACH model" portable multi-parameter measurement device to determine the pH, conductivity, TDS, and salinity of the groundwater.

Three methods of water analysis were used for major cations and anions determination. These methods include the use of Atomic Absorption Spectrometry (Varian AA240FS fast Sequential AAS) to determine Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) cations, Flame Photometry to determine Sodium (Na^{+}) and Potassium (K^{+}) cations, and Titrimetric method to determine Chloride Cl^{-}, Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^{-}) and Sulphate (SO_4^{2-}) anions.

1.3 RESULTS AND DISCUSSIONS

The physical and chemical properties of the groundwater within study area was analyzed based on Total Dissolved Solids (TDS), Hydrogen-Ion exponential (pH), conductivity, salinity, major cations and anions distribution (Table 1), statistical (Table 3) and graphical presentations (Figures 1 – 3), to establish its suitability for consumption and irrigational purposes.

1.3.1 Total Dissolved Solids (TDS)

The TDS values obtained in-situ within the study area ranged from 109.2 to 4320 mg/l with an average value of 2282.66 mg/l. The values are similar to the TDS values obtained from an Iron Ore mining site within a basement complex, at Itakpe, Kogi State (Akpah, 2008). These values are commonly associated with brackish water having high concentration of calcium ions, magnesium ions, sodium ions, sulphate ions and bicarbonate ions as the dominant ions (Freeze and Cherry, 1979). The highest TDS value was observed at Zing borehole while the least TDS was observed at a borehole in Mika town and a hand-dug well at Tapenla community. Only the groundwater at Tapenla and Mika have TDS values falling within the "Fresh water" category according to Davis and Dewiest (1966) classification while the remaining samples fall within the brackish water category. This can also explain the reason for the salty taste of the groundwater in most of the sampled areas.

High TDS values in the groundwater of the study area could also be the result of high evaporation intensity, considering the period at which the samples were collected (peak of dry season).

Fifteen (15) of the groundwater samples (88.2%) have TDS values higher than NIS, EPA and WHO recommended limits of 500, 500 and 1000 (NIS, 2007); (EPA, 2004) and (WHO,2011) respectively, for TDS in water used for drinking purposes, only two (2) groundwater samples (11.8%), (i.e.) from Mika and Tapenla communities have values within the recommended limits.

Table 1: Groundwater Physical and Chemical Analysis results

S/N	Sample ID	Ca^{2+} (mg/l)	Mg^{2+} (mg/l	K^{+} (mg/l	Na^{2+} (mg/l	CO_3^{2-} (mg/l	HCO_3^{-} (mg/l)	Cl^{-} (mg/l	NO_3^{-} (mg/l	SO_4^{2-} (mg/l	TDS (mg/l	pH	Conductivity (mS/cm)	Salinity
1	**GW01ZN**	107.38	5.66	2.3	52	0	2.4	3.10	0.02	2.83	4320	7.40	8.04	4.5
2	**GW02AB**	8.34	3.63	2.7	20	0	2.1	0.25	0.01	0.17	1176	7.00	2.32	1.2
3	**GW03MN**	7.47	8.90	1.4	42	0	3.3	0.75	0.03	0.17	2320	8.11	4.46	2.4
4	**GW04KK**	21.30	8.89	1.4	58	0	5.2	0.45	0.01	0.17	3040	7.45	5.77	3.1
5	**GW05KI**	2.69	10.20	0.6	40	0	2.7	0.45	0.01	0.33	1150	7.73	3.40	1.8
6	**GW06MK**	2.55	2.44	1.5	29	0	1.6	0.40	0.01	0.33	109.2	6.64	2.17	1.1
7	**GW07WY**	41.36	8.31	1.9	62	0	6.3	0.35	0.01	0.17	3470	7.59	6.57	3.6
8	**GW08MZ**	19.43	5.03	1.2	32	0	4.0	0.25	0.01	0.17	2200	7.87	4.24	2.2
9	**GW09KJ**	20.28	12.27	1.7	59	0	5.8	0.35	0.01	0.50	3280	7.73	6.20	3.4
10	**GW10MY**	7.15	3.01	4.0	44	0	1.7	0.90	0.01	0.83	1903	7.03	3.69	1.9
11	**GW11BK**	17.34	5.47	0.9	38	0	4.6	0.25	0.01	0.33	2420	7.55	4.64	2.5
12	**GW12DL**	20.12	10.01	2.2	42	0	4.8	0.65	0.01	0.17	2950	7.50	5.61	3.0
13	**GW13KPS**	37.17	11.89	1.8	41	0	3.4	1.65	0.01	1.83	3150	7.65	5.97	3.2
14	**GW14NJ**	24.70	9.70	2.1	36	0	3.1	1.40	0.01	0.17	2840	7.85	5.40	2.9
15	**GW15TP**	0	0	1.2	12	0	0.5	0.25	0.01	8.17	205	7.27	4.24	0.2
16	**GW16KS**	6.98	8.34	2.4	38	0	2.4	0.80	0.01	3.33	1992	7.51	3.84	2.0
17	**GW17BD**	8.57	6.96	1.2	51	0	3.5	0.55	0.01	0.67	2280	7.87	4.37	2.3
	Average	**20.76**	**7.10**	**1.8**	**41**	**0**	**3.4**	**0.75**	**0.01**	**1.20**	**2282.66**	**7.52**	**4.76**	**2.4**

