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Evaluation of Temporal Changes in Deep Well Water Quality in Igabi Local Government Area of Kaduna State

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Abstract

The research work was carried out in Igabi Local Government of Kaduna State. Thirty water samples from boreholes were randomly collected within the major towns in November to April (Dry), and May to October (Rainy season). The samples were analyzed for physical, chemical, and bacteriological parameters and to observe any changes in the groundwater quality of the area. Analysis of variance (ANOVA), Pearson Correlation were performed on the data obtained using SPSS 10.0 for a window for significant variations and inter-element relationship. High mean turbidity was recorded in boreholes in Danfili (12.2 NTU), Kwarau (6.2 NTU). Mean turbidity of 4.3 NTU was recorded in Dry season for wells with Rigachikun having 5.1 NTU. It was observed that a negative correlation exists between well depth and heavy metal concentration. There was also a linear relationship of 0.686 between well distance and nitrate (faecal contaminant). Mean value for Fluoride (0.22 mg/l), Sodium (20.78 mg/l), Calcium (15.7 mg/l), Iron (0.013 mg/l), Nitrate (3.69 mg/l), Cadmium (0.00102 mg/l) Chloride (22.107 mg/l) recorded for sampled wells were all within WHO standard. A high value of 24 mg/l and 25 mg/l for Nitrate was recorded in Saminaka Road and Danfili. An indication of contamination during the rainy season indicates surface-groundwater intrusion (influx). The results of the bacteriological analysis indicated that most wells sampled have a range of 1 cfu/100 ml to 7 cfu/100 ml with Danfili Mani having the highest value (7 cfu/100 ml) which make it unsaved (not Potable).

Keywords

Temporal Change, Analysis, Groundwater, Physiochemical, Bacteriological,

Quality

1. Introduction

Nigeria with a total landmass of 923,763 km^2 is drained by two major rivers of rivers Niger and Benue with several tributaries running into them. Nigeria is the home to thirty-six states with seven hundred and seventy-seven local government areas, of which Igabi local government area is one. Kaduna state has a total landmass of 46,053 km^2 and is located on longitude 10˚20 0ʹN and latitude 7˚45 0ʹE. According to NPC [1], the state is located in the North-Western part of Nigeria with its capital in Kaduna town. The bedrock geology is predominantly metamorphic rocks of Nigerian basement complex consisting of Biotite Gneisses and older Granites. Kaduna State experiences a typical tropical continental climate of wet and dry type of season. The population of the residents in the state is to 6,113,503 as at 2006 National population count. The headcount of the study area as of 2006 provided by NPC was 430,753, making it the fourth-largest local government area in the state. Igabi local government area is boarded to the South by Kaduna South and Kaduna North Local government areas. The Local government area is boarded to North by Birnin Gwari and Zaria local government areas. The complex nature political and socio-economic activities within the area have placed an unprecedented population increase, which has taken its toll on the various social amenities, such as water quality, roads, and health facilities. Urbanization and population growth without commensurate facilities can seriously degrade groundwater quality, particularly shallow aquifers. Shortages of water supply and declining quality are associated with over-extraction of the groundwater resources.

Water, by several researchers, is said to be life [2] [3] [4] [5] and an invaluable resource and the benefits to humankind. The idea of water quality has raised a number of questions, which are often controversial because of wide differences in technological and individual perceptions. The economic and aesthetic considerations describing water quality also become a major concern. Technologically, water quality can be termed to be the appropriate physical, chemical and bacteriological parameters, which must be within the recommended standards for its consumption. Numerous authors prefer to describe water quality in terms of the processes occurring in the various catchment or ecosystem. Li *et al.* [6] stated that groundwater quality reflects the interplay between natural hydrogeology and human activities. The prevailing state of increase in population and unequal distribution of social amenities across major cities in most developing countries around the world had posed numerous challenges to the effectiveness and efficiency of infrastructures. The neglect of rural areas in such parts of the world in terms of basic infrastructures such as pipe-borne water and sanitation facilities has exposed the villagers to a variety of health-related problems, such as water-borne diseases. However, the large-scale industrial growth has caused se-

rious concerns regarding the susceptibility of groundwater contamination due to discharge of waste materials.

