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Assessment of the Groundwater Quality of Damboa Area in the Bornu Depression of Northeast Nigeria

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Abstract: *Groundwater resources are essential for the sustenance of domestic, agricultural, industrial and other activities within the ecosystem. However, the usefulness of this resources depends on its quality. This study was conducted to asses the quality of groundwater in Bornu Depression. The study area, Damboa is located in the Bornu area of Northeast Nigeria. It is located within latitudes 10°52´24"N to 11°29´43"N and longitudes12°30´00"E to 13°09´28"E in an area of about 642.132 km^2. The elevation is on the average of about 452m above sea level, and is generally undulating lowland. Twelve (12) parameters (pH, electrical conductivity, total hardness, alkalinity, calcium, magnesium, sodium, potassium, chloride, nitrate and fluorides) were used in the assessing water quality. SAR values showed a range of 1.0to13.0meq/L. The maximum concentration of SAR13.0meq /L was recorded at Kumsi location and minimum concentration of 1.0meq /L was recorded at Ambiya location. The calculated values of SAR integrated with the Electrical Conductivity indicated that the groundwater in the study area can be utilized for irrigation purpose without any threat of imposition of any hazard (saline or alkaline hazard) to crop soils. Thus, the analytical data from the study area confirms that groundwater the studied site maybe suitable for domestic and irrigational purposes excluding a few locations.*

Keywords: *Water resources, rural area, potability, analytical parameters, Physicochemical*

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1.0 Introduction

Groundwater is referred to as the subsurface water that occurs beneath the water table in soils and rocks of fully saturated geologic formation. Groundwater is a significant resource to the global society because most domestic, agricultural, industrial and other practices depend on the availability of quality groundwater. Studies have shown that without anthropogenic interferences, the quality of groundwater from several regions is functional for almost all forms of demanding applications (Amos-Uhegbu, 2012). However, contamination of groundwater by some agrochemicals, industrial wastes, domestic wastes and other contaminants has gradually resulted in some levels of contaminants such as those reported by Donuma *et al*. (2023), Ohaegbuchu *et al*. (2023), Etesin and Inim (2021), Adeniran *et al*. (2023), Belle *et al*. (2021), etc. Groundwater contamination has severe health consequences including death because water can transport, dissolve or disperse almost all toxic compounds (Omali *et al*., 2023). For example, Ezeudu *et al*. (2024) reported potential health risks due to heavy metal-contaminated groundwater samples from Oba in Anambra state, Nigeria. Similar studies have also been reported concerning other parts of Nigeria and the global society (Ezechinyere and Stanislaus, 2023; Mutileni *et* al., 2023; Taiwo *et al*., 2023). A polite consideration of the future of the environment and the well-being of man points towards the much required solutions based on documented information. Therefore, this study is aimed at investigating the quality of groundwater within Bornu depression in Nigeria.

1.1 Geology of Bornu Basin

The Bornu basin which is the Nigerian sector of the Chad basin(Fig. 1) belongs to the Western - Central Africa Rift (WCARS) system that was formed due to the mechanical separation of the African crustal blocks in the Cretaceous (Genik, 1992). Paleo-environmental reconstruction of the evolution and stratigraphy of the Bornu basin has been carried out by many workers despite of the non-existence of significant outcrops in the area (Carter et al. (1963), Matheis (1976), de Klasz (1978), Petters and Ekweozor (1982), Wright et al. (1985), Avbovbo et al. (1985), Genik (1992), Okosun (1992, 1995), Olugbemiro et al. (1997), and Obaje et al. (2004) and others. The majority of these studies were from exploratory oil wells and boreholes data, and also from the stratigraphic correlation of rocks of adjoining basins like the upper Benue trough.

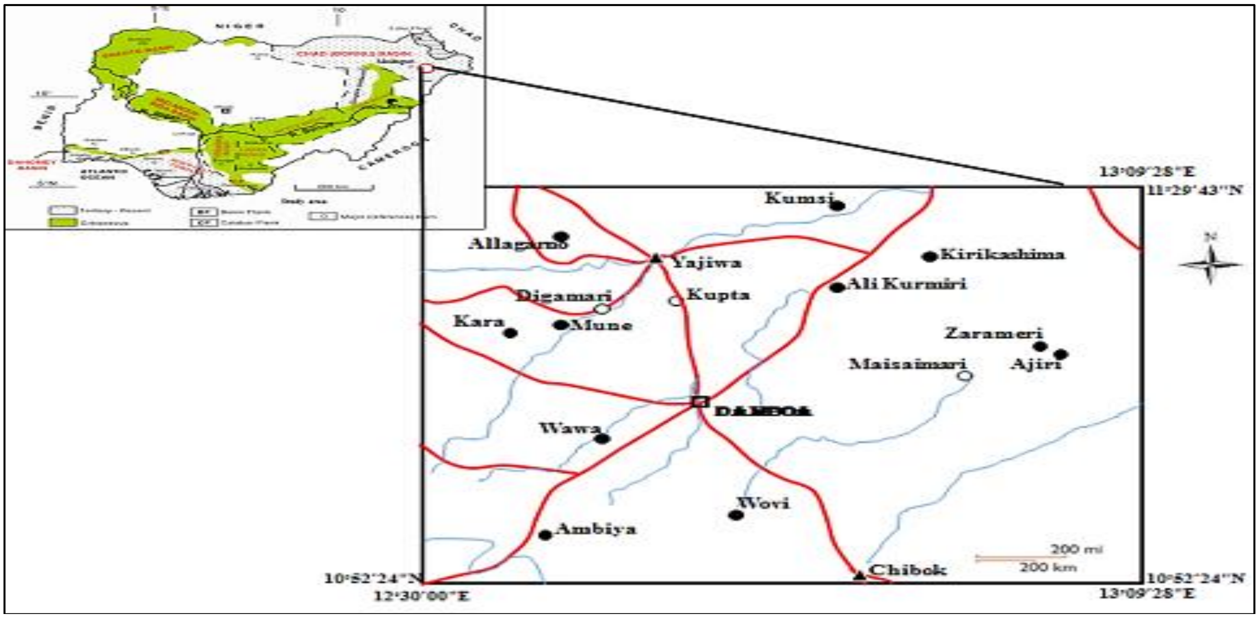

Fig. 1: Map showing the study location, Damboa in the Bornu Basin (inset: Geological map of Nigeria showing the location of the study area; modified from Obaje*et al.*,2011).

Sediment deposition in the Bornu basin started in the Albian with the unconformable deposition of a sparsely fossiliferous, poorly sorted, medium to coarse-grained feldspathic Bima Sandstones on the Precambrian basement (Fig. 2). The Bima Sandstone is overlain by the Gongila Formation and it is composed of calcareous shales and sandstones indicative of a shallow-marine environment of deposition (Wright et al., 1985).The deposition of the Gongila Formation in the Turonian is presumed to mark the onset of the marine incursion into the Chad basin (Olugbemiro *et al.*, 1997; Obaje et al., 2004). The Gongila Formation is overlain by the Fika (Shale) Formation and was deposited during the continued marine transgression in the Turonian–Coniacian. The Fika Formation is overlain by the Gombe Sandstone which was deposited during the Maastrichtian in an estuarine/deltaic environment. It is composed of intercalation of siltstones, shales, and clay stones but not the coal seams as have been reported from the Upper Benue Trough (Obaje et al., 1999, 2004). The Tertiary period was characterized by the deposition of the Keri–Keri Formation outside the Bornu basin. Therefore, the Chad Formation lies unconformably on top of the Gombe Sandstone which occurred during the uppermost Pliocene-Pleistocene period. The Chad Formation, which conceals the older sediments, consists of fluviatile and lacustrine clays and sands, with lenses of diatomite up to a few meters thick (Wright et al., 1985).

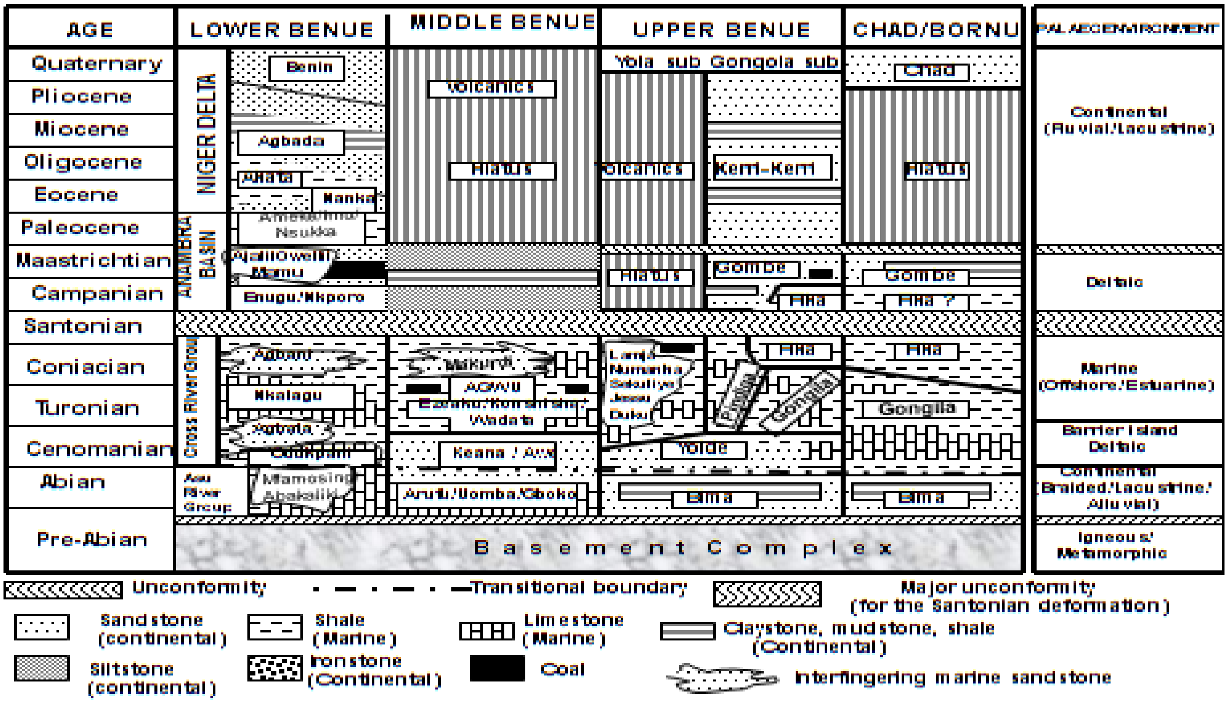

Fig. 2: Stratigraphic successions in the Benue Trough, the Bornu basinand therelationship to the Niger Delta (Modified from Obaje et al., 2006)

2.0 Materials and Methods

Damboa, the study area is located within the Bornu Basin, Northeast Nigeria. It lies within latitudes 10°52´24″ to 11°29´43″N and longitudes 12°30´00″ to 13°09´28″E**.** For the assessment of groundwater quality of the study area, the following four areas of Damboa region were selected: Damboa, Maisaimari, Kupta and Digamari.The sampling was conducted once a month from June 2021 to September 2021 and representative groundwater samples were collected from 12 sampling locations (Table 1). To obtain the representative groundwater samples, the bore wells were flushed for about 5-10 minutes; and the water samples were subsequently collected in clean 2-litre polythene bottles, which were first cleaned by rinsing with distilled water. The temperature was measured on the spot, and the water samples were subsequently taken to the Laboratory and the parameters were analyzed within 24 hrs of collection following the standard methods (APHA, 2005).

Table 1: Details of sampling locations

S/N	Area	Location	Latitude (N)	Longitude (E)	Elevation (m)	Depth of Ground water table (m)	Usage
A1	Damboa	Wawa	11°06′01″	12°40′00″	454	7.0	Domestic/ Irrigation
		Wovi	10°58′50″	12°46′55″	514	9.0	Domestic
		Ambiya	10°56′51″	12°36′54″	482	11.0	Irrigation
A2	Maisaimari	Ajiri	11°13′58″	13°04′57″	421	10.0	Domestic
		Zaramezi	11°14′50″	13°03′57″	515	13.0	Domestic/ Irrigation
		Kirikashma	11°22′56″	12°57′56″	475	13.5	Domestic/ Irrigation
A3	Kupta	Ali Kurmiri	11°20′07″	12°52′55″	469	16.0	Domestic
		Yajiwa	11°22′52″	12°43′19″	407	14.0	Irrigation
		Kumsi	11°27′59″	12°52′55″	436	12.5	Domestic/ Irrigation
A4	Digamari	Mune	11°17′09″	12°38′00″	470	7.5	Domestic
		Kara	11°15′55″	12°34′53″	497	8.0	Irrigation
		Allagamo	11°25′01″	12°37′52″	521	9.0	Domestic/ Irrigation

3.0 Results and Discussion

The quality of groundwater as determined by its chemical constituents is of great importance in determining the suitability of a particular groundwater for an intended use (Amos-Uhegbu, 2012). The physicochemical characteristics of groundwater play a significant role in assessing its quality. From the results of the physicochemical and other parameters of groundwater samples in the area, the water temperature remained low throughout the study period at all locations of groundwater (Table 2). The temperature of groundwater fluctuated from a minimum of 16.5°C at Wovi location in June to a maximum of 28.5°C at the Yajiwa location in September. The average value ranged from 17.4°C ±0.9 at Wovi location to 28.1°C ±0.4 at the Yajiwa location. In the 4-month study period, all the locations were neutral to alkaline pH with values very close to 7, except at Yajiwa and Zarameri locations. Yajiwa location indicated 6.45 and 6.55, in June and August respectively; while Zarameri location indicated the highest pH of 8.2 in June. The average value ranged from 6.7±0.5 at the Yajiwa location to 8.0 ±0.5 at the Ambiya location.

The lowest conductance value 430µS/cm was recorded at the Wawa location in July and the highest value of 1150 µS/cm was recorded at the Kirikashma location in September. The average values ranged from 580 µS/cm at the Wawa location to 1000 µS/cm at the Kirikashma location (Table 2).

The alkalinity of groundwater samples in the area is attributable to the bicarbonates was foundin the range of 42 to 140 mg/l, with the lowest value of 42 mg/l at Ambiya location in June and the highest value of 140 mg/l at the Kirikashma location in September. It is a measure of variable complex mixtures of anions and cations and the average values ranged from 57mg/lat the Ambiya location to 118mg/l at the Wovi and Ajiri locations.

Water hardness is generally the total amount of dissolved calcium and magnesium in water. The average value of total hardness of the groundwater samples of the study area varied from 190 mg/lat the Kara location to 380 mg/l at the Wovi location. The maximum value of 400 mg/l was recorded at the Wovi location in June and minimum value of 144 mg/lwas recorded at the Kara location in July.