Table 2: Statistical Summary of Physico-chemical Analysis Results.

Parameter	Unit	WHO (MCL)	NIS (MCL)	EPA, Sec (MCL)	Mean	Max	Min	Number of Samples
pH (Field)		6.5 – 8.5	6.5 – 8.5	6.5 – 8.5	7.52	8.11	6.64	17
Spec Cond	µS/cm	1400	1000		4.76	8040	2.19	17
TDS	mg/L	1000	500	500	2282.7	4320	109.2	17
Ca^{2+}	mg/L	75			20.75	107.4	0	17
K^{+}	mg/L	55			1.79	4.0	0.6	17
Mg^{2+}	mg/L	50	0.2		7.10	12.27	0	17
Na^{+}	mg/L	50	200		40.94	62	12	17
Cl^{-}	mg/L	250	250	250	0.75	3.1	0.25	17
HCO^{3-}	mg/L	1000			3.38	6.3	0.5	17
SO_4^{2-}	mg/L	250	100	250	1.2	8.17	0.17	17
CO_3^{2-}	mg/L			120	0	0	0	17
NO_3^{-}	mg/L	50	50	10	0.01	0.03	0.01	17

Based on the classification by (Wilcox, 1955), only the groundwater from the hand-dug well at Tapenla is of best quality for irrigation, 58.8% of the samples are waters involving hazard and 29.4% of the groundwater samples require leaching and perfect drainage for it to be used for irrigational purposes. The groundwater sample at Mika with TDS of 109.2 mg/l is out of the ranges based on Wilcox's classification, therefore it is assumed "not good" to be used for irrigation.

1.3.2 Correlation Matrix

Correlation Matrix is used to account for the degree of mutually shared variability between individual pairs of groundwater quality variables. The results of the correlation matrix for physi-chemical data obtained for the study area is presented in Table 3. The strong to perfect correlation between the chemical parameters, is an indication of a common source (El Arabi et al. 2013).

The correlation matrix obtained (Table 3) showed a strong correlation coefficient between Ca^{2+} and Cl^- (0.82) which indicates that they are of common source. A moderate correlation exists between Mg^{2+} and HCO_3^- (0.54), Na^+ and HCO_3^- (0.74), while a weak correlation is shown between Ca^{2+} and SO_4^{2-}, Ca^{2+} and Mg^{2+}, etc.

Table 3: Correlation Matrix

		pH	**Cond.**	**TDS**	**Ca^{2+}**	**K^+**	**Mg^{2+}**	**Na^+**	**Cl^-**	**HCO_3^-**	**SO_4^{2-}**
pH		1	-0.97	0.35	0.14	0.08	0.48	0.45	0.17	0.31	0.06
Cond	µS/cm		1	-0.25	-0.14	-0.03	-0.34	-0.40	-0.18	-0.20	-0.13
TDS	mg/L			1	0.76	0.14	0.49	0.77	0.56	0.67	-0.30
Ca^{2+}	mg/L				1	0.04	0.06	0.39	0.82	0.11	0.47
K^+	mg/L					1	0.16	-0.09	0.26	-0.07	-0.13
Mg^{2+}	mg/L						1	0.47	0.08	0.54	0.04
Na^+	mg/L							1	0.23	0.74	-0.46
Cl^-	mg/L								1	-0.19	0.15
HCO_3^-	mg/L									1	-0.56
SO_4^{2-}	mg/L										1

1.3.3 Graphical Presentation of Hydrochemical Data

Piper, Durov and Schoeller diagrams were used to show the different hydrochemical species within the study area.

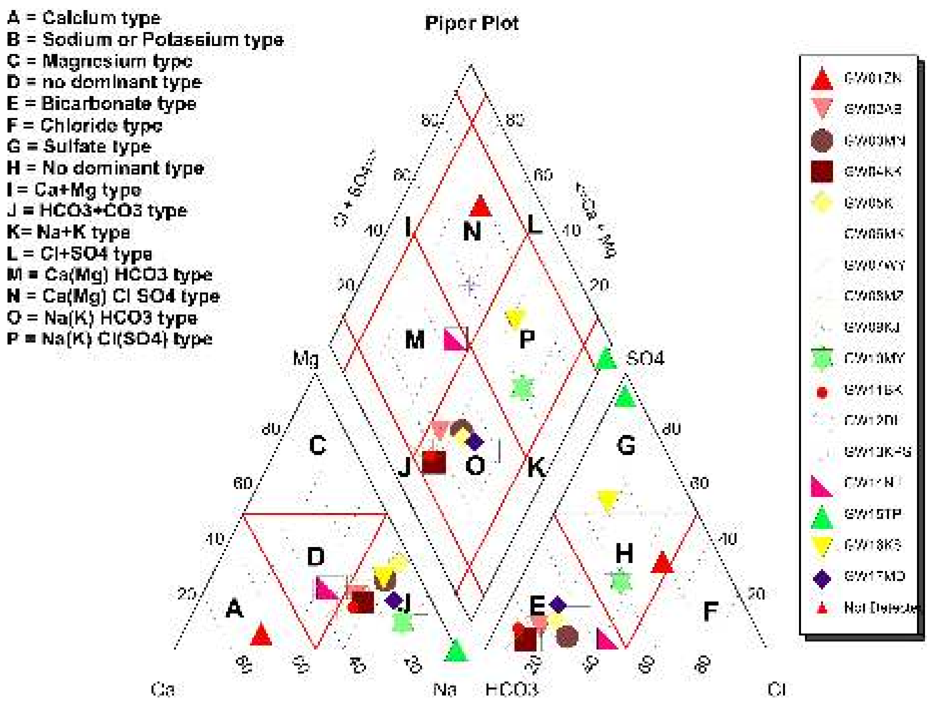

Fig 2: Piper Diagram of groundwater of Zing and Environs, showing the dominant water species.

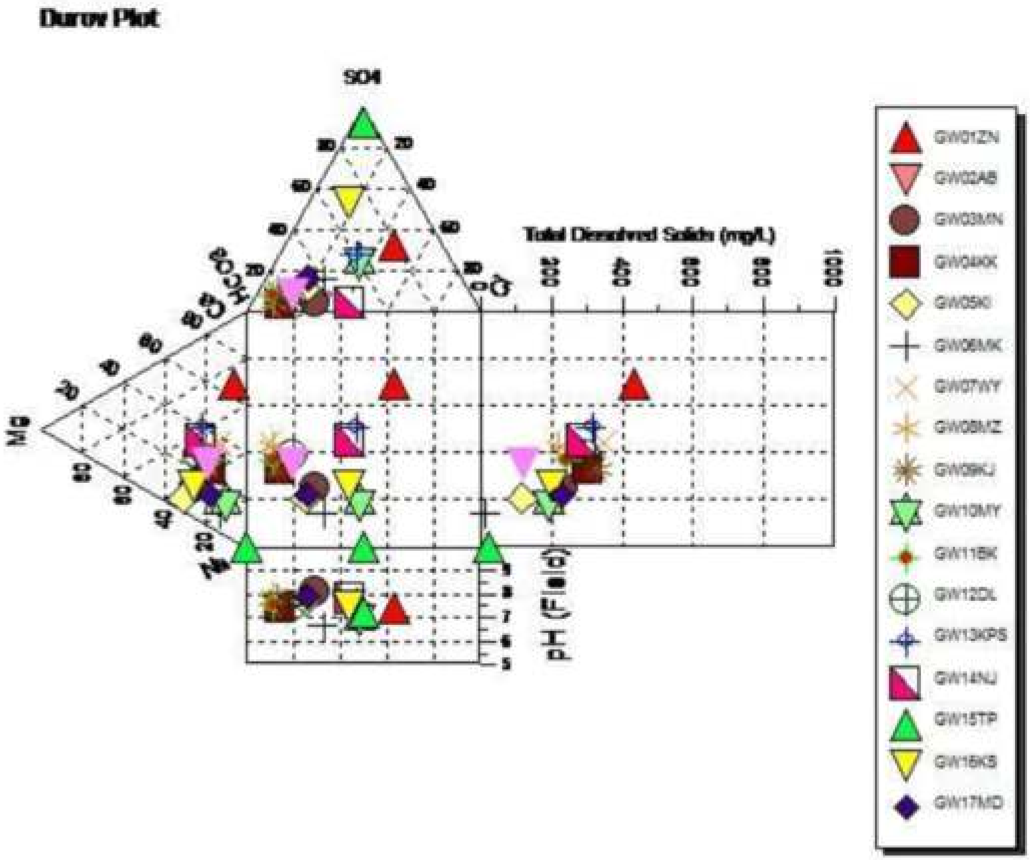

Fig 3: Durov plot of groundwater of Zing and environs.

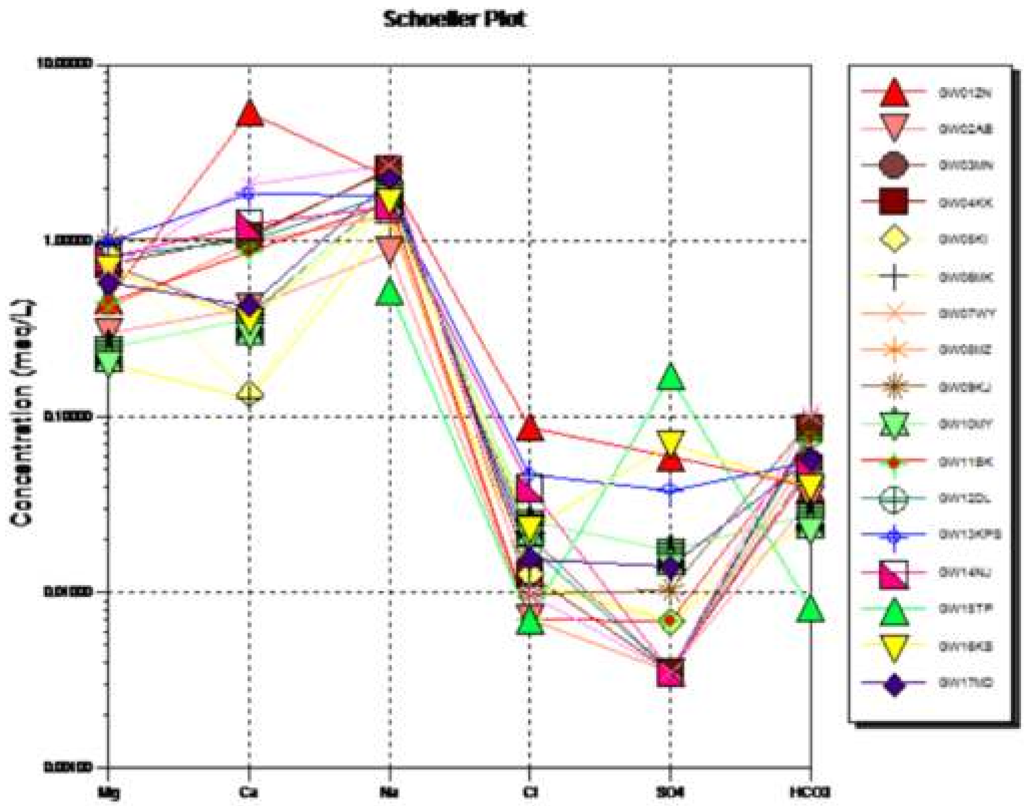

Fig 4: Schoeller Plot of the Study Area.

Sodium - Bicarbonate water type is the most dominant water type within the study area. This is also confirmed by the graphical presentations using Piper, Durov and Schoeller diagrams of the cation and anion values for the study (Figures, 2, 3 and 4).

1.3.6 Hydrogen-Exponential (pH)

The Hydrogen-ion exponential (pH) values (Table 1) measured insitu from the study area ranged from 6.64 to 8.11 with an average of 7.52. Based WHO, EPA and NIS guidelines which all limits pH values within the range of 6.5 to 8.5 (WHO, 2011); (EPA, 2004) and (NIS, 2007), it is safe to conclude that all the sampled groundwater from the study area are within permissible limit but the groundwater sample at Mika borehole is slightly acidic with a pH value of 6.64.

1.3.5 Conductivity and Salinity

The conductivity values measured in-situ, of the sampled groundwater within the study area ranged from 2.17 to 8.04 mS/cm with a mean value of 4.76 mS/cm. All the groundwater samples have values higher than the guideline of 1400 µS/cm recommended by the World Health Organization (WHO, 2011) and 1000 µS/cm recommended by the Nigerian Industrial Standards (NIS, 2007). The highest conductivity value of 8.04 mS/cm (equal to 8,040 µS/cm) was observed at Zing borehole. This, and with the large variation in the groundwater salinity also observed at Zing borehole, groundwater sample could be influenced by different processes such as evaporation, anthropogenic activity and the interaction water – rock mixing processes.

Salinity values ranged from 0.2 to 4.5 with an average value of 2.4. The borehole at Zing show the highest salinity as expected considering the corresponding electrical conductivity (EC) value and the hand-dug well at Tapenla show the least value of 0.2. However, it is note-worthy that sampling was carried-out during the dry season; therefore reduced salinity is expected during wet season due to groundwater recharge from meteoric source and subsequent mixing.

1.3.6 Major Cations and Anions Distribution

1.3.6.1 Calcium (Ca^{2+}): Calcium concentrations in the study area, ranges from 0 to 107.38 mg/l with an average of 20.76 mg/l (Table 1). From the results, Zing town has a relatively higher concentration with 107.38 mg/l which is more than twice the concentration at Wuro-yaya with 41.36 mg/l, which is the second highest calcium concentration from the study area and Tapenla has no (0 mg/l) calcium concentration. Such wide ranges of Calcium concentrations suggest that multiple sources and/or complex hydrochemical processes affected the distribution of this particular element in groundwater. Calcium (Ca) is one of the elements considered essential to human and animal health. Lack of it can result to poor development of bones and dentition (WHO, 1997). WHO (1997) recommended an upper limit of 200 mg/l and a lower limit of 75 mg/l. 1000 mg/l daily dietary intake is recommended by the US Committee on Dietary Reference Intake (USCDRI, 1997). Only the water sample at Zing borehole met the minimum calcium requirement as recommended by the WHO, all others are below the minimum requirement and all the samples are below the required daily dietary intake recommended by US Committee on Dietary Reference Intake. This low concentration in calcium concentration could give rise to serious deficiencies in both humans and animals unless a supplementary source is provided.

1.3.6.2 Magnesium (Mg^{2+}): Magnesium (Mg^{2+}) concentrations in the study area ranged from 0 to 12.27 mg/l with an average of 7.10 mg/l. The groundwater at Kwoji recorded the highest magnesium concentration while the hand-dug well at Tapenla showed no magnesium concentration in it at all; it may be that it occurs below the detection limit of the instrument used. This result showing a wide range could also imply multiple sources and/or complex hydrochemical processes. All the samples analyzed are below WHO recommended limit of 50 mg/l (WHO, 2011) but only the hand-dug well at Tapenla met the NIS recommended limit of 0.2 mg/l (NIS, 2007), as all the other samples are above the limit recommended by Nigerian Industrial Standards (NIS). Magnesium is common in natural waters as (Mg^{2+}), and along with calcium, is a main contributor of water hardness.

The source of magnesium (Mg^{2+}) in the groundwater from the study area is most-likely to be contribution from the leaching of biotite, visibly present in most of the rock of the study area.

1.3.6.3 Sodium (Na^{+}): Sodium (Na^{+}) concentrations in the groundwater of the study area ranged from 12 to 62 mg/l, having an average of 40.94 mg/l. Wuro-yaya has the highest while Tapenla has the lowest sodium concentrations. The World health Organization (WHO) proposed a guideline limit of 50 mg/l while NIS proposed 200 mg/l as its guideline limit for sodium concentration in water for consumption (WHO, 2011); (NIS, 2007). All the samples analyzed are within NIS recommended limit while 70.58% of the samples are below the WHO recommended limit and 29.41% of the samples are above the WHO proposed limit. The likely source of sodium in the groundwater of the study area is the leaching of sodium from plagioclase feldspars common in all the granite rocks sampled.

1.3.6.4 Potassium (K^+): Potassium and sodium are common constituents of natural waters, even though sodium is being more prevalent than potassium; it also plays an important role in the classification of the chemistry of natural waters. Potassium (K^+) concentrations from the study area, varies from 0.6 to 4.0 mg/l with a mean value of 1.79 mg/l. WHO proposed a guideline of 55 mg/l for potassium, (WHO, 2011). As of the time of this report, no guideline was reported for either NIS or EPA. All the samples analyzed are well below the recommended limit proposed by the World Health Organization. Potassium (K^+) in the groundwater of the study area may have been from either the microcline or the biotite (or both) components of the granites of the study area.

1.3.6.6 Bicarbonate (HCO_3^-): Bicarbonate concentrations in the groundwater of the study area ranged from 0.5 to 6.3 mg/l, with an average of 3.38 mg/l. WHO proposed a guideline of 1000 mg/l for bicarbonate concentration in water used for consumption purposes. All the samples are below this limit proposed by the World Health Organization. Bicarbonate concentration in groundwater of the study area is most-likely to be of meteoric source.

1.3.6.6 Sulphate (SO_4^{2-}): Sulphate in the study area has concentrations ranging from 0.17 to 8.17 mg/l, with an average value of 1.20 mg/l. The hand-dug well at Tapenla has the highest sulphate concentration while boreholes at Abuja, Monkin, Kakulu, Wuro-yaya, Manzalang, Dila and Nyaja have the lowest sulphate concentrations. The WHO, EPA and NIS recommended a maximum limit of 250, 250 and 100 mg/l respectively, for sulphate in drinking water. All the samples analyzed have concentration lower than the maximum recommended limits with the highest concentration of just 8.17 mg/l at Tapenla. High sulphate concentrations can influence the taste of water and can also have laxative effects. It occurs in water predominantly in the form of simple SO_4^{2-}. Schoeneich and Garba (2010) reported that sulphate concentrations above 250 mg/l in non-polluted water on the Crystalline Hydrogeological province of Nigeria have not yet been reported.

1.3.6.7 Chloride (Cl^-): Chloride in the groundwater of the study area ranged from 0.25 to 3.10 mg/l, with an average value of 0.75 mg/l. The highest concentration was observed at Zing borehole water sample. The relatively high chloride concentration at Zing could be due to effluent contributions from sewage drains as a result of growing urbanization due to the recently transferred State College of Education to the area. A proposed guideline of 250 mg/l was recommended by WHO, EPA and NIS. All the samples analyzed are within the proposed limits. According to Schoeneich and Garba (2010), chloride (Cl^-) concentration in water, in the crystalline aquifers, is entirely of atmospheric origin, as no chloride is released in the process of weathering.

1.3.6.8 Nitrate (NO_3^-): Nitrate (NO_3^-) in groundwater of the study area ranged between 0.01 to 0.03 mg/l, having an average of approximately, 0.01 mg/l. Nitrate is the stable oxidation state of nitrogen. It is formed by oxidation of nitrite, NO_2. Organic substance in soil is decomposed to ammonia, it is oxidized by nitrosifying bacteria to nitrite (NO_2), and at the end oxidized by nitrifying bacteria to nitrate (NO_3). It can also be of meteoric origin. Nitrate is an important indicator of faecal pollution and other organic pollution. WHO and NIS set a Maximum Contaminant Levels (MCL) of 50 mg/l while EPA gave an MCL of 10 mg/l. All the samples analyzed are within the limits recommended, therefore, the waters in the study area can be said to be safe for consumption, based on its nitrate content.

1.3.7 Assessment of Groundwater Quality for Irrigation Purposes

The inhabitants of the communities under study are mostly farmers and the groundwater can play an important role in aiding irrigation practices. Therefore, the suitability of the groundwater was assessed using Sodium Absorption Ratio (SAR), Percent Sodium (%Na), Soil Permeability Index (PI) and Chloro-Alkaline Index (CAI) (Table 4).

1.3.7.1 Sodium Absorption Ratio (SAR): According to Richard (1954) classification with respect to SAR, all the calculated SAR values for the groundwater samples collected within the study area and analyzed have values within the range of SAR values which indicates that there is no sodium hazard and can be considered of "excellent" quality for irrigational use.

1.3.7.2 Percent Sodium (%Na): The suitability of the groundwater for irrigation using Percent Sodium (Wilcox, 1955), showed that 11.8% of the samples collected can be considered "Good" for irrigation purposes (these includes groundwater samples from Zing, and Kpantisawa boreholes), 52.9% are "Permissible" (includes groundwater samples from Abuja, Kakulu, Wuro-Yaya, Manzalang, Kwoji, Bakinya, Dila, Nyaja and Madaki), 29.4% are considered "Doubtful" (includes groundwater samples from Monkin, Kan-Iyaka, Mika, Mararaban Yorro and Kassa), while, the groundwater at Tapenla is of "Poor" quality, therefore, should not be used for irrigation.

1.3.7.3 Soil Permeability Index (PI): According to Doneen (1964) classification using Soil Permeability Index (PI), the groundwater samples collected within the study area have thirteen (13) of the samples fall under Class I order (groundwater from Zing, Abuja, Monkin, Kakulu, Kan-Iyaka, Wuro-Yaya, Manzalang, Kwoji, Bakinya, Dila, Kpantisawa, Nyaja, and Kassa), while, four (4) of the groundwater samples are of Class II order (groundwater from Mika, Mararaban Yorro, Tapenla and Madaki), therefore, they are all good to be used for irrigation.

1.3.7.4 Chloro-Alkaline Index (CAI): The Chloro-Alkaline Index (CAI) of the groundwater samples collected from the study area (Table 14) showed that all the samples analyzed have negative CAI values, indicating a base – exchange reaction between Na^+ and K^+ in the groundwater with Ca^{2+} and Mg^{2+} in the rocks.

Table 4: Calculated values of Sodium Adsorption Ratio (SAR), Percent sodium (%Na), Permeability Index (PI) and Chloro-Alkaline Indices (CAI).

Sample ID	Sample Location	SAR	%Na	PI	CAI
GW01ZN	Zing	1.32	28.43	30.37	- 24.8
GW02AB	Abuja	1.45	56.63	65.61	- 93.0
GW03MN	Monkin	2.46	62.75	69.85	- 92.5
GW04KK	Kakulu	2.65	58.58	65.13	- 225
GW05KI	Kan-Iyaka	2.47	64.00	71.06	- 175
GW06MK	Mika	3.10	79.76	90.14	- 129
GW07WY	Wuro-Yaya	2.30	49.91	55.24	- 274
GW08MZ	Manzalang	1.56	50.53	58.16	- 141
GW09KJ	Kwoji	2.56	56.25	62.74	- 260
GW10MY	Mararaban Yorro	3.46	76.72	82.67	- 66
GW11BK	Bakinya	2.02	55.67	64.86	- 166
GW12DL	Dila	1.91	50.67	57.57	- 93.5
GW13KPS	Kpantisawa	1.49	39.10	43.74	- 35.6
GW14NJ	Nyaja	1.55	44.14	49.55	- 39.5
GW15TP	Tapenla	0	100	119.23	- 54
GW16KS	Kassa	2.28	61.96	68.52	- 84.5
GW17MD	Madaki	3.12	60.02	76.31	- 111.5

Note: All calculations are based on converted milli-equivalent per litre (Meq/l) value of mg/l

CONCLUSION

Hydrochemical studies of the area including graphical presentations using Piper, Durov and Schoeller plots revealed the dominance of HCO_3 – Na water type/specie. This indicates recharge of the aquifer to be mainly from meteoric source. The groundwater was also evaluated to determine its suitability for use in irrigation. On a general note, the groundwater quality with regards to chemical elements within Zing and environs as at the time of this report, can be said to be safe for human and animal consumption as well as other domestic uses and can also be considered good for irrigational purposes.

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