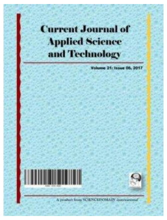

Current Journal of Applied Science and Technology

27(5): 1-8, 2018; Article no.CJAST.41524
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Comparative Analysis of Groundwater Quality in Basement and Sedimentary Formations of Katsina State, North-Western Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author RLD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MMS and AKI managed the analyses of the study. Author MMS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/41524
Editor(s):
(1) Jakub Kostecki, Professor, Faculty of Civil Engineering, Architecture and Environmental Engineering, University of Zielona Góra, Poland.
Reviewers:
(1) C. R. Ramakrishnaiah, Visvesvaraya Technological University, India.
(2) Falowo Olumuyiwa Olusola, Rufus Giwa Polytechnic, Nigeria.
(3) Aniekan Edet, University of Calabar, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/24911

Original Research Article

Received 9th March 2018
Accepted 15th May 2018
Published 31st May 2018

ABSTRACT

This study was aimed at assessing and comparing the quality of groundwater for safe use in two geologic formations (Basement complex and sedimentary) of Katsina State, Nigeria. A total of twenty (20) boreholes; ten (10) from each formation were selected at random from various locations across the state. The water samples from these boreholes were analysed for 13 physicochemical and bacteriological parameters in order to ascertain their level and confirm wether they meet the World Health Organisation (WHO) standards for drinking water [12].
The Mean levels of Total alkalinity, Sulphate and magnesium were above WHO limit in Basement complex samples while; the mean concentration of iron in the sedimentary zone was above WHO limit. There was a significant difference (<0.05) in the Chloride and TDS concentration between the two formations. Most of the samples analysed met the requirement for drinking water, probably due to the natural filtration process the water has undergone.

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Keywords: Borehole; safe drinking water; underground water; geologic formations.

1. INTRODUCTION

The population of Nigeria is projected to hit the 200 million mark by the year 2020. This increasing population has put the scarce resources under stress. Water is the most important resource needed for the survival of mankind. Therefore, efficient development of groundwater resources is of particular importance in northern Nigeria where due to the low rainfall and the length of dry season, surface water sources are often inadequate [1]. To provide alternative to surface water which in most cases is unsafe, underground water development seems the most viable and safer option. Water quantity is important but, the quality of water is of paramount importance because of the preponderance of water–borne diseases that could lead to diseases outbreak among the populace. A number of studies have been conducted on the assessment of available groundwater resources in various parts of the country. Du preeze [2] wrote on the distribution and chemical quality of groundwater in Chad and Basement complex of northern Nigeria. [3,4,5] also wrote on parameters such as water quality, aquifer transitivity, age of groundwater, table depth to surface and relative location of groundwater as potential resources [1].

The provision of groundwater supply in Katsina state as part of a coordinated development programme for rural development is seen as an essential service imperative to the entire state's development. The provision of groundwater for rural areas is undertaken by the Katsina State Rural Water Supply and Sanitation Agency (KTRUWASSA). The agency in conjunction with International donor agencies such as the United Nations Development Programme (UNDP), Department for International Development (DFID) UK, and Japan International Cooperation agency (JICA) etc. carry out groundwater exploitation by sinking of boreholes in all geologic formations. The agency has put so much effort in providing the rural populace with safe drinking water by drilling an estimated 1850 boreholes from 2016 to 2017 alone. However, despite the efforts of these organizations, the main source of many villages for water supply essentially consisted of seasonal streams, rainfall pools and other such reservoirs. These sources are invariably polluted and constitute hazards to health [6].

The long residence time of groundwater brings it into contact with the rock formations so that it tends to have higher concentration of dissolved solids than surface water and at times contains inorganic matter in higher concentration. Groundwater quality could vary by such spatially varying factors as lithology, texture and structure of the rocks [4], and in areas with heavily polluted atmosphere, rain water quality is heavily altered [7]. This study compared the quality of groundwater from two different geologic formations for safe drinking, by testing for Physicochemical parameters; Iron (Fe), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Nitrate (NO_3^{2-}), Sulphate (SO_4^{2-}), Fluoride (F-), Dissolved oxygen (DO), Total Dissolved Solids (TDS), Total Hardness, Total alkalinity: and bacteriological parameters; Total coliform and Faecal coliform from selected locations of Basement Complex and sedimentary rocks in Katsina State.

2. STUDY AREA

Katsina State is in North-western Nigeria, and is located along latitude/longitude 12°15′N 7°30′E. The State is bounded in the East by Kano State, in the West by Sokoto State, in the South by Kaduna State and in the North by the Niger Republic. The latitudinal position of Katsina State and its interior location away from the sea determines the climate which is characterized by two main seasons (dry season from November to May and wet season from June to October). Therefore the climate is a hot one with maximum day temperatures reaching 38°C during the peak of the dry season. The area is affected by two wind patterns, the harmattan wind from the Sahara which is responsible for the cool months of December to February (about 24°C) and the Southwest Monsoon Trade Winds blowing across the Atlantic Ocean which is responsible for the rains of June to October (Nigerian Meteorological Agency, 2013). Average relative humidity is put at 42%. Average rainfall is from about 800 mm to 1000 mm.

The rocks in Katsina State comprise the following major rock groups: Basement Complex (Igneous) and sedimentary rocks [8]. The igneous rocks are the major rock group, and underlain with lateritic capping in some of them. Outcrops consist almost entirely units of resistant migmatites, quartzites, conglomerates

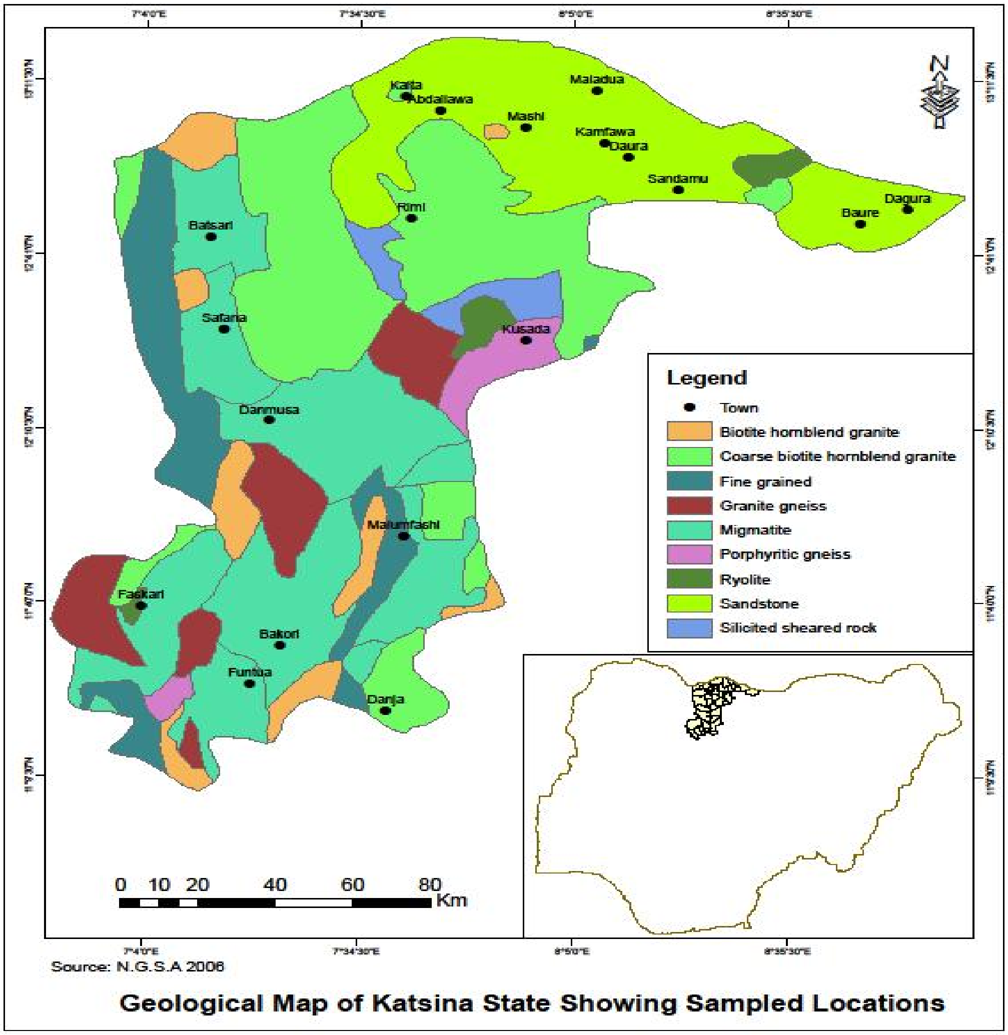

Fig. 1. The Geology of Katsina State. N.G.S.A [2006]

and granites, although there are small exposure of softer gneisses and semi-pelitic rocks in some stream channels [9]. The Sedimentary rocks are the second most abundant rock type (occupying about 33% of the State), while some most of the western part is underlain by the Igneous rock. The contact relationship between most of the rocks could only be inferred, because exact contacts between the rocks have been concealed by overlying material [10].

Within the study area, aquifers result from three main factors; tectonic movements, weathering process and original mineral composition. The types of water bearing zones are; Fractures in the poorly decomposed igneous or basement formation; Intergranular permeability; Moderately decomposed rock, and zones of compositional change in highly weathered areas.

3. METHODOLOGY

Water samples were collected in two sets of 1L polyethylene bottles (prewashed with acid, and rinsed with de-ionised water and labelled accordingly) from boreholes drilled in both the Basement Complex and Sedimentary rocks in the State. A total of twenty (20) boreholes were randomly selected– ten from each of basement and sedimentary formations. The borehole waters were allowed to flow for about 2 minutes before the water was collected. Samples for the determination of cations were stabilized with a drop of dilute hydrochloric acid on collection. All the samples were preserved in ice on-site before being transported to the laboratory and stored in the refrigerator and were analyzed within 24 hours of collection. Samples for microbial analysis were collected in sterilized 250 ml glass bottles, preserved in ice on-site before being transported to the laboratory, refrigerated and analysed within 24 hours of collection. Thirteen (13) parameters were chosen based on their importance in characterizing water quality of an area. The TDS was determined in-situ using pre-calibrated TDS meter (Orion, Model 114). The Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) concentration were determined using atomic absorption spectrophotometer. Iron (Fe) was determined by colorimetric method using thioglycollic acid which reduces iron (III) to iron (II) and forms a reddish purple colour. Chloride was determined by titration with a standard solution of silver nitrate with 8% potassium chromate solution added as an indicator. Sulphate (SO_4^{2-}) concentration was determined by turbidimetric method. Total hardness was determined by titration with EDTA (sodium ethylendiamine tetracetate) using Eriochrome black T as indicator. Nitrates were determined by the cadmium reduction method. All analyses were carried out using standard methods [11]. The microbial analysis was carried out using the filter membrane method and presumptive count and each sample was incubated for at least 24 hours. The samples were analysed at Aqua Tetra Laboratory, Katsina, Katsina State.

The statistical tools that employed in this study are both descriptive and inferential. Mean and Standard Deviation is also used in the analyses of the data.

4. RESULTS AND DISCUSSION

The result of the chemical and microbial analysis of groundwater of the two rock formations (Sedimentary and basement formations) are summarized in Tables 1- 4. It could be observed that the values for Total alkalinity, sulphate, and iron are above World Health Organization [12] maximum permissible limit in the basement complex while, the values for the same parameters are within the WHO limit [12] in the sedimentary zone. The Total dissolved solids (TDS) ranges between 0.98 – 5.40 mg/l with a mean value of 2.55 mg/l in the basement complex compared to a range of between 0.60 – 9.12 mg/l and an average value of 4.54 mg/l in the sedimentary zone, and the difference was significant (<0.05). The amount of TDS in water is a function of dissolved ions in water, and may be natural via bedrock dissolution or anthropogenic through industrial effluents. Dissolved Oxygen values have a range of between 0.80 - 11.60 mg/l with mean value of 6.10 mg/l in the basement complex, and range of 0.20 – 15.40 mg/l with an average of 3.83 mg/l in the sedimentary zone. Dissolved Oxygen deficiency confer bad odour to water due to anaerobic decomposition of organic matter. The values of Total hardness, sulphate (SO_4^{2-}), nitrate (NO_3^-) and fluoride (F^-) fall between 10.00 –500.00 mg/l, 38.60 – 500.00 mg/l, 0.08 – 3.90 mg/l and 0.10 – 0.80 mg/l respectively, with mean values of 172.90 mg/l, 259.46 mg/l, 1.66 mg/l and 0.38 mg/l respectively, in the basement complex, compared to ranges of 6.00 – 118.00 mg/l with an average of 48.80 mg/l , 28.40 – 397.60 mg/l with a mean of 229.96 mg/l, 0.28 – 2.40 mg/l with mean value of 1.22 mg/l, and 0.10 – 0.90 mg/l with an average of 0.38 mg/l respectively in the sedimentary zone. The sulphate concentration is above the limit of 200 mg/l [12,13] in both formations. High sulphate enrichment in groundwater can be traced to bedrock dissolution via migration or application of sulphate rich manure/fertilizer in the soil. The low level of nitrates is an indication of absence of pollution from septic percolation. High nitrate level in drinking water causes infant methaemoglobinaemia (blue-baby syndrome), gastric cancer, metabolic disorder in children as well as livestock poisoning. The high value of hardness, even though is within maximum permissible limit, make the water hard for users. High concentration of fluoride in ground water causes a disease known as fluorosis which affects mainly the teeth and bones of animals/man [13].

The values for Chloride (Cl^-) in the basement complex fall between 6.40 – 45.00 mg/l with a mean of 21.49 mg/l while that of the sedimentary zone fall between 7.80 – 29.78 mg/l with an average of 13.40 mg/l indicating higher levels in basement complex, which agrees with an observation made by Tukur [14] in a study. The difference was statistically significant (<0.05). These values fall within the permissible limit of 250.0 mg/l [12,13]. High chloride content in groundwater may indicate pollution by sewage, effluent or marine sources [15].

The values for the cations, Calcium (Ca), Magnesium and iron (Fe), have ranges of 2.90 – 54.60mg/l, 2.10 – 62.2mg/l, and 0.02 – 0.24mg/l respectively, with means of 20.53mg/l, 20.54mg/l and 0.09mg/l respectively for the basement complex while the ranges are between 4.60 – 50.00mg/l, 3.20 – 32.20mg/l, and 0.01 – 0.36mg/l for Ca, Mg and Fe respectively, with averages of 17.32mg/l, 16.67mg/l and 0.17mg/l respectively, in the sedimentary zone. The values for Calcium (Ca) are within the recommended permissible value of 75.00 mg/l [12] in both formations. Calcium is necessary in animals for the formation of strong teeth and bones. The concentration of magnesium (Mg) is above the acceptable limit of 20mg/l in both formations. Studies by Amadi [15] have shown that magnesium in water is better and easily absorbed than dietary magnesium. Epidemiological data in man has proved that intake of water containing sufficient amount of magnesium prevents hypertension and nervous disorder [16].

The iron (Fe) concentration is within the recommended limit of 0.3 mg/l [12,13] in the basement complex while it is above the limit of 0.3mg/l [12,13] in the sedimentary zone. The human body needs iron (Fe) for basic metabolic activities as it is a useful ingredient of the blood. Lack of iron in the body causes goitre. Iron infiltrates into the groundwater as a result of chemical weathering of rock/lateralization. It is responsible for the reddish-brown colour in laterites [17].

The values for Total coliform (TC) ranges between 0.00 – 1.00 Cfu/100ml with a mean of 0.10 Cfu/100ml in both basement complex and sedimentary zone. The result indicates absence of faecal coliform (*E. coli*) bacteria in both

Table 1. Water quality data from selected boreholes in sedimentary formation

BH No	TA	DO	Cl-	TH	SO_4^{2-}	Fe	NO_3^{2-}	F-	TDS	Ca	Mg	TC	FC
AKA	496	8.00	29.8	114	85.2	0.36	1.50	0.40	1.60	16.4	4.80	0.00	0.00
KKA	204	15.4	9.22	52.0	170	0.02	0.28	0.20	0.60	22.5	32.2	0.00	0.00
MMS	250	8.40	9.93	15.0	398	0.02	0.30	0.10	1.56	14.4	8.2	0.00	0.00
KDR	478	1.00	14.2	95.0	284	0.02	0.43	0.50	4.90	50.0	25.6	0.00	0.00
KSD	350	0.90	12.8	8.00	355	0.02	1.70	0.70	8.10	12.8	15.7	0.00	0.00
KDR	494	0.90	16.3	118	355	0.10	2.10	0.10	4.30	24.2	22.0	1.00	0.00
RSD	66.0	1.30	7.80	6.00	383	0.01	2.40	0.90	5.20	15.2	19.4	0.00	0.00
DMD	160	1.20	16.3	16.0	114	0.02	1.45	0.20	4.50	4.60	17.2	0.00	0.00
UBR	126	1.00	8.50	29.0	28.4	0.06	0.98	0.40	5.50	4.90	3.2	0.00	0.00
DBR	16.0	0.20	9.22	35.0	128	0.35	1.10	0.30	9.12	8.20	18.4	0.00	0.00

Source; Laboratory analysis 2016

Table 2. Mean and standard deviation (SD) of parameters in sedimentary formation

Parameter	Minimum	Maximum	Mean	S.D
TA	16.0	496	264	181
DO	0.20	15.4	3.83	5.08
Cl^-	7.80	29.8	13.4	6.57
TH	6.00	118	48.8	44.1
$S0_4^{-2}$	28.4	398	230	140
Fe	0.01	0.36	0.17	0.12
NO_3^-	0.28	2.40	1.22	0.74
F^-	0.10	0.90	0.38	0.26
TDS	0.60	9.12	4.54	2.75
Ca	4.60	50.0	17.3	13.2
Mg	3.20	32.2	16.7	9.16
TC	0.00	1.00	0.10	0.32
FC	0.00	0.00	0.00	0.00

Source; Data analysis 2016

Table 3. Water quality data from selected boreholes in basement formation

BH No	TA	DO	Cl-	TH	SO_4^{2-}	Fe	NO_3^{2-}	F-	TDS	Ca	Mg	TC	FC
DKS	139	6.40	45.4	108	251	0.02	3.90	0.70	3.00	6.20	2.10	0.00	0.00
YRM	23.0	11.6	12.8	10.0	48.3	0.04	2.50	0.20	2.00	12.0	2.60	0.00	0.00
YBT	211	6.30	6.40	121	227	0.08	3.75	0.80	1.20	7.40	4.50	0.00	0.00
SSF	296	5.80	22.7	13.0	309	0.04	2.54	0.20	1.40	2.90	7.40	0.00	0.00
NDM	554	0.80	14.2	151	241	0.24	0.08	0.60	5.40	23.7	33.4	0.00	0.00
GMF	260	2.80	9.20	48.0	38.6	0.08	2.43	0.20	0.98	12.6	3.20	1.00	0.00
SDJ	486	5.30	23.4	288	454	0.06	0.28	0.20	4.00	32.0	48.4	0.00	0.00
DFS	376	7.50	19.1	500	483	0.14	0.45	0.20	1.40	45.5	28.8	0.00	0.00
UBK	498	9.30	29.8	170	42.6	0.24	0.60	0.60	3.60	8.40	12.8	0.00	0.00
DFT	456	5.20	31.9	320	500	0.02	0.13	0.10	2.56	54.6	62.2	0.00	0.00

Source; Laboratory analysis 2016

Table 4. Mean and standard deviation (SD) of parameters in basement formation

Parameter	Minimum	Maximum	Mean	S.D
TA	23.0	554	330	174
DO	0.80	11.6	6.10	3.04
Cl^-	6.40	45.4	21.5	11.9
TH	10.0	500	173	155
$S0_4^{-2}$	38.6	500	260	180
Fe	0.02	0.24	0.09	0.09
NO_3^-	0.08	3.90	1.66	1.52
F^-	0.10	0.80	0.38	0.26
TDS	0.98	5.40	2.55	1.44
Ca	2.90	54.6	20.5	17.9
Mg	2.10	62.2	20.5	21.6
TC	0.00	1.00	0.10	0.32
FC	0.00	0.00	0.00	0.00

Source; Data analysis 2016

TA ;Total alkalinity, DO; Disolved oxygen, Cl; Chloride, TH; Total hardness, SO4; Sulphate, Fe; Iron, NO3; Nitrate, F-; Fluoride, TDS; Total dissolved solids, Ca; Calcium, Mg; Magnesium, TC; Total coliform, FC; Faecal coliform

Table 5. WHO drinking water standard 2014

Parameter	WHO Standard 2014	Compliance
TA	500	Above limit in BF, within limit in SF
DO	No Guideline	
Cl^-	250 mg/l	Within limit in both BF and SF
TH	No Guideline	
$S0_4^{-2}$	200 mg/l	Above limit in both BF and SF
Fe	mg/l	Above limit in BF, within limit in SF
NO_3^-	50 mg/l	Within limit in both BF and SF
F^-	1.5 mg/l	Within limit in both BF and SF
TDS	No Guideline	
Ca	75	Within limit in both BF and SF
Mg	50	Within limit in both BF and SF
TC	0	Within limit in both BF and SF
FC	0	Within limit in both BF and SF

formations. The presence of TCC and FCC in water is a clear indication of groundwater contamination by human or animal faeces. Faecal contamination of groundwater is responsible for most water borne diseases such as cholera, typhoid, meningitis and diarrhoea [15]. Poor sanitary situation of an area such as close proximity of unlined soak away/pit-latrine can be introduced into the shallow aquifer via infiltration. The maximum allowable limit is 10.0 cfu/100ml for TC and 0.0 cfu/ml for FC [13,12].

5. CONCLUSION

The quality of groundwater is determined by many factors such as the chemistry of the saprolite [4] through which groundwater percolates, nature of chemical reactions between the water and the minerals in associated rocks, the velocity of the water body and the contact time between the host rock and percolating water. In basement complex, groundwater can move from one aquifer to another, and the quality may be modified by each in turn. The background value of the chemical elements in groundwater should have some direct bearing to the geology of the environment from which it is taken [1]. Thus one expects to find similarity in ions concentration in samples from similar geologic formations. The comparative analysis of the water quality from two different geologic formations (basement complex and sedimentary formation) in Katsina State has established high Total alkalinity, sulphate and magnesium in the basement complex areas in comparison to the sedimentary zone. The study has also shown high levels (above the recommended value by WHO) of iron in the sedimentary zone, in comparison to the basement complex. The differences that exist between the parameters from the two formations were not significant, except for TDS and Chloride (<0.05).

The presence of faecal contamination in both formations has not been established by this study. Overall, the quality of water from both formations is very good.

6. RECOMMENDATION

Water can be polluted through natural and or anthropogenic means. All sources of contamination should be properly checked and monitored. Global best practices should be adhered to during construction and installation of boreholes. Good sanitary conditions must be maintained around groundwater sources to prevent contamination through seepage. More interventions are needed to provide adequate supply of safe drinking water in the rural areas to curtail the use of surface waters such as ponds, streams and rivers which are prone to contamination due to poor sanitary habits, and could lead to outbreaks of diseases such as diarrhea, cholera, typhoid and other water-borne diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24911