

Geochemical Analysis of Ground Water in Maiduguri and Its Environs of Borno State, North Eastern Nigeria

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Abstract

This research work is aimed at geochemical assessment of groundwater in Maiduguri and its environs to determine the physical and chemical characteristics of groundwater and its suitability for both domestic, industrial, and agricultural use. The method employed for this research includes geological collection of data from field which involves, (mapping, sampling of groundwater), and laboratory analysis on the samples obtained from the field to assess the status of some major and trace elements in the water samples which have direct impact on human health and can lead to diseases such as acute kidney disease and chronic kidney disease among inhabitants. Twenty-three (23) samples were collected from hand pump wells and boreholes as well as tube wells. At each sample point the geographical coordinates was taken using a portable global positioning system (GPS) device. Water samples was also collected using a clean rubber container which was rinsed with a distilled water, after which the physical parameters like the TDS, EC, and temperature was determined at the point of sample collection while the chemical parameters was analyzed in Multi User science research laboratory (MUSRL) ABU Zaria to determine the concentration of some major and trace elements (Na, K, Ca, Pb, Cd, and F). The values obtained from both physical and chemical analysis were compared to those of world health organization (WHO), and Nigerian Standard for drinking water quality (NSDWQ). The concentration of Na ranges from 14.00mg/l to 104mg/l and it falls within the permissible standard of 200mg/l, K values ranges from 2.3mg/l to 8.00mg/l and Ca values ranges from 3.999mg/l to 85.487mg/l while those of trace elements like Pb which has 0.0904mg/l, Cd has 0.045mg/l and F values ranges from 0.000025 to 0.000141 mg/l are higher than the required standard for drinking water and will pose health impact on human if there is continuous usage of the water from the study area and this can result to diseases such as renal failure, dental caries and insulin resistance. Therefore, water within the study area has to be treated so as to ascertain its suitability for drinking.

Keywords: groundwater, geochemistry, parameters, borehole, GPS.

Introduction

Good drinking water quality is essential for the wellbeing of all people. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. Water quality analysis is an important issue in groundwater studies (Nur et al., 2012) Variation of groundwater quality in an area is a function of physical and chemical

parameter. Unfortunately, in many countries around the world, some drinking water has become contaminated, which has impacted on the health and economic status of the populations. It is fact that polluted water is one of the biggest killers and is responsible for 27000 deaths a day in the world's poorest countries (Virtual & Project, 2004). Ground water contamination, include industrial spills, leaking oil and chemical storage tanks and diffuse sources of Ground water contamination include pesticides and fertilizer use (Jalo, 2015).. Minerals are good for human health but in appropriate quantity. If minerals are consumed in high or low intake, it may impose life threatening risk to human health³. Among all the minerals, fluoride is one of the important in ground water that prevents the tooth decay and controls the metabolic bone diseases (Khwaja et al., 2017), (Kasidi, S and Victor, V 2019) Evaluation of water quality for human consumption for agricultural and industrial activities has not been given attention especially in developing countries like Nigeria. The chemical composition of water is an important factor to be considered before it is used for domestic or irrigation purpose (Dinesh & Rajesh, 2013). Water is the primary need of every living thing on this planet earth which is essential for sustaining life. Hence, the need for the analysis of water hydro-geochemically and bacteriologically in other to know the acceptable quality for various purposes which must be pursued (Zouahri et al., 2014). Groundwater is never chemically pure; dissolution of substance takes place in the course of its percolation through the rock-water interaction makes it acquire some of these dissolved chemical constituents (Khwaja et al., 2017). The chemical composition of groundwater is important if the water is to be used for domestic, industrial and agricultural purpose (Dinesh & Rajesh, 2013). The dissolved geochemical constituents in water affect its usage for various purposes. The concentrations of the dissolved constituents are correlated with the standards of the World Health Organization (Nwachukwu et al., 2022) or other organizations charged with the responsibility of providing safe drinking water to the ever-increasing population (Carrard et al., 2019). The importance of hydro-geochemical investigation on the water resources of any region cannot be over emphasized. Geology and waste disposal practices have greatly modified the chemistry of surface and groundwater in many areas especially the developing countries of the world. Modification in water chemistry can lead to health problems or unpleasant taste, and may also affect agricultural and industrial activities (Zouahri et al., 2014)

The objectives of this study are to:

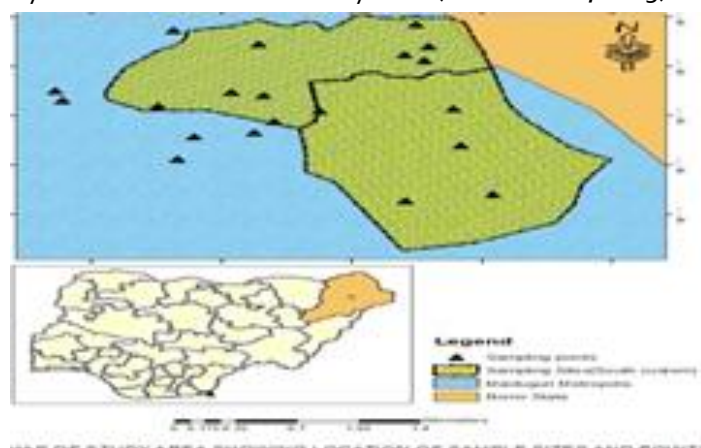
1. Evaluate groundwater quality for domestic, and industrial purposes.
2. Analyse the major trace elements present in the water.
3. Determine the processes responsible for the modification of groundwater chemistry.

Location and accessibility

The study area falls within Maiduguri capital city of Borno State Northern Nigeria which is called Maiduguri metropolitan council. It is located between the latitudes 11° 48'–11° 52' North and latitude of 10° 00'– 13° 06' East. The area is accessible by road and foot path.

Geology of the study area

The study area figure below, falls within the Nigeria sector of the Chad basin. The basin is the largest area of inland drainage in Africa, and it covers about 2,335,000 km² (Patrick et al., 2015). It is located on continental plate therefore; it is regarded as interaction basin. The Nigerian sector of Chad basin covers about one tenth of the total area with some areas which extends to Niger republic, Chad and Cameroon (Virtual & Project, 2004). The Nigeria sector of the Chad basin is part of the western central African rift system WCAS that was found in responds to the mechanical separation of Africa coast blocks in the cretaceous. The basin belongs to the West Africa rift sub-system WAS component as WCAS. The Chad basin was formed at the start of tertiary age in a huge structural depression, the Nigerian sector of which was affected by Pre-Paleozoic and Paleozoic granites and crystalline schist of the basement complex and an upper argillaceous- are nacreous series of mainly marine fade and, the filling up of the basin occurred during two quiet distinct cycle of continental deposition, separation by a phase of uplift and erosion in cretaceous and early Paleocene ages. (Nwachukwu et al., 2022), published an account of the geology and hydrogeology of the Nigeria sector of the Chad basin and suggested that water pressure might be high following the discovery of an artesian water wells. More detailed account of the occurrence of pressure water in the Chad Basin of Borno state was published by .(Kwami et al., 2018) following the recognition of three water bearing zones, namely the upper, middle, and lower aquifer zones. The Chad Basin is believed to have originated by the influence of two tectonic frame work that affected other Nigeria sedimentary basin in the cretaceous period. It is originated by a process of regional down-wrapping coupled with faulting which produced series of troughs and up-lifted blocks in the crystalline basement rock. The chad basin is genetically related to the Benue rift system (Ishaku et al., 2015).



Materials and Methodology

Materials. The materials used such as atomic absorption spectrophotometer (ASS), UV-Vis spectrophotometer, Digital generic EC/TDS and temperature meter, PH meter were well cleaned. The method used for this research includes geological collection of data from the field, and the use of relevant literatures from various organizations. Laboratory research

was also carried out for the samples obtained from the field, to test the presence of trace elements.

Determination of Physical Parameters

Determining the PH: measurement of the acidity and alkalinity of the water samples were done with the use of pH meter at the point of sample collection. The pH meter was immersed into a rubber container containing the water sample, and then the reading automatically displays which was noted in the log sheet

Determining the electrical conductivity (EC) of the water samples was obtained using the 3 in 1 generic EC/TDS and temperature meter. After removing protective cap of the instrument, rinsed with distilled water and switched on, it is immersed into the container containing the water sample, the shift button is pressed to move to the EC mode where the reading automatically displays and the value taken when the readings stabilize.

Determining temperature of the water samples were determined by immersing the generic EC/TDS and temperature meter into the container containing the sample, afterward it displays the reading automatically on the display screen below any of the 2 parameters encompassed in the meter.

Determining total dissolved solids (TDS) of the water samples was determined by using the digital generic EC/TDS and temperature meter. When switched on the shift button was pressed to enable the TDS mode after which the instrument was immersed into the container containing the sample water and was recorded when the reading was stable.

Laboratory work: After the successful sampling, the samples were taken to MUSL ABU Zaria for determining the chemical parameter i.e the trace elements.

Measurement Procedures for Chemical Parameters: The chemical analysis of the water samples collected from the study area were analyzed at Multi User Science Research Laboratory (MUSRL) of Ahmadu Bello University Zaria, Under this particular work, machine with model number AA280FS, Agilent Technologies of USA was used to measure the chemical concentration of; Cd, Pb, Na, K and Ca Atomic absorption spectrophotometric (AAS) method was employed and that of, Fluoride UV-Vis Spectrometer, model No Carry 300, of Agilent technologies USA was used, the method employed for the fluoride determination is the spectroscopic method. Atomic absorption spectrophotometer is based upon the observation that atoms of an element can absorb electromagnetic radiation. Thus the atomic absorption spectrophotometer comprises an atomizing device, a light source and detector. A lowering of response in the detector during the atomization of a sample in a beam of light as a consequence of atomic absorption was calibrated and was sensitive at the ppm level. The samples were 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 was prepared as a solution, and secondly it was element specific, that only one element was analyzed at a

time. There were methods in which all the chemical elements determined from one solution. ASS is comparatively cheap both in capital out lay and in running cost. It most frequently finds it use in one of three specific applications.(Kwami et al., 2018)

The determination of light elements with atomic numbers too low to be measured by XRF Routine analysis of transition metals readily leached from soil or stream sediment Non-routine trace element analysis using specialized application of ASS, for example is atomized in a graphite furnace, this allows exceptionally low detection limit to be achieved for elements difficult to measure using other analytical technique.

Procedure

Method was created by entering the parameter investigated e.g. Na or Ca. Lamp for the element analyzed and click "on" and set started. The controlled and fuel supply was gently turned on the pressure was up to 15Psi the flames window click and started. Then the graph window was opened and the slit adjusted so as to obtain the absorbance. The graph axis was finally adjusted and the window was then closed. The reference window was calibrated and the identity of the standard and concentration. The sample was finally measured by clicking on the icon measure and result was displaced on the window.

Discussion of Results

Table 1 Chemical Parameters

SC-S1 Bulabulin B/Gada		11°50'4.15"N, 13°9' 40.51"E				
Elevation	Source	Temp	Ph	Tds (G/L)	Ec	Depth 18m
320m	Upper aquifer	34.4	6.31	189	378	
SC-S2 Gidan Madara		11°49'34.92"N 13°9'20.11"E				
329m	Upper aquifer	31.4	6.80	160	320	36m
SC-S3 Layin Bori		11°49'58.4"N 13°9'56.2"E				
315m	Upper aquifer	33.4	6.23	153	306	38m
SC-S4 Gwange F/bariki		11°49'38.24"N 13°9'51.41"E				
325m	Upper aquifer	32.4	6.81	165	330	21m
SC-S5 Bayan gwange4		11°49'36.95"N 13°9'57.32"E				
322m	Upper aquifer	31.4	6.84	107	214	75m
SC-S6 Kanti bakwai		11°49'51.43"N 13°10'26.83"E				
318m	Hand pump	33.6	6.80	205	410	25m
SC-S7 GW zuwa da wuri		11°50'6.60"N 13°10'25.30"E				
330m	Upper aquifer	33.4	7.14	213	426	42m
SC-S8 GW layin Bola		11°49'57.43"N 13°10'27.74"E				
329m	Middle aquifer	34.4	6.19	260	520	298m
SC-S9 GW Sabon layi		11°49'54.06"N 13°10'23.33"E				
329m	Upper aquifer	31.4	6.76	218	436	94m

SC-S10 Hajiya zulai 11°49'31.39 N 13°10'32.35"E						
301m	Hand pump	32.8	6.60	105	210	27m
SC-S11 Layin Dunoma 11°49'16.05"N 13°10'33.69"E						
307m	Upper aquifer	33.4	8.07	96	192	32m
SC-S12 Lagos Str. Forest Quarters 11°49'21.37"N 13°9'55.57"E						
300m	Upper aquifer	33.8	6.90	108	216	57m
SC-S13 Forestry quarters 11°49'26.01"N 13°9'59.22" E						
305m	Upper aquifer	33.8	6.79	104	208	65m
SC-S14 11°49'30.44" N 13°10'7.50" E						
292m	Upper aquifer	33.4	6.35	157	314	43m
SC-S15 Lagos street KTK 11°49'19.67"N 13°9'44.42" E						
353m	Upper aquifer	35.4	7.15	126	252	67m
SC-S16 Sabon gari Gangare 11°49'32.54" N 13°9' 37.72 E						
304m	Upper aquifer	33.4	6.45	170	340	46m
SC-S17 Sabon Gari 11°49'10.43"N 13°9'41.39" E						
303m	Upper aquifer	33.6	6.60	165	330	60m
SC-S18 Sabon Gari 11°49' 45.13" N 15°9' 44.06" E						
311m	Hand pump	32.6	6.41	193	386	70m
SC-S19 GW.Filin Bariki 11°4' 45.36"N 13°9' 55.39"E						
316m	Upper aquifer	33.4	6.33	180	360	75m
SC-S20 G/Madara. 11°49' 38.92" N 13°9'18.83" E						
275m	Upper aquifer	32.6	6.32	184	368	56m
New GRA-S1 11°48'53.02"N 13°10'23.53"E						
322m	Upper aquifer	36.6	6.13	1.80	360	78m
New GRA-S2 11°48'55.56"N 13°10'39.44"E						
319m	Middle aquifer	31.8	6.21	162	334	325m
Old GRA-S1 11°48'26.86"N 13°9'39.93"E						
319m	Upper Borehole	Aqua. 30.6	6.58	094	188	97m

(Virtual & Project, 2004), (Jalo, 2015)..

Discussions of physical parameters

Hydrogen ion exponent (pH), scale, the PH of 1-6.8 is acidic, 7.0 are neutral and 7.2-14 is alkaline. Furthermore, the scale ranking is such that the PH of less than 4.5 is strongly acidic, 6.0-4.5 is acidic and 6.0-6.8 is weakly acidic. On the other hand, PH of 7.2-7.8 is weakly alkaline, 7.8-8.2 is alkaline and above 8.2 is strongly alkaline. In the case of the study area, the pH values ranges from 6.13 to 8.07 which are found in NEW GRA-S1and SC-S11 respectively. The average value is not define so the water is said to be alkaline.

Electrical conductivity, when conductivity value is less than $250\mu\text{S}/\text{cm}$ or between 250 and $750\mu\text{S}/\text{cm}$, then the water is good for irrigation. Moderately, good when conductivity is between 750 and $2250\mu\text{S}/\text{cm}$, bad between 2250 and $4000\mu\text{S}/\text{cm}$ and very bad above $4000\mu\text{S}/\text{cm}$. Moreover, in the study area, Electrical conductivity varies between 188 and $520\mu\text{S}/\text{cm}$ and it was present in all the locations of the groundwater sample collected. Therefore, the water is said to be good for irrigation as prescribed by NSDWQ.

Total dissolved solid (TDS) values ranges between 1.8 to $260\text{mg}/\text{l}$ with an average value of $6.57\text{mg}/\text{l}$, which is farther below the value 500 WHO (standard of water quality for drinking and fish farming).

Temperature: Increasing temperature indicates increasing energy, or molecular motion of water, this is because of the effect of evaporation from the open water table. The temperatures of water obtain from the study area ranged between $30.07 - 36.6^\circ\text{C}$ with the average value of 1.44°C .

Summary of physical parameters for the study area presentation of chemical parameters,

Physico-Chemical and Microbiological Analysis of under Ground Water was carried and it is concluded that the quality of water samples was acceptable according to physico-chemical analysis while as per Bacteriological standards, the water needs to be treaded before using it in domestic purposes. Physico-chemical characterization of groundwater samples are taken from Maiduguri (Khwaja et al., 2017).