The unrestricted alertness about water quality is at its peak now but at the same time, the danger signals have not shown any decline. Study of water quality has remained an important pre-occupation with the environmentalist both from the practical and from the academic viewpoints.

The most common sources of drinking water in most rural areas of developing countries include streams, rivers, wells and boreholes, which are mostly untreated and associated with various medical risks [7]. One of the targets of the millennium development goals (MDGs) in terms of healthy living for the masses can be achieved through the supply of safe and convenient water [8].

With Nigeria facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development, there, therefore, the need for the study of the most common sources of water within a developing rural community such as Igabi Local government area of Kaduna State, Nigeria. Most freshwater bodies all over the world are being polluted, thus reducing the potability of water.

The Nationwide Rapid Assessment of Drinking Water Quality (RADWQ) conducted in 2004/05 by the Federal Ministry of Water Resources, Nigeria showed that some groundwater sources were contaminated by a variety of pollutants across the country. The results from the findings also indicated poor water quality, which could hinder the realization of the Millennium Development Goals (MDGs) targeted at having a certain proportion of the people without sustainable access to safe water.

In most rural settlements in Nigeria, (Igabi Local Government inclusive) access to clean and potable water is a great challenge, resulting in water-borne diseases. The outbreak of water-borne diseases (like cholera, dysentery, and typhoid fever) recently in 2013 in some parts of Kaduna state may not be unconnected with the Portability of their sources of drinking water. This study, therefore, is aimed at evaluating the temporal changes in groundwater quality in Igabi Local Government Area of Kaduna State, Nigeria.

2. Materials and Methods

Sample Collection

To understand the true status of the various water bodies consumed, it is important to ensure that the samples are collected at points where populations are dense and water is constantly drawn from the wells. Having satisfied this requirement, the analysis was carried out using AOAC [9] so that results obtained by the physical and chemical analysis can be directly compared with the available standards within the country that is the NSDWQ [10] and WHO [11]. The samples were collected from the various identified deep wells within the community in the morning by 6:30 am and in the evening by 6:30 pm. Water samples were collected separately for each analytical parameter in different plastic

containers of 250 ml and 500 ml for parameters of physicochemical analysis, heavy metals and bacteriological analysis respectively. The containers were labelled for ease of identification according to the works of Musa [3] and Musa and Fumen [5]. The information carried on the sample label includes location, date and time of collection. Standard procedures as stated by [9] were followed to determine various parameters (physical, inorganic and organic) of the samples collected. Thirty samples of borehole waters were collected for the study starting from November to April (Dry season) and from May through to October (Wet Season).

The plastic containers to be used to collect samples were thoroughly washed and rinsed three times with the samples before the actual samples were collected. The samples collected were acidified with nitric acid (HNO) to maintain a steady-state of pH. Plastic containers were used to prevent sample contamination from metallic containers. The samples were generally preserved in an icebox at a temperature of 4˚C to allow the samples to maintain its natural state during the cause of transportation to the laboratory. This follows the standards specified in the works of Musa, *et al.*, [12]. The samples collected at the early hours of the day were separated from those of late hours and where transported to the National Water Resources Institute Laboratory in Kaduna in an iced box at a temperature of about 4˚C prior to the analysis [13] [14]. An average of ten samples was collected and analyzed for each of the boreholes. The groundwater samples were analyzed for physical and chemical parameters according to APHA [13].

Some of the physical parameters analyzed include pH, turbidity (NTU), Total dissolved solid (mg/L), electrical conductivity (μs/cm), temperature (˚C). The chemical parameters includes calcium content (mg/L), fluoride content (mg/L), magnesium content (mg/L), nitrate (mg/L), sodium (mg/L), chloride (mg/L), and biocarbonate (mg/L) while lead (mg/L), Iron (mg/L), manganese (mg/L), zinc (mg/L), cadmium (mg/L) and chromium (mg/L) were considered for the presence of heavy metals.

