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Hydrogeochemical Assessment of Groundwater Quality in Keffi Town, North-Central Nigeria

[1]J.H. Chiroma, [1]O.S. Ayanninuola*, [1]A.Z. Loko
[1]Department of Physics,
Nasarawa State University, Keffi.
Email: ayanninuola@gmail.com

Abstract
The geochemical assessment of groundwater quality in Keffi Town, North-Central Nigeria was carried out in this study. Six (6) samples of groundwater were collected and analyzed using different analytical techniques in the chemical section, Central Research Laboratory, Nasarawa State University, Keffi. The physical parameters such as pH, temperature (°C), Total Dissolved Solid (TDS), and CO_2 were analyzed using multi parameter, ion specific meter. Electrical Conductivity (EC) was measured using a mark electronic switch gear, conductivity meter. Chloride (Cl^-) analyses was carried out using titration and volumetric methods. The pH ranged from 7.0 to 7.8, temperature from 25.7 to 26.0°C, electrical conductivity (EC) from 162.8 to 158 µS/cm, total dissolved solid (TDS) from 97.5 to 950mg/l and carbondioxide (CO_2) from 35.2 to 176mg/l. The analytical result presents the concentration of chloride (Cl^-) from 11 to 60mg/l. The geochemical profile reflects that the groundwater within Keffi town is slightly acidic and neutral in nature. The slightly high average electrical conductivity (714.28µS/cm) of the water samples implies that some of the groundwater samples are saline rather than fresh in nature. The analyzed parameters falls below WHO acceptable values of 6.5 – 8.5 for pH, 27°C for temperature, 1200mg/l for TDS, 1250 µS/cm for EC, 250mg/l for Cl^- respectively. Comparing these results with the required acceptable values revealed that all the physical parameters and the ions analyzed in the groundwater samples were within the WHO (2011) permissible standards.

Keywords: Geochemical, Assessment, Keffi Town, Physical Parameters, Groundwater quality.

INTRODUCTION
Water is the most abundant substance on the earth surface. It's a clear liquid having the chemical formula of H_2O, required by all forms of life on earth. Its unique properties make it the important and abundant substance in the universe.

Groundwater is water that lies beneath the ground surface filling the pore spaces between grains in bodies of sediment and elastic sedimentary rock and filling cracks and crevices in all types of rock (Abdullahi & Iheakanwa, 2013). Groundwater accounts for about 98% of the world fresh water and is distributed throughout the world (Tijani, 2016).

Accessing quality groundwater has been a major concern for both the rich and the poor most especially in Nigeria as almost 75% of the entire population depend solely on groundwater for consumption.

**Author for Correspondence*

The quality of groundwater is of vital importance, whether for industrial or domestic purposes. The quality of groundwater for different purposes depend largely on its physical, chemical and bacteriological compositions and as a result of this, various concerned agencies have set out permissible standards for water usage. According to Davis *et al*, (1966), these standards are based on two main criteria, namely; the presence of objectionable taste, odour and the presence of substances with adverse physiological effects. However, mineral enrichment from underlying rocks can change the chemistry of groundwater, making it unsuitable for consumption.

Most rural areas in Nigeria depend solely on rivers, streams and hand dug wells for water supply while urban settlements depend on treated pipe borne water and boreholes for their water supply.

In large areas of the basement complex, the principal source of groundwater is well. These wells have a depth of approximately 16 to 32meters. Even though the waste products are disposed by septic tanks and the minimum distance required between septic tank and the wells should be about 30m (Olorunfemi & Fasuyi, 1993), this is not so well with some borehole in the study area where some are within the range of 5-20m.

The quality of groundwater depends on various chemical constituents and their concentration, which are mostly derived from the geological data. Industrial and environmental solid wastes have emerged as one of the leading cause of pollution of surface and groundwater. In many parts of the country available water is rendered non-portable because of the presence of heavy metals (Amarachi *et al.,* 2012)

In Keffi town, North-Central Nigeria, scarcity of portable water has been posing serious challenges to the people of the area for a longtime and obtaining safe drinking water for domestic and other uses have been very difficult. The consequence of water scarcity in some communities in the area, especially during the peak of the dry season often manifests in the outbreak of some water borne diseases like diarrhea, cholera, guinea worm, typhoid etc. Even though the efforts of government agencies and international agencies like the Nasarawa State Ministry of Water Resources (NSMWR), Nasarawa State Water Board (NSWB), United Nations International Children Emergency Fund (UNICEF), the European Union (EU), have recorded significant success in making safe drinking water available to few communities and therefore, curbing the menace of these diseases, a lot still need to be done in many other communities.

The assessment of groundwater quality status is important for socio economic development of any region. It is therefore difficult to imagine any programme for human development that does not require a readily available supply of portable water. The physical, chemical and biological characteristics of water determine its usefulness for domestic, industrial and agricultural purposes (APHA, 1998)

Many researchers have also shown that mineralogical composition of the underlying rock(s), secondary products and the nature of the surface run-offs are factors that affects quality of groundwater (Tijani, 1994; Amadi *et al.,* 1987). It has also been established that geology has a role to play in the chemistry of surface water (Piper, 1944; Abimbola *et al.,* 2002).

The need to ascertain the quality of water used by humans has become very intense in the past decade (Tijani, 2016). Groundwater is gaining more and more importance in the study area owing to the ever increasing demand for water supply especially in areas with inadequate pipe borne and surface water supply. The suitability of groundwater for drinking (domestic), industrial (manufacturing industry) and irrigation (agricultural) purposes depends on its hydrogeochemical composition.

This study was carried out within Keffi Town, North-Central part of Nigeria defined by latitudes 8.85^{o}N and longitude 7.87^{o}E or lies on the geographical coordinates of latitudes between N08^{o}49′54″ – N08^{o}50′55″ and longitudes E07^{o}52′24″ – E07^{o}57′25″ (138km^{2}). Keffi aside from being a zonal headquarters of the Nasarawa West Senatorial District, Keffi town has a close proximity to the Federal Capital Territory (Abuja) of about 53km distance by road.

As of 2006, Keffi has a population of 92,664 and national population census, (2006), making it the 2nd biggest city in Nasarawa State. It operates on WAT time zone, which means that it follows the same time zone as Lafia.

The study was carried out to assess the hydrogeochemical characteristics and physiochemical parameters of groundwater in Keffi town as well derived data that can be used for environmental monitoring of the town.

Physiography of the Study Area

The study is characterized by two distinctive seasons, the wet season which last from the beginning of May and ends in October, the annual rainfall of the area ranges between 1100mm to about 2000mm.

Temperature are generally high in Keffi especially during the day, partly due to its location in the tropical sub-humid climate situated at 338meters above the sea level, there is gradual increase in temperature from January to March and the onset of rain in April ushers in a noticeable decline in temperature.

Average monthly temperature ranges between 26.8^{o}C – 27.9^{o}C with the hottest month being March/April while the coldest month being December/January. But wind velocity is relatively steady unlike other parameters.

The vegetation of the area which lies in the guinea savanna is a derivative of the tropical deciduous forest that existed centuries ago. Aboki et al, added that the vegetation is characterized with grassland tree, savanna and finding woodland or gallery forest along the valleys. The dominant woody species in this area include *terminalialaxitora, alliziazygia, ficus exasperate, ficussyncomorous, Khayasenegalesis, tamarindusindica (tsamiya), parkiabiglobosa (dorawa), vittellaniapradoxa* (shear butter) exposing wide area of land to sheet erosion.

The area is drained by very few scattered rivers and streams for instance, River Antau, River Mannu, River Kodo which flows towards south direction as one of the major river within the study area and very few others flowing in south-west direction .The area has scattered drainage pattern which is a function of the hilly nature of the study area.

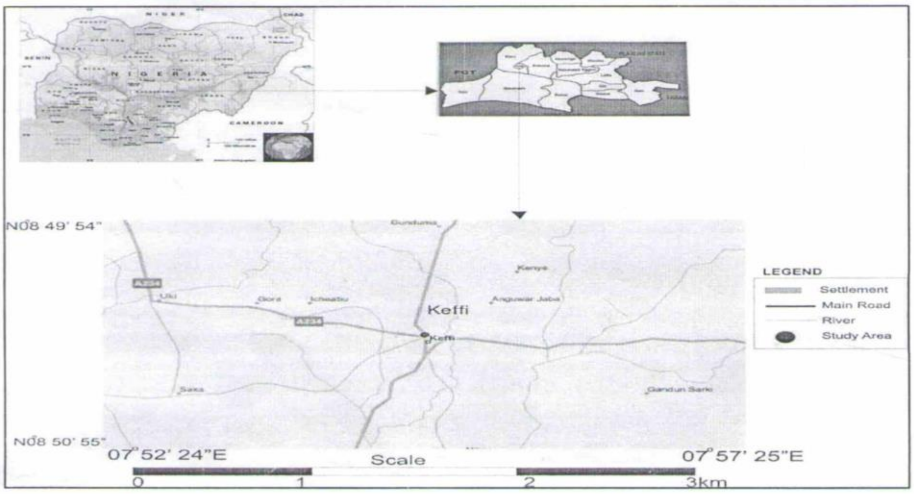

Figure 1. Location and Accessibility Map of the Study Area

Geology of the Study

Keffi is one of the ancient cities in North-Central Nigeria and the town falls within the North-Central Nigeria Basement Complex (Wright, 1970) precisely within the migmatite-genesis complex. The Basement Complex of Nigeria consist of migmatites and magmatic genesis, slightly migmatized to unmigmatized paraschits with interbeds of meta and non-metalgenous rocks, also referred to as the younger metasediments or the schist belts and the older granite suite comprising mainly different varieties of granite rocks/granitoids, including charnockites (hypersthene granites), syenites, as well as minor gabbroic and dioritic rocks. Unmetamorpho seddolenite and rhyolite porphyry dykes, pegmatite dykes and numerous veins of quartzofieldspathic materials are intrusions commonly found in the basement complex.

The Basement Complex of Nigeria also consists of predominantly Archaean polycyclic gray gneicses of granodioritic to tonalitic in composition, reminants of unconformable Proterozoic cover now represented by variably migmatizedmeta sediments which are preserved in synclinorial schist belts; and many syntectonic to late tectonic intrusions (Offodile, 2002; Ajibade *et al.,* 1987). The Proterozoic sediments have been classified into the older metasediments of early Proterozoic age and the younger metasediments of the pan African age (Dada, 1989).

Reactivated Archaean basement often referred to as the migmatite-gneiss complex, occupies nearly half of the surface area of Nigeria. It includes the migmatite-gnesisses of the zinder in-lier in Nigeria-Republic in northeast; those of Obudu and Oban-massif in southeast Nigeria, the migmatite-gneiss complex in neighboring Cameroon Republic. The migmatite-gneiss complex is dominated by quartzo-fieldspathic-biotide-hornblende bearing gneiss, schist and migmatite in which minerals such as garnet, silimanite,kyanite and staurolite suggest high amphibolite facies metamorphism divided the basement complex of Nigeria into the migmatite gneiss complex, the schists belts and the older granites and related rocks (NGSA, 2006a).

In Keffi area, there are not much record of the detailed work carried out on the various units of the Basement Complex. Most part of the study area had been mapped as under lain by only the migmatites and migmatitic gneiss. Occurrences of a schist belt was only shown in parts of the area in the geological map of Nigeria produced by the geological survey of Nigeria in 1994 as well as the most recent geological map of Nigeria (NGSA, 2007; Malomo, 2004).

