Assessment of Groundwater Quality in Chikun Local Government Area of Kaduna State, Nigeria

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Abstract

This study examined groundwater quality in Chikun Local Government Area of Kaduna State and how it can be harnessed as a useful resource for water supply in order to improve on the management of water resources. This was achieved through the determination of the quality of groundwater in the area. The study randomly collected fifty (50) water samples from wells and bore holes in the peak of rainy and dry seasons for two years (2019 – 2020) in the five selected wards within Chikun Local Government Area and a range of water quality parameters were measured and compared with WHO standards for drinking water. The laboratory analysis results revealed that the level of magnesium (0.581mg/l), mercury (0.0143mg/l), iron (0.82mg/l), lead (0.69mg/l), calcium (2.03mg/l) and total dissolved solid (105mg/l) in the water sample were quite high and have exceeded the maximum permissible limits of 0.5mg/l for magnesium, 0.001mg/l for mercury, 0.3mg/l for iron, 0.01mg/l for lead, 2.0mg/l for calcium and 100mg/l for total dissolved solid by the National Standard Water Quality (NSWQ) and World Health Organization (WHO). With the exception of magnesium, mercury, iron, lead and calcium, all other physico-chemical parameters measured fall within or below the maximum permissible limit.

Keywords: Water quality, Groundwater samples, Hydrochemical investigation, Hydrogeology, Anthropogenic activities.

Introduction

Water is a unique resource, having no substitute and of fixed amount, though its quantity and quality vary over space and time. There has been continuous increase in population, particularly in the developing world, and consequently the demand for water for various uses (for example, domestic, industrial or manufacturing, agriculture, transport, power generation, sport, recreation and tourism). This increase in demand has led to water shortage in many parts of the world and water shortage has remained an endemic problem anytime anywhere. Apart from domestic need of water, other human activities such as fishing and farming are dependent on water (Lapworth, *et al.,* 2016).

In recent times, groundwater has become one of the most important natural resources in many countries of the world. In its natural state, it is generally of excellent quality and an essential natural resource since water is naturally purified when it is slowly percolating through soil. Compared to surface water, groundwater has a number of essential advantages: higher quality, well protected from surface contaminants, less susceptible to drought, and much more evenly spread over large regions than surface water. These advantages have resulted in wide use of groundwater for water supply. In some countries in the world such as Denmark, Malta, Saudi Arabia, groundwater is the only source of water supply while in other countries, it is the most important part of total water resources. For example, groundwater in Tunisia is 95% of the country's total water resources, 83% in Belgium, 75% in the Netherlands, Germany and Morocco (Dhaka and Bhaskar, 2017).

Nigeria's groundwater resources have been under increasing threat of declining water levels and pollution in recent years due to rapid demographic changes, which have coincided with the establishment of human settlements lacking appropriate water supply and sanitation infrastructure. This applies especially to peri-urban areas like Chikun Local Government Area, the study area, which surrounds the larger metropolitan towns in the country (Abduljalal, *et al.,* 2017). Chikun Local Government Area has developed with no proper water supply network, in spite of the efforts of Kaduna State government in providing portable water for the residents. The problem now is that with the increase in demand for water for various uses in the area, it is impossible to meet the whole demand from a single source; besides, relying heavily on one single source of water supply in the face of existing unfavorable and fickle climatic conditions is very precarious. In addition, groundwater level in several parts of Chikun Local Government Area has been falling rapidly and the quality deteriorating due to increase in abstraction and the number of wells and boreholes drilled for domestic water use has rapidly and indiscriminately increased due to rising population and changing lifestyles (Samari, *et al.,* 2015).

A World Bank sponsored study of the pollution case of surface and groundwater in Chikun Local Government Area with emphasis on Mararaban Rido, Kakau, Nassarawa and Sabon Tasha wards as well as river Kaduna in 1988 was the first empirical evidence which reported that groundwater in the Chikun Local Government Area is being polluted (World Bank, 1995). The result indicated that out of the sampling sites studied, the point at which River Romi entered into the Kaduna River is the one having the highest pollution load, which was attributed to the effluents being discharged from the refinery through the Romi River and River Romi is known to be recharging groundwater of most parts of Chikun local government area. Since then, there had been limited academic research on the pollution of groundwater in Chikun Local Government Area. A climax of these academic researches was a study by Samari, *et al.,* (2015) that focused on water quality from hand dug wells in Bayan Dutse, Narayi in Chikun local government with emphasis on the physico-chemical paramaters of the samples taken. The study found that due to the location, water in hand dug wells are polluted by runoff from sewage system.

From available literature on groundwater prospecting in the study area, there is no study on the use of Water Quality Index technique to assess groundwater quality in Chikun Local Government Area of

Kaduna State. Using Water Quality Index technique to assess groundwater condition in Chikun Local Government Area would assist in reducing water shortage from unsafe sources and from health problems leading to death.

Therefore, assessment of groundwater quality is necessary to protect groundwater sources in the Chikun Local Government Area since the resource is being threatened by contamination.

Materials and Methods

The study Area

Chikun Local Government area lies between Latitude 10° N and 10° 50" North of the equator and Longitude 6° 4" E and 7° 5" East of the Greenwich Meridian. It is located on the Southern part of Kaduna State and share common boundaries with Kaduna North Local Government and Igabi in the North. In the Southwestern part, it shares border with Niger State and in the East and with Kajuru and Kachia Local Government Area (Figure 1). At present Chikun Local Government Area has Kujama as its administrative headquarter, Gonin Gora, Narayi, Nassarawa, Trikania, Sabon Tasha, Ungwar Romi, Ungwar Sunday, Ungwar Yelwa, Karatudu and part of Barnawa as it's component area covering a total land size of 4801 square kilometers (Danjuma, 2015).

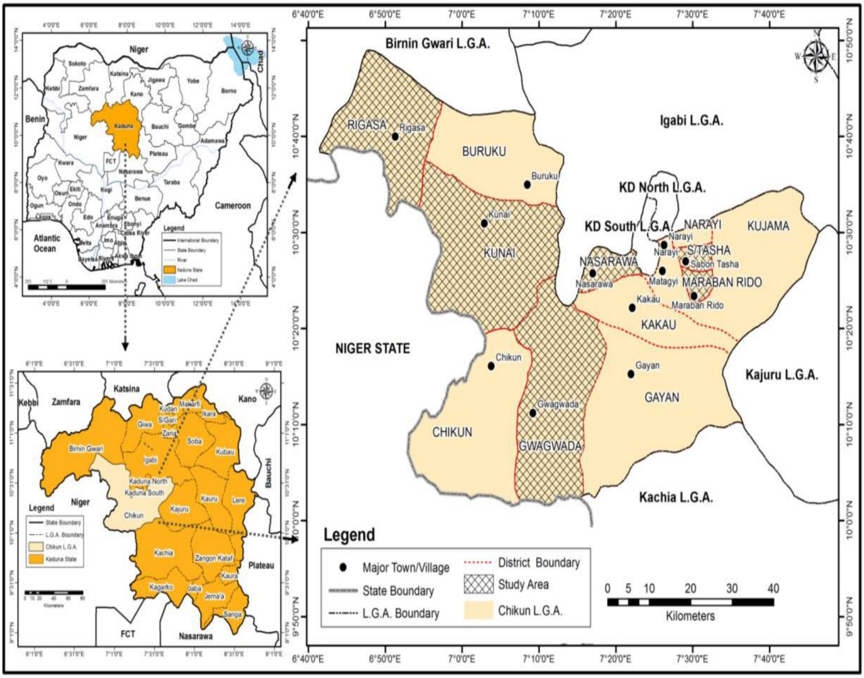

Figure 1: Chikun Local Government showing the study area.

Source: GIS Lab. Department of Environmental Management, Kaduna State University, (2019).

The assessment of groundwater quality for Chikun Local Government Area of Kaduna State was designed and carried out in stages as follows: pre-field preparation which included preparation of maps for the study area; pre-field survey of the area; sampling technique adopted for water sample collection from hand-dug wells and borehole across the study area (Chikun Local Government Area of Kaduna State) and data collation and analysis. Two main types of groundwater abstracting structures were identified in Chikun Local Government Area. They are boreholes and hand-dug wells. Samples from groundwater sources from the five (5) wards selected were collected for the years 2019 and 2020 during both the peak of dry and rainy seasons of 2019 and 2020. Groundwater samples collection was done between 7 am to 1 pm during the study period, about two litres volume of water sample from each source (wells and boreholes), was collected in separate two litres plastic cans and transported to the laboratory for analysis and stored in order to keep the composition of water samples unchanged. The analysis of parameters on the priority basis had been taken up, Sixteen (16) water quality parameters were considered in the analysis of water quality index representing four hazard classes (salinity, permeability/infiltration, specific ion toxicity hazard and miscellaneous hazard). The choice of a well and borehole depended on its distance from a previously chosen one in the locality, the consent of the owner to make the well or borehole available for study. Water samples from different locations within the study area were collected as per the guidelines of random sampling technique and new two litres acid washed plastic-cans were used.

Boreholes fitted with motors for water lifting were allowed to run the water for 5 minutes and other fitted with hand pump were allowed to run for 15 minutes in order to flush out stationary water. All sample containers were flushed with several volumes of water before the samples were collected. As water is dynamic in nature and during sampling it enters the new environment from its natural environment, its chemical composition may not remain same but may tend to adjust itself according to its new environment and its content alters at very different rates particularly with organic materials. Before sampling from taps/hand pumps, exit was opened and closed several times to get rid of dirt particles, the tips of the tap/hand pump were cleaned sufficiently long time to ensure sterilization, the water is then allowed to run free in a pencil thick stream for approximate 5 minutes before filling the bottle. The sample bottle is closed under sterile conditions and labelled. Immediately on arrival, samples were refrigerated at approximately 4°C. Then, the chemical characteristics including metals were determined as per the standard methods for examination of water and wastewater (American Public Health Association [APHA] 2012). A total of fifty (50) samples were collected, that is, ten samples (five samples from wells and the other five samples from boreholes) in each of the five settlements per season per year for laboratory analysis.

Results and Discussions

The results of the hydro-chemical analyses are presented in Table 1, highlighting the results of laboratory analysis of water samples, statistical analysis as well as comparing the concentration of the physico-chemical parameters of groundwater with that of World Health Organization (W.H.O) standards for portable water are discussed.

Table 1: Mean Values of Concentration Physico-chemical Parameters in Groundwater of Chikun Local Government Area (2019-2020)

Parameter	Unit	WHO (MPL)	Ward	Mean Values	
				Well	Borehole
pH		6.6-8.5	Gwagwada	7.073	6.825
			Kunai	6.9485	6.426
			Mararaban Rido	6.829	6.852
			Nassarawa	6.476	6.564
			Sabon Tasha	6.8255	6.43
Turbidity	NTU	50mg/l	Gwagwada	48.35	34.99
			Kunai	46.5	16.8
			Mararaban Rido	49.35	22.65
			Nassarawa	41.7	15.63
			Sabon Tasha	48.1	48.48
Electrical Conductivity (EC)	µs/cm	15000 (µs/cm)			
			Gwagwada	639.165	690.348
			Kunai	554.693	596.967
			Mararaban Rido	570.144	688.179
			Nassarawa	664.402	572.345
			Sabon Tasha	694.801	697.549
Total Dissolved Solids (TDS)	mg/l	100 mg/l			
			Gwagwada	85	34.99
			Kunai	90	16.8
			Mararaban Rido	90	22.65
			Nassarawa	105	15.63
			Sabon Tasha	48.1	48.48
Calcium	mg/l	2.0 mg/l			
			Gwagwada	2.03	1.899
			Kunai	0.404	1.83
			Mararaban Rido	1.937	1.972

			Nassarawa	1.532	2.212
			Sabon Tasha	1.933	1.899
Magnesium	mg/l	0.5 mg/l			
			Gwagwada	0.581	0.515
			Kunai	0.299	0.698
			Mararaban Rido	0.524	0.526
			Nassarawa	0.486	0.563
			Sabon Tasha	0.571	0.534
Sulphate	mg/l	100 mg/l			
			Gwagwada	45.665	37.85
			Kunai	16.415	23.39
			Mararaban Rido	28.215	43.5
			Nassarawa	28.435	33.92
			Sabon Tasha	35.955	34.98
Iron	mg/l	0.3 mg/l			
			Gwagwada	0.517	0.596
			Kunai	0.225	0.31
			Mararaban Rido	0.437	0.589
			Nassarawa	0.827	0.675
			Sabon Tasha	1.149	0.828
Lead	mg/l	0.01 mg/l			
			Gwagwada	0.009	0.083
			Kunai	0.007	0.009
			Mararaban Rido	0.056	0.092
			Nassarawa	0.056	0.098
			Sabon Tasha	0.069	0.107
Mercury	mg/l	0.001 mg/l			
			Gwagwada	0.0143	0.00138
			Kunai	0.000855	0.0234
			Mararaban Rido	0.00139	0.0016
			Nassarawa	0.002	0.00127
			Sabon Tasha	0.00185	0.00128

Source: Field Survey and Laboratory Analysis (2019 and 2020)

pH

The pH value of water samples in the study area indicated a minimum mean value of 6.4 in the sample collected at Nassarawa and a maximum mean value of 7.07 in the sample collected at Gwagwada for wells and with a maximum mean value of 6.85 in the samples collected at Mararaban Rido. A minimum value of

6.43was observed in samples from Sabon Tasha for boreholes as presented in Table 1.

The varying pH values in the groundwater system may be attributed to the variation of photosynthetic activity, disposal of untreated wastewaters, agricultural and anthropogenic activities (Rilwanu, 2017).

The standard values of pH for drinking water as per WHO is between 6.5 and 8.5 and 95.63% of the samples analyzed from the entire study area during both rainy and dry seasons, have pH values within the permissible limits of World Health Organization (WHO) and could be classified as suitable for drinking purpose**.** However, pH alone cannot be taken as a criterion for determining portability of water.

Turbidity

The Turbidity values (NTU) for the groundwater samples is presented in Table 1. The values obtained for wells indicated a minimum mean value of 46.5 and a maximum mean value of 49.35 NTU and that of boreholes indicated a minimum mean value of 15.63 and a maximum mean value of 48.48 NTU in the samples collected for both rainy and dry seasons in the study area respectively. Further, it was observed that the turbidity values of groundwater samples during the rainy season showed an increasing trend when compared to dry season. However, all the samples have turbidity values within the permissible limits of World Health Organization (WHO) (maximum 50 NTU).

Electrical Conductivity (EC)

The values of electrical conductivity (□s/cm) are presented in Table 1. The observed values of electrical conductivity in area during the study period, with a maximum mean of 694.80 µs/cm and a minimum mean of 554.69 µs/cm in groundwater samples collected from wells and with a maximum mean of 697.54 µs/cm and a minimum mean of 572.34 μs/cm in groundwater samples collected from borehole for both seasons during the study period in the area. The electrical conductivity values showed an increasing trend in boreholes compared to wells due to the dissolution of salts, minerals and other soil constituents increase with the groundwater table. Most of the inorganic salts such as NaCl, are responsible for the increasing the electrical conductivity values of groundwater systems. The results obtained revealed that of groundwater in the entire study area belongs to permissible category. This result compares favourably with that of Vivan, *et al.*, (2012) who opined that the electrical conductivity is a useful parameter for water quality indicating salinity hazards. In general waters with conductivity values below 750 (□s/cm) are satisfactory; conductivity values ranging between 250 and 750 (□s/cm) are widely used for crop growth. Akpoborie (2011) observed that a sudden rise in conductivity in the water indicated addition of some pollutants to it, and that the area having higher electrical conductivity also has high pH. Groundwater has normally a large amount of dissolved inorganic matter and therefore high values are not unexpected.

Total Dissolved Solids (TDS)

The Total Dissolved Solids values for the groundwater samples are given in Table 1.

The Table showed that Total Dissolved Solids value varies from a minimum mean value of 48 mg/l in the groundwater samples collected at Sabo Tasha ward to a maximum mean value of 105 mg/l in samples collected at Nassarawa ward for wells had a maximum mean of 48 mg/l and for samples collected at Sabo Tasha, while a minimum value of 15 mg/l was obtained in samples collected at Nassarwa ward for boreholes. Furthermore, Total Dissolved Solids values showed an increasing trend in concentration during rainy season compared to dry season. This may be due to the dissolution of more quantity of constituents of soil particles as groundwater table increases during rainy season.

Calcium

The values of calcium obtained for the five (5) settlements from wells and boreholes in the study area with minimum and maximum mean values are presented in Table 1.

Table 8 revealed that the calcium concentration varies from a minimum mean of 0.40 mg/l in the groundwater samples collected at Kunai to a maximum mean of 2.03 mg/l in samples collected at Gwagwada for wells, while the concentration varies from a minimum mean of 0.001 mg/l in the groundwater samples collected at Sabon Tasha, to a maximum statistical mean of 1.97 mg/l in samples collected at Mararaban Rido for boreholes. Most of the samples showed an increasing trend in calcium concentration in boreholes compared to wells. Tse and Adamu (2012) have expressed opinion that the high concentrations of calcium have no health hazard. Yusuf (2015) attested to this as he reported that calcium is an essential macro element owing to its functions in bone structure, muscle contraction, blood clotting, etc. Excess of calcium has a teratogenic action in chicks and depresses the functioning of muscles and nerve tissues. However, it should be noted that in human beings, Hyper-calcimea causes coma and death if serum calcium rises to 160 mg/l. Besides, it is important to note that calcium showed strong significant correlation with total hardness and total dissolved solid.

Magnesium

The values of magnesium obtained for the five (5) selected wards from wells and boreholes in the study area with minimum and maximum mean values are presented in Table 1. The magnesium concentration varies from a minimum mean of 0.05 mg/l in the groundwater samples collected in Kunai ward; to a maximum mean of 0.58 mg/l in samples collected in Gwagwada ward. It was observed that most of the samples showed an increasing trend in magnesium concentration in boreholes compared to wells.

Magnesium is also an essential macro nutrient for human beings. It forms part of structure of the body. It plays a critical role in cell metabolism. Magnesium toxicity in higher doses greater than 400 mg/l causes nausea, muscular weakness and paralysis in humans and mammals (Vivan, *et al.*, 2012). New-born infants develop hyper magnesemia if mother is treated with $MgSO4$ drugs. The results of magnesium analysis have revealed that most of the samples have exceeded the permissible limits of 0.5 mg/l.

Sulphate

The concentration of sulphate in groundwater in the study area is presented in Table 1. The sulphate concentration varied from a minimum mean of 16.4 mg/l in the groundwater samples collected at Kunai ward, to a maximum mean of 45.66 mg/l in the samples collected at Nasarawa ward for wells and with a minimum statistical mean of 37.85 mg/l in Gwagwada ward for boreholes. It was noticed that the sulphate values showed an increasing trend in concentration in boreholes compared to wells. This may be attributed to the dissolution of more quantity sulphate minerals at increased depth due to rise in the groundwater table by recharge process. Considerable quantity of sulphate has also been added to the hydrologic cycle from precipitation (rainfall). The agricultural run-off and irrigation drainage carry these sulphate minerals in soil and due to variation in the temperature conditions, the breakdown of organic substances in soil, leachable sulphates present in fertilizers and other human interferences are the expected causes for the high concentration of sulphates (Asiwaju-Bello and Ololade, 2013). Generally, the concentration of sulphate in all the groundwater samples (boreholes and wells) collected fall within the permissible limits of 100 mg/l of WHO.

Iron

The dissolved iron content in the groundwater of the study area showed from a minimum mean of 0.22 to a maximum mean of 1.14 mg/l for wells during the study period and iron concentration ranged from a minimum mean of 0.22 to a maximum mean of 0.82 mg/l for boreholes in the same study area as presented in Table 1.

The maximum permissible limit for iron is 1.0mg/l, beyond this limit, taste and appearance are affected and has adverse effects on domestic uses such as staining of clothes and utensils. If the concentration of iron exceeds 0.3 mg/l, it affects water supply structures as well as promotes iron bacteria. It was observed that the concentration of iron in the samples are above permissible limits.

Lead

Lead concentration in groundwater in the study area is presented in Table 1. The concentration of lead ranged from a minimum mean of 0.0024 mg/l to a maximum mean of 0.05 mg/l for wells and a minimum mean value of 0.97 mg/l and a maximum mean value of 1.91 mg/l for boreholes. Thus, the concentration of lead observed is well above the safe limit for most of the groundwater samples in the study area. As the maximum permissible limit is 0.01mg/l of World Health Organization.

Mercury

The concentration of mercury ranges from a minimum mean of 0.008 mg/l to a maximum mean of 0.0143 mg/l for wells and a minimum mean value of 0.00127, a maximum mean value of 0.0234 for boreholes as presented in Table 1. The concentration of mercury observed is well above the safe limit for most of the groundwater samples in the study area. The results compare favourably with a study by Kalip, et al., (2020) titled "Assessment of Radon and Heavy Metals in Groundwater Sources from Kaduna and Environs, Nigeria" the results obtained in this study indicate that the concentration ranged between 1.07 and 1.67 mg/l, and 1.11 and 1.77 mg/l for borehole and hand dug well water samples, respectively. Mean concentrations were 1.16 mg/l for boreholes and 1.76 mg/l for wells. While the average values are within the maximum permissible limits set by USEPA, but were far greater than the 0.001mg/l WHO average. However, several incident values from wells and boreholes exceeded the USEPA maximum permissible limits, while the annual effective doses of all samples were within the recommended limits.

Table 2: WQI of Wells in Chikun Local Government Area

Parameters	Test Results (Vn)	Standard Permissible Value (Si)	Units	Relative Weight (Wi)	Quality Rating (Qi)	Weighted Value {(Wi) *(Qi)}
Ph	6.8	6.5-8.5		0.04000	88.4	3.54
Turbidity	46.78	50		0.11764	6.66	0.784
Total Hardness	27.32		NTU	0.03333	326.6	10.88
TDS	93		Mg/l	0.00200	24	0.048
Electrical Conductivity	624.7	15000	µs/cm	0.13333	94.36	12.58
CO_2	30.52	50		1.00000	2.8	2.8
Nitrite	Nill	0.2	Mg/l	0.10000	42.1	4.21
Sulphate	30.9	100	Mg/l	1.00000	6	6
Copper	0.912	1.0	Mg/l	0.00000	0	0
Iron	0.626	0.3	Mg/l	0.02500	135	3.375
Cadium	0.502	0.01	Mg/l	0.20000	70.2	14.04
Calcium	1.15	2.0	Mg/l	10.0000	121	1200
Mercury	0.004	2.0	Mg/l	0.00500	4.75	0.0237
Lead	0.039	0.001	Mg/l	1.00000	212	212
Magnesium	0.437	0.01	Mg/l	0.20000	28.6	5.72
Coliform Bacteria	0.00	1.0	Mpn/ml	0.00000	0	0
				= ***13.8563***		***1476.001***

$$WQI = \frac{1476.001}{13.8563} = 106.521$$

Table 3: WQI of Boreholes in Chikun Local Government Area

Parameters	Test Results (Vn)	Standard Permissible Value (Si)	Units	Relative Weight (Wi)	Quality Rating (Qi)	Weighted Value {(Wi) *(Qi)}
Ph	6.65	6.5-8.5		0.04000	88.4	3.54
Turbidity	23.4	50		0.11764	6.6	0.78
Total Hardness	60		NTU	0.03333	50.0	1.6
TDS	80		Mg/l	0.00200	6.0	0.012
Electrical Conductivity	699.8	15000	µs/cm	0.13333	44.79	5.971
CO_2	33.0	50		1.00000	97	97
Nitrite	Nill	0.2	Mg/l	0.10000	30.1	3.01
Sulphate	44.9	100	Mg/l	1.00000	5	5.0

Copper	1.70	1.0	Mg/l	0.00000	0	0
Iron	0.71	0.3	Mg/l	0.02500	55	1.375
Cadium	0.1	0.01	Mg/l	0.20000	76	15.2
Calcium	0.11	2.0	Mg/l	10.0000	98	980.0
Mercury	2.13	2.0	Mg/l	0.00500	0.415	0.021
Lead	0.1	0.001	Mg/l	1.00000	70	70.0
Magnesium	0.5	0.01	Mg/l	0.20000	2.6	0.52
Coliform Bacteria	0.0	1.0	Mpn/ml	0.00000	0	0
				= ***13.8563***		***1184.029***

WQI = $= \frac{1184.029}{13.8563} =$ ***85.450***

Table 4: Water Quality Classification Based on Arithmetic WQI Method

WQI	Value Water Quality
0-50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

Source: Brown *et al.*, 1972

The physico-chemical analysis carried out for the groundwater in Chikun Local Government Area, Kaduna State revealed that the quality of most water samples investigated were poor. Thus, 45% of the overall samples (from the entire study area) are non-portable, on comparing the laboratory results obtained with that of standards prescribed by World Health Organization (WHO) for drinking water. Amongst the parameters responsible for non-portability, it is seen that heavy metals, total hardness and total dissolved solids are the three (3) parameters that stood out.

Similarly, the Water Quality Index (WQI) analysis carried out for the groundwater of Chikun Local Government Area revealed that most samples exhibited poor water quality as such considered unfit for drinking, the results from Water Quality Index in Tables 2, 3 and 4 rates samples from boreholes as poor with a score of 106.521 and samples from wells were rated good with a score of 85.450. The findings here is line with a study by

Abduljalal, et al (2017) that analyzed water quality of selected wells in Gonin-Gora area of Kaduna metropolis, the study randomly collected samples from nine (9) different wells and concentration levels of ten (10) physico-chemical parameters were determined to ascertain how fit groundwater in the area is for human consumption. Laboratory analysis of samples and inferential statistics was used to determine the difference between the laboratory values of the samples and World Health Organization standards for drinking water. The results revealed that there was significant difference between the levels of concentration of the selected parameters of samples and World Health Organization standards for drinking water. The study recommended that water from open hand dug wells in the area should be treated before human consumption.

Conclusion

In Chikun Local Government Area of Kaduna State, Nigeria, the interaction between hydrological configurations and anthropogenic activities pollutes surface water. Therefore, groundwater becomes the vivacious and reliable source of fresh water for domestic, agricultural and industrial uses. This study aimed to evaluate the quality of groundwater and its associated susceptibility and risk in Chikun Local Government Area, Kaduna State, Nigeria. The groundwater quality assessment revealed the influence of varied contaminant sources close to wells and boreholes, which serve as critical resource for the livelihoods of the inhabitants of Chikun Local Government Area of Kaduna State.

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