3. Results and Discussions

The average results collected during the study period for the physical parameter for the various types of boreholes considered are presented in Table 1 while the results for the chemical parameters and the heavy metals are presented in Table 2 and Table 3 respectively. The results for the physical parameters during the wet season shows that pH ranged between 6.69 and 7.92 with an average value of 7.32 which implies that the pH values for the various wells were within the NSDWQ [10] and WHO [11] standards. The results obtained for the dry season is similar to the findings of Munyangane *et al.*, [15] that studied the assessment of some potentially harmful trace elements (PHTEs) in the borehole water of Greater Giyani, Limpopo Province, South Africa: possible implications for human health. The pH values for the dry season were observed to lower than those observed during the wet season, which is, could be linked to reducing rate of

Table 1. Results of physical parameter for boreholes.

Location	Season	pH	Turbidity (NTU)	TDS (mg/l)	Electrical. Conductivity (μs/cm)	Temperature ˚C
1B	Wet	7.31	0.49	35.60	30.40	29.70
	Dry	7.40	0.98	16.60	43.00	31.30
2B	Wet	7.18	3.80	157.00	120.00	30.40
	Dry	7.70	2.90	140.00	134.00	34.80
3B	Wet	7.31	4.02	173.00	267.00	30.20
	Dry	6.56	5.30	278.00	46.00	31.58
4B	Wet	7.34	3.72	40.90	37.90	30.30
	Dry	7.30	2.20	27.00	340.00	32.30
5B	Wet	6.69	2.10	22.50	97.10	30.10
	Dry	7.90	2.70	40.30	75.00	33.40
6B	Wet	7.42	4.70	90.30	123.00	31.00
	Dry	7.10	6.30	83.70	167.00	34.56
7B	Wet	7.64	5.00	65.00	134.00	30.80
	Dry	7.30	4.20	42.00	192.00	35.80
8B	Wet	7.18	4.45	82.20	120.00	31.40
	Dry	7.20	4.09	63.00	132.00	34.60
9B	Wet	7.17	5.10	204.00	21.20	31.20
	Dry	7.18	4.70	123.00	11.60	35.90
10B	Wet	7.92	5.00	165.00	267.00	30.20
	Dry	7.40	4.00	88.00	156.70	35.75

intrusion of dissolved chemicals either from the atmosphere or from the surrounding environment. The dry season pH value ranged between 6.56 and 7.90 with an average of 7.30. The values were observed to be the standards NSDWQ [10] and WHO [11] and also similar to the findings of Talal [16] who studied the assessment of water quality and trace metals in sediment of Southern Marshes. pH values less than 6.5 are considered too acidic for human consumption which can cause different health complications such as acidosis. The acidic nature of most of the samples might be due to high mineral-rich rocks making up the aquifers [17]. pH is also one of the most important operational parameters for water treatment such as disinfection or coagulation-flocculation and pH adjustment is a common practice in water treatment to ensure for it potability.

Turbidity largely has not been seen as an important tool in water quality parameter but is considered as an alternate microbiological parameter because it is closely linked to the microbiological safety of drinking water. The average mean turbidity value for the wet season was determined to be 3.84 NTU while that of the dry season was determined to be 3.74 NTU. This result is in accordance with the study carried out in 2009 in some part of Kaduna State by the National

Table 2. Results of chemical parameters (boreholes).

Location	Season	Calcium	Fluoride	Magnesium	Nitrate	Sodium	Chloride	Bicarbonate
1B	Wet	6.20	0.22	7.06	2.12	9.70	14.49	10.00
	Dry	7.50	0.01	8.00	1.60	3.50	10.20	18.00
2B	Wet	19.00	0.22	31.80	3.52	18.20	28.00	22.00
	Dry	24.00	0.30	42.70	1.05	10.20	10.00	38.00
3B	Wet	45.00	0.12	28.00	4.30	34.00	62.90	12.31
	Dry	49.00	0.10	55.00	1.90	12.90	26.10	38.00
4B	Wet	28.00	0.33	19.90	3.92	15.40	22.80	9.40
	Dry	17.00	0.23	30.00	3.20	11.10	12.50	29.20
5B	Wet	26.00	0.41	15.00	3.70	5.84	18.90	15.00
	Dry	30.00	0.38	26.00	1.40	5.10	8.00	23.00
6B	Wet	5.15	0.44	10.90	1.90	28.00	12.00	9.50
	Dry	7.00	0.25	14.00	0.10	13.00	7.40	18.20
7B	Wet	10.10	0.26	15.00	30.00	9.20	20.10	11.80
	Dry	14.00	0.10	18.00	16.00	19.30	12.85	38.00
8B	Wet	32.00	0.13	8.10	12.00	17.30	15.13	21.00
	Dry	57.00	0.10	18.00	7.00	25.10	4.96	32.00
9B	Wet	9.00	0.34	12.10	27.00	18.60	32.61	18.00
	Dry	15.00	0.23	18.00	5.80	8.00	12.30	29.00
10B	Wet	10.90	0.02	5.00	18.00	8.50	13.00	19.00
	Dry	12.10	0.01	8.06	8.40	7.50	8.20	23.00

Water Resources Institute, Kaduna to assess the quality of the various water bodies used for domestic purposes and similar to the works of Duy Vinh *et al.* [18]. The maximum level of turbidity for drinking water as stated the Food Act [19] of the United States is 5 NTU while that of the WHO [11] is less than 1 for health purposes.

The Total Dissolved Solids (TDS) for the various samples ranged from 22.50 to 204.00 mg/l and 16.60 to 278.00 mg/l for the dry and wet season respectively. This clearly indicates that during the wet season particles find their ways into the various underground water bodies, which increases the particles, present in the boreholes. The increase observed during the dry season for some of the boreholes could be linked to the various geological formation of the area, which is soft sedimentary rocks. The dissolution of the soft rocks is known to form milky colours of water, which was observed in some of the boreholes. This is similar to the work of Adawe [20]. He studied the quality assessment of selected water boreholes in Mogadishu, Somalia. The observed values of TDS during the study period were below the recommended values of NSDWQ [10] and WHO [11]. This result indicated that with a lower volume of water or dilution, lower turbidity values were obtained. Higher correlation of 0.894 exists between turbidity in

Table 3. Results of heavy metals (boreholes).

Location	Season	Lead	Iron	Manganese	Zinc	Cadmium	Chromium
1B	Wet	0.004	0.10	0.03	0.18	0.004	0.000
	Dry	0.001.	0.11	0.02	0.17	0.002	0.000
2B	Wet	0.002	0.23	0.34	1.40	0.003	0.000
	Dry	0.005	0.18	0.25	1.30	0.002	0.000
3B	Wet	0.002	0.11	0.18	2.05	0.002	0.000
	Dry	0.001	0.09	0.14	2.00	0.001	0.000
4B	Wet	0.001	0.11	0.02	1.21	0.003	0.000
	Dry	0.001	0.10	0.03	1.18	0.002	0.000
5B	Wet	0.002	0.20	0.06	2.19	0.002	0.000
	Dry	0.001	0.18	0.04	2.01	0.001	0.000
6B	Wet	0.003	0.12	0.04	2.11	0.002	0.000
	Dry	0.001	0.10	0.03	2.01	0.001	0.000
7B	Wet	0.004	0.12	0.08	1.50	0.002	0.010
	Dry	0.001	0.06	0.04	1.10	0.001	0.000
8B	Wet	0.003	0.20	0.07	1.30	0.002	0.001
	Dry	0.002	0.18	0.05	1.15	0.001	0.000
9B	Wet	0.001	0.25	0.02	121.00	0.002	0.000
	Dry	0.001	0.21	0.09	1.18	0.001	0.000
10B	Wet	0.003	0.23	0.25	2.07	0.001	0.010
	Dry	0.001	0.19	0.16	2.00	0.002	0.000

