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Physico-chemical, Heavy Metals and Radioisotope Concentratios in Underground Water from Kaduna, Kafanchan and Zaria Senatorial Areas of Kaduna State, Nigeria

Muhammad D. Faruruwa[1] and Oladoja S. Titilayo[2*]

[1]Department of Chemistry, Nigerian Defence Academy (NDA), Kaduna, Nigeria.
[2]Federal Ministry of Education, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author MDF designed and proofread the manuscript. Author OST analysed, interpreted, performed the statistical analysis, and wrote the draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The Physico-chemical parameters heavy metals and radioisotopes were analysed in drinking water collected from selected wells in three senatorial areas (Kaduna, Kafanchan and Zaria) in Kaduna state. The water samples were analysed using the American Public Health Association (APHA) standard methods for the physico-chemical analysis, Atomic Absorption Spectrophotometry (AAS) for the heavy metal determination and also the X-Ray Florescence (ED-XRF) for the radioisotopes determination. The results obtained were compared with the permissible limits recommended by the Nigerian Industrial Standard (NIS) and the World Health Organization (WHO) for drinking water. The results for the water samples are as follows: pH (2.06 – 6.56), Conductivity (0.14 – 0.78 mS/cm), Temperature (25.2 – 28.4°C), TDS (0.07 – 0.78 mg/L), COD (11.52 – 27.52 mg/L), Cu (0.0000 –

**Corresponding author: E-mail: titioladoja@yahoo.com;*

0.0560 mg/L), Cr (0.0005 – 0.0056 mg/L), Cd (0.0000 – 0.0040 mg/L), Pb (0.0004 – 0.0080 mg/L), Ni (0.0000 – 0.0048 mg/L), Fe (0.0000 – 0.0900 mg/L) and Co (0.0001 – 0.0040 mg/L). Thorium and Radium were not detected in the water samples collected from all the sampling locations. The water quality analysis results showed that some of the well water samples had pH, Ni and Cd values that were above the recommended limits and all the water samples had COD values that were above the recommended values and as such were considered not good for drinking.

Keywords: Physico-chemical parameters; heavy metals; radioisotopes; well water.

1. INTRODUCTION

Water is necessary for healthy living and must be available to consumers in sufficient quantity and at high quality [1]. Groundwater is a significant source for the provision of good quality drinking water to humans and animals. Access to potable water is one of the Millennial Development Goals (MDGs) in all developing nations of the world. This goal is yet to be achieved because an estimated two billion people worldwide lack access to potable water [2]. In Africa and Asia, millions of people rely solely on underground of water and will continue to do so for many years to come [3]. Presently, it is estimated that more than 300 million people in Africa live in a water-scarce environment. By 2025, eighteen African countries are expected to experience water stress [4]. In Nigeria alone, about 52% of the population lack access to safe drinking water [5]. About 8.3 million residents in Lagos (62.6% of the state population) and some industries lack access to pipe borne water, thus depend solely on groundwater (shallow, hand dug wells and boreholes) for their domestic and industrial use [6].

In most of the developing countries, rapid population growth and urban development are increasing groundwater pollution and raising public health concerns about groundwater quality [7,8]. Importantly, groundwater can also be contaminated by naturally occurring sources. “Soil and geologic formation containing high levels of heavy metals can leach those metals into groundwater [9], and underground waters [10].” The various possible sources of underground pollution include domestic and industrial effluents, agricultural chemicals and fertilizers, soil erosion, oil spills and leakages, mining activities, infiltration from dumpsites and salt water intrusion [11,12]. Unfortunately, most of the wells are located in close proximity to refuse and dumpsites, underground sewage tanks, and pit latrines [13]. Studies showed that the contamination of well water were due to their proximity to urban sources of pollution [14-16].

It is reported that 80% of all illness in developing countries is related to water and sanitation [17]. That is why the determination of groundwater quality for human consumption is paramount and imperative for the well-being of the ever increasing human population. Important information can be attained concerning the suitability of the water, the origin of deviations from the norm, their effects on the functions and bio-diversity of the water source by checking for colour change, temperature variations, occurrence of acidity, degree of hardness, pH, amount of dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) [18].

Another challenging aspect of water quality is the presence of heavy metal contamination. Levels of metals significantly increases with increase in industrial activities. Unlike the organic pollutants, heavy metals cannot be biologically and/or chemically degraded and they may either accumulate locally or be transported over long distances. Moreover, several factors such as redox conditions, organic matter content, and association onto the surface of minerals like clay, Fe, and Monoxyhydroxides influence their behaviour [19]. Consumption of heavy metal contaminated water predisposes the consumer to a lot of health risks. Effects of heavy metal poisoning in man include; reduced growth and cancer development, organ damage, nervous system damage, and in extreme cases death [20].

Regulating radioisotope levels in drinking water is gradually receiving global attention because of its health implications. Besides natural radioactivity, exposed water reservoirs can be contaminated by artificial radioisotopes (i.e. rivers and lakes by radioactive fallout caused by accidents or nuclear explosions). Exposure to radioactivity increases the risk of various cancer in humans. Radon gas, Polonium, Lead and Bismuth increase the risk of lung and stomach cancer, uranium and thorium increase toxicity risks to the kidneys and bones while radium increases the risk of bone cancer (bone sarcomas) and head carcinomas [21]. With these enormous health risks and the increasing effect of anthropogenic sources on water contamination, it is imperative that continuous monitoring and assessment of water be carried out in our environment, especially in underground sources of water which are the most common sources of drinking water in the country.

Kaduna State is not left out in the global water assessment campaign, as the dry season in the northern region of Nigeria are often characterised by intense water shortage, drought and intense sunlight. This research will help create more awareness on the state of water quality in the three senatorial areas in Kaduna State, so as to assist the state government in their quest of understanding and finding lasting solution to the problem. This step will also improve proper health measures.

2. MATERIALS AND METHODS

2.1 Study Area

Kaduna state is in the North Central Nigeria with Territory (Abuja), and shares common borders with Katsina, Federal capital territory, Abuja, Niger state and Plateau State. The State is made up of three senatorial zones; Kaduna, Zaria and Kafanchan. Kaduna is located between Latitude 10.9° and 10.15^o north of the equator and between Longitude 7.5^o and 7.9^o east of Greenwich meridian and occupies central portion of Northern Nigeria (Kaduna, 2007). Zaria lies on the geographical coordinates of 9^o 1'0" North and 8° 13'0" East. Kafanchan lies on the geographical coordinates of 9^o 35'0" North and 8^o 18'0" East.

2.2 Sample Collection, Pre-treatment and Preservation

The groