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Hydrochemical Assessment of Surface and Groundwater in Some Selected Communities of Borno and Yobe State

S. Adamu¹, H. M. Sadiq¹, D. D. Muhammed¹, A. K. Kolomi², I. B. Wulo¹, M. M. Aji¹, M. Muhammad³, S. Abdullahi⁴

¹Department of Geology University of Maiduguri, Nigeria,

²Center for Arid Zone Studies University of Maiduguri, Nigeria

³Federal Polytechnic of Oil and Gas Bonny, Rivers State Nigeria

⁴Department of Geology, Federal University Gusau

ABSTRACT

The study area comprises three communities of Ala, Daura in Borno State and Kyalari in Yobe State, North-eastern Nigeria which forms part of the Chad Basin. Twenty-five (25) water samples were collected from major sources which comprises of nine (9) hand dug wells, ten (10) surface water and six (6) boreholes. The physical parameters analyzed revealed pH values ranging from 6.5 - 8.1 and electrical conductivity varies between 67 – 1050 $\mu\text{S}/\text{cm}$. The results of the chemical parameters shows that Ca^{2+} ranges between 3.5 to 66.5 mg/l, while Mg^{2+} varies from 4.8 to 28.2 mg/l, Na^+ and K^+ varies between 0.7 to 1241.0 mg/l and 2.0 to 112.0 mg/l respectively. HCO_3^- ranges from 77.5 mg/l to 337.0 mg/l while Cl^- varies from 4.0 to 160.0 mg/l. The concentration of SO_4^{2-} varies between 0.7 mg/l to 283.0 mg/l. This study confirms that they are normal for domestic, agricultural and small-scale irrigation purposes. The study shows that some cation and anion are within WHO limits of 2020 permissible limit of drinking water standard except for WARODI wells which show abnormally higher values above the WHO standard. The mean concentration of the cations shows that $\text{Na}^+ > \text{Ca}^{2+} > \text{K}^+ > \text{Mg}^{2+}$ while for the anions are $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$ respectively.

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INTRODUCTION

Three communities of Ala in Marte local government and Daura in Damasack local government of Borno State and Kyalari in Yunusari local government of Yobe State located within the Nigerian sector of the Lake Chad Basin within latitudes $11^{\circ}25'$ to $13^{\circ}30'N$ and longitudes $11^{\circ}35'$ to $14^{\circ}00'E$ (Figure 1).

The study area is wholly underlain by the sedimentary rocks dominated by late Plio-pleistocene Chad Formation, consisting of interbedded clays, silts and subordinates' sands of continental origin probably up to 1000 m thick (Schoeneich, 2001). Today, there is a global concern about pollution as the major causes of ill health where the state of the water is control by its migration characteristic and temperature gradients.

The simplest classification of water is based on the total concentration of dissolved solids measured in milligram per liter (mg/l). Water is considered to be polluted when it is not suitable for specified purpose. Thus, the quality of water varies with use to which it is put. Domestic waste and industrial activities are the major sources of water pollution, though pollutants may also enter water through air and oil migration.

Generally, therefore, the nature of polluted water will depend very much on the area in which it is located (Eduvie, 1991). The simplest classification of water is based on the total concentration of dissolved solids measured in milligram per liter (mg/l). Water is considered to be polluted when it is not suitable for specified purpose.

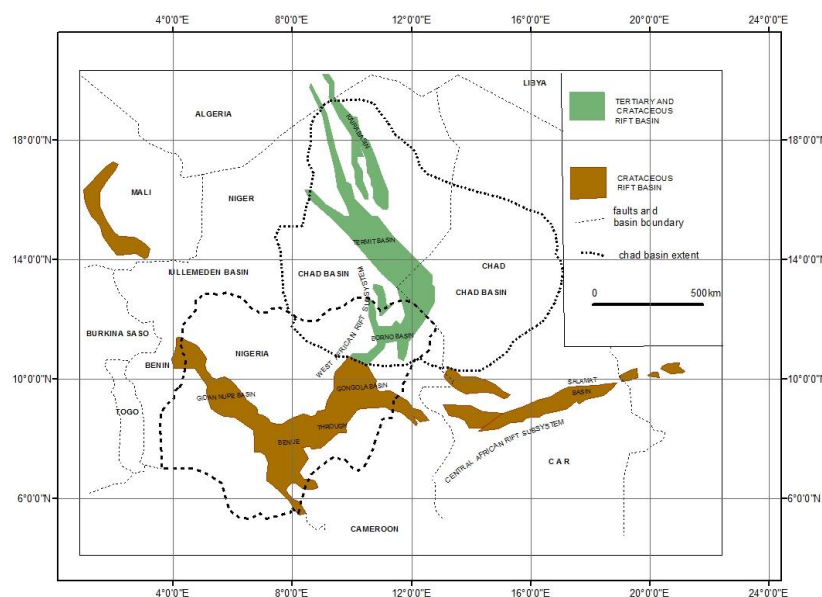


Fig. 1: Location of the study area (After Genik, 1993)

Thus, the quality of water varies with use to which it is put. Domestic waste and industrial activities are the major sources of water pollution, though pollutants may also enter water through air and oil migration. Generally, therefore, the nature of polluted water will depend very much on the area in which it is located (Eduvie, 1991). The effects of pollution in water include color change, alteration of pH, alteration of number of free solids, the level of biochemical and chemical oxygen demands. The above changes have critical effects on life processes (Sani, 2016). According to (WHO, 2020) water once polluted, becomes poisonous to aquatic plants and animals and the successive ecosystem either directly or as a result of the food chain the ingest the pollutants and gradually accumulate same in their bodies to the point of being toxic and in extreme cases may causes death. Extensive research conducted in various parts of the world such as Hem (1985), Okagbue (1988) and Todd (1980) have documented a large body of inorganic elements which so far are considered essential in human nutrition and play vital roles as structural and functional

components of metalloproteinase and enzymes in cellular processes. This paper attempts to look into the major elemental concentration of the various water sources in three communities located within the Nigerian sector of Chad Basin with the aim of assessing their chemistry and suitability for domestic, animal and small-scale irrigation purposes

TOPOGRAPHY AND DRAINAGE

The study area is generally featureless characterized by flat alluvial Holocene landmass, with scanty outcrops of Pleistocene Chad Formation, which gently dips northeast towards Lake Chad. The only features which break the flat terrain are sand dunes in the north west part of the study area as well as the 260 km long and 5 - 6-metre-high prominent sand ridge named "Bama Ridge," considered to be formed at the shore of Mega – Chad Lake in the early Holocene, some 10,000 years ago (Zarma et al, 2015). In essence, the Bama Ridge separates flat depositional land in the north east from slightly undulating erosional surface in the south west.

As observed from this study, Bama Ridge may have tectonic predisposition. The sand dunes occupy mostly Gudumbali, Kukawa, Ngazai, and

Damasck. Hummocky type of sand dunes with high topographic elevation is also found close to Geidam as observed during the field work. The inter-dunal valleys were covered by clay beds with the sand ridge traceable to about 40 km in west and southwest of the study area. The ridges are clearly seen around Gubio, Magumeri, Maiduguri and towards Bama it extends to Banki area within the study area. The ridge is probably an ancient Holocene shoreline of the Lake Chad which dip at an angle of 5° (Zarma et al, 2015).

The drainage system of the area is characterized by the Hadeja-Yobe River System and the Ngadda, Yedseram and Komadugu-Gana River System all flowing toward Lake Chad. Most of these rivers are influent streams that end in inland deltas (Figure 2). None of the rivers is perennial or effluent in nature and most of them flows into marshy area on the plain and disappear by evapotranspiration before reaching Lake Chad. However, the Komadugu-Yobe in the northwest and the Yedseram River to the southeast are relatively large rivers that discharge into Lake Chad during the wet season. In the northern part of the study area, the Komadugu-Yobe passes through the sand dunes in a narrow flood plain which is marked by larger alluvial tracks on the inner bends of the river. Flooding of these tracks by the overflow from the river creates permanent marshy lands. Although near Lake Chad, the flood plain fans out in several tributaries with scattered marshy areas and Cut-off River meanders. The Komadugu-Yobe River begins to flow in June or July and reaches its peak discharge in August and October. After the wet season, discharge from Komadugu, Yedzaram and Ngadda decreases rapidly with patch of pools of water remaining in the main stream channels.

The Komadugu Goma River joins the River Goa as a tributary to River Forumduma which joined River Forumduma Gana as tributaries and finally empties its water into the Lake Chad. River Kaha and River Dorma are also part of tributaries to

River Forumduma which empties its water into Lake Chad (Figure 2).

The Yedseram River which flows through Bama has a relatively small catchment area its flow, which is seasonal usually begins in July at the Bama area because of long distance of the river meander channels flowing from Republic of Cameroun through Adamawa State before reaching Bama area and ceases to flow by December. The river breaks up into a series of braided channels and deltas flowing across the extensive fadama around Dikwa, Marte and Monguno area and finally emptying into Lake Chad (Fig: 2).

The Ngadda River cuts through the Bama Ridge at Maiduguri in a well-developed channels and flows through a system of braided channels. Further north, the river gradually loses its identity as it fingers out on a marshy plain to form deltas bars which joint the Jere bowl. Upstream from Maiduguri, the Ngadda River passes through Lake Alou, a seasonal lake. The surface area of the Lake Alou is about 4 square kilometres. The Lake receives its water during wet season from delta fans spread from far southern part of the study area without a clear river or channels (Figure 2). While Amanna River, initially flowing to Lake Chad and later, after formation of Bama ridge it diverted its channel into Gongola River.

According to Schoeneich (2004), Water present in the study area consists of both atmospheric, surface and groundwater. The atmospheric water is mainly derived from rainfall which progressively falls from 800 mm/a in the southern part of the study to about 400 mm/a to the northern part of the study area. (Schoeneich, 2004) is of the view that, there is no recharge taking place if depth of annual precipitation is less than 700 mm/a (Fig. 3).

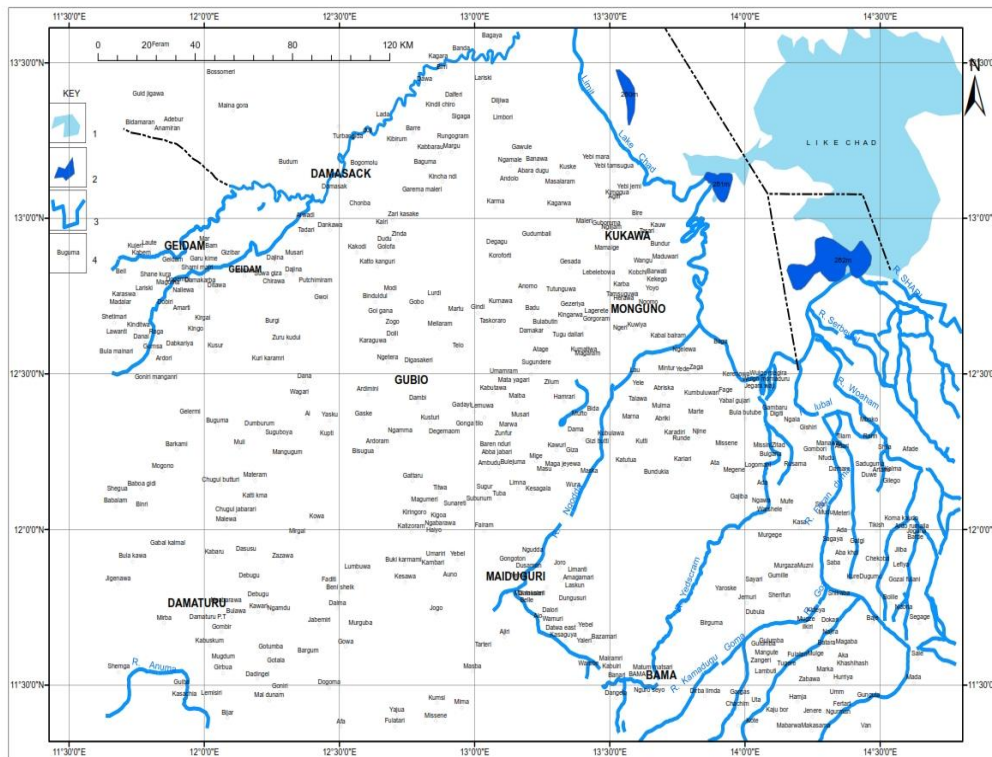


Figure 2: Drainage Map of the Study Area (Modified After Geological Survey, 1960).

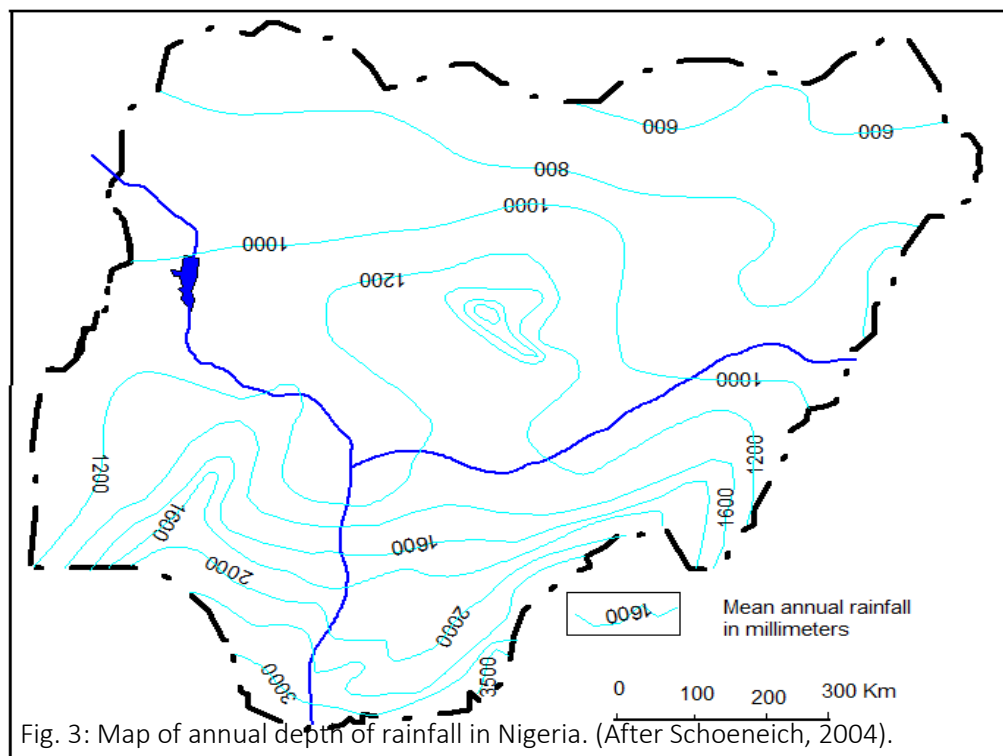


Fig. 3: Map of annual depth of rainfall in Nigeria. (After Schoeneich, 2004).

The groundwater in the research area is contained mainly in the Chad Formation with the greater part of the groundwater (7817km^3) is salty water with only the upper most part consisting of 1713km^3 being fresh

water according to (Schoeneich, 2001). This fresh water occurs mainly in the Chad Formation within three geologic formations namely the Upper, Middle and Lower Aquifers (Fig. 4)

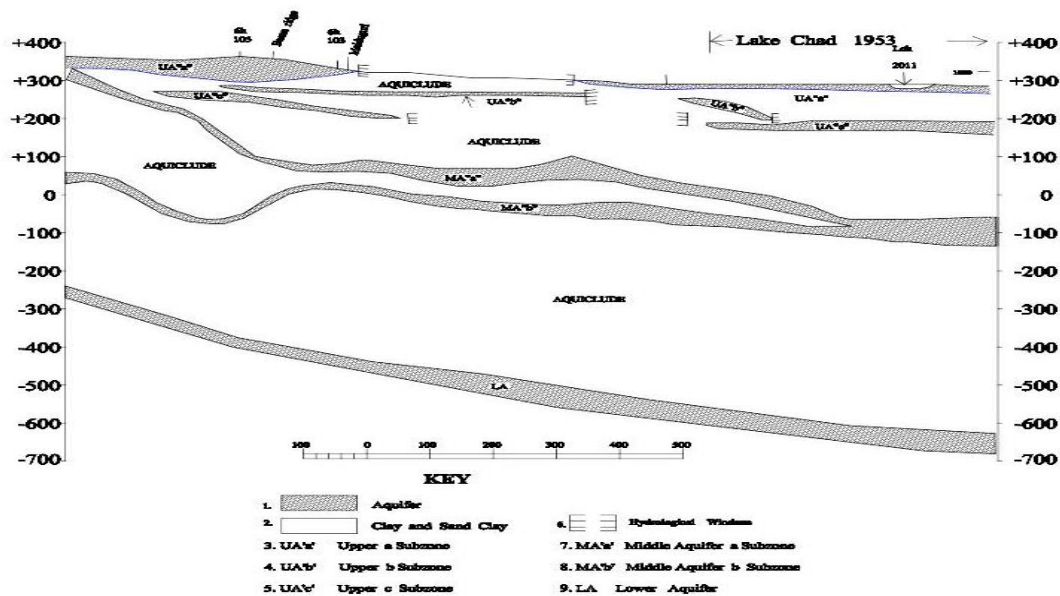


Figure 4: Map of hydrogeological cross-section A-B of Chad Formation showing the three aquifers, (Upper, Middle and Lower Aquifer) The Middle Aquifer is separated into a and b subzone (After Sani, 2016)

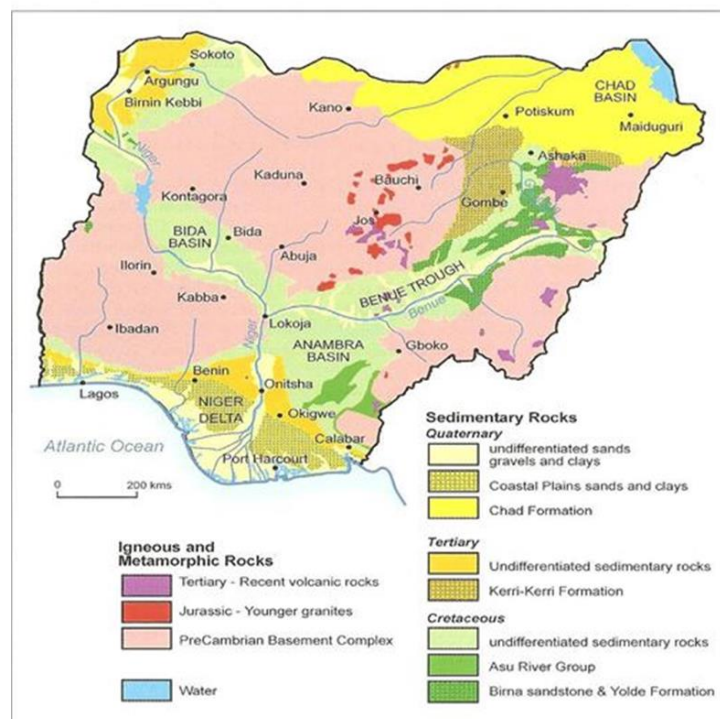


Figure 5: Generalized Geological Map of Nigeria (after MacDonald et al., 2005)

GEOLOGICAL SETTING

According to Kogbe (1976) and Avbovbo (1986) the geological history of the area started in the Upper Albian with the deposition of mainly marine sometimes deltaic and fluvatile interbedded clays, silts and sands (Fig: 5). It is possible that after Maastrichtian, this sedimentation continued up to Paleocene leaving the continental series of sandstones interbedded with claystones and siltstones called Kerri-Kerri Formation. There was no evidence of deposition after that until almost late Pliocene when sedimentation resumed and lasted without interruption to date. The product of this deposition is what is referred to as Chad Formation which consists of interbedded clays, silts and subordinate sands of continental origin measuring up to 1000 m in thickness (Carter et al, 1963, Kogbe, 1992 and MacDonald et al, 2005).

MATERIAL AND METHODS

Twenty-five (25) water samples were collected which comprises of nine (9) hand dug wells, ten

(10) surface water and six (6) from boreholes. These constitute the major source of water supply in the research area. The top film of the surface water and groundwater were removed, two litres of water samples was then collected in clean dry plastic bottles filled completely and cap tight to avoid excessive agitation or exposure to sunlight. Each sample was then labelled and preserved in the refrigerator until when they are ready for chemical analysis. The position of each sample location was taken using Global Positioning System (GPS) Garmin type. Physical parameters of the samples such as electrical conductivity, temperature, total dissolve solid and hydrogen exponent were measured directly on the field at spot. The analytical method employed includes Atomic Absorption and Spectrometer which was adopted for the analysis of Mg^{2+} and K^{2+} . While digital titration method was used in the determination of SO_4^{2-} , HCO_3^{-} and Cl^{-} . The flame photometer was used in determining Ca^{2+} and Na^{+} respectively (Figure 6).

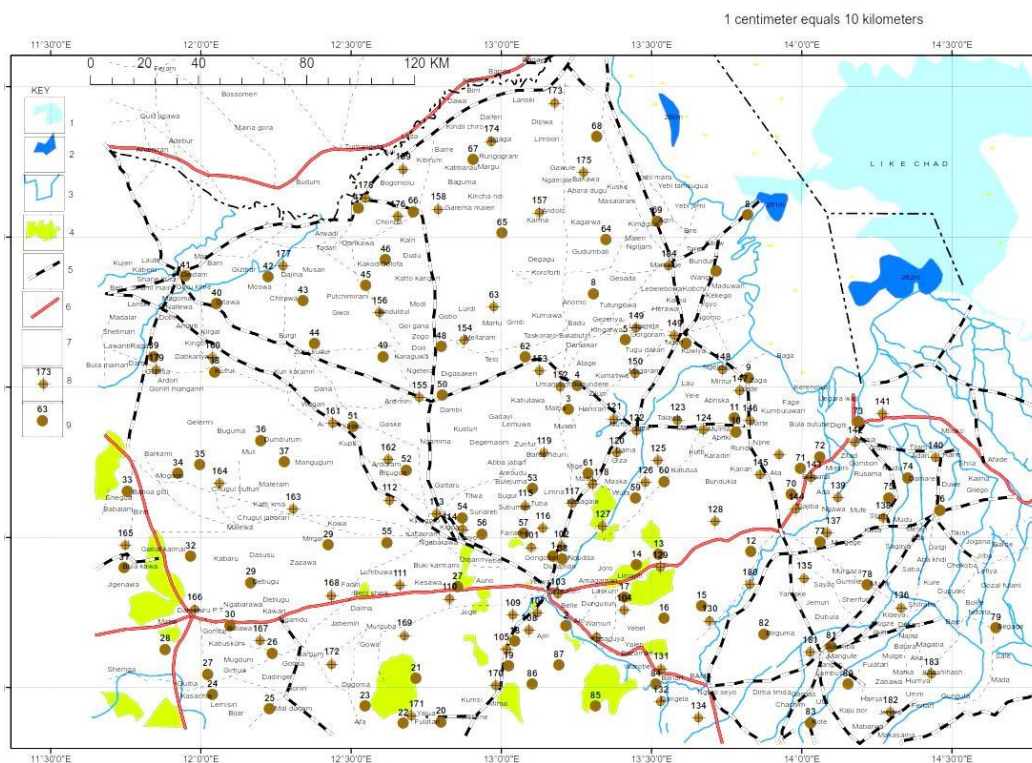


Figure 6: Distribution of the sample locations in the study area

DISCUSSION

The results of the water analyzed is presented in table one and two (1 and 2) below. From the result of physical parameters measured, it can be read as follows pH ranges from 6.5 to 8.1 while electrical conductivity (EC) varies from 67 to 1050 $\mu\text{S}/\text{cm}$ respectively. The results of temperature also varies from 28 to 39 $^{\circ}\text{C}$ with 33.4 $^{\circ}\text{C}$ as overall means of the temperature both in surface and groundwater but the temperature in groundwater is higher due to increase in depth (Table 1). The results of chemical parameters measured in milligram per liter shows that, Ca^{2+} ranges from 3.5 to 66.5 mg/l while that of Mg^{2+} varies between 4.8 to 28.2 mg/l. The Na^{+} and K^{+} values range from 0.7 to 1241.0 mg/l for Na^{+} and 2.0 to 112.0 mg/l for K^{+} respectively. The concentration of HCO_3^{-} in the water varies between 77.5 to 237.0 mg/l while that of Cl^{-} ranges from 4.0 to 160.0 mg/l. The value of SO_4^{-} in the water varies from 0.7 to 283.0 mg/l. The mean concentration of the cations shows that $\text{Na}^{2+} > \text{Ca}^{2+} > \text{K}^{+} > \text{Mg}^{2+}$ respectively.

From the results, studies reveal that, sodium has the highest concentration in the water as observed from Warodi well 24 and well 25 with the concentration of 814.0 and 1241.0 mg/l this high concentration may reflect the geochemical interaction of transported materials with those occurring in the area while calcium concentration

may be attributed to its abundance in the earth crust or are released as weathered products of feldspars, amphiboles and pyroxenes. Magnesium may have been sourced from amphiboles, pyroxenes, or olivines from the basement rocks or from clay minerals derived from such rocks (Elueze et al, 2001). The source of HCO_3^{-} which has a mean concentration of 129.7mg/l (Table 1 and 2) can be attributed to CO_2 charge waters (Tijjani, 1994) while the warm temperature of groundwater observed in boreholes and hand pumps up to 39 $^{\circ}\text{C}$ is attributed to the fact that the groundwater in such areas occurs within the middle confined aquifers of the Chad Basin and temperature increases with depth (Barber and Jones, 1965). The chloride concentration in the water with average of 54.2mg/l suggests that the chemical characteristics of the water are influenced by recharge from meteoric water as observed from hand pumps due to its shallow depth and mostly phreatic aquifer or the weathering and release of ions from the underlying basement rocks (Olayinka et al, 1999 and Sani, 2006) The high values of physical parameters such as EC, pH and temperature in the groundwater as compared to surface water may be due to incorporation of dissolved components of overburden and anthropogenic influences arising from contamination.

Table 1: Physico-chemical mean data of surface and groundwater compared with WHO, 2020 Standard

Measured parameters	Ranges	Groundwater	Surface water	Overall mean	Acceptable level	Excessive level
Temperature	28 -39	34.2	32.2	33.4	-	-
pH	6.5 – 8.1	7.18	7.89	7.46	6.5	6.5 – 8.5
EC	74 - 1050	548.53	235.1	423.16	-	-
Ca^{2+}	3.5 – 66.5	37.57	11.84	27.28	75	200
Mg^{2+}	4.8 – 28.2	13.6	9.21	11.84	125	150
Na^{+}	0.7-1241.0	178.51	13.50	112.50	120	-
K^{+}	2.0 -112.0	31.01	10.11	22.65	200	-
HCO_3^{-}	77.5-237.0	136.77	119.20	129.74	200	-
Cl^{-}	4.0-160.0	67.73	33.80	54.16	250	600
SO_4^{-}	0.7-283.0	90.09	25.01	64.06	200	400

Table 2 Physical and Chemical Characteristic of Surface and Groundwater in parts of Chad Basin Nigeria

Sample No	Source of water	pH	Temperature (o°)	Electrical conductivity (mμ/cm)	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻
DAURA 1 *	Groundwater	8.0	33	381	22.4	10.6	13.6	6.0	105.0	6.0	46.8
MELERI 4*	„	7.3	33	252	53.0	9.6	66.0	9.0	187.0	34.0	85.6
KANARAM 5 *	„	7.4	32	306	25.6	14.0	25.6	4.0	144.5	16.0	56.9
BULABULIN 7 *	„	7.5	33	241	9.2	17.0	9.5	4.6	90.5	28.0	9.0
NJOLLOM 8 *	„	7.4	32	400	26.2	7.3	68.5	10.5	143.5	24.0	15.7
BAGADA 9 *	„	7.5	33	254	11.4	12.5	6.0	8.5	95.0	18.0	2.6
ALI BANYE 10 **	„	6.5	39	1050	49.0	6.0	75.0	13.6	98.0	160.0	96.0
MARTE 12 **	„	6.5	39	984	57.0	17.0	71.4	10.0	179.0	130.0	76.0
ALI MARTE 14 **	„	6.8	35	1012	63.0	13.5	102.4	12.7	191.0	120.0	100
KANZOMO 15 **	„	6.7	36	1002	33.6	12.3	75.4	13.6	133.5	94.0	68.3
MUSSENE 16 **	„	6.7	37	906	66.5	11.0	74.3	12.0	237.0	80.0	97.5
KALARI 21 ***	„	7.7	34	138	8.4	16.7	8.0	2.0	122.5	12.0	0.7
KALARI FULANI 22 *	„	7.3	33	502	33.4	4.8	27.0	30.4	78.0	30.0	188.2
WARODI 24 *	„	7.3	31	400	48.2	9.4	814.0	102.2	138.5	120.0	224.8
WARODI 25 *	„	7.1	31	400	56.7	27.5	1241.0	112.0	108.5	144.0	283.0
DAURA 2 ****	Surface water	8.3	36	562	26.0	25.4	25.0	37.5	220.0	96.0	134.7
DAURA 3 *****	„	7.3	32	74	3.5	28.2	3.6	3.8	87.0	56.0	6.0
KANARAM 6 ****	„	8.3	36	127	27.0	8.4	72.2	11.0	216.0	44.0	12.6
MARTE 11 ****	„	8.1	28	215	4.5	11.0	18.1	13.0	98.0	44.0	8.5
NEW MARTE 13 ****	„	7.9	29	795	11.8	5.7	12.4	2.7	87.0	18.0	9.4
NEW MARTE 17 *****	„	8.0	33	268	23.7	10.0	12.4	14.0	111.0	56.0	34.6
KALARI 18 *****	„	8.1	32	67	4.5	7.5	2.5	2.7	77.5	4.0	17.2
KALARI 19 *****	„	7.6	31	81	5.6	5.0	6.8	4.6	112.5	4.0	7.0
KALARI 20 *****	„	7.7	32	81	5.8	5.5	5.0	6.8	87.0	4.0	11.0
KALARI 21 *****	„	7.6	33	81	6.0	5.8	2.0	5.0	96.0	12.0	9.1

*Hand dug wells **Boreholes ***Hand pumps ****Stagnant surface water *****Flowing River

WATER TYPES

Water can be classified chemically base on the mineralization of ionic contents (Schoeneich, 2001) states that, water can be classified chemically based on mineralization prevailing mega-ions and some trace elements or some dissolved gases. Therefore, water can be classified either on Piper trilinear diagram, Wilcox diagram, Schoeller plot or other parameters. Piper diagram was produced based on the values of the major elements analyzed

from the water samples. A plot of cations and anions were done on triangle and was projected in a diamond shape representing both anions and cations, from the plot; water type is classified base on water sampled collected from surface water, impounded surface water pond, flowing River and groundwater tapping Upper aquifer through hand dug wells and boreholes tapping Middle aquifer.