However, the area is underplayed by four lithological units of schists, gneisses, migmatites and granites, with pegmatites and quartz veins as minor intrusion.

Hydrogeological Setting of the Basement Complex

Basement complex rocks are poor aquifers as they are characterized by low porosity and negligible permeability, resulting from their crystalline nature. Appreciable porosity and permeability may be developed through weathering and fracturing depending on the lithology and texture of the parent rock. The availability of groundwater would depend on the presence and extent of the weathered overburden regolith and the presence of faults and fractures in the underlying bedrock (Olayinka *et al.*, 1999).

The Regolith includes both the residual soil and the saprolite. The latter is derived from in-situ weathering and has become largely disaggregated. The residual soil usually developed from the underlying saprolite unit by further dissolution and leaching combined with other chemical, physical and biological processes (NGSA, 2006b; Olurunfemi & Fasuyi, 1993). Over very long periods, infiltrating carbonic acid-charged rainfall will react with alkaline mineral, leaching and the more soluble and mobile components and precipitating less mobile minerals with the formation of kaolinite and Fe-Al oxides. Such apparently leached portion of the weathered unit, (hard part) or stone lines, are almost always in the vadose zone and thus of significance in the relation to its recharge.

Dissolution of minerals and leaching tends to increase porosity, permeability and specific yield, but the decomposition of secondary clay minerals tend to reverse this process (Tijani, 1994). Schistose metamorphic rocks, and also zones of tectonic disturbances, are likely to promote deeper weathering and thicker regolith, although the presence of abundant Fe-Mg minerals (such as biotite), which readily weathered to produce secondary products, is likely to further reduce permeability. Most hand-dug wells tap their water from the weathered regolith. The bedrock included both the fractured bedrock. The bedrock in the basement complex is highly fractured nature of this zone the groundwater yield is high compared to the weathered overburden (saprolite). The water is held within the fractures.

Materials and Methods

The study involved both field and laboratory activity. The field activity involved the collection of water samples from randomly selected boreholes and in-situ measurement of physical parameters while the laboratory work involved chemical analyses of ions concentrations. Groundwater samples were collected from six(6) randomly shallow boreholes depth less than 40m. These boreholes are the primary source of domestic water supply in the study area.

The water samples were collected directly from the boreholes as it was been pumped from the source (aquifer) into a cleaned labeled 120ml plastic bottles which were earlier rinsed with the particular water to be sampled. The samples were then stored in an iced packed cooler for analysis before taking them to the laboratory. In-situ tests of physical parameters were carried out at every sampled site using ITANA model HI 83200 multi-parameter ion specific meter. These measurements include temperature, pH and total dissolved solids (TDS) while the CO_2 of the groundwater were calculated. The electrical conductivity was measured using a mark electronic switch gear conductivity meter (APHA 1998)

Chloride (Cl^-) analysis was carried out using titration and volumetric methods. Other parameters such as temperature, TDS, pH were analyzed using ITANA model HI 83200 multi-parameter ion specific meter in the Central Research Laboratory, Department of Chemistry, Nasarawa State University, Keffi.

Results and Discussions

The data obtained from field measurement and laboratory analyses were subjected to statistical treatments using SPSS 22.0 and subsequently compared with the recommended standards. Then ultimate conclusion was drawn in the quality of the ground water from the study area. The analytical result for ground water samples from study area are presented in Table 1.

Table 1: Descriptive Statistics of Analyzed Groundwater` Samples Compared with WHO Standards.