Calcium and magnessium carbonates are the main source of hardness in fresh water. Calcium (Ca) is one of the most pronounced minerals in the samples, the concentration of which was observed to vary from 115.2 to 249.8 mg/l. The maximum concentration of 249.8 mg/l was recorded at the Wovi location in June and a minimum concentration of 115.2 mg/l was recorded at the Kara location in June. The minimum average value ranged from 117.6 mg/l ±1.5 at the Kara location to 247.6 mg/l ±2.1 at the Wovi location (Table 2).

The concentration of Magnesium (Mg) was observed to vary from 5.34 to 35.28 mg/l. The maximum concentration of 35.28 mg/l was recorded at Kumsi location in the month of August and minimum concentration of 5.34 mg/l was recorded at Mune location in the month of June. The average value ranged from 8.5 mg/l ±1.7 at Kara location to 33.2 mg/l ±2.1 at Wovi location.

The nitrite-nitrogen of the groundwater samples ranged from 14 to 146 µg/l. The minimum value 14 µg/l was found in July at the Ali Kurmiri location and the maximum value 146µg/l was reported in June at the Ali Kurmiri location. The average values ranged from 15.75 µg/l ±4.78 at the Zarameri location to104.25µg/l ±24.9 at the Ajiri location.

The Orthophosphate-Phosphorus of the groundwater samples ranged from 11 to 146µg/l. The maximum concentration of Orthophosphate-Phosphorus 146 µg/l was recorded at the Ali Kurmiri location in June and a minimum concentration of 10 µg/l was recorded at the Zarameri location in June. The average values ranged from 12µg/l at the Zarameri location to 100µg/l at the Ajiri location.

The Fluoride concentration of the groundwater samples ranged from 0.1 to 1.8mg/l. The maximum concentration of Fluoride 1.8µg/l was recorded at the Wovi location in June through to September, and a minimum concentration of 0.1mg/l was recorded at Kumsi location from July to September.

Potassium (K) is usually found as ions in natural waters. The concentration of potassium under the present study ranges from 2.0 to 20.0 mg/l. The maximum concentration of 20.0 mg/l was recorded at Ali Kurmiri in June and a minimum concentration of 2.0 mg/l was recorded at the Ambiya location in June. The average values ranged from 2.0 mg/l at the Ambiya location to 20.00 mg/l at the Ali Kurmiri location (Table 2).

3.1 Sodium adsorption ratio

The sodium adsorption ratio of the groundwater samples recorded ranged from 1.0 to 13.0 meq/l.

The maximum concentration of sodium adsorption ratio of 13.0 meq/l was recorded at the Kumsi location and a minimum concentration of 1.0 meq/l was recorded at the Ambiya location (Table 2, Fig. 3).The percentage sodium of the groundwater samples ranged from 5.0 to 49.0%. The maximum percentage concentration of sodium 49.0 was recorded at the Kumsi location and a minimum percentage concentration of 5.0 was recorded at the Ambiya location(Table 2).

Table 2: Showing results of physicochemical parameters analysis of ground water samples from Damboa area of Bornu, Northeast Nigeria.

Location / Number	Na (%)	SAR (meg/l)	Av.K (mg/l)	Av. F (mg/l)	Av. Ortho-P (μg/l)	Av. Nitrate-N (μg/l)	Av. Na (mg/l)	Av. Mg (mg/l)	Av. Ca (mg/l)	Average Total hardness (mg/l)	Average Alkalinity(mg/l)	Average Conductivity (μS/cm)	Av. pH	AverageWater Temperature (ºC)
Wawa 1	32.0	5.5	20.0	0.4	20.0	40.0	30.0	17.5	220.0	275.0	60.0	580.0	7.50	18.0
Wovi 2	44.0	8.0	20.0	1.8	30.0	42.0	40.0	35.0	250.0	380.0	118.0	880.0	7.75	18.0
Ambiya 3	5.0	1.0	2.0	0.5	40.0	50.0	50.0	20.0	240.0	325.0	57.0	590.0	8.00	18.0
Ajiri 4	28.0	7.0	7.0	0.3	100.0	120.0	40.0	15.0	200.0	250.0	118.0	880.0	8.00	22.0
Zaramezi 5	25.0	6.0	3.0	0.7	12.0	20.0	35.0	17.5	230.0	300.0	70.0	700.0	7.80	20.0
Kirikashma 6	28.0	5.5	14.0	0.8	70.0	70.0	30.0	12.5	175.0	240.0	110.0	1000.0	7.80	17.0
Ali Kurmiri 7	35.0	7.0	20.0	1.0	60.0	65.0	45.0	30.0	220.0	345.0	90.0	1000.0	7.80	20.0
Yajiwa 8	30.0	6.0	6.0	0.9	20.0	30.0	35.0	12.5	170.0	200.0	110.0	800.0	6.70	23.0
Kumsi 9	49.0	13.0	16.0	0.1	20.0	30.0	50.0	35.0	225.0	375.0	100.0	600.0	7.75	16.0
Mune 10	25.0	5.8	7.0	0.5	28.0	45.0	30.0	12.5	140.0	200.0	90.0	580.0	7.75	18.0
Kara 11	32.0	8.0	10.0	0.6	18.0	20.0	40.0	10.0	135.0	190.0	110.0	610.0	7.60	18.0
Allagamo 12	48.0	9.0	12.0	0.8	44.0	60.0	35.0	20.0	140.0	220.0	100.0	590.0	7.70	22.0

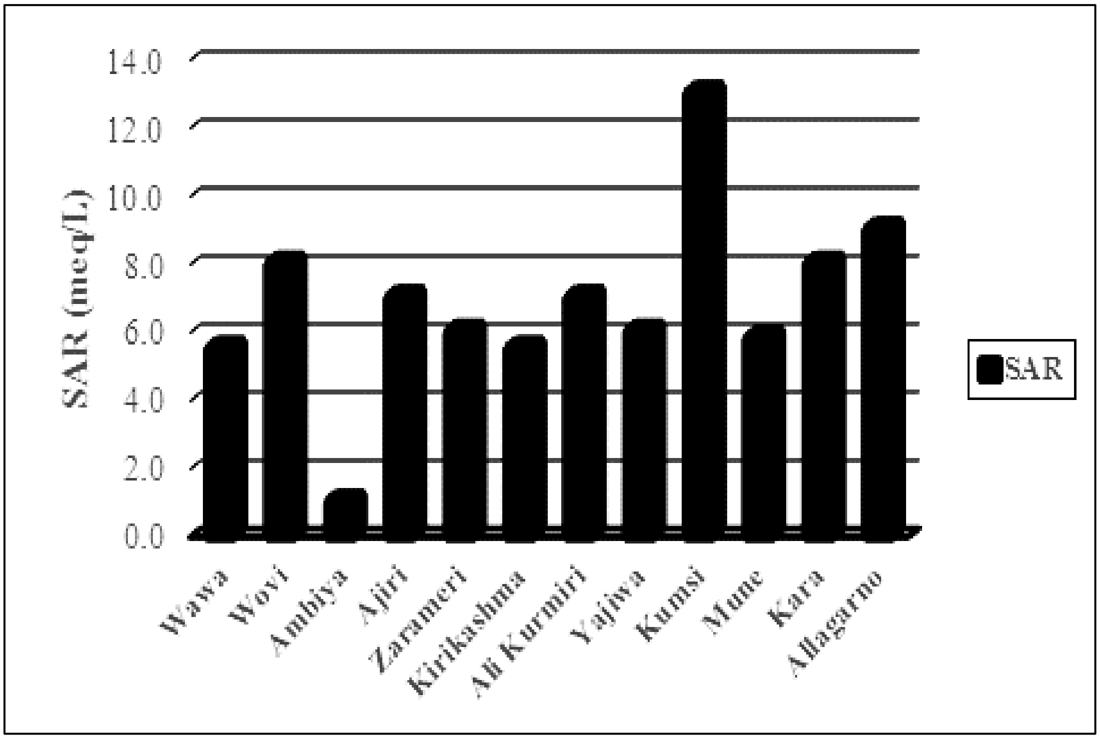

Fig. 3: Sodium Adsorption Ratio (SAR) (meq/l) at different sampling locations

Groundwater chemistry differs depending on the source of water, the types of rocks, topography, climate; the degree to which it has been evaporated and the mineral it has encountered. The groundwater quality may yield information about the environments through which the water has circulated. The temperature range (16.0 to 23.0°C) suggested that most of the locations contain water of shallow type (near-surface groundwater).

Direct influences on the groundwater temperature includes all heat inputs to the groundwater through the sewage network, regional-heat pipes, power lines and such underground structures as auto and metro tunnels, underground garages etc.

Anthropogenic heat generation such as domestic heating, industry and transport also contribute to enhance groundwater temperature (Miller, 1997). Conductivity is a measure of the ability of water to conduct an electric current. It is used to estimate the amount of dissolved salts. It increases as the amount of dissolved mineral (ions) increases. The larger variation in electrical conductivity is mainly attributable to lithological composition and anthropogenic activities prevailing in this region (Khodapanah *et al*., 2009). Higher conductivity at the Kirikashma and Ali Kurmiri locations may be due to the accumulation of dissolved solids from the upland areas by rainwater and the leaching of dissolved solids from effluents through the alluvial deposits. (Ravindra and Garg, 2007). The pH is a measure of the hydrogen ion concentration in water.

The pH value of water indicates whether the water is acidic or alkaline. The slightly acidic pH (6.50) at the Yajiwa may be due to the microbial load decomposition in soil and water, while Neutral to Alkaline pH (>7.0) may be due to limestone-rich lithology of the valley, liberating Ca and Mg into the solution (Yongjin et al., 2006). Alkalinity refers to the quantity and kinds of compounds that collectively shift the pH into the alkaline range (pH over 7). Bicarbonates, carbonates and hydroxides are mainly responsible for alkalinity (Cole, 1983). Alkalinity in waters is due to any dissolved ions that can accept or neutralize protons. In the present groundwater samples, alkalinity was mainly contributed by bicarbonates which is a characteristic feature of valley lithology. Its concentration remained moderate (42 mg/lto 140 mg/l). A large amount of alkalinity may impart a bitter taste, harmful for irrigation as it damages soil and hence reduces crop yields (Yongjin *et al*., 2006). The most common problem associated with groundwater is hardness, largely associated with Calcium (Ca) or Magnesium (Mg) rich lithology. Hard water causes no health problems, but can be a nuisance as it may form soap curds on pipes and other plumbing fixtures. According to Shrivastava et al., (2009) classification, the total hardness values of the study area fall between hard (136 to 300mg/l) and very hard (>300mg/l) and are therefore not fit for domestic purposes. The high values of total hardness in the area may be due to the presence of rich limestone deposits in the valley. Among cations, Ca was dominant followed by Mg. The major source of Ca and Mg inthe water of the area may be due to the lacustrine deposits such as limestone, calcite, gypsum and dolomite. The dominance of Ca ion over Mg ion is attributable to the abundance of these rocks in the study area (Sawyer and McCarthy 2007). Sodium is another cation that is important for both domestic and agricultural purposes, though with the associated problem of its conservative nature once it enters into the system, and its effect on the physical properties of soils. In the study area, the appreciable concentration might have resulted in cation exchange of calcium and magnesium ions by mineral water interaction. The concentration of potassium was recorded low at the majority of the sites, however, at certain sites its concentration was high, which may be due to the use of fertilizers. The composition of cations in the study area depicted the sequence Ca>Mg>Na>K. Nitrogen is a major constituent of the earth's atmosphere and occurs in many different gaseous forms such as elemental nitrogen, nitrate and ammonia. Natural reactions of atmospheric forms of nitrogen with thunderstorms during rainfall result in the formation of nitrate and ammonium ions. While nitrate is a common nitrogenous compound due to natural processes of the nitrogen cycle, anthropogenic sources have greatly increased the nitrate concentration, particularly in groundwater. The major anthropogenic sources are septic tanks, and the agricultural application of nitrogen-rich fertilizers.

Levels of nitrates in groundwater in some instances are above the safe levels proposed by the UNEP and thus pose a threat to human health. In rural areas, the incidence of methemoglobinemia appears to be the result of high nitrate levels in private wells. Methemoglobinemia, or blue baby syndrome, robs the blood cells of their ability to carry oxygen; therefore to prevent the detrimental biological effects, treatment and prevention methods are required to protect groundwater aquifers from nitrate leaching and high concentrations. Treatment through ion-exchange and other processes can rehabilitate already contaminated water; while prevention, such as proper management of domestic sewage, plant debris, animal excreta and reduced dependence on nitrogen-rich fertilizers for agricultural use can lower the influx of nitrates (Voznaya, 1981).

Phosphorus is an essential nutrient for plant and animal growth that passes through cycles of decomposition and photosynthesis. The high concentration of total phosphorus especially at the Ajiri location is indicative of the influx of domestic wastes and fertilizers from agricultural use into the groundwater system (HEC, 1972).

3.2 Suitability of water for drinking purpose

The water samples of the study area did not contain any physicochemical parameter above the WHO international standards, 2004, except total hardness and Fluoride concentration which were higher than the permissible limits of WHO standards, indicating that these waters are hard and contain significant concentration of fluoride. Hence, the waterin the study area could be said to be portable for human consumption with few exceptions. Fluoride exists naturally in water sources and is derived from fluorine, the thirteenth most common element in the Earth's crust. It is well known that fluoride helps prevent and even reverse the early stages of tooth decay. Tooth decay occurs when plaque buildup (a sticky film of bacteria that accumulates on teeth and breaks down sugars in food). The bacteria produce damaging acids that dissolve the hard enamel surfaces of teeth. If the damage is not stopped or treated, the bacteria can penetrate through the enamel causing tooth decay (also called cavities or caries). Cavities weaken teeth and can lead to pain, tooth loss, or even widespread infection in the most severe cases.

Fluoride combats tooth decay in two ways:

- It is incorporated into the structure of developing teeth when it is ingested.
- It also protects teeth when it comes in contact with the surface of the teeth.

Fluoride has been found to have a significant mitigating effect against dental caries and it is accepted that some fluoride presence in drinking water is beneficial. Optimal concentrations are around 1 mg/l. However, chronic ingestion of concentrations much greater than 1.5 mg/l (the WHO guideline value) is linked with the development of dental fluorosis and, in extreme cases, skeletal fluorosis. High doses have also been linked to cancer. Health impacts from long-term use of fluoride-bearing water have been summarized as: <0.5 mg/l: dental caries, 0.5-1.5 mg/l promotes dental health, 1.5-4 mg/l dental fluorosis, >4 mg/l dental, skeletal fluorosis, >10 mg/l crippling fluorosis. Dental fluorosis is by far the most common manifestation of chronic use of high-fluoride water. As it has the greatest impact on growing teeth, children under age 7 are particularly vulnerable. Fluoride is considered an essential element though health problems may arise from either deficiency or excess amount. Much of the fluoride entering the human body is obtained from drinking water. The concentration of fluoride at 0.4 ppm in drinking water can lead to mild type of dental fluorosis (Dinesh, 1999). Wovi location samples showed very high concentration of fluoride and as a result the residents are suffering from dental fluorosis. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric volcanic particles. Fluoride can also come from the runoff and infiltration of chemical fertilizers in agricultural areas; and may also come from liquid waste from industrial sources.

3.3 Suitability of water for Irrigational purposes

The suitability of groundwater for irrigation depends on the ionic concentration of Ca, Mg and Na. Salts can be highly harmful. They can limit the growth of plants physically, by restricting the taking up of water through modification of osmotic processes. Also salts may damage plant growth chemically by the effects of toxic substances upon metabolic processes. Good quality of waters for irrigation is characterized by an acceptable range of sodium adsorption ratio and percent sodium. Sodium concentration plays an important role in evaluating irrigational quality of groundwater because irrigation with Na-enriched water results in ion exchange reactions: uptake of Na+ and release of Ca^{2+} and Mg^{2+}. This causes soil aggregates to disperse, reducing its permeability (Tijani, 1994). All the study sites had very low SAR values, indicating that groundwater samples had excellent quality for irrigation with no danger of exchangeable sodium except Kumsi (Fig. 3). Based on % sodium all sites belong to the good water class category (20-50%) except Ambiya (< 20%) which belongs to the excellent category (Todd, 2003). Low SAR and %Na may be due to the presence of significant quantities of divalent cations such as Ca and Mg which are more strongly bonded and tend to replace monovalent ions like sodium and potassium.

The combination of electrical conductivity (EC) and SAR had also been used to determine the suitability of water for irrigation.

Further assessment using the US salinity hazard diagram (Fig. 4); shows that almost all the locations fall within medium salinity and low alkali hazard (C_2S_1) category except Wovi and Ajiri locations that are indicating high salinity and low alkali hazard (C_3S_1) category. In addition to this, Kumsi location has been found to indicate medium salinity and medium alkali hazard (C_2S_2 category). These groundwater sources can be used to irrigate all types of soils with little danger of exchangeable sodium but the groundwater of Wovi and Ajiri locations which fall under high salinity and low alkali hazard (C_3S_1) category may not be fit for irrigation purposes (Fig. 4).

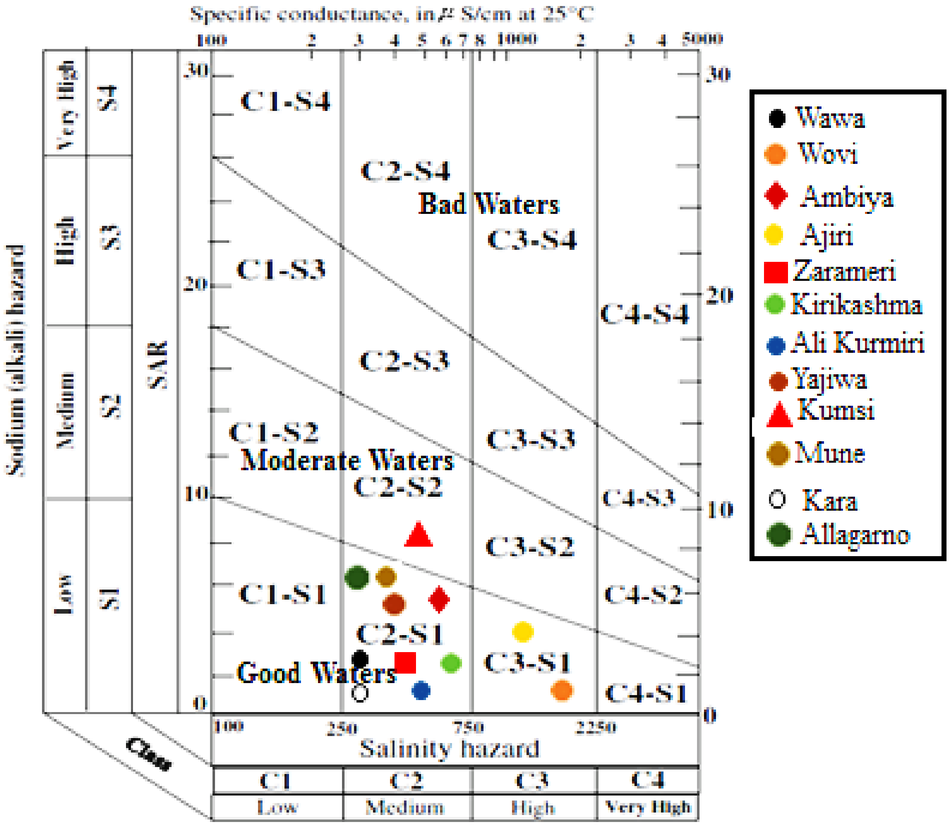

Fig. 4: USSL diagram for classification of irrigation waters (United States Salinity Laboratory Staff, 1954)

Further investigation using the plot of %Na against Electrical Conductivity indicates that the water quality at Wovi, Ajiri, Kirikashma and Ali Kurmiri locations are 'Good to Permissible' while others are 'Excellent to Good' for irrigation purposes (Fig. 5).

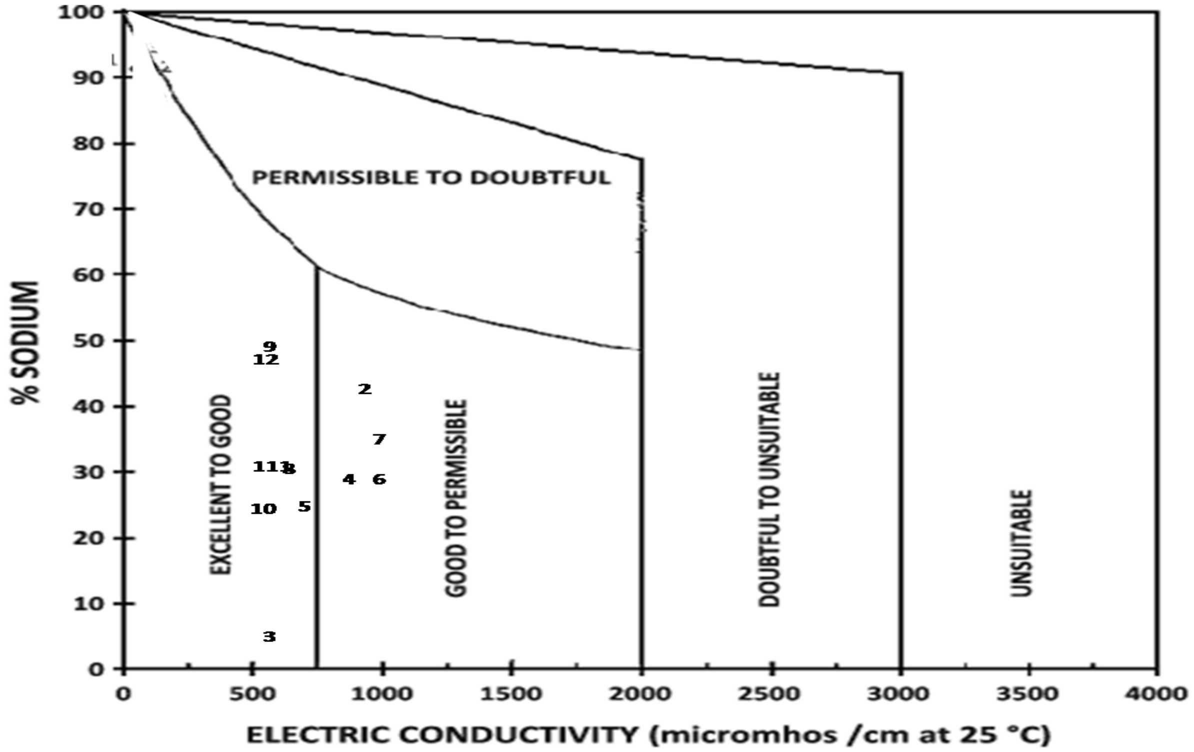

Fig. 5: Plot of %Na against Electrical Conductivity

4.0 Conclusion

The physicochemical features of water are important indicators that provide information about water quality. The present studies revealed that groundwater in the aquifers of Damboa area are fresh and alkaline in nature. The results revealed that varied lithology and anthropogenic activities played an important role in influencing the chemistry of the studied groundwater sources. The chemistry showed that these waters are hard and highly mineralized. Calcium and magnesium are the dominant cations and bicarbonate is the dominant anion. The excess of alkaline earths imparts hardness to the groundwater of the area. During the present study, it was found that the samples of the study area did not contain any physicochemical parameter above the limits prescribed by World Health Organization International Standards, 2004 except total hardness and Fluoride. Wovi location samples showed very high concentration of fluoride and as a result the residents are suffering from dental fluorosis. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric volcanic particles. The sodium adsorption ratio of groundwater samples recorded a range of 1.0 to 13.0meq/L. The maximum concentration of sodium adsorption ratio 13.0meq/L was recorded at Kumsi location and a minimum concentration of1.0meq /L was recorded at Ambiya locations. The sodium percentage of the groundwater samples ranged from 5.0 to 49.0%. The maximum concentration of percent sodium 49.0 was recorded at the Kumsi location and a minimum concentration of 5.0 was recorded at the Ambiya location. Thus, the analytical data from the study area confirms that the groundwater in the study area is suitable for domestic and irrigational purposes with a few exceptions.

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Compliance with Ethical Standards Declarations

The authors declare that they have no conflict of interest.

Data availability

All data used in this study will be readily available to the public.

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data public.

Competing interests

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CAU initiatated the process, MUU led in the field work and drafted the initial manuscript, CAU reviewed the manuscript, CDA and PIA collaboratted in making the (work) manuscript a success. All the authors were involved in the final presentation of the manuscript.