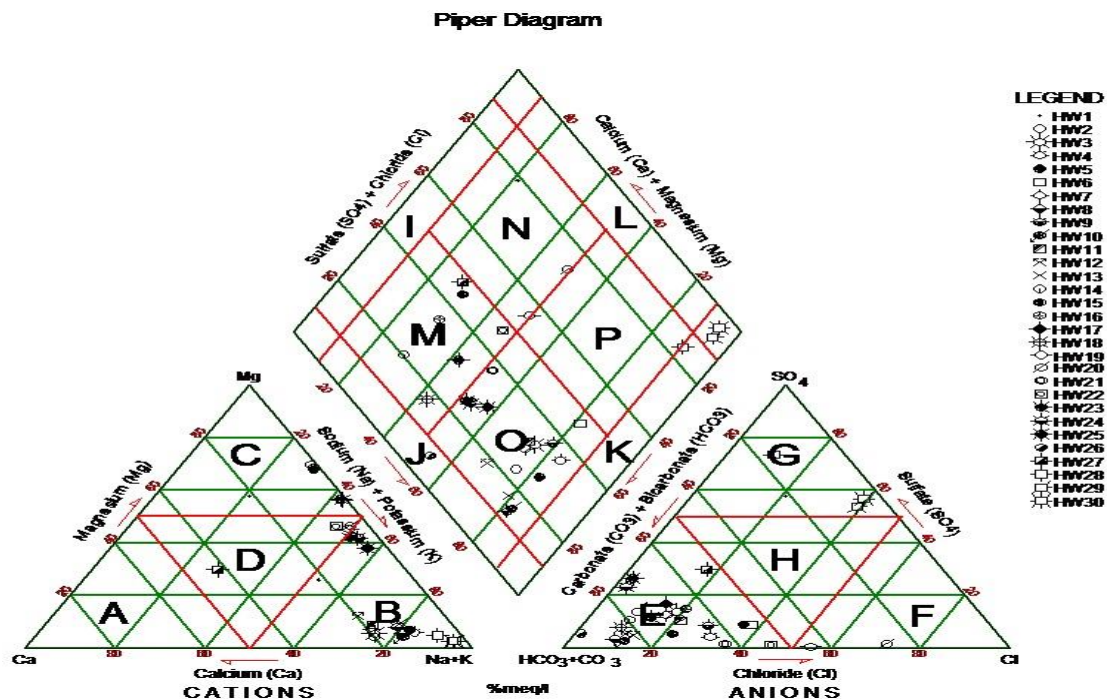


Figure 7a: Piper Trilinear plot diagram representing the analyses of water types from surface water and phreatic aquifer within the study area.

From the two results plotted on piper trilinear diagram of the study area (Black and Hanshow, 1965). A = Calcium type; B = Sodium or Potassium type; C = Magnesium type; D = No dominant type; E = Bicarbonate type; F = Chloride type; G = Sulphate type; H = No dominant type; I = Ca+Mg type; J = $\text{HCO}_3 + \text{CO}_3$ type; K = Na + K type; L = Cl = SO_4 type; M = Ca (Mg) HCO_3 type; N = Ca(Mg) ClSO_4 type; O = Na(K) HCO_3 type and P = Na(K) $\text{Cl}(\text{SO}_4)$ type. Water around Kalari and Warodi is

more of Sodium and potassium rich with Sulphate bicarbonate ions and became the dominant water type of $\text{NaSO}_4\text{HCO}_3$ while the southern part of the study area is rich in $\text{NaHCO}_3\text{SO}_4$ water type. Piper plot is useful for showing multiple and trends in major ions. It divides water into types according to their placement near the four corners of the diamond triangle

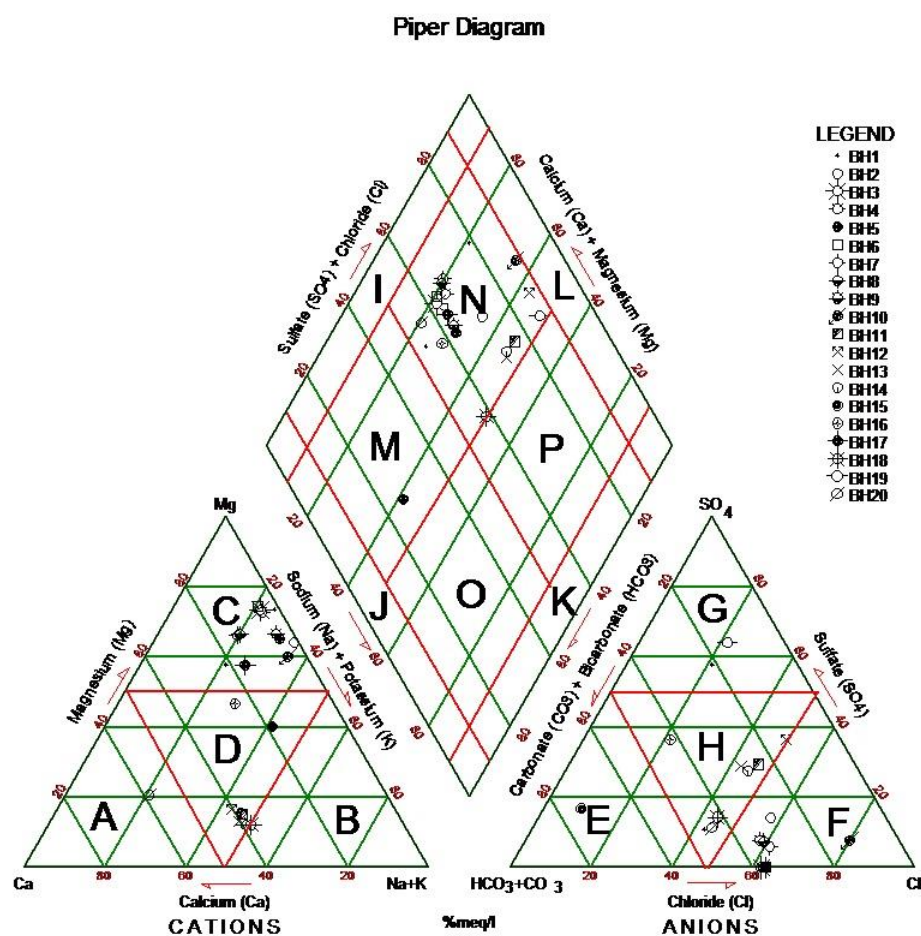


Figure 7b: Piper Trilinear plot diagram representing the analyses of water types tapping middle aquifer within the study area.

