COVENANT JOURNAL OF PHYSICAL AND LIFE SCIENCES, VOL. 10, NO. 1, JUNE 2022;
ISSN: print 2354-3574; electronics 2354-3485 DOI:

Assessment of Groundwater Quality in the Western Part of Bayero University New Campus and it's Environs

[1]Auwal, M. A, and [2]Yerima, M. K.

[1]Department of Geology, Bayero University, Kano.
[2]Department of Geology, Bayero University, Kano.
: abdussalermauwal@gmail.com; +(234) 8061276785

Abstract:
This research aimed at assessing the quality of groundwater for safe drinking in the western part of BUK's new campus and its environs, Kano state. In achieving the aim, a total of ten (10); five (5) boreholes and five (5) hand-dugged wells were selected at random across the area, taking into consideration the fact that thousands of staff and students depend on these sources. Water from each of the selected wells was sampled in a sterilized 500 mL plastic container and taken to the laboratory for analysis. Fourteen relevant parameters on the test of water quality were taken into consideration. Analysis of physical parameters was made in-situ using a PC400 portable pH/COND/EC/Temp meter. The result reveals that electrical conductivity is the only parameter with a mean concentration of 437.9 mg/L higher than the maximum permissible limit of 400 mg/L sets by the World Health Organization, 2011. The mean values of other physical parameters are within the standards. Chemical parameters analysis reveals that chloride (335.5 mg/L), calcium (781.3 mg/L), sodium (62.5 mg/L) and magnesium (115.9 mg/L) are the parameters with concentrations higher than the maximum permissible levels of 250 mg/L, 100 mg/l, 50 mg/L and 50mg/L respectively, all in Tudun Malumai area. Therefore, with the exception of this area, all other sources investigated are safe for drinking by meeting the standard requirements. The high concentration of chloride in the Tudun Malumai area is attributed to the use of inorganic fertilizers and animal feeding. Distillation, one of the oldest, and yet still very effective method of purifying water sources is highly recommended.

Keywords: **BUK, Drinking Water, Groundwater Quality, Physico-chemical Analysis**

1. INTRODUCTION

Groundwater is the most preferred and effective source of water for agricultural and domestic uses. Groundwater supply has increased significantly in recent times and becomes the main water source for all purposes in rural and urban areas of West Africa, especially in the dry season [1]. The surface water resources in this region, influenced by seasonal rainfall include rivers, lakes, and dams [1]. Groundwater occurs everywhere but sometimes its availability in economic quantity depends solely on the distribution of the subsurface geologic units that are referred to as the aquifers. This implies that where groundwater is not potentially endowed enough, there may be either complete lack or inadequacy due to increasing industrial and domestic needs [2].

Water is an indispensable material for a multitude of domestic and industrial purposes and naturally exists in three main sources, rainwater, ground/water and surface water [3]. As it percolates into the earth it is subjected to some purification actions by the numerous chains of pervious and impervious strata or layers. Some level of purity is achieved in turbidity, colourr, odour and taste when it reaches the surface through wells, shafts, springs and boreholes [4]. Clean and fresh drinking water is essential for humans and other life forms and access to it is important to every community [5]. According to the World Health Organisation [6], about 1.1 billion people lack access to the drinking water supply. In most cities, town and villages in Nigeria, valuable manpower are spent on seeking and fetching water which lacks regular quality assessment [7]. Groundwater serves as a cheaper source of domestic water supply that includes natural springs, wells and boreholes. Borehole water is groundwater available in an aquifer obtained by installing pumps to draw the water to the consumers. The major problems of boreholes are the chemical content of the ground water, which must be analyzed to ascertain if these dissolved products are within the permissible limits for consumption. Adeyemi [5] reports high level of ions in ground water from developing countries including Nigeria.

Hand-dug wells provide a cheap and low-tech solution and are excavation of the ground dugged to reach the water table. Since shallow aquifers are exploited, Mustapha and Nabegu [8] revealed that the well may be susceptible to possible contamination from surface water including sewage and leachate. Kushreshtha [3] stressed that the quality of ground water resources depend on the management of human waste, as well as the natural physico-chemical characteristics of the catchment areas. Colour, odour, taste, pH, total hardness, total coliforms and other dissolved ions have been reported as indices of water contamination [4]. The significance of maintaining proper water quality to human health has been reported by [7], contamination was considerably for both open and rope-pump shallow wells.

Hence this study investigates the quality of groundwater from both boreholes and hand-dug wells for safe drinking, by testing parameters like pH, Temperature, Electrical conductivity (EC), Total Hardness, the Ionic concentration of

Calcium (Ca), Magnesium (Mg), Iron (Fe), Chlorine (Cl), Nitrate (NO_3), Sulphate(II)oxide(SO_4^{2-}), Bicarbonate (NHO_3^-), Sodium (Na^{2+}), Lead (Pb^{2+}) and Total Dissolved Solids (TDS) in the Western Part of Bayero University New Campus and its Environs, Kano State, Northwestern Nigeria, taking into consideration the fact that thousands of staffs and students living in the campus depend on this source, thus understanding the level of groundwater quality and its portability rate is of paramount importance, especially in a community setting like the university and its environs.

2. STUDY AREA

The study area covers the western part of BUK's new campus in Ungogo LGA; Langel, Janguza and Tudun Malumai wards in Tofa LGA located in the western part of Kano State, Northwestern Nigeria. It has an estimated land area of about 20 km^2 with an estimated population of about 100,000 (NPC, 2006). It lies between Latitude 11°57'26"N to 11°59'12"N and Longitude 8°23'26" E to 8°25'52"E.

The area lies within the tropical savannah zone of Nigeria. Temperatures are high throughout the year, the mean maximum temperature is 31^{o}C and the mean minimum temperature is 18^{o}C. The annual rainfall varies from 1200 mm in the south to 650 mm in the north. Indeed, there are two main seasons – the rainy season starts in May or June and ends in October or November while the dry season is from November to April [9, 10].

2.1 Geology of the Study Area

Underlying the study area are rocks of the Nigerian Basement Complex which are products of a series of Orogenic events. The rocks mapped are predominantly granites with minor xenolith. Age determination from different parts of the Basement Complex shows that it has witnessed at least three Orogenic events from Achaean to Pan African. Hence, it's polycyclic in nature [11]. The Pan African Orogeny resulted in the emplacement of the granites in the Basement Complex. This, therefore, indicates that the material for the formation of the granitoids in this study might have been sourced from the partial melting of crustal rocks. The granites of the study area vary in texture and composition and comprise of three textural variants, name fine-grained, medium-grained and coarse-grained granites (Fig. 1).

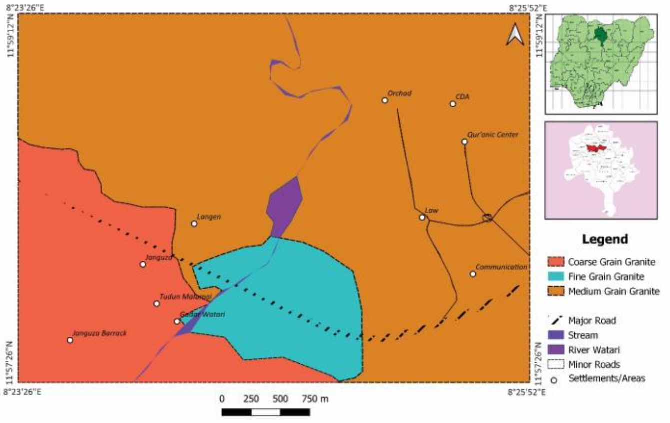

Fig. 1: Simplified geological map of the study area showing the type of rock unit in the study area.

2.2 Hydrogeology of the study area

The study area falls within the crystalline Basement of Nigeria. The fractures in the rocks determine their hydrogeological properties and this depends on texture and mineralogy. The type of aquifer in the study area is fractured basement. The decomposed materials overlie crystalline rocks and are largely covered by a thin layer of superficial material consisting mainly of gravels and silty materials. The fracturing in the study area is mainly due to jointing and shearing probably associated with the Pan African orogeny. The granitic basement aquifer with deeply weathered rocks beneath and fractured rocks with hydraulic conductivity yielded appreciable amount of water in the study area. The depth to water table of hand-dugged wells in the study area ranges from 4.1m to 7.2m with an average of 5.1m, while the average depth of the wells is 8.8m. The depth to water table of boreholes ranges from 25.1m to 28.2m with an average of 27.0m, while the average depth of the boreholes is 30.8m.

Groundwater in the study area flow perpendicular to the water level contours (Fig. 2) and from higher topography to the low laying areas. This corresponds to the western and other parts (recharge areas) towards the south western part (discharge area). At the recharge areas, the static water levels are deeper from the ground surface compared to the static water levels at the discharge area.

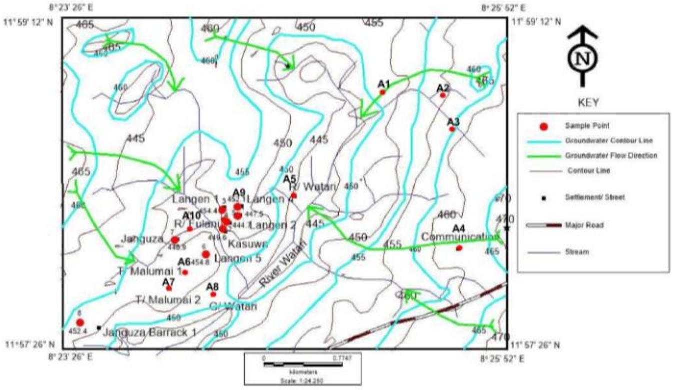

Fig. 2: Groundwater configuration map of the study area showing the flow direction of groundwater in the study area.