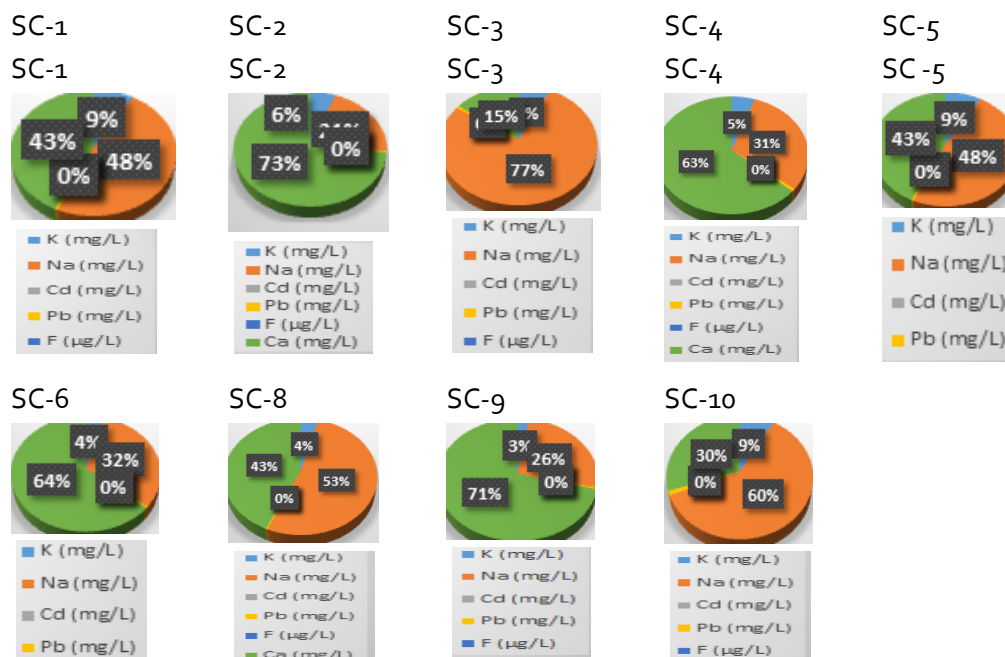
Table 2 Result sample obtained at south of custom Maiduguri the chemical parameters of the water samples collected

Sample ID	K (mg/L)	Na (mg/L)	Cd (mg/L)	Pb (mg/L)	F ($\mu\text{g}/\text{L}$)	Ca (mg/L)
SC S1- $11^\circ 50' 4.15''\text{N}, 13^\circ 9' 40.51''\text{E}$ (Borehole)						
SC-S1	6.40	36.00	0.028	0.344	0.0025	32.289
SC S2- $11^\circ 49' 58.4''\text{N}, 13^\circ 9' 56.2''\text{E}$ (Borehole)						
SC-S2	3.90	14.00	0.020	0.299	0.005	48.058
SC – S3- $11^\circ 59' 58.4''\text{N}, 13^\circ 9' 56.2''\text{E}$ (Borehole)						
SC-S3	5.00	54.00	0.025	0.459	0.0004	10.392
SC S4- $11^\circ 49' 38.24''\text{N} 13^\circ 9' 51.41''\text{E}$ (Borehole)						
SC-S4	3.50	20.00	0.029	0.436	0.0019	41.503
SC S5- $11^\circ 49' 36.95''\text{N} 13^\circ 9' 57.32''\text{E}$ (Upper Aquifer Borehole)						
SC-S5	6.40	36.00	0.028	0.344	0.0025	32.289
SC S6- $11^\circ 49' 51.43''\text{N} 13^\circ 10' 26.83''\text{E}$ (Handpump)						
SC-S6	3.80	32.00	0.023	0.482	0.00787	63.852
SC- S8- $11^\circ 49' 57.43''\text{N}, 13^\circ 10' 27.74''\text{E}$ (Borehole)						
SC-S8	8.00	104.00	0.021	0.538	0.0045	85.486

SC- S9-11°49'54.06"N13°10'23.33"E (Borehole)						
SC-S9	3.50	36.00	0.025	0.625	0.0121	97.963
SC- S10-11°49'31.39 N13°10'32.35"E (Borehole)						
SC-S10	3.90	28.00	0.022	0.541	0.011	13.882

(Virtual & Project, 2004), (Jalo, 2015)..

Table 3 Pie chart of percentage distribution of chemical parameter at SC-S1 – S10



(Virtual & Project, 2004), (Jalo, 2015)..

Discussion of chemical parameters

Potassium concentration analyzed in the sample ranges from 2.30mg/l to 8.00mg/l, and it doesn't have any standard as those compared by WHO or by the NSDWQ.

