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Assessment of Groundwater Quality in Damboa Town, Northeastern Nigeria.

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Abstract: *This study is conducted to assess the quality of groundwater in Damboa town, Borno State, Nigeria. In doing this, a resistivity method of Geophysical survey of major part of the town was conducted to determine the depth of the groundwater in the area. Also, 20 water samples from 5 wells and 15 boreholes in the town were analysed for some recommended parameters by the World Health Organization for safe water consumption. The results of the geophysical survey showed that all the wells in the area have their sources from the upper aquifer (30–100 m depth) while sources of water in boreholes are from either the Middle Aquifer (270- 330m depth) or the lower aquifer (425–530 m depth). The results of the geochemical analysis and interpretation of the water samples, using Omisoft and excel plots, show that the major contaminants of groundwater in Damboa town are Manganese and nitrate . While no physiological effects due to high level of Manganese in drinking water have been established in humans, excess nitrate in drinking water can cause methaemoglobinanaemia in infants below three months (WHO, 2008). Due to high concentration of nitrate, none of the water from the wells and about 53% of the water samples from the boreholes in Damboa town is in conformity with the acceptable international standard for safe water consumption. However, the duration and rate of consumption of this high concentration of nitrate in drinking water that will be detrimental to human health is unknown.*

Keywords: *Assessment, Groundwater, Quality, Damboa, Aquifer*

I. Introduction

Ground water refers to water collected under the Earth's surface. Marte (1983) stated that groundwater accounts for over 80% of the domestic water supply in the Sahelian region of Nigeria and Damboa town falls within this region. Groundwater pollution is a change in the properties of groundwater due to contamination by microbes, chemicals, hazardous substances and other foreign particles. The sources of groundwater pollution are either natural (mineral deposits in rock) or man-made. Natural sources are less harmful compared to hazardous chemicals generated by human activities.

Arabi, Funtua, Alagbe, Zabosrki and Dewu (2014) observed that urbanization, population increase, dewatering of aquifers for irrigation and extensive use of chemical fertilizers are some of the factors that have direct effects on quantity and quality of groundwater resources especially in arid and semi arid region of northern Nigeria.

This study was carried out not only to investigate the quality of the groundwater from the upper unconfined aquifer and that of the confined middle aquifer system of the Chad Basin in Damboa town but also to ascertain whether the water in this system is within the acceptable limit for human consumption as set by World Health Organisation ,WHO (2008) or not. The findings have important health implications not only for the inhabitants of Damboa town but also for water managers and scientists in Borno State, Nigeria and other developing countries in carrying out water quality related investigations. This is because groundwater quality is an important factor in the context of sustainable water management.

Body

Damboa town, is situated about 88km to Maiduguri, the capital of Borno State, in the Northeastern part of Nigeria. It is located within the Latitude 119'25.920"N and longitude 1245'15.840"E and The climate is semi arid dry tropics with low rainfall and high temperature. The area under investigation is located within Nigeria sector of Chad Basin. Groundwater in this deposit occurs under both confined and unconfined conditions. The Upper aquifer generally unconfined and semi – confined, while the Middle and Lower Aquifers are confined. The Middle zone aquifer is the most extensive and most widely exploited of the three well known aquifers of the Chad Formation (Yusuf, Goni, Hassan; 2014). About 80% of the populations in Damboa town are farmers and their major contributions to the national development are grains and livestock production.

The integrity of underlying aquifers are mainly affected by pollution from above ground sources (Kumar et al., 2013).). Any chemical present on the surface can travel underground and cause groundwater pollution. The seepage of the chemical depends on the chemical type, soil porosity and hydrology. Babaji and

Ndubusi (1988) said that runoffs from the scarce rainfall of the Sahelian region are being charged with ever increasing loads of organic and mineral impurities that naturally recharge the aquifers. Marte (1983) specifically identified Nitrogen-based fertilizers as the most commonly identifiable pollutant in groundwater in rural areas. If applied in excessive amounts, the excess nitrate not consumed by plants can be flushed down to groundwater. Although nitrate is relatively non-toxic it can cause a serious blood disorder in infants (Offodile, 2002)

II. Methods

The resistivity method (VES) of geophysical survey was employed to obtain the resistivity of the groundwater in Damboa town. In doing this, twenty-nine (29) Vertical Electrical sounding (VES) data were acquired on the established three traverses labeled A.A", B-B" and C-C". the traverses are each 600m in length, while the traverses are separated by a distance of 150m. The ABEM SAS 1000C tetrameter was used for the resistivity measurement. Throughout the survey, the half-current electrode separation (AB/2) varying from 1to 150m was used. The field resistivity data was interpreted using the 1-D inversion program of Pirttijarvi (2005). The curves were then interpreted with a minimum number of layers that are deemed necessary, and the corresponding thickness are reproduced by a number of iteration until the model parameter of all the VES curves totally resolved with minimum residual error. In order to account for the near-surface inhomogeneities in the data and retrieve the subsurface geology that best fit the VES data, a 2-D inversion was carried out on the data using WinGLink software (2007). According to Jupp and Vozoff (1975), inversion of the field observation is the standard procedure to obtain an estimate of the true resistivity distribution in the subsurface. Secondary resistivity and secondary resistivity-derived parameters were used to determine the potential aquifer horizon.

Also, the area under investigation was divided into 20 grids each of which was 1 km by 1 km. This covered an area of approximately 20km^2. After taking inventory of the fundamental groundwater sources in the area, a total of 20 water samples-15 samples from boreholes and 5 from wells ,were collected for this study. One water sample was taken per grid and after each sample is collected, an insitu measurement was made for conductivity, pH, TDS and temperature using Conductivity meter (HACH made), pH meter, TDS meter and thermometer respectively. Geochemical analysis of the water samples were carried out to obtain the cations and the anions content of each sample. The physico-chemical parameters obtained from the analysis of each sample were then interpreted using both Excel plots and Omisoft (a software written in syntax of FORTARAN 90). This software, among other things, determines the level of hardness of the water samples and the overall portability of the groundwater in Damboa town based on the set standards by the World Health Organisation, WHO (2008).

Flow Chart

Collection of Water samples

↓

Labeling

↓

Physical analysis (pH, Temp., Elect. Conduct.,TDS)

↓

Chemical analysis (cations, anions,)

↓

Data Interpretation (Omisoft and Excel plot)

III. Results And Discusion

The results of the electrical resistivity of the area under investigation identified three main aquifers: an upper aquifer which is an unconsolidated fine to coarse water-bearing sand with resistivity values ranging from 120 Ohm-m to 1005 Ohm-m ($9.95x10^2$-$8.33x10^3$ µS/m) at 30–100 m depth, a middle aquifer (eastern part of the town) which is a fresh water saturated sand zone most likely intercalated with some clay and has a resistivity ranging from 32-300 Ohm-m ($3.33x10^3$-$2.13x10^4$ µS/m) about 40–90 m thick occurring from 230 m depth and a lower aquifer consisting of 100 m of medium to coarse sands and clays has a resistivity values ranging from 30-256 Ohm-m ($3.9x10^4$ -$3.33x10^4$ µS/m) and occurs at a depth of 425–530 m. The upper and middle aquifer were separated by a layer of clay of about 130m thick with resistivity ranging from 35Ohm-m to 79Ohm-m ($1.27x10^4$-$2.86x10^4$ µS/m) while the middle and lower aquifer is separated by another layer of clay of thickness 100m and resistivity ranging from 35Ohm-m to 79Ohm-m ($1.27x10^4$-$2.86x10^4$ µS/m).

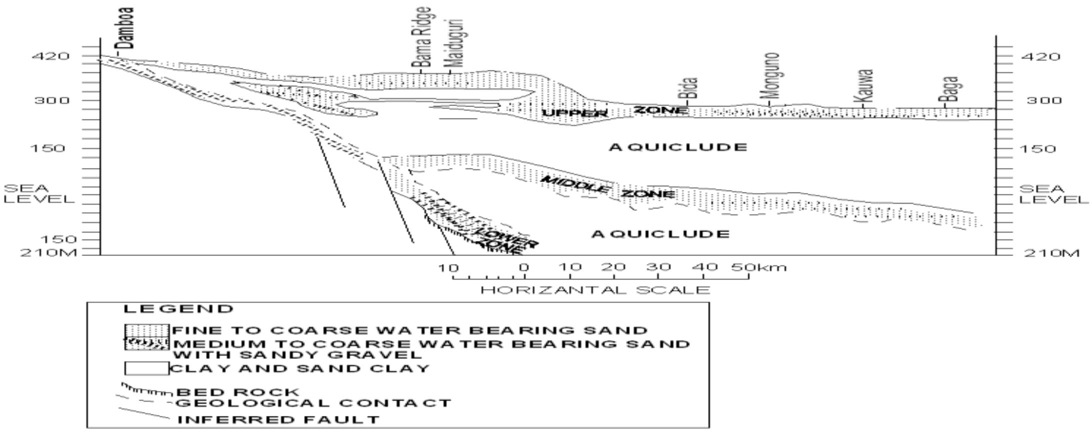

Figure 1:Borehole cross section from Damboa town and the environs.(Courtesy: Adamu et al, 2013)

The results of the geochemical analysis of the 20 water samples for the nineteen(19) physico-chemical parameter recommended by the World Health Organisation,WHO (1996) for safe water consumption are shown in the tables below. Tables 1and 2 show physical parameters measured well samples and borehole samples respectively.pH of water samples from the well ranges from 6.8-8 with an average of 7.32 while ph of borehole samples ranges from 6.6-8.2 with an average of 7.25. This distribution of pH suggests that the groundwater in Damboa town is acidic-alkaline (almost neutral) in nature.pH values of all the water samples are within the Maximum permissible limit set by WHO, 2008 for safe water consumption.

Table 1. Results of physical parameters for well samples from Damboa

Parameters	WLD1	WLD2	WLD3	WLD4	WLD5	*H.D.L	*M.P.L
pH	6.8	6.8	7.5	7.5	8	7-8.5	6.5-9.2
Temp. (^oC)	28	27	30.5	31	30	25	29
E. C (µS/m)	120	130	200	600	690	<1000	1000
TDS (mg/l)	140	130	132	162	159	200	500

***H.D.L-** Highest Desirable Limit; ***M.P.L-** Maximum Permissible Limit; **E.C-** Electrical Conductivity; **TDS -** Total Dissolved Solids

Table 2. Results of physical parameters for Borehole samples from Damboa

PARAMETERS	pH	Temp.(^0C)	E.C (µS/m)	TDS (mg/l)
BHD1	6.8	34.5	162	100
BHD2	6.5	32	199	50
BHD3	6.6	30	245	141
BHD4	6.6	34.5	200	150
BHD5	6.6	32	210	156
BHD6	7.2	33	215	156
BHD7	7.2	33	150	150
BHD8	6.5	33	153	137
BHD9	7.5	34.5	147	132
BHD10	8.2	31	180	156
BHD11	7.5	30	170	151
BHD12	8	29	213	156
BHD13	7.5	29	169	310
BHD14	8	32	327	350
BHD15	8	30.5	600	121
H.D.L	7-8.5	25	< 1000	200
M.P.L	6.5-9.2	29	1000	500

Minimum and maximum temperatures obtained for well samples vary from 27 ^{0}C to 31°C, with a mean value of 29.3°C. The temperatures recorded for borehole samples vary from 29 to 34.5°C, with an average of 31.9°C. Tables 1 and 2 show that all the water samples, collected from the wells and borehole in Damboa, except WLD1 and WLD2 and BHD12 and BHD 13, were found to have temperatures higher than the natural background levels of 22 to 29°C for waters in the tropics (Stumn and Morgan, 1981). Although cool waters are generally prefered for drinking purposes, water with temperature slightly above the normal human body temperature is acceptable in the tropics. However, high temperature conditions may not be desirable for groundwater meant for drinking purposes as it encourages the growth of micro-organisms, which have the potentials of altering the odour, taste and colour of the water. EC and TDS values as shown in Table 1 for well samples ranged from 120 to 690 µS/m and 50 to 350 mg/L. Their mean values are 348 µS/m and 144.6 mg/l respectively. Also in borehole samples, the EC values range from 147 to 600 µS/m, with a mean value of 222.7µS/m; the TDS vary from 50 to 350 mg/L with a mean value of 161.1mg/L. The EC and TDS values for all the well samples analysed are well within WHO acceptable limit for drinking water. The water will also be suitable for irrigation. Figures 2 and 3 show the plots of physical parameters against well samples and borehole samples respectively.

Table 3: Geochemical data of cations in well samples

Parameters	WLD1	WLD2	WLD3	WLD4	WLD5	*H.D.L	*M.P.L
Na (mg/l)	150	6	15	50	21	< 20	200
Ca (mg/l)	52	80	90	25	24	< 100	500
Mg (mg/l)	20	36	44	40	17	50	150
Al (mg/l)	0	0	0	0	0	0.1	0.2
Fe (mg/l)	0	0.2	0.4	0	0	< 0.3	3
Mn (mg/l)	0.4	0.2	0.2	0.5	0.3	<0.1	0.4
Zn (mg/l)	0	0.01	0.01	0.02	0	< 3	3
Ag (mg/l)	0	0	0.02	0	0	0.005	0.1
Cu (mg/l)	0.01	0	0.03	0.01	0.02	< 0.5	0.5
Hardness	72	116	134	65	41	< 100	500

Table 4: Geochemical data of cations in borehole samples

PARAMETERS	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)	Zn (mg/l)	Ag (mg/l)	Cu (mg/l)	HARDNESS
BHD1	19	20	41.5	0	0.5	0.09	0.03	0.01	0.05	62
BHD2	15	71	8.22	0.001	0.11	0.5	0	0	0.03	79
BHD3	9	30	11.1	0	0.03	0.7	0	0	0.02	41
BHD4	9	48	13.9	0.001	0.08	0.5	0	0	0	59
BHD5	14	50	24.1	0	0	0.4	0	0	0.11	74
BHD6	13	50	34	0	0	0.5	0	0	0.1	84
BHD7	2	50	20	0.01	0.01	0.4	0	0	0.04	70
BHD8	2.5	79	23	0	0	0.3	0.01	0.01	0.06	93
BHD9	10	24.5	33	0.01	0	0.5	0	0	0.07	57
BHD10	15	18	23	0	0	0.7	0	0	0.04	41
BHD11	20	21	27	0	0	0.9	0.01	0	0.11	48
BHD12	35	14	43	0	0	0.4	0.01	0.02	0.03	57
BHD13	39	8	32	0.01	0.01	0.2	0	0	0.2	40
BHD14	30	22	21	0	0.01	0.3	0	0	0.02	41
BHD15	29	11	25	0.01	0.01	0.5	0.01	0	0	36
H.D.L	<20	<100	50	0.01	<0.3	<0.1	<3	0.005	< 0.2	< 100
M.P.L	200	500	150	0.02	3	0.4	3	0.1	0.2	500

Tables 3 and 4 show values of cations obtained from the geochemical analysis of water from well samples and borehole samples respectively. In table 3, the values of Sodium from well samples vary from 6-150mg/l with an average of 48.4mg/l. Sodium in samples WLD1,WLD4 and WLD5 exceed the Higeset desirable limit set by WHO,2008. Also in table 4, the values of Sodium from borehole samples vary from 2-39mg/l with an average of 17.4mg/l. All the water samples from the borehole meet the Higeset desirable limit set for sodium by WHO, 2008 except BHD12, BHD13, BHD14 and BHD15. But all the water samples analysed meet the maximum permissible limit set for sodium by the WHO,2008. The values of calcium in well sample shown in table 3 vary from 24-90mg/l with an average of 54.2mg/l while its values in borehole samples shown in table4 vary from 8-79mg/l with an average of 34.4mg/l. None of the water samples analysed exceed the Highest desirable limit set for calcium by WHO, 2008. Tables 3 and 4 also show that Magnessium, Aluminium, Zinc,Silver and Copper are present in both the well and borehole samples but none of theses cations exceed the Higeset desirable limit set for each of these parameters by WHO, 2008 in all the samples analysed.