Parameters	Number of Samples	Min.	Max.	Mn.	SD.	WHO (2011)
Temp (^oC)	6	25.7	26.0	25.85	0.11	27
Ph	6	7.0	7.8	7.45	0.24	6.5-8.5
TDS (mg/l)	6	97.5	950	429.38	264.71	1200
EC (µS/cm)	6	162.8	1581	714.63	692.13	1250
Cl^- (mg/l)	6	11	60	207.58	19.86	250
CO_2 (mg/l)	6	35.2	176	88	47.66	-

All units except Temperature (^oC), pH, and Electrical Conductivity (µS/cm) are in mg/l,SD = Standard Deviation, Min = Minimum, Max = Maximum, Mn =Mean

The temperature of the water is an important parameter which determines a greater extent, change in water quality. Temperature is noted for its effect on the rate of chemical and biochemical processes significance in water. The major temperature in the water samples analyzed in this study ranges from 25.7^{o}C to 26.0^{o}C with an average of 25.85^{o}C.

The pH of the water samples in the study area ranged from 7.0 to 7.8 with an average of 7.45 which indicate that the groundwater is slightly acidic to neutral water types.

These limit are within the permissible limits of 6.5 - 9.5 set by WHO, (2011) however, many locations such as Abdu Zanga Primary School, AgwanWaje, G.R.A, Karofi, Keffi South and Kofar Hausa have pH below the recommended values with AngwanWaje having the highest value of 7.8mg/l. The entire samples meet WHO and NAFDAC guideline. All the water samples have pH values below 8.

The pH values of the mobile elements remain in solution in normal groundwater until they have been disturbed by groundwater movement. Acidity in groundwater in these areas could be attributed partly to see page and atmospheric precipitation of carbonic acid, which infiltrates into the groundwater system to reduce the pH of the groundwater and increase acidity.

This is the residual left when a certain amount of water is vaporized by the sum of the ionic concentration of the major constituents which are usually Cl^- and other anions.
Total Dissolved Solid (TDS) ranged in value from 97.5 to 950mg/l with an average value of 429.38mg/l. This is far below the stipulated value of 1200mg/l for drinking water hence the water is not harmful in view of this parameter, this agrees with (Afolabi & Olutomilola, 2017)

Conductivity varied between 162.8µS/cm to 1581µS/m, the lowest value 162.8µS/cm was at sample no. v and highest 1581µS/cm at sample no. iv with an average of 714.63µS/cm.
Chloride occurs mostly in the form of Sodium chloride, it is generally soluble and essential to animals and man. However, in higher concentrations it inhibits plant growth and can be harmful to man. Chlorine shows lower water rock ratio than main rock forming element indicating that rock such as trachy – andesite and anhydride is obviously not the source of chlorine and sulphide but can be found in water through human treatment for good drinking water. The major source of chloride in water include; fertilizer and air, it has little absorption in clay and highest occurrence in sea water. The major source of chloride in the study area could be from granite, fertilizer and air. From the result obtained it showed that chloride concentration ranges from 11 – 60mg/l with an average of 27.58mg/l. This range falls below the WHO permissible standard for drinking water and therefore poses no problem for the groundwater quality.
Groundwater carbon dioxide (CO_2) in the sampled water from the study area varied from 35.2 – 176mg/l with an average of 88mg/l.

The concentrations of major parameters in the water samples are below the WHO (2011) permissible limit for drinking water at most location reveals a satisfactory in water quality in these areas (Egboka *et al*., 1989,).

Conclusion

The results of the analyzed groundwater samples were presented in table 1 above. The result revealed the concentrations of physical and chemical parameters including; temperature (^oC), pH, TDS (mg/l), EC (µS/cm), Cl^- (mg/l) and CO_2 (mg/l). The average concentration values of each parameter on the groundwater samples were found to be; 2.85, 7.45, 429.38, 714.63, 207.58 and 88 respectively. This work assessed the physical and chemical parameters of groundwater in some selected bore-holes within Keffi town North-Central Nigeria. The analysis revealed that the groundwater within Keffi town is slightly acidic and neutral in nature. The slightly high average electrical conductivity (714.28µS/cm) of the water samples implies that some of the groundwater samples are saline rather than fresh in nature based on the health (1987) classification. Majority of physical and chemical constituents are well within the official WHO (2011) safe limits.

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