Table 4 Dietary Reference adequate Intake values

Age group	Dietary reference intake (g/day)
Infants 0–6 months	0.4
Infants 7–12 months	0.7
Children 1–3 years	3.0
Children 4–8 years	3.8
Male youth and adults 9 – 13 years	4.5a
Male youth and adults 14 ≥ 70 years	4.7a
Female youth and adults 9 –13 years	4.5a
Female youth and adults 14 ≥ 70 years	4.7a
Pregnancy n/a	4.7a
Lactation n/a	5.1a

The framework for DRI development has been described by others (IOM 2006, 2008; Taylor, 2008)

United Kingdom guidelines for adults are 3.7 g/day with no requirement for additional intake in pregnancy and lactation. The adequate intake for adults (19–70 years of age) is 4.7 g/day (Khwaja et al., 2017). This is equivalent to 78 mg/kg body weight per day for a 60 kg adult. The adequate intake is based on potassium's effect of countering salt sodium chloride sensitivity in African Americans, as well as epidemiological evidence linking higher levels of potassium intake with decreased risk of bone loss and kidney stones.

Calcium- The concentrations of calcium analyzed in the samples ranges from 3.999-85.487mg/l with values are above the desirable limit of 75mg/l, (Wang, 2012), except SC-S6 that have 63.852mg/l which is close to the desirable value. Over 99% of total body calcium is found in bones and teeth, where it functions as a key structural element.

Sodium (Na): The concentration of sodium analyzed in the samples ranged from 14.00mg/l to 104mg/l and it fall within 200mg/l of NSDWQ. Sodium ion is ubiquitous in water, most water supplies contain less than 20mg of sodium per liter but in some countries, levels can exceed 250mg/l. (Janardhana Rao et al., 2016).

The concentration of Cadmium present in the analyzed samples ranged from 0.020 mg/l to 0.045mg/l which is greater than the said 0.003mg/l standard as prescribed by the Nigerian standard for drinking water quality. Cadmium concentration in unpolluted natural water is usually below 1µg/l (Carrard et al., 2019). Median concentration of dissolved cadmium measured at 110 stations around the world were <1µg/l. the maximum value recorded being 100µg/l in Peru (Wang, 2012).

Lead concentration as analyzed in the samples ranged from 0.278mg/l to 0.904mg/l which is higher or above the 0.01mg/l NSDWQ. This level of lead in drinking water may be reduced by corrosion control measures such as addition of lime and the adjustment of the pH in the distribution system from <7 to 8-9(14,15). Lead can also be released from flaking lead carbonate deposits on lead pipe and from iron sediment from old galvanized plumbing and service connections, even when the water is no longer plumb solvent. If a concentration of 5µg/l in drinking water is assumed, the total intake of lead from this source can be calculated to range from 3.8µg/day for an infant to 10µg/day for an adult.(Khwaja et al., 2017)

The concentration of fluoride analyzed in the samples ranged from 0.000025mg/l to 0.000141mg/l which is below 1.5mg/l standard of the NSDWQ. So the water is said to be good for both domestic, agricultural and industrial use but it need to be treated for it could result to dental caries. Traces of fluoride are present in many water, higher concentration are often associated with underground sources, in seawater a total fluoride concentration of 1.3 has been discovered [19]. Soils in most African countries are rich in fluoride containing minerals, so levels in drinking water can be high e.g 8mg/l in the United Republic of Tanzania (Janardhana Rao et al., 2016).

Table 5 Standard for drinking water quality WHO (2011)

Chemical parameters	F	Ca	Cd	Pd	Na	Ph	TDS	EC	Tempe
Permissible limit (mg/l)	1.5	75	0.003	0.01	40	6.5-8.5	2000	1200	No limit

Table 6 Nigerian standard for drinking water quality

Parameters	Cd	F	Pd	Na	pH	TDS
Maximum permissible limit (mg/l)	0.003	1.5	0.01	200	6.5 – 8.5	

Conclusion and Recommendation

Water quality is a function of physical, chemical and biological characteristics that has been imposed on it by the underlying geology. The physical and chemical analysis such as pH, EC, TDS and Temperature of twenty three water samples were carried out. From the result all showed the safety for drinking purpose.

The results obtained from the analysis showed some similarities and variations among the samples and also considering the immense role that groundwater plays in the life and existence of people, analyzing the quality of the ground water scheme in the study area revealed that the values obtained were within the permissible limits recommended by (Virtual & Project, 2004) However, almost all the samples are of good quality for drinking and domestic use.

Recommendation

More research should be conducted to serve as a guide for future development and advancement of groundwater in the study area.

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