Water that plots at the top of the diamond is higher in $\text{Ca}^{2+} + \text{Mg}^{2+}$ and HCO_3^- and is the region of waters with temporary hardness. Water plotted at the lower corner of the diamond is composed primarily of $\text{Na}^+ + \text{K}^+$ and HCO_3^- . It represents the combination of major and minor constituents of groundwater in the study area. According to the diagram, sodium and potassium is the dominant and calcium is the least in hand dug wells tapping Upper aquifer while in boreholes tapping Middle aquifer, calcium is the dominant element and the potassium is least. According to Furtak and Langguth (1967) it can be deduce based on percentage with 53% of the water in the area belong to earth alkaline type with higher alkaline proportion while 41% belong

to or fall within acidic water type with only 5% being normal for domestic consumption.

This work is further plotted on Schoeller plot, is a semi-logarithmic plot to represent major ion analyses in milliequivalents per liter and to demonstrate different hydrochemical water types on the same plot. Schoeller diagram represents the combination of major and minor constituents of groundwater and surface water in the study area. According to the diagram, sodium is the dominant and calcium is the least in hand dug wells tapping Upper aquifer while in boreholes tapping Middle and Lower aquifer, magnesium is the dominant element and the chloride is least in the plot as presented below in Figure 8a and 8b

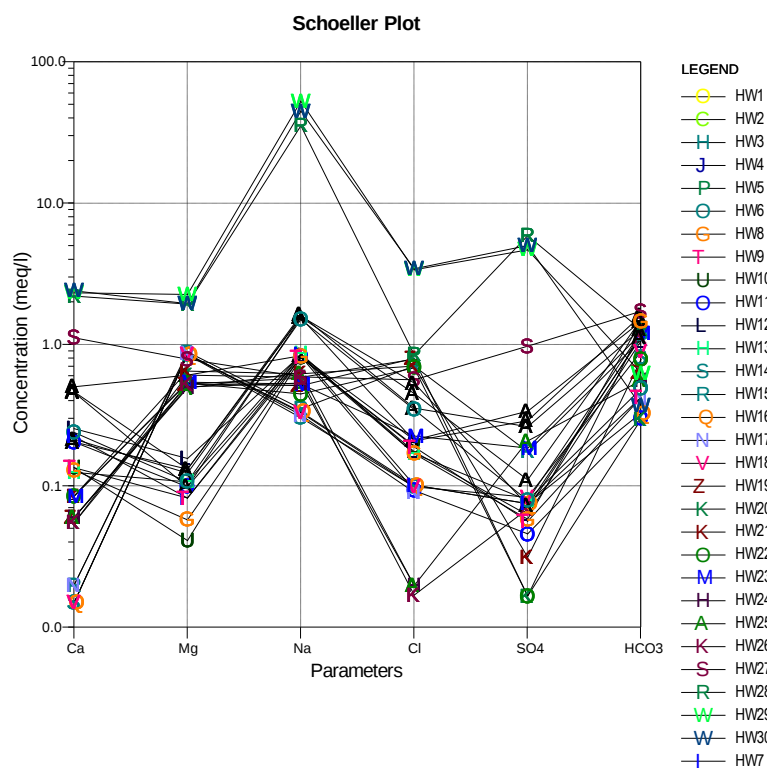


Figure 8a: Results of water quality plotted on Schoeller diagram tapping Upper aquifer in hand dug wells.

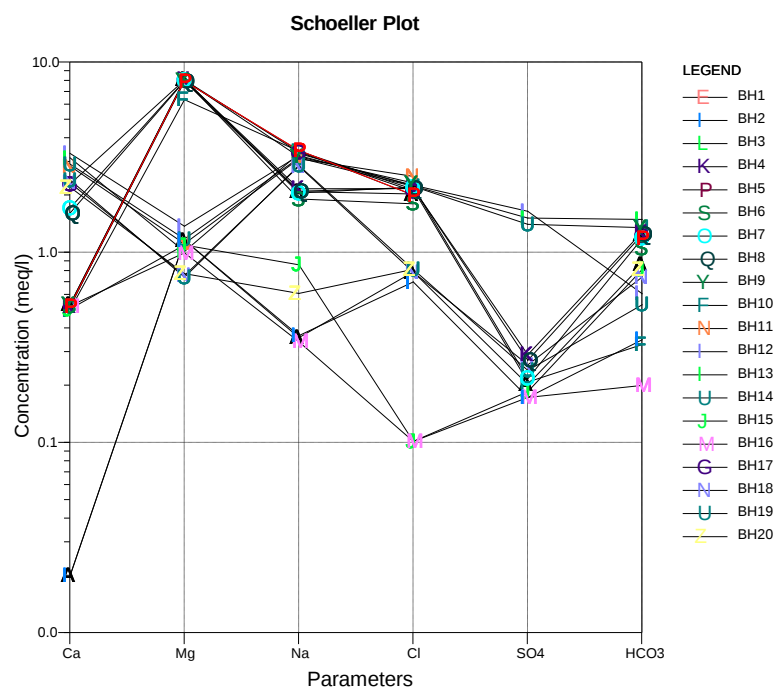


Figure 8b: Results of water quality plotted on Schoeller diagram tapping Middle and Lower aquifer in boreholes.

Suitability of water for drinking, domestic use and agriculture based on its major ions

The first thing to think about the Basin is that, is there enough water to drink both for domestic uses and livestock rearing before talking of small-scale irrigation. This is the question to answer before talking about its suitability of the water in the research area. In fact, there is no enough water for consumption. The only available water in the study area is little water from A and B sub-zones in Upper aquifer bed with sodium, magnesium and sulphate are higher above the WHO, 2021 limit as detected from analyses of water samples.

Wilcox plot enable water to be classified base on the conductivity of the water analysed in the study area. From the Wilcox plot it can be read

that, one of the samples is excellent for irrigation with low sodium hazard with conductivity < 250 $\mu\text{S}/\text{cm}$ while ten of the samples are good for irrigation with conductivity between < 250 – 750 $\mu\text{S}/\text{cm}$ and five of the sample are moderately good for irrigation with conductivity between 750 – 2250 $\mu\text{S}/\text{cm}$ in the Upper aquifer tapping through hand dug wells. In the borehole tapping Middle and Lower aquifer, five of the samples is excellent for irrigation with low sodium hazard with conductivity < 250 $\mu\text{S}/\text{cm}$ while twenty of the samples are good for irrigation with conductivity between < 250 – 750 $\mu\text{S}/\text{cm}$, This means that the water in deeper Chad Formation is more conductive than those in the phretic zone as a result of higher total dissolve solid (Figures 9a and 9b).