the wet season and that of the dry season. However, higher turbidity was recorded in Dan fili (H/Mani), 6.3, Rigachikun 6 and Igabi with 5.1 NTU. This result is similar to that obtained by Musa, *et al.,* [12], in their study of Physico-chemical Assessment of Groundwater use in some selected settlements in Minna, Niger State. They concluded that most wells get contaminated because of their closeness to the pollution source. The results also agreed with that of Musa, [3] work on the effect of domestic waste leachates on quality parameters of groundwater that concluded that the closer (within 8 m) a shallow well`s location to an open dumpsite, the higher the value of physico-chemical parameter it will contain. This may be due to absence of serious construction activities around the studied areas that will allow for quick influx of sediment into groundwater via overland flow as observed by Perera *et al.* [21]. The suspended particles clouding the water may be due to such inorganic substances as clay, rock flour, silt, calcium carbonate, silica, iron, manganese. This result was affirmed by Ehinola [22] and Finkl & Charlier [23] that concluded that groundwater characteristic is greatly affected by geological formation of the area.

The presence of Electrical conductivity (Ec) in water samples is an indication of dissolved ions hence electrical characteristic. Thus, the higher the EC, the

higher the levels of dissolved ions in the sample. Electrical conductivity gives a suggestion of the amount of TDS in water [24]. The Ec of all the samples ranged from 21.20 to 267.00 µS/cm with an average of 121.76 µS/cm for the wet season while during the wet season ranges between 43.00 to 340.00 µS/cm with an average of 129.73 µS/cm during the dry season. This is similar to the findings of Mishra and Bhatt [25]. They studied the Physico-chemical and microbiological analysis of underground water in VV Nagar and nearby places of Anand District, Gujarat, India. It is observed that some of the wells during the dry season recorded high Ec as a result of the geological formation of the area and the agricultural activities being carried within the immediate environment.

In carrying out Physico-chemical parameters of water samples, the temperature is considered as an important factor, which is known to have an impact on many reactions, including the rate of disinfectant decay and by-product formation [26]. As the water temperature increases the disinfectant demand and by-product formation, nitrification, microbial activity, algal growth, taste and odour episodes, lead and copper solubility increases [27]. It is required that the temperature of drinking water should not exceed 15˚C because the palatability of water is enhanced by its coolness [28]. In addition to cool water tasting better than warm water, temperatures above 15 degrees Celsius can speed up the growth of nuisance organisms such as algae which can intensify taste, odour, and colour problems. The temperature during the dry season ranged between 31.3˚C - 35.8˚C with an average of 33.80˚C while the wet season ranged between 29.7˚C - 31.4˚C and average of 30.53˚C.

The Total Dissolved Solid results show that during the wet season the mean value (164.03 mg/l) was above the WHO standard of 150 mg/l with a standard deviation of 28.7 mg/l. Total Dissolved Solid was also observed to be high in Abuja Road (260 mg/l) and 379 mg/l was recorded in Saminaka Road, Rigasa. These results conformed to that of Adeoye *et al.,* [29] work on Evaluation of Water Quality Standards and Sanitary Conditions in Moniya Abattoir, Ibadan. This may be as a result of higher recharge during the wet season which encourages lateral influx of contaminants and other unwanted materials through the aquifer. On the other hand, the pH, and, Electrical conductivity are within the range of the set standard with a mean of 6.88 and 201 us/cm respectively.

It was observed that chloride concentration is very low in Kwarau (a mean value of 6.3 mg/l) and Igabi with a mean value of 12.97 mg/l as compared with mean value of 22.07 mg/l during the period of study. This result indicated that Chloride concentration is low where there is less urban and suburban development. This result is conformity with previous work carried by Federal Ministry of Water Resources in 2009 in some parts of Kaduna State.