From table 3, the values of iron present in well samples vary from 0-0.4mg/l with a mean of 0.12mg/l while its values in table 4 vary from 0-0.11mg/l with a mean of 0.05mg/l. All the water samples meet the Higeset desirable limit set by WHO, 2008 except WLD3 in table 3 and BHD1 and BHD2 in table 4. But none of the water samples analysed exceed the Maximum Permissible limit set for iron by WHO, 2008. Iron is not considered detrimental to health but, if in excess, it can affect the colour of fabrics. From Table 3, the values of

Manganese present in well samples vary from 0.2-0.5mg/l with a mean of 0.32mg/l while its values in table 4 vary from 0.09-0.11mg/l with a mean of 0.46mg/l. None of the well samples and only BHD1 from the borehole meets the highest desirable limit set by WHO, 2008 but none of the well samples and eight (8) of the samples from the boreholes exceed the Maximum Permissible limit set by WHO, 2008. Manganese is an essential element for humans and other animals and occurs naturally in many food sources. Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source for drinking-water. Excess manganese in water can cause water discoloration over a long period. Also, there are reports of adverse neurological effects following extended exposure to high levels in drinking water especially in animals but this has not been confirmed in humans.

Hardness is the sum of Ca^{2+} and Mg^{2+} concentrations expressed in terms of mg/l of calcium carbonate. As shown in table 3 and 4, hardness values from well samples range from 31-134 with a mean of 85.6 while borehole samples have hardness values range 36-93 with a mean value of 58.8. This shows that none of the samples from the borehole and two of the well samples (WLD2 and WLD3) exceed the highest desirable limit set WHO, 2008 for drinking water. Also, based on the classification by Sawyer and McCarty (1967) (as cited by Arabi et al, 2010) as shown in table 5 below, three (3) water samples from the well (WLD1, WLD4 and WLD5) and twelve (12) from the borehole samples can be classified as being soft while two (2) water samples from the well and three (3) from the borehole can be said to be moderately hard. Figure 6 and 7 show the harness values in wells and boreholes respectively.

Table 5: Classification of water hardness (Sawyer and Mc Carty, 1967)

Hardness range (mg/l of CaCO3)	**Water classification**
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
>300	Very hard

Courtesy: Arabi et al (2010)

Table 6: Geochemical data of anions in well samples

Parameters	WLD1	WLD2	WLD3	WLD4	WLD5	*H.D.L	*M.P.L
Cl^- (mg/l)	0.15	0.58	0.96	0.45	0.32	1	5
F- (mg/l)	0.1	1.2	0.4	1	0.5	0.5	1.5
SO_4^{2-}(mg/l)	0.66	1.07	1.04	0.75	1.10	<2	5
PO_4^{3-}(mg/l)	0	0.01	0	0	0.01	2	5
NO_3^- (mg/l)	65	80	112	94	62	3	50

Table 7: Geochemical data of anions in borehole samples

PARAMETERS	**SO_4^{2-}**	**PO_4^{3-}**	**F^-**	**Cl^-**	NO_3^-
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
BHD1	0.10	0.17	0.1	0.10	72
BHD2	0.22	0.03	0.02	0.75	68
BHD3	1.12	0.03	0.5	0.05	40
BHD4	0.10	0.11	0.03	0.90	60
BHD5	0.10	0.1	0.19	0.13	54
BHD6	0.07	0.23	0.24	0.50	70
BHD7	0.08	0.27	0.7	0.08	47
BHD8	0.11	0.23	1.2	0.10	57
BHD9	0.10	0.22	0.58	0.20	48
BHD10	0.11	0.18	1	0.07	30
BHD11	0.09	0.19	1	0.75	60
BHD12	0.10	0.24	0.89	0.04	45
BHD13	0.11	0.03	1.1	0.18	40
BHD14	0.12	0.11	0.98	0.10	2.5
BHD15	0.20	0	1	0.30	2.5
H.D.L	<2	2	0.5	100	3
M.P.L	5	5	1.5	500	50

Tables 6 shows that chloride, fluoride, phosphate and sulphate with values in the ranges 015-0.96mg/1, 0.1-1.2mg/1,0-0.01mg/l and 0.66-1.10mg/1respectively in well samples and while in table 7, chloride, fluoride, phosphate and sulphate have values in the ranges 0.05-0.75mg/l,0.02-0.98mg/l, 0-0.27mg/l and 0.07-0.22mg/l respectively. This shows that they are all within the range of the highest desirable level as specified by WHO, 2008. Only nitrate values exceeded the Maximum permissible limit of 50mg/l in all the water samples from the well as shown in table 6 and seven (7) of the water samples from the borehole in table 7, all other anions measured in the the water samples are within the range specified by WHO, 2008 for drinking water. Figure 10 compares the concentration of nitrate in wells and boreholes Excessive nitrate in drinking water has the potential to cause Cyanosis and Asphyxia (blue baby syndrome) in infants less than three (3) months.

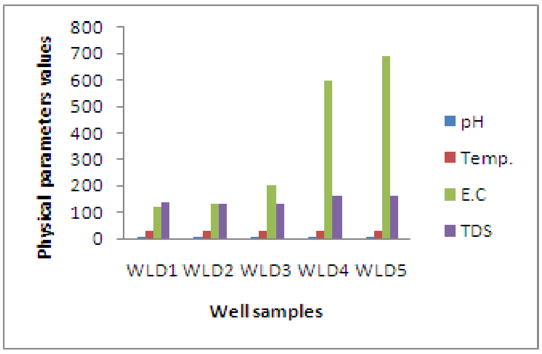

Figure 2: Plots of physical parameters values vs well samples

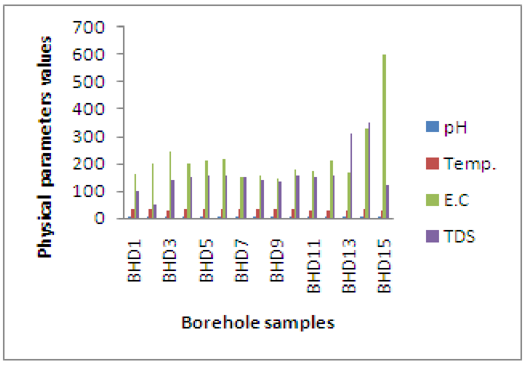

Figure 3: Plots of physical parameters values vs Borehole samples

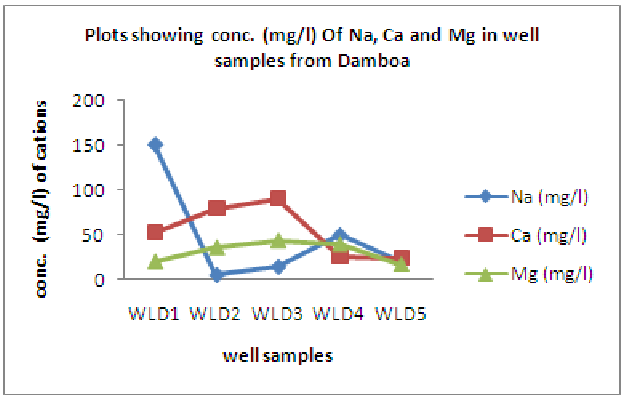

Figure4A: Plots of concentrations of alkaline and alkaline earth metal against well samples

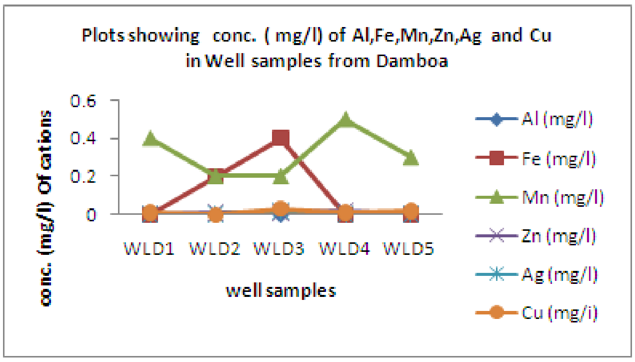

Figure 4B: Plots of concentration of other cations against well samples

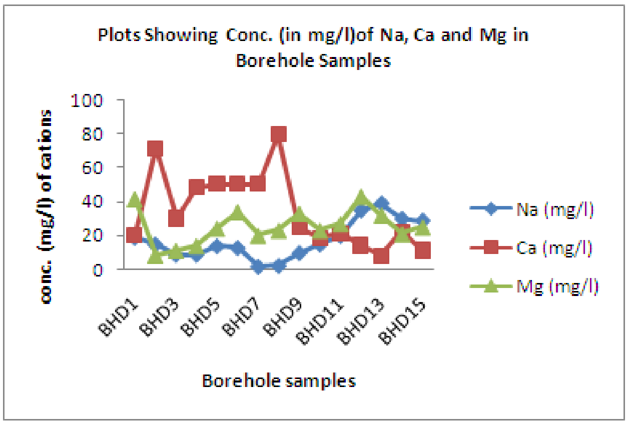

Figure 5A: Plots of concentrations of alkaline and alkaline earth metal against borehole samples

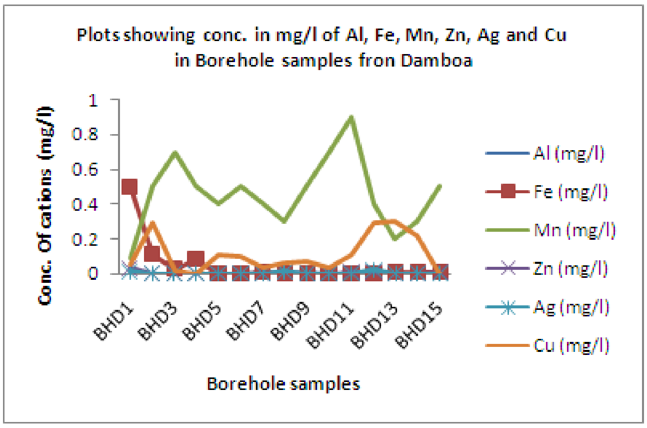

Figure 5B: Plots of concentration of other cations against Borehple samples

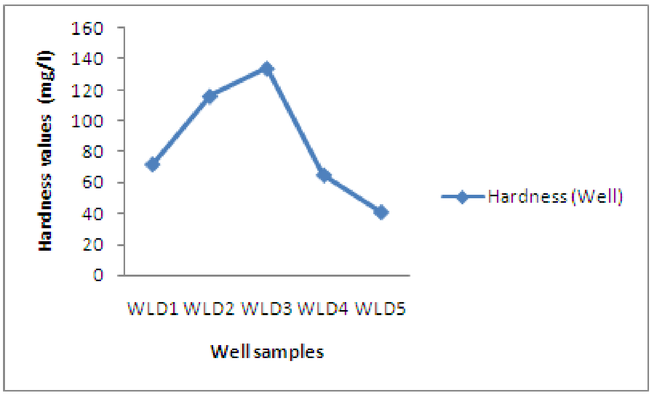

Figure 6: Plots of hardness values against well samples

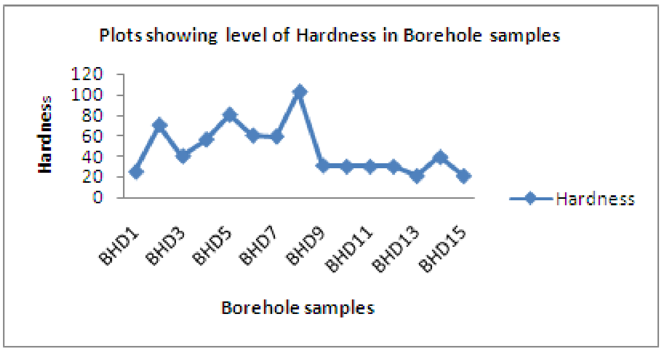

Figure 7: Plots of hardness values against borehole samples

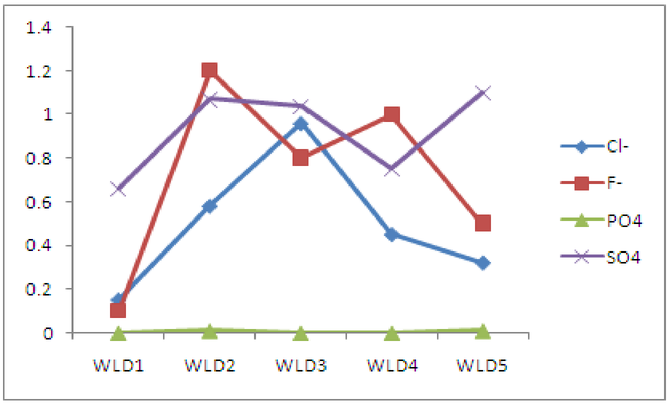

Figure 8: Plots of concentration of anions against well samples

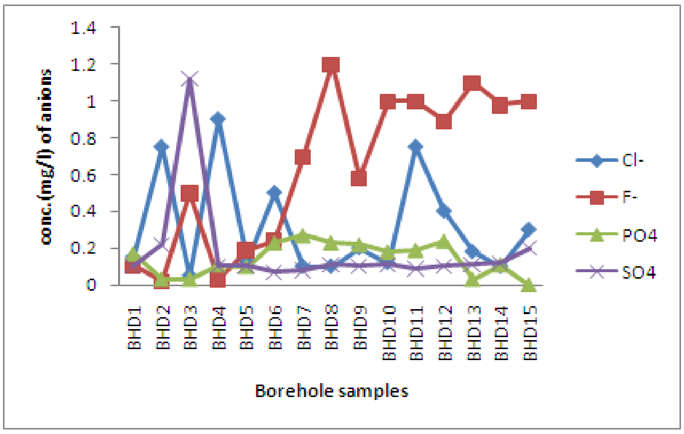

Figure 9: Plots of concentration of anions against Borehole samples

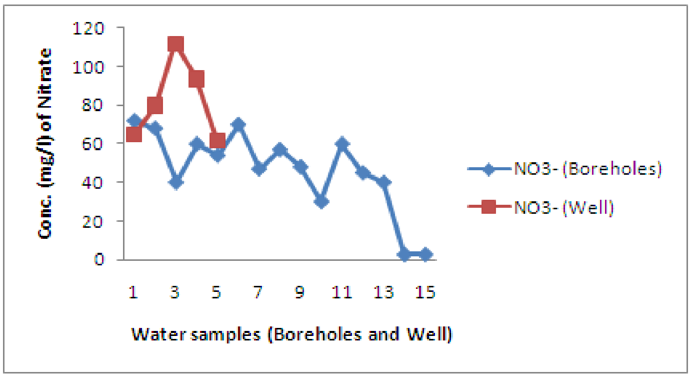

Figure 10: Plots of concentration of nitrate in both the well and Borehole samples

IV. Conclusion

The results of the geophysical survey showed that all the wells in the study area have their sources from the upper aquifer (30–100 m depth) while water in most boreholes are from the Middle Aquifer (270-330m depth) and the rest from lower aquifer (425–530 m depth). Also, the results of the analysis and interpretation of groundwater from Damboa town show that the major contaminants of groundwater in Damboa town are Manganese, Mn^{2+} and nitrate NO_3^{2-}. While the reports of adverse neurological effects following extended exposure to high levels of Manganese in drinking water have not been established in humans, excess nitrate in drinking water has been confirmed to have the potential to cause methaemoglobinaemia in infants below three (3) months (WHO,2008). Based on the findings in this study, the groundwater in the area studied is suitable for agricultural purpose and other culinary purposes. However, due to very high concentration recorded for nitrate, none of the water from the wells and about 53% of the water samples boreholes in the town meets the World Health Organisation standard for safe water consumption. However, the duration and rate of consumption of this high concentration of nitrate in drinking water that will be detrimental to human health is unknown.

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