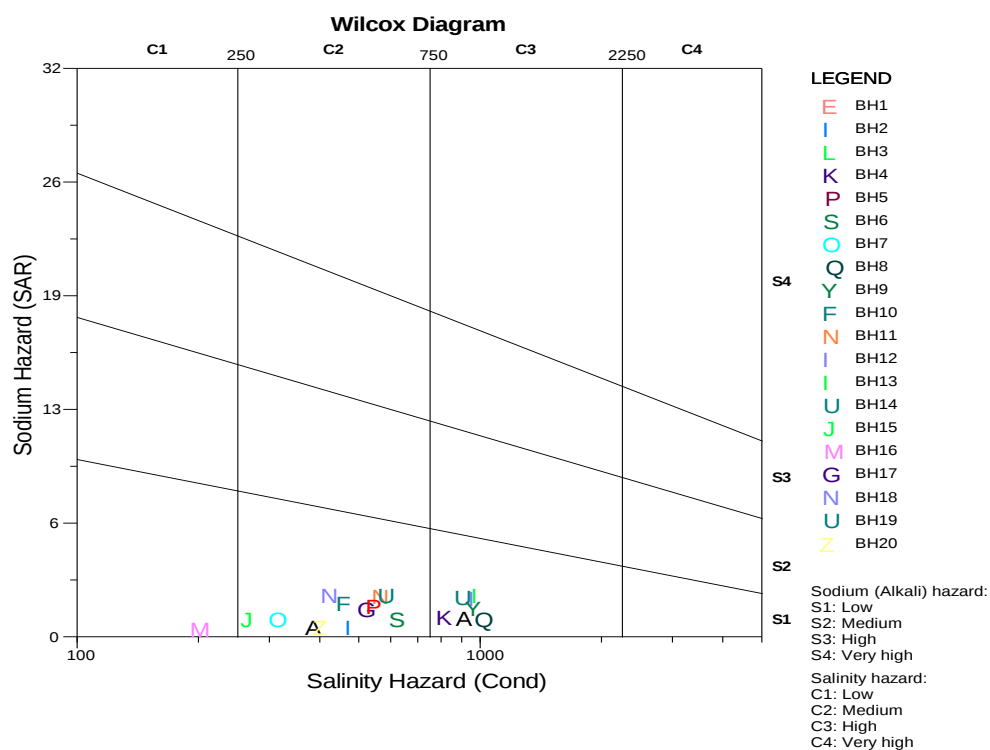


Figure 9a: Wilcox plot of hand dug wells tapping Upper aquifer in Chad Formation

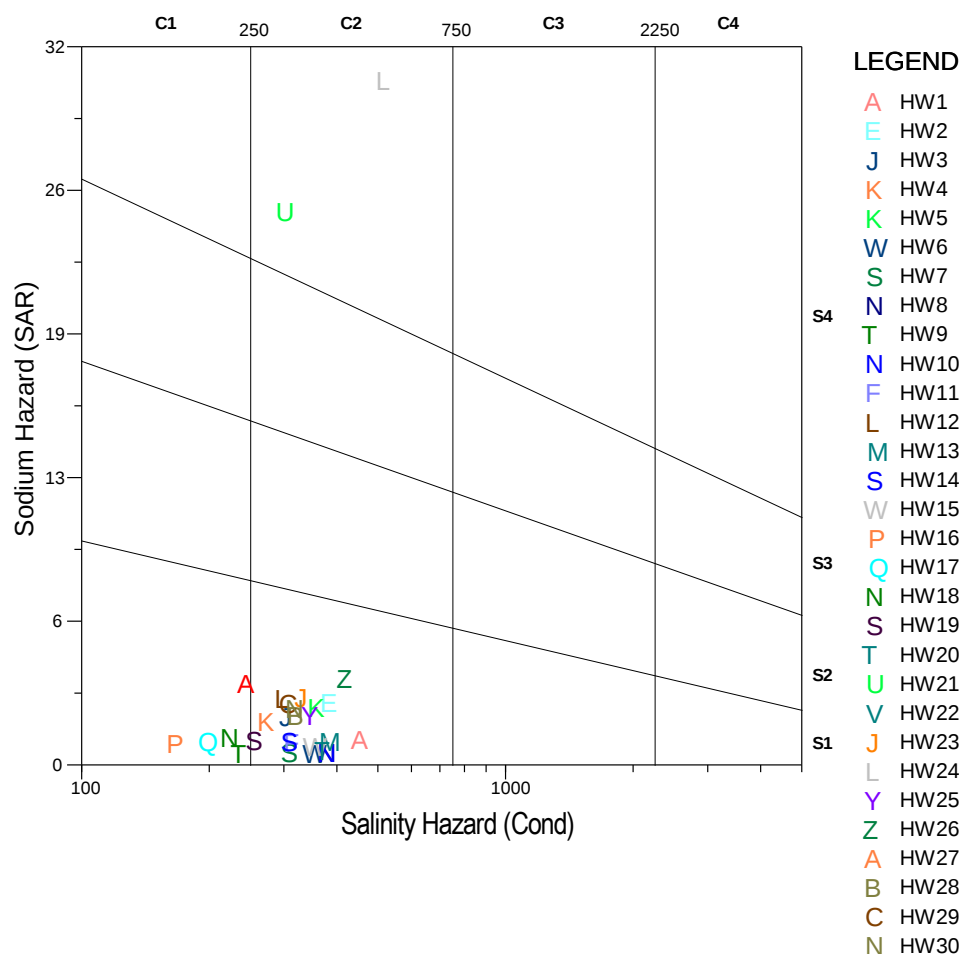


Figure 9b: Wilcox plot of boreholes tapping Middle and Lower aquifer

CONCLUSION

Results of hadrochemical studies of both surface and groundwater in parts of the Chad basin shows that the water is acidic and alkaline. The study further reveals that the Warodi wells 24 and 25 is highly enriched in sodium and other anions which are above the permissible limits (WHO, 2020) which may cause laxative effect such as gastrointestinal pains thereby leading to death in most cases. This has been confirmed in this study as animals that drank the water from these wells died instantly according to the villagers and so all the wells were abandoned. Further research may be required for the confirmation of this to ascertain the result of higher pollution of the wells in the area. It may be

also recommended that, other water sources be developed to supplement the existing ones and also the need to advance this research to microbial, heavy metals and isotopic studies is necessary to ascertain the reason for higher major elements in the wells.

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