3. METHODOLOGY

Samples of water were collected from boreholes and hand-dug wells drilled into the various Basement Complex rocks within the area. In all, ten samples were randomly collected – five from each of boreholes and hand-dug wells. The samples were collected in early June (rainy season). Total of fourteen parameters were chosen base on those found to be relevant to the study area and taking into consideration World Health Organisation Geneva reviewed chemical parameters in drinking water standards for developing countries [12], hence, justifying the reason for the choice.

The PH value, Temperature, Electrical Conductivity and Total Dissolved Solids of all the samples were measured shortly after collection, using Apera PC400 Portable pH/COND/EC/Temp Meter.

The Calcium (Ca^{2+}), Sodium (Na^{2+}), Iron (Fe^{2+}), Magnesium (Mg^{2+}) and Lead (Pb^{2+}) concentrations were determined using the atomic absorption spectrophotometer. The total iron concentration was determined by a colourimetric method using thioglycolic acid which reduces iron (III) to iron (II) and forms a reddish-purple. In the case of chloride concentration, it was determined by titration with a standard solution of silver nitrate using an indicator of 8% potassium chromate solution, appearances of red precipitate signify the titration endpoint and the corresponding concentration read off in mg/1.

Sulphate (SO_4^{2-}) concentration was determined using the turbinate method while the nitrate-nitrogen (NO_3^-) was determined by the colourimetric method respectively.

Finally, the total hardness was determined by titration with sodium dihydrogen ethylenediamine tetraacetate dehydrate – (E.D.T.A. – Salt, Na_2 H_2 C_{10} H_{12} O8 H_2 $2HO_2$) using Eriochrome Black T as an indicator. The samples were analysed at the Soil and Water Laboratory, Geography Department, BUK and Central Laboratory Complex, BUK.

Hydrogeochemical facies were worked out by developing Piper and Durov diagrams with the aid of "Geochemist's Workbench" computer software.

TABLE I
SAMPLING LOCATION AND WELLS CODE

Location	Code	Latitude	Longitude	Well Type
Orchad BUK	A1	11º 58’ 47“	8º 21’ 11“	Borehole
CDA BUK	A2	11º 58’ 46“	8º 21’ 31“	Borehole
Qur’anic Center BUK	A3	11º 58’ 36“	8º 25’ 34“	Borehole
Fac. of Comm. BUK	A4	11º 57’ 58“	8º 25’ 36“	Borehole
Watari River	A5	11º 58’ 15“	8º 24’ 43“	Open Well
Tudun Malumai 1	A6	11º 57’ 50“	8º 24’ 07“	Borehole
Tudun Malumai 2	A7	11º 57’ 46“	8º 24’ 03“	Open Well
Gadar Watari	A8	11º 57’ 44“	8º 24’ 15“	Open Well
Kwanar Langel	A9	11º 58’ 12“	8º 24’ 24“	Open Well
Rugar Fulani	A10	11º 58’ 5“	8º 24’ 19“	Open Well

4. RESULT AND DISCUSSION

The quality of drinking water is a major determinant of health for users. For this reason, periodic quality control measures are necessary. However, groundwater sources in many communities in Kano State, generally lack regular quality control checks. This study was therefore aimed at evaluating groundwater quality in the western part of BUK's new campus and its surrounding communities, with a view to providing data that might be useful to policymakers and water service providers. It was identified through Physico-chemical quality analysis that most of the water samples were within the acceptable quality parameters recommended by the WHO.

The physicochemical parameters for all borehole samples analysed were within the standards of the WHO, and four out of five hand-dugged well samples were also within the standards of the WHO. The exception is in Tudun Malamai area coded A7, where hardness, chloride, calcium, sodium and magnesium ion concentration were found above the permissible limit set by WHO. The pH of borehole water samples was found within the range of 6.54 – 7.87 with an average of 7.24, while that of hand-drugged wells is within 6.11 – 7.65 with a mean value of 7.06. This indicates that the water samples were slightly acidic to neutral. In fact, the geology of the sampling site could partly contribute to the final pH of the groundwater According to [13], the geology around the aquifers of the study area is dominated by crystalline silicate rocks and regolith which impart acidity to the water.

The value of electrical conductivity depends on the concentration, types of soluble ions as well as the temperature of the water [14]. In this study, the conductivity values of borehole water samples ranged between 116 and 821 µS/cm while between 124 and 1326 µS/cm for hand-drugged wells (Tables 2 and 3). The mean conductivity value for borehole samples analysed was 356.6 µS/cm compared to 439.2 µS/cm for hand-dugged wells. Generally, groundwater in this study had low electrical conductivities, implying low mineral content.

Total dissolved solids (TDS) in drinking water has been associated with natural source, sewage, industrial wastewater, urban run-off and chemicals used in the water treatment process. High concentrations of TDS may confer undesirable taste, odour and colour on water, posing adverse reactions to the consumer [15]. The TDS in this study exhibited a wide variation with a minimum value of 118 mg/l in borehole samples and a maximum value of 583 mg/l in hand-dugged wells, with an average of 170.4 and 239.9 mg/l respectively (Table 2 and 3). All the TDS values were below the maximum allowable value of 600 mg/l prescribed by the WHO (2011). Moreover, these results are similar to those obtained by [13] which showed that the average TDS of groundwater in the Basement Complex areas of Kano State is 108 mg/l.

TABLE II
PHYSICO-CHEMICAL PARAMETERS RESULT OF BOREHOLE SAMPLES, MEAN AND WHO STANDARDS (2011)

Parameter	Sample Code					Mean	WHO Standard
	A1	A2	A3	A4	A6		
pH	6.54	7.01	7.51	7.87	7.25	7.24	8.5
Temperature (ºC)	30	31.8	32.8	33.6	30.6	31.76	25
Conductivity (цS/cm)	190	116	405	251	821	356.60	1400
TDS (mg/l)	135	118	297	179	123	170.40	600
Hardness (mg$CaCO_3$/l)	99.45	128.7	249.6	93.6	136.5	141.57	500
Chloride, Cl^- (mg/l)	37.28	44.38	56.8	44.38	152.6	67.09	250
Sulphate, SO_4 (mg/l)	0.18	0.16	0.24	0.28	0.22	0.22	250
Nitrate, NO_3^- (mg/l)	2.8	4.2	5.6	5.6	5.6	4.76	10
HCO_3^-, (mg/l)	50.2	95.16	56.12	71.98	98.82	74.46	150
Iron, Fe^+ (mg/l)	0.962	0.341	1.075	0.573	1.210	0.83	2
Calcium, Ca^+ (mg/l)	39.96	10.50	84.98	44.73	100.4	56.11	100
Magnesium, Mg^+ (mg/l)	6.181	5.077	29.00	9.031	19.31	13.72	50
Sodium, Na^+ (mg/l)	21.25	15	17.50	20	45	23.75	50
Lead, Pb^+ (mg/l)	0.00	0.01	0.01	0.01	0.01	0.01	0.01

TABLE III
PHYSICO-CHEMICAL PARAMETERS RESULT OF HAND-DUGGED WELL SAMPLES, MEAN AND WHO STANDARDS (2011)

Parameter	Sample Code					Mean	WHO Standard
	A5	A7	A8	A9	A10		
pH	7.65	7.20	6.11	7.17	7.19	7.06	8.5
Temperature (ºC)	38.5	31.2	30.9	30.5	29.5	32.12	25
Conductivity (цS/cm)	202	1326	124	257	287	439.20	1400
TDS (mg/l)	143	583	87.4	182	204	239.88	600
Hardness (mg$CaCO_3$/l)	273	721.5	101.5	132.6	197	285.12	500
Chloride, Cl^- (mg/l)	49.93	335.5	51.48	35.5	44.38	103.36	250
Sulphate, SO_4 (mg/l)	0.22	0.73	0.09	0.19	0.21	0.29	250
Nitrate, NO_3^- (mg/l)	4.2	8.4	4.2	4.2	5.6	5.32	10
HCO_3^-, (mg/l)	97.6	109.8	68	85.4	61	84.36	150
Iron, Fe^+ (mg/l)	4.402	0.772	0.326	0.846	0.532	1.38	2
Calcium, Ca^+ (mg/l)	36.90	781.3	3.087	3.404	5.744	166.09	100
Magnesium, Mg^+ (mg/l)	17.58	115.9	2.684	2.285	3.719	28.43	50
Sodium, Na^+ (mg/l)	21.25	62.5	15	28.75	31.25	31.75	50
Lead, Pb^+ (mg/l)	0.00	0.01	0.01	0.00	0.01	0.01	0.01

High potable water temperature may impart undesirable taste and odour as well as the corrosive ability of the water

[12]. This may also facilitate the growth of microorganisms, hence affecting water quality [12]. In this study, sample temperatures for both the boreholes and hand-dugged wells were between 29.5 and 38.5 °C. These temperatures were all above the WHO maximum limit of 25 °C. This could be attributed to the environmental temperature as well as the climatic conditions prevailing in the study area at the time of sampling. Hence, the water temperatures recorded here may only highlight environmental characteristics without any suggestion for adverse effects on human health.