The result shows that the values of fluoride (0.189 mg/l), Magnesium (15.704 mg/l), Nitrates (6.35 mg/l), Sodium (12.979 mg/l), and Chloride (22.107 mg/l) fall within the national and WHO [11] standards of 1.5 mg/l, 50 mg/l, 200 mg/l and 250 mg/l accordingly. These results are related to that of National Water Resources Institute of 2009 on the Assessment of Drinking Water Quality in

Kaduna and Taraba State.

Results of the analysis of the heavy metals (Table 3) in the sampled boreholes indicated most of them exist in a trace form and this called for continuous ground water monitoring and assessment in the area. Zinc had a mean value of 1.5517 mg/l during the wet season, though within acceptable limit but still high and with a mean of 1.38 during the period of study. Cadmium in the sampled boreholes water have a value of 0.002 mg/l in the same period which is slightly high though within the maximum permissible limit (0.003 mg/l) of WHO [11] Standard. This result shows that frequent water surveillance need to be undertaken in the area. On the other hand, the mean value of Chromium, (0.00016 mg/l), Lead (0.00003 mg/l), Iron (0.132 mg/l) is within the NSDWQ [10] and the WHO [11] standard. Manganese had a mean value of 0.00175 mg/ which is very close to the maximum limit of 0.2 mg/l of the National standard. These results are in line with previous work carried out by National Water Resources Institute Kaduna on the Assessment of Ground water Quality in Kaduna State.

4. Conclusions

This study clearly showed that bad location (distance and depth) of well or borehole may influence their quality as obtained from the results. Any well within 2.4 meter will contain high nitrate concentration above the WHO standard and well sited within 9 meter to dumpsite or pollution source will be liable to faecal contamination.

The borehole located on Saminaka road, Rigasa, was discovered to have high turbidity, and a faecal coliform of 1 cfu/100 ml which is above the national and international standard of 0 cfu/100 m. In this location, the Zinc level was high (1.395 mg/ml) and iron was 0.23 mg/ml, despite within the limit of the set standard but still high. The discoveries at this location may be connected to the location of the borehole to a drainage channel and its proximity to an old dumpsite. Boreholes located in Igabi and Rigachukun area have turbidity of 3.81 and 5.32 NTU respectively which is slightly higher than the WHO/NSDWQ of 5 and 3 NTU respectively. In Rigachukun town, the iron level in boreholes was slightly high (0.365 mg/l and 3.67 mg/l). This result is above the National Standard of Drinking Water Quality (NSDWQ) of 0.3 mg/l, but it is portable when compared with the World Health Organisation (WHO) and standard of 1.0 mg/l. It can be concluded that iron is an issue of concern in boreholes and groundwater in most part of the study area. It was observed in literatures that coloration that comes with water having high iron content, stained containers and fixtures make it objectionable. The results of the heavy metals indicated a mean value of 1.566 for Zinc, 0.00267 mg/l for Cadmium, and 0.087 for Manganese which are close to the maximum acceptable limit of WHO standard of 3 mg/l for Zinc, 0.003 for Cadmium and 0.1 for Manganese. The slightly high level of Manganese and Iron during April and July period make the water slightly turbid during this period. Water samples from Danfili amd Saminaka Road are found not to be safe for drinking and higher iron found in Rigachikun makes the water objectionable.

5. Recommendations

The following recommendations were suggested based on the result of the study. It is recommended that increased campaigns be carried out for improved household and community sanitation in Rigasa and Danmani in particular and rural areas in the developing countries in general.

- Wells located within 9 meters from pollution source and wells less than 2.4 meters depth should be abandoned and future wells should be constructed beyond 15 meters from pollution source.
- Apron (cap) should be provided to protect inflow of surface waste into the wells.
- Proper lining should be provided to serve as additional sieve and protect against lateral flow of contaminants.
- Proper solid waste disposal method should be adopted, phasing out open dumpsites to safeguard public health from water borne diseases.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

Cfu	Colony-forming unit
mg/l	milligram per litre
NPC	National Population Commission
NSDWQ	Nigerian Standard Drinking Water Quality
NTU	Nephelometric Turbidity Unit
RADWQ	Nationwide Rapid Assessment of Drinking Water Quality
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization