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Physical And Hydrogeochemical Analysis Of Groundwater In Bolori Ward Of Maiduguri, Borno State, Northeastern Nigeria

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Abstract:
Groundwater is useful for various applications depending on its chemistry. Surface and subsurface water are both important source of water for domestic, agricultural and industrial uses. The physico-chemical parameters of groundwater of the study area which falls within Maiduguri, the capital city of Borno State, Northeastern Nigeria were studied to ascertain the water quality. A total of twenty (20) water samples were directly collected from Motorized and Hand pump Boreholes within the study area. The GPS coordinates were recorded and the physical parameters of Temperature, Total dissolved solids, electrical conductivity and pH were measured in-situ for each sample. Water sampling was done using clean rubber bucket and then poured into two 120 ml rubber bottles which were rinsed thoroughly with distilled water. The sampling bottle is filled to the brim, acidified with a drop of nitric acid; the lid is well tightened and sealed with masking tape to prevent contamination. Chemical analysis of the samples was done in Ahmadu Bello University laboratory to determine the concentrations of F, Mg, Na and Cl. The results of both the physical and chemical parameters of water samples of the study area were obtained and compared to the WHO permissible limit which shows Sodium, Magnesium and Chloride are within the permissible limits, except fluoride which is less than the required limit in some locations and probably leading to dental caries.

Key Word: *Groundwater, Physico-chemical, Bolori, Dental caries*

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I. Introduction

Water is the world's most abundant natural resource and it is in constant circulation. About 71% of the earth's surface is mostly oceans and other large water bodies, with 1.6% of water at the subsurface in aquifers and in the air as vapor, clouds and precipitation (Amadi et al, 2006). It is a dispersion medium for all biochemical reactions which constitutes the living process and takes part in many of these reactions. Life is impossible without water, as such, water is life. It is absolutely essential not only to humans, but also plants and animals. Therefore, the quality of water is very important. The quality of groundwater is controlled by factors such as the type/nature of the aquifer, source of recharge, the drainage area and the permeability of the zone of aeration (Amadi et al, 2006). Groundwater quality is an important factor in the context of sustainable water management, the integrity of underlying aquifers is mainly affected by pollution from above ground surface, particularly solid waste disposal (Kumar et al., 2010). Uncontrolled urban growth and its resultant effect, especially in developing nations like Nigeria, can adversely affect the quality of underlying groundwater if not properly controlled. Once groundwater is contaminated; its quality cannot be easily restored because it is expensive, and difficult to clean up (Ramakrishnaih et al., 2009). Thus, this contamination may result to several diseases.

II. Regional Geology

The study area falls within the Nigerian sector of the Chad Basin, locally known as the Bornu Basin (fig. 1). It is one of Nigeria's inland basins occupying the northeastern part of the country and the southeastern sector of the Chad Basin and represents about one-tenth of the total extent of the Chad Basin, which is common to five countries, namely, Cameroon, Central African Republic, Niger, Chad, and Nigeria. The Chad Basin is an intracratonic inland basin covering a total area of about 2,335,000 km^2 with Niger and Chad Republics sharing more than half of the basin. The basin belongs to a series of Cretaceous and later rift basins in Central and West

Africa whose origin is related to the opening of the South Atlantic (Obaje et al. 2004). In Nigeria, other inland basins of the same series include the Anambra Basin, the Benue Trough, the Mid-Niger, Nupe or Bida Basin and the Sokoto Basin. The Bornu Basin falls between latitudes 11°N and 14°N and longitudes 9°E and 14°E covering Borno State and parts of Yobe and Jigawa States of Nigeria. The Chad Basin belongs to the African Phanerozoic sedimentary basins whose origin is related to the dynamic process of plate divergence (Burke, 1976; Petters, 1982). The Plio-pleistocene Chad formation and the quaternary sediments are the main sources of groundwater in Maiduguri and environs. The Chad formation dips gently east and northeast towards Lake Chad in conformity with the slope of the land surface (Goni, 2006). The stratigraphy (fig. 2) of the Bornu basin has the Bima Sandstone at the bottom and oldest overlain by the Gongila Formation, the Fika Shale, the Kerri-Kerri and Chad Formations respectively.

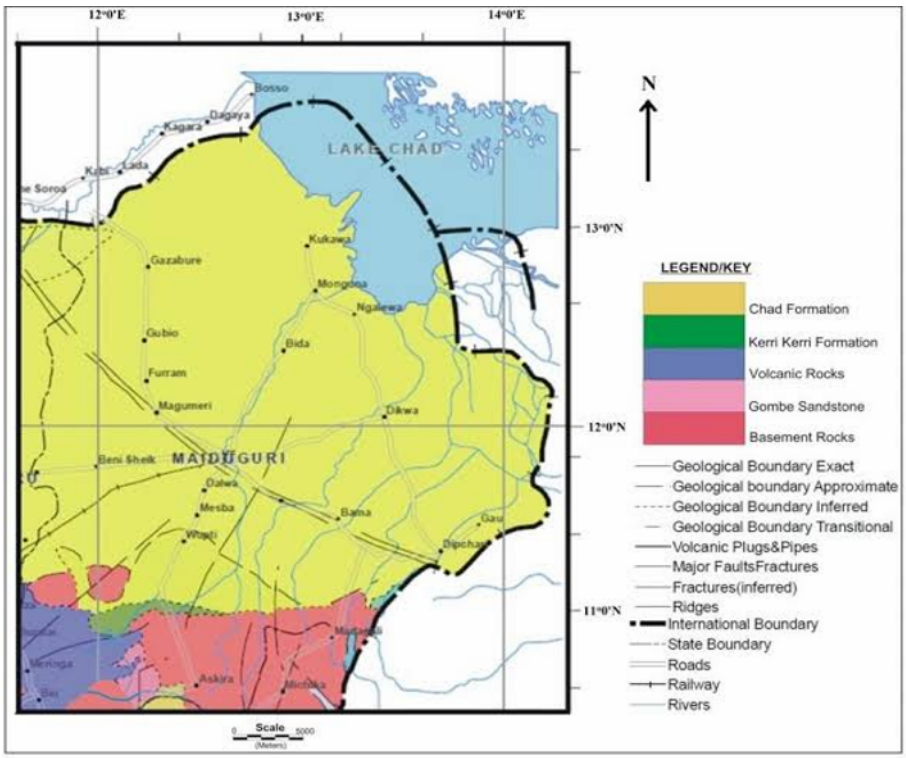

Figure 1: Geology of the Bornu basin (NGSA, 2006)

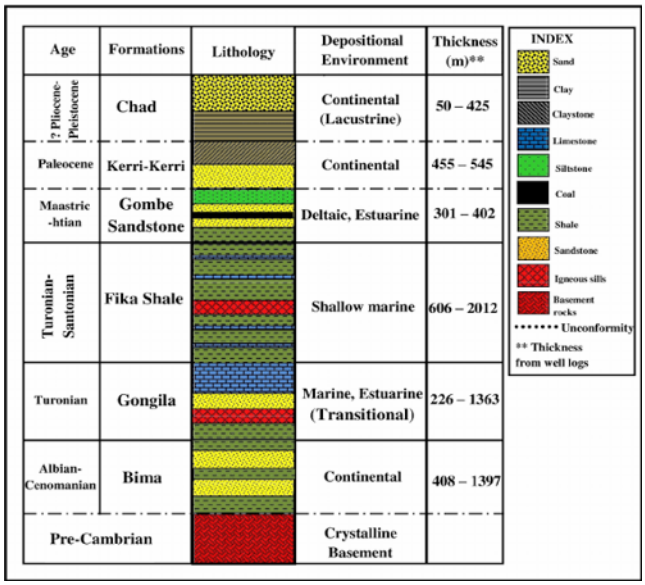

Figure 2: Stratigraphy of the Bornu Basin, Northeastern Nigeria (after Okosun 1995; Avbovbo et al. 1986; Carter et al. 1963)

III. Materials And Methods

Materials used during the field work include the PH/EC meter, TDS meter, GPS, permanent marker, distilled water, nitric acid, syringe, rubber bucket, pen, field notebook, masking tape, Topo map of 1:50, 000 scale and rubber container. A rubber container was used for collecting water so as to determine physical parameters of the water samples, masking tape and permanent marker were used for labeling the samples. PH, EC and TDS meter were used to determine the physical parameters, GPS was used in obtaining the coordinates, distill water was used to rinse both the rubber container and sample bottles while nitric acid was dropped to preserve the trace elements.

During the field work, a total of twenty (20) samples were collected from motorized and hand pump boreholes within the study area. A GPS device is used to record the coordinates at each sampling location. The water sample was directly collected from the sources using a clean rubber bucket and poured into a sample bottle that has been carefully rinsed with distilled water at each location and labeled with a sample ID. All physical parameters were measured and recorded in-situ immediately after sampling. The same procedure was done for all the twenty samples. To protect the sample from contamination, the sampling vial is completely filled, acidified with a drop of nitrate (HNO_3), and then the lid is tightly closed and sealed with masking tape.

The samples were analyzed for the concentrations (mg/L) of Mg, Na, and Cl using Atomic Absorption Spectrometry (AAS) while the spectroscopic method was employed for Fluoride determination both at Multi User Science Research Laboratory (MUSRL) of Ahmadu Bello University, Zaria. The samples are presented in solution and aspirated via a nebulizer and atomized in acetylene-air or acetylene nitrous oxide flame. There are two limitations to the routine use of AAS in silicate analysis. Firstly, the sample must be prepared as a solution, and secondly it is element specific, that is only one element can usually be analyzed at a time.

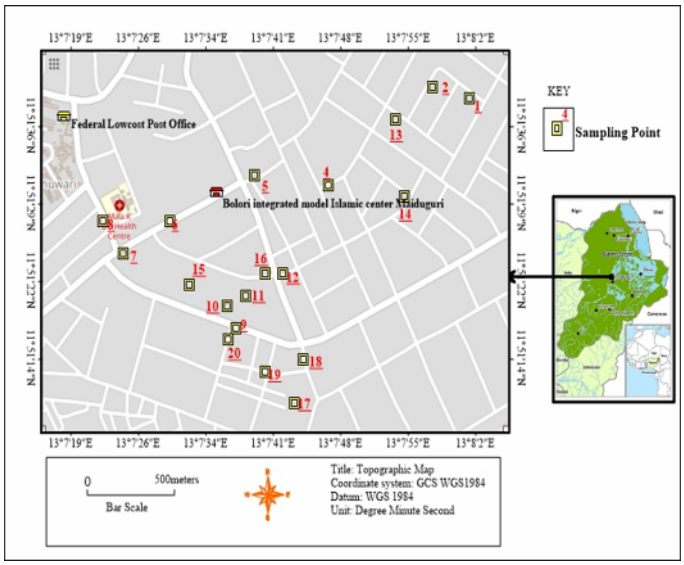

Figure 3: Topography of the study area showing sample locations

IV. Result And Discussion

The results of physical parameters obtained in-situ (Table 1) and the chemical data (Table 2) of the samples were presented below.

Table 1: Physical parameters of the samples in the study area

Sample Number	Longitude	Latitude	Elevation (M)	pH	TDS (mg/l)	Ec (us/cm)	Temp. (°C)	Water Source
1	11°51'38"N	13°8'2"E	318	7.1	724	935	31.8	Hand pump borehole
2	11°51'39"N	13°7'58"E	309	6.9	635	859	30.3	Motorized borehole
3	11°51'36"N	13°7'54"E	310	6.7	411	735	29.5	Hand pump borehole
4	11°51'30"N	13°7'47"E	308	7.0	528	902	31.2	Motorized borehole
5	11°51'31"N	13°7'39"E	304	6.8	312	615	33.1	Hand pump borehole
6	11°51'27"N	13°7'30"E	315	6.5	416	723	30.4	Motorized borehole
7	11°51'24"N	13°7'25"E	315	6.3	535	698	32.5	Motorized borehole
8	11°51'27"N	13°7'23"E	319	6.4	458	748	29.8	Motorized borehole
9	11°51'17"N	13°7'37"E	264	6.8	295	839	29.5	Hand pump borehole
10	11°51'19"N	13°7'36"E	299	7.2	377	974	31.0	Hand pump borehole
11	11°51'20"N	13°7'38"E	320	6.9	493	917	32.5	Hand pump borehole
12	11°51'22"N	13°7'42"E	311	6.8	615	651	30.3	Hand pump borehole
13	11°51'28"N	13°7'54"E	321	6.5	580	858	31.4	Motorized borehole

14	11°51'29"N	13°7'55"E	318	6.7	443	689	29.7	Hand pump borehole
15	11°51'21"N	13°7'32"E	315	6.7	712	839	30.8	Motorized borehole
16	11°51'22"N	13°7'40"E	335	6.4	595	715	30.1	Hand pump borehole
17	11°51'10"N	13°7'43"E	322	6.2	388	598	32.3	Hand pump borehole
18	11°51'14"N	13°7'44"E	324	6.3	412	612	29.5	Hand pump borehole
19	11°51'13"N	13°7'40"E	299	6.1	652	545	31.2	Hand pump borehole
20	11°51'16"N	13°7'38"E	303	6.1	521	632	33.4	Hand pump borehole

Table 2: Concentration of some selected elements of the samples in the study area

Sample Number	Longitude	Latitude	Fluoride (mg/l)	Sodium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)
1	11°51'38"N	13°8'2"E	0.36	36.00	2.90	34.00
2	11°51'39"N	13°7'58"E	0.29	30.00	0.90	23.00
3	11°51'36"N	13°7'54"E	0.40	14.00	1.70	25.00
4	11°51'30"N	13°7'47"E	0.44	18.00	1.30	15.00
5	11°51'31"N	13°7'39"E	0.58	32.00	1.50	7.50
6	11°51'27"N	13°7'30"E	0.48	42.00	1.00	7.40
7	11°51'24"N	13°7'25"E	0.36	94.00	1.10	12.60
8	11°51'27"N	13°7'23"E	0.16	124.00	3.10	19.00
9	11°51'17"N	13°7'37"E	0.27	178.00	2.00	16.00
10	11°51'19"N	13°7'36"E	0.14	142.00	0.90	12.30
11	11°51'20"N	13°7'38"E	0.38	140.00	1.20	3.60
12	11°51'22"N	13°7'42"E	0.20	168.00	0.80	9.00
13	11°51'28"N	13°7'54"E	0.14	162.00	2.50	6.70
14	11°51'29"N	13°7'55"E	0.34	124.00	1.30	6.80
15	11°51'21"N	13°7'32"E	0.54	162.00	1.40	3.30
16	11°51'22"N	13°7'40"E	0.34	198.00	1.00	6.20
17	11°51'10"N	13°7'43"E	0.33	195.00	1.10	6.00
18	11°51'14"N	13°7'44"E	0.24	102.00	1.60	5.50
19	11°51'13"N	13°7'40"E	0.22	50.00	2.30	25.00
20	11°51'16"N	13°7'38"E	0.29	64.00	2.70	9.00

Hydrogen Ion Exponent (pH) of water is the measure of the acid-base equilibrium and in most natural waters; it is controlled by the carbondioxide-bicarbonate-carbonate equilibrium system. The pH of most drinking water lies within the range 6.5-8.5. Natural waters can be of lower pH, for example as a result of either acid rain or higher pH in limestone areas. From the results obtained within the study area, the pH value ranges from 6.1-7.2. All the samples collected fall within the Nigerian Standard for Drinking Water Quality (NSDQW) pH range of 6.1-8.5. This implies the pH level of the samples does not pose any health threat on human within the study area.

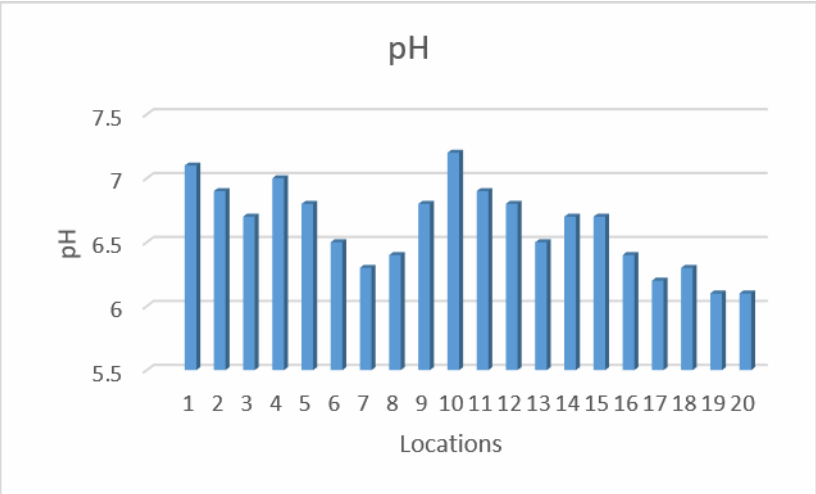

Figure 4: Histogram showing pH variations

Total Dissolved Solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS standard for drinking water level (WHO, 1993) as follows: less than 300 mg/l is excellent; 300 to 600 mg/l is good; 600 to 900 mg/l is fair; 900 to 1200 mg/l is poor; and greater than 1200 mg/l

is unacceptable. However, water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste. The total dissolved solids in the study area ranges from 295 – 724 mg/1. Among all the samples, only sample 1 is excellent as drinking water though the other samples are also fit for drinking.

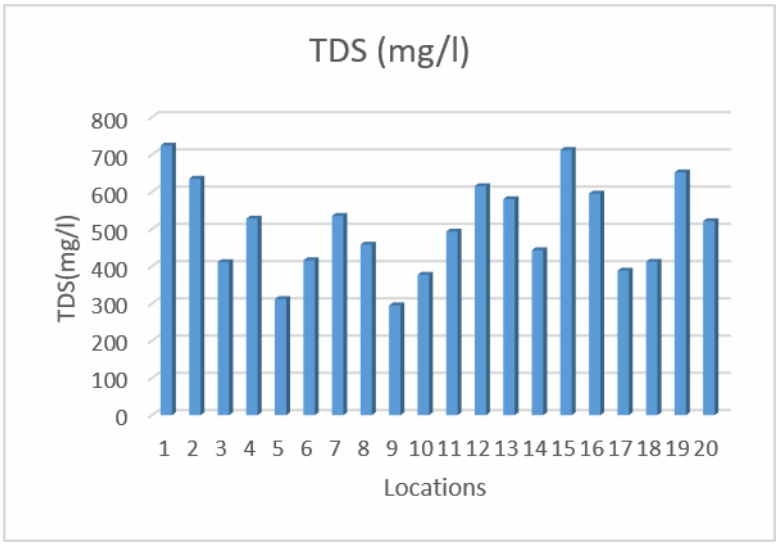

Figure 5: Histogram showing TDS variations within the study area

Electrical Conductivity (EC) of a solution is a measure of its ability to carry an electric current; the more dissolved ionic solutes in water, the greater its electrical conductivity. Conductivity can be regarded as a crude indicator of water quality for many purposes, since it is related to the sum of all ionized solutes or TDS content. The relationship between conductivity and TDS is not directly linear, however, since the conductive mobility of ionic species is variable. EC which can be used as index of salinity hazards in assessment of water quality for irrigation should be measured at sampling site. EC value of less than 250 to 750 µS/cm is good; from 750 to 2250 µS/cm is moderately good; from 2250 to 4000 µS/cm is bad and EC above 4000µS/cm is very bad. The EC of all the samples in the study area range between 545 – 974 µS/cm, so it shows that the conductivity is within the limits for which it is good to be used for irrigation and also consumption.

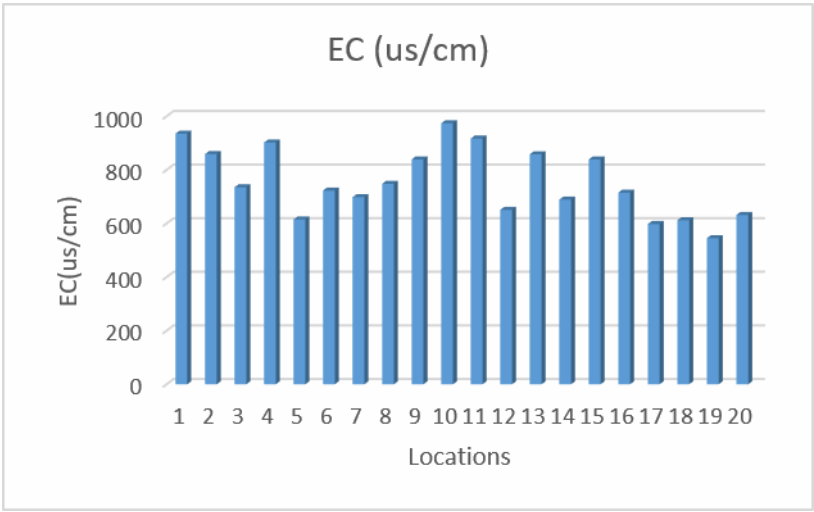

Figure 6: Histogram showing EC variations

Temperature is critical because it is an important quality in environmental parameters. It is important to measure groundwater temperature, by doing so, the characteristics of the Physical, Chemical and Biological properties can be known as well its possible effect to human health. The standard temperature for fish farming is between 30 to 33 °C. Therefore, the temperatures of some samples collected from the study area are not suitable for fish farming and also exceed the standard temperature of drinking water according to WHO which 25 °C.

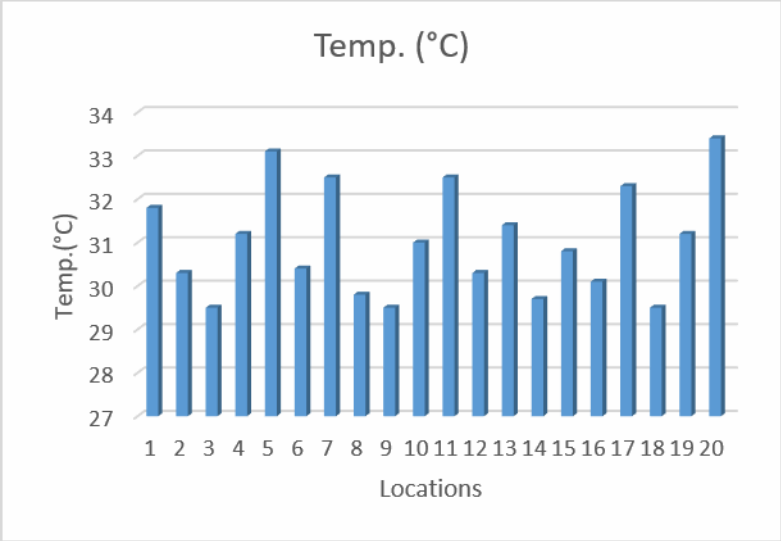

Figure 7: Histogram showing Temperature variations

Fluoride (F) is a common element that does not occur in the elemental state in nature because of its high reactivity. It accounts for about 0.3 g/kg of the earth's crust and exist in the form of fluorides in a number of minerals, of which Fluorspar, Cryolite and Fluorapatite are the most common. Fluoride may be an essential element for animals and humans. However, fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental Fluorosis (prevalence of 12 – 33%) at drinking water concentrations between 0.9 and 1.2 mg/l was reported by (Dean, 1942). Optimal concentrations are around 1 mg/l. However, chronic ingestion of concentrations much greater than the WHO value of 1.5 mg/l is linked with development of dental Fluorosis and in extreme cases, skeletal Fluorosis. From the results in Table 2 and Figure 8, it was observed that the concentration of Fluoride in 95 % of the study area is very low (0.14 – 0.54 mg/l), thus posing a health risk of causing dental caries when consumed. It is therefore not suitable for drinking until a proper treatment is done. Low Fluoride content in the study area is associated to the sedimentary nature and low content of Fluoride bearing minerals mostly associated with igneous and metamorphic rocks.

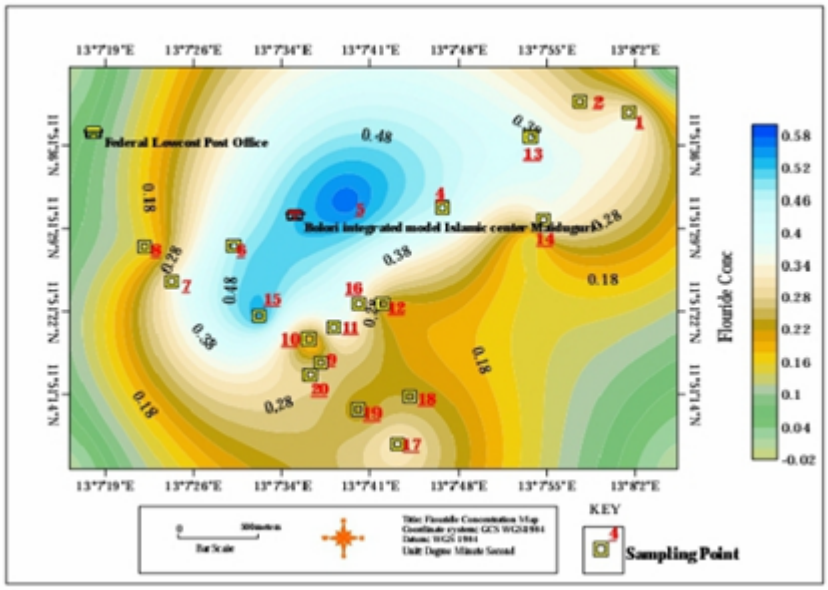

Figure 8: Map showing Concentration of Fluoride in the study area

Magnesium (Mg) is an alkaline earth metal and is the eighth most abundant element on Earth. It is essential for proper functioning of living organisms and found in minerals like dolomite, magnetite, etc. Human body contains about 25 g of magnesium (60 % in bones and 40 % in muscles and tissues). WHO standard for Mg in water should be 50 mg/l. In the study area, Mg concentration ranges from 0.80 to 3.10 mg/l, which shows it is within the WHO permissible limit.

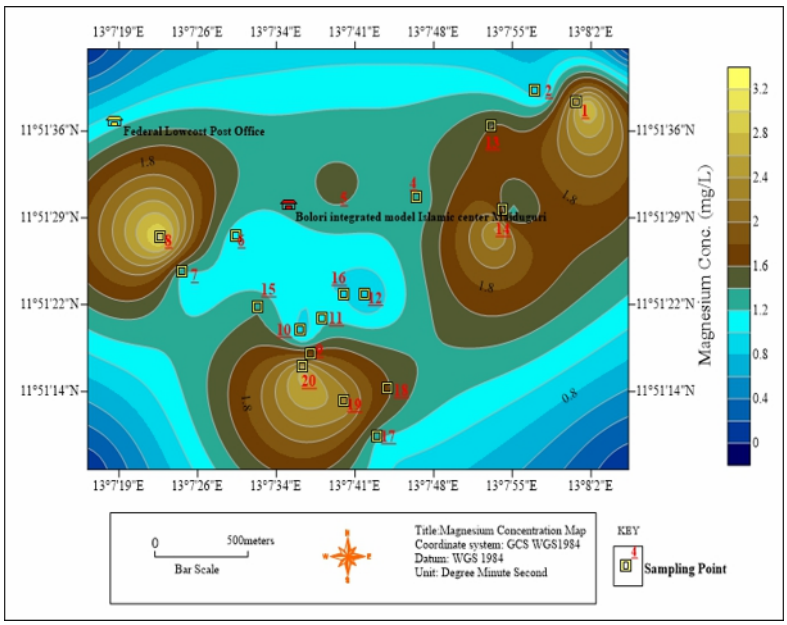

Figure 9: Map showing Concentration of Magnesium in the study area

Sodium (Na) concentration in the samples analyzed range between 14.00 – 198.00 mg/l (Table 2) which implies it is a hard water, though it is within the permissible limit of drinking water according to (NSDQW). Sodium is among the general elements essential for human health and metabolism and should be available in drinking water. However, if this element occurs above certain limits greater than 200 mg/l, the water may be hazardous to health. For healthy person, sodium content in water is unimportant except when combine with excessive Concentration of Sulphate. Such a combination is dangerous as it can cause gastrointestinal irritation. For persons placed in low Sodium diet because of heart, kidney, circulatory ailment or complication of pregnancy, sodium must not be more than 200 mg/l in the drinking water. In general, sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride. Acute effects may include nausea, vomiting, convulsions, muscular twitching and rigidity, cerebral and pulmonary edema, among others. However, the people of the locality are most prone to muscular twitching due to nutrient deficiencies and sodium content in the water.

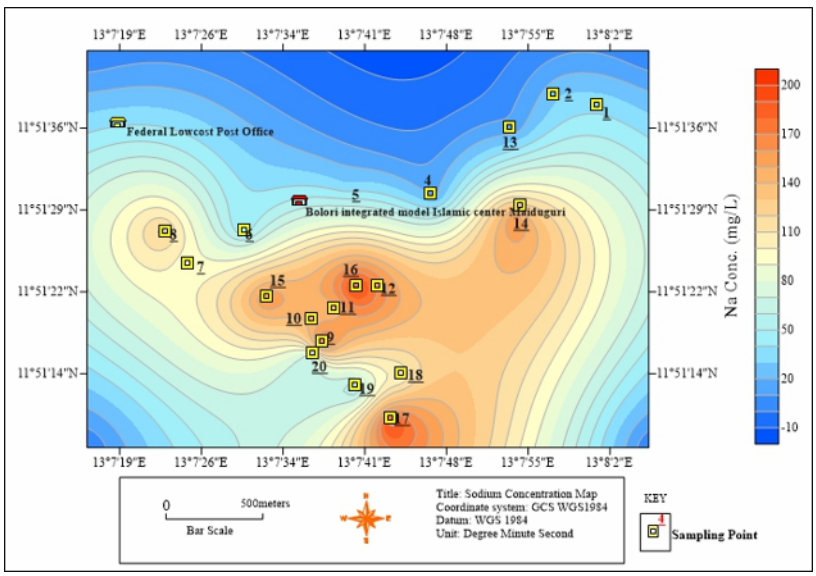

Figure 10: Map showing Concentration of Sodium in the study area

Chloride is a naturally occurring element that is common in most natural waters and is most often found as a component of salt (sodium chloride) or in some cases in combination with potassium or calcium. The presence of chloride in groundwater can result from a number of sources including the weathering of soils, salt-

bearing geological formations, deposition of salt spray, salt used for road de-icing, contributions from wastewaters and in coastal areas, intrusion of salty ocean water into fresh groundwater sources. Elevated chloride levels can sometimes be reduced by reconstruction of your well, or in other cases, by the use of a water treatment device, and it is recommended that advice from a qualified groundwater professional be sought prior to deciding what solution best meets your particular situation. The most common water treatment devices for reducing the chloride content of drinking water are reverse osmosis, anion exchange or distillation treatment systems. Chloride concentration in the study area ranges between 34.0 – 4.40 mg/l which is good for drinking because it does not exceed the maximum permissible limit of NSDWQ.

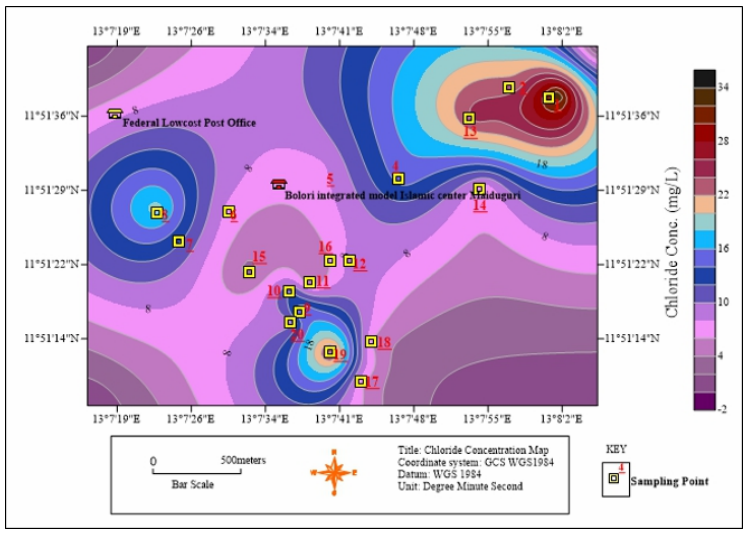

Figure 11: Map showing Concentration of Chloride in the study area

V. Conclusion

The qualitative analysis of groundwater in the study area revealed that the groundwater is safe for industrial and agricultural uses. This is due to the fact that all the physical parameters are within the permissible limit. The chemical concentrations of Cl, Na and Mg are also within the WHO permissible limits except for Fluoride (F) which is below the permissible threshold and is not recommended for domestic use especially consumption which can cause dental caries. To make water suitable and healthier for drinking, such water should be treated thoroughly. There are in-situ or ex-situ methods available for the treatment of low Fluoride in groundwater. In-situ treatment involves building artificial recharging structures in suitable places which will increase its concentration; rainwater harvesting through existing wells also prove effective to increase the groundwater Fluoride concentration. Ex-situ methods which are conventional treatment methods like adsorption, reverse osmosis, coagulation and precipitation can be practiced at community level or at households to treat low Fluoride concentration before ingestion. In the study area, the recommended treatment method is the ex-situ or conventional method.

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