Total hardness is chemically expressed as the total concentration of Ca^2+ and Mg^{2+} as milligram per liter equivalent of $CaCO_3$ [16]. Physically, hardness could be referred to as the resistance of water to lather soap [17]. The total hardness values recorded for borehole samples ranged from 93.6 to 249.6 mg/L (Table 2), while from 101.3 to 721.5 mg/L for open wells. The total hardness measurements for all the borehole samples were below the 500 mg/L recommended by the WHO for drinking water (Table 2), suggesting that they were all compliant with the WHO guideline and also safe for drinking. The high value of hardness (721 mg/L) in A7 open well is attributed to the high concentration of calcium and magnesium sourced from biotite which make the water very hard.

TABLE IV
CLASSIFICATION OF WATER HARDNESS

Soft	< 50
Reasonably soft	50 – 100
Slightly hard	100 – 150
Reasonably hard	150 – 250
Hard	250 – 350
Very Hard	> 350

Source: Schutte (2006)

The average calcium ion concentration for the borehole water samples was 56.1 mg/l compared to that of hand-dugged wells, 166.1mg/l. Calcium ion (Ca^{2+}) can occur naturally in groundwater through the dissolution of carbonate minerals and the decomposition of sulphate, phosphate and silicate minerals [18]. The low concentrations of Ca^{2+} observed in this study could be attributed to the absence of sulphate and phosphate containing rocks in the study area rather than pollutants [19].

The magnesium ion (Mg^{2+}) concentration in all borehole samples was lower than the WHO standard of 50 mg/l for potable water (Table 2). The highest concentration of Mg^{2+} above the WHO standard was 115.9 mg/l at A7 hand-dugged well. The source of magnesium in the groundwater sampled in this area may be attributed to geological sources such as biotite abundant in the basement rocks of the sampled area.

Excess chloride ions in water may not pose any health risk to consumers; however, high concentrations of chloride and sodium ions in water may interact to form sodium chloride which could impart a salty taste to the water [18]. Chloride content in borehole samples has a mean of 67.1 mg/L lower than the maximum acceptable limit of 250 mg/L recommended by the WHO. Thus, the concentration of the chloride was considered satisfactory. While for hand-dugged wells, the chloride concentration ranges from 35.5mg/L in A9 to 335.5 mg/L in A7. The high concentration of chloride in Tudun Malumai area may be attributed to use of inorganic fertilizers and animal feeding as rearing of cattle and farming were taken place close to the water source. Because the use organic fertilizers produce different chemicals, such chemicals may have been mixed with surface water near the well, and eventually, the contaminated water percolate downward through available cracks and flow to the water table thereby altering the groundwater chemistry.

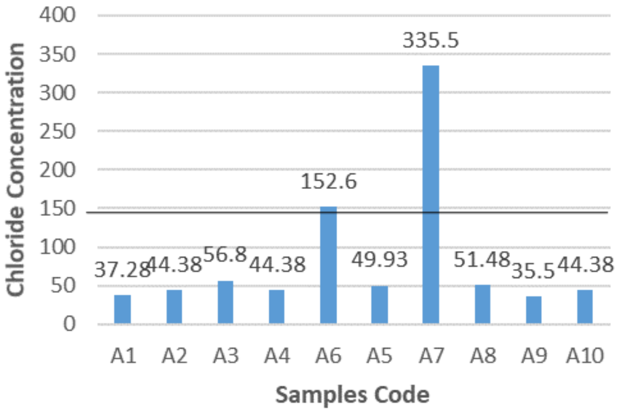

Fig. 3: Chart showing chloride concentration in all samples with highest level in A7 (The black bold line indicates the WHO maximum permissible limit (150 mg/l))

There are two samples in Tudun Malumai area, a borehole (A6) and an open well (A7) but their physiochemical properties vary significantly, this can be as a result of difference in depth of the two wells, the borehole has depth to water table of 25.3 m, hence pollutant from anthropogenic sources find it difficult to percolate to the aquifer. While the hand-dugged well has 7.2m as depth to water table, thereby making it possible for pollutants from anthropogenic sources such as farming activities to percolate and alter the water chemistry.

Nitrate and nitrite are the forms of nitrogen most commonly associated with groundwater contamination [20]. Although the presence of nitrate does not pose any health threat to adults, ingestion by infants can cause low oxygen levels in the blood, a potentially fatal condition [21]. For this reason, the WHO has established a drinking-water maximum allowable threshold of 10 mg/l nitrates as nitrogen [12]. All borehole samples analysed contained varying concentrations of nitrate ranging from 2.8 to 5.6 mg/L with a mean of 4.7 mg/L (Table 2), while the levels range from 4.2 to 8.4 mg/L in hand-drugged wells, with an average of 5.3mg/L. The concentration of nitrate in the water samples was within the permissible range of 0.0 - 10.0 mg/L as recommended by the WHO for drinking water.

A high concentration of iron in groundwater may not pose any health hazards but may not be patronised by consumers due to the unpleasant odour and taste that is normally associated with groundwater with higher iron concentrations [22]. The total iron concentration was between 0.3 and 1.2 mg/L in borehole samples, and 0.3 to 4.4 mg/L in open wells (Tables 2 and 3). Thus, the water from all the samples is considered satisfactory for human consumption.

Bicarbonate was observed in the range of 50.2 to 98.2 mg/L in borehole samples, and 61 to 109.8 mg/L in open wells, all of the groundwater samples are within the permissible limit (150 mg/L) as per the WHO guidelines. Weathering of carbonate and/or alumino-silicate minerals with a secondary contribution from the dissolution of CO_2 gases are the primary sources of HCO_3 in the groundwater. This CO_2 can be produced by the oxidation of organic matter and by root respiration in the unsaturated zone, followed by the dissolution in the recharge water to form bicarbonate [23]. In addition, bicarbonate is also produced by the dissolution of carbonate and the weathering of silicate minerals. If an aquifer is rich in organic material, there is a high possibility of the depletion of oxygen due to organic decomposition.

Na^+ is a naturally occurring elements in groundwater. It is directly added into groundwater from industrial and domestic wastes and contribute salinity of water. Na^+ is one of the important cations occurring in natural waters and is derived from weathering of rocks. Domestic wastes and industrial wastes are rich in Na^+ and contribute to the salinity of the water. At lower concentrations, there are no adverse effects on health. The Na^+ value of all the samples varies in the range of 15 to 62.5 mg/L. A high concentration of Na^+ ion in drinking water may cause heart problems and high Na^+ in irrigation water may cause salinity problems [24]. So, all of the groundwater sampled from the study area falls within the permissible limit (200 mg/L) suggested by WHO. Lead concentration ranges from 0.00 to 0.01mg/l, no sample is found above the permissible level of 0.01mg/L set by WHO (2011).

4.1 Graphical Presentation of Hydrogeochemical Data

During the circulation of water in rocks and soils, ions leached out and dissolve in groundwater. The geological formations, water-rock interaction and relative mobility of ions are the prime factors influencing the geochemistry of the groundwater [25]. Because of chemical analysis results of water in form of tables may be difficult to interpret. The graphic representations are used to discuss the water-rock interaction in the study area. Hydrogeochemical facies were worked out by developing Piper (Fig. 4) and Durov (Fig. 5) diagrams for the study area.

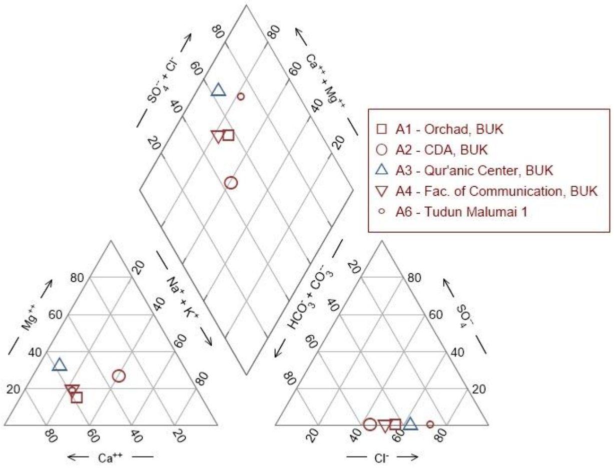

Fig. 4(a): Graph of chemical classification of water from boreholes of the study area (Modified after Piper, [28])

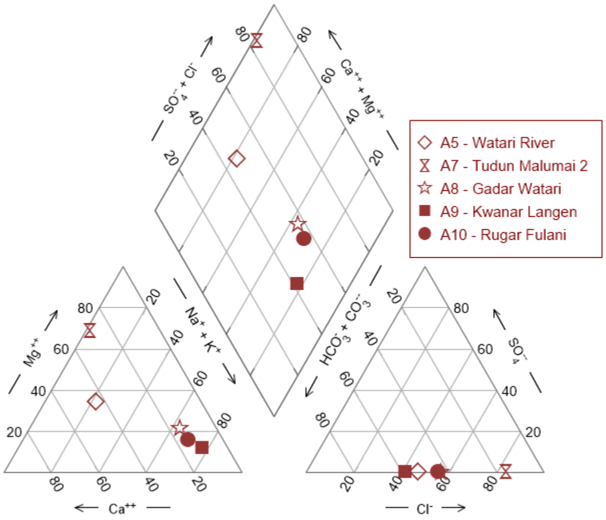

Fig. 4(b): Graph of chemical classification of water from open wells of the study area (Modified after Piper, *[28]*)

Based on the Piper plot of the samples (Fig. 12), four water types were identified from the study area (NaCl, CaCl, $MgHCO_3$ and mixed water types). Samples A8 and A10 belong to sodium chloride water type (NaCl), samples A3, and A6 belong to Calcium Chloride water types (CaCl), Samples A5 and A2 belong to $MgHCO_3$ and sample A1, A4, and A9 belong to mixed water types.

Durov introduced another diagram which provides more information on the hydrochemical facies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding the quality of groundwater and its evaluation. The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest; the sides form a binary plot of total cation vs. total anion concentrations; the expanded version includes electrical conductivity (µS/cm) and pH data added to the sides of the binary plot to allow further comparisons.

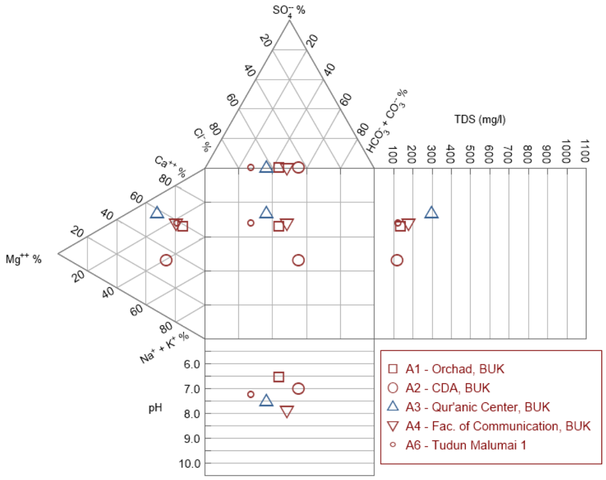

Figure 5(a): Graphical presentation of borehole water samples of the study area showing mechanisms controlling the geochemistry of water types and TDS level based on the major ions measured (after Durov, [27])

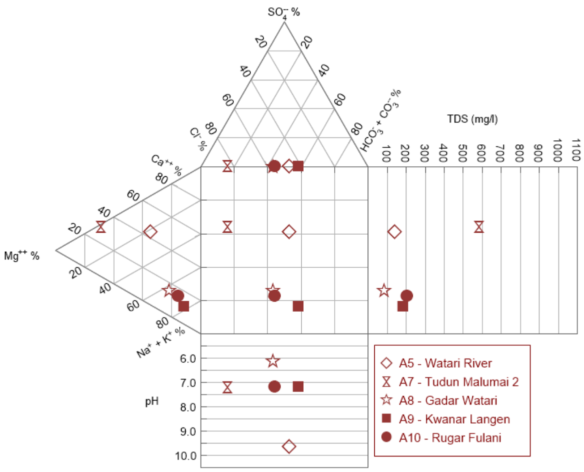

Figure 5(b): Graphical presentation of hand-dugged wells of the study area showing mechanisms controlling the geochemistry of water types and TDS level based on the major ions measured (after Durov, [27]

5. CONCLUSION

Physicochemical assessment of borehole and well water samples from western part of BUK new campus and it's environs was carried out in this research. All borehole water sources investigated have parameters within the WHO standards. The levels of heavy metals were also found to be within the recommended levels set by WHO in the borehole water samples. For the five hand-dugged wells, only one sample at Tudun Malamai area coded A7 have high levels of hardness, chloride, iron, calcium, sodium and magnesium ion concentration above the standard set by WHO safe limits, there is the tendency of high potential health hazards to the inhabitants of the area that uses this water source for drinking and other domestic purposes without treatment. The geology of Tudun Malamai and the degree of weathering, influence the groundwater chemistry, because of different mineralogy and degree of weathering. Consequently, different minerals are eventually weathered and leached down to the water table thereby altering the groundwater chemistry. From the result obtained, water quality monitoring is encouraged to be a continuous process. Proper sanitation and treatment should be strictly observed around the vicinity of the boreholes and the well water.

6. REFERENCES

[1] Pimentel D, Houser J, Preiss E, White O, Fang H, Mesnick L, Barsky T, Tariche S, Schreck J, Alpert S, "Water resources: agriculture, the environment, and society source: an assessment of the status of water resources.," *Bioscience 47(2):*, p. 97–106, 1997.

[2] Akpan., AP., Ugbaja AN, Gorge NJ, "Integrated geophysical, geochemical and hydrogeological investigation of shallow groundwater resources in parts of the Ikom-Mamfe Embayment and the adjoining areas in Cross River State, Nigeria.," *J. of Env. E. Sci.*, 2013.

[3] Kushreshtha, S. I. N., A global outlook for water resources to the year 2012, Water Resource Management. New York: Academic Press Inc. 12 (1), 1-18., 1998.

[4] Bashiru, F. I, "Ground water microbiology and Geochemistry.," *J. Willy and Sons,* p. 424, 2004.

[5] Adeyemi, O. Oloycde, O. B., and Oiadi, A. T. , "Physico-chemical and microbial characteristics of leachete contaminated ground water.," *Asian J. of Biochem, 2:,* pp. 343-348, doi: 10.3923/ajb.2007.343-348, 2007.

[6] WHO - World Health Organization, "World Health Report - Fighting Disease, Fostering Development," World Health Organization, Geneva, 2006.

[7] Hafiz, K. K, Mensah, G. I, Bekoe, M, Bonus, C and Akyen, M. L, "Bacteriological quality of sachet water produces and sold in Teshic- Nungua, Surburbs of Accra Ghana," *African J. of F. and Agr. Dev.*, no. 9 (4):10, pp. 190-103, 2009.

[8] Nabegu, A. B., and Mustapha, A., "Enhancing awareness and participation of municipal solid waste management in Kano Metropolis, Nigeria," *World Scientific News,* vol. 5, pp. 46-53., 2014.

[9] Olofin, E. A., "Some Aspect of Physical Geography of Kano State Region and its Related Human Responses.," *Department of Geography, BUK,* 1987.

[10] Schoeniech, K., "Geol. 400 Hydrogeology Lecture Notes Unpublished," *Department of Geology, ABU Zaria*, 1998.

[11] McCurry, P., "The Geology of the Precambrian to Lower Paleozoic rocks of Northern Nigeria, a review in Geology of Nigeria. 1nd Revised Edition.," *C.A. Kogbe, Elizabethan Publication. Lagos . 15 – 39.*, 1976.

[12] WHO, "Guidelines for drinking water quality," World Health Organization, Ganava, http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/index.html. Accessed: 12 Aug 2021, 2011.

[13] Adamu, G. K.,Tukur, R. and Kankara, A. I, "Ground Water Quality Assessment in the Basement Complex Areas of Kano State Nigeria," *American Journal of Engineering Research (AJER),* 2013.

[14] Hem, J. D, "Study and interpretation of the chemical characteristics of natural water," *US Geological Survey Water Supply Paper, University of Virginia, Charlottesville,* vol. 3rd edn, p. 263, 1985.

[15] Spellman, F. R and Drinan, J. E, The Drinking Water Handbook, vol. 2nd edn., Boca Raton: CRC Press, 2012.

[16] Nitsch, C, Heitland, H. J, Marsen, H and Schlüssler, H. J, "Cleansing agents In Ullmann's encyclopedia of industrial chemistry," *Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim,* pp. 1-23, 2000.

[17] Todd, D. K, Groundwater hydrology, 3rd edn., Wiley, Hoboken, 2008.

[18] Cobbina, S. J, Nyame, F. K and Obiri, S, "Groundwater quality in the Sahelian Region of Northern Ghana, West Africa," *Res J Environ Earth Sci* , p. 4:482–491, 2012.

[19] Nude, P. M and Arhin, E, "Overbank sediments as appropriate geochemical sample media in regional stream sediment surveys for gold exploration in savannah regions of Northern Ghana," *J Geochem Explor* , p. 103(1):50–56. doi:10.1016/j. gexplo.2009.06.005, 2009.

[20] Böhlke, J. K, Smith, R. L and Miller, D. N, "Ammonium transport and reaction in contaminated ground water—application of isotope tracers and isotope fractionation studies," *Water Resour Res,* p. 42: W05411. doi:10.1029/2005WR004349, 2006.

[21] Spalding, R. F., and Exner, M. E., "Occurrence of nitrate in groundwater, a review.," *J. Environ. Qual*, vol. 22, pp. 392 - 402, 1993.

[22] Gardner, S. J and Pelig-Ba, K. B, "Health problems related to groundwaters in the Obuasi and Bolgatanga areas, Ghana," British Geological Survey Technical Report, WC/95/43, 1995.

[23] Ramesh, K. and Bhuvana, J. P, "Hydrochemical Characteristics of Groundwater for Domestic and Irrigation Purposes in Periyakulam Taluk of Theni District, Tamil Nadu," *Int. Res J Env Sci*, pp. 19-27, 2012.

[24] Chadrik, R. and Arabinda, S., "Assessment of drinking water quality, a case study of Ambala Cantonment area, Hariyana, India," *Int J Env Sci*, vol. 2, pp. 933-945, 2011.

[25] Yousef, A. F., Saleem, A. A., Baraka, A.M. and Aglan, O. Sh.,, "The impact of geological setting on the groundwater occurrences in some Wadies in Shalatein-Abu Ramad area, SE desert, Egypt.," *European Water*, pp. 25/26: 53-68., 2009.

[26] WHO - World Health Organization, "Guidelines for Drinking Water Quality.," *Vol. 1.World Health Organization.Geneva,*, p. p.129, 1984.

[27] Durov, S. A., "Natural Waters and Graphic Representation of their Composition.," *Doklady Akademii Nauk SSSR*, vol. 59, pp. 87 - 90, 1948.

[28] Piper, A. M., "A graphic procedure in the geochemical interpretation of water samples.," *American Geophysical Union Trans.*, vol. V.25, pp. pp. 914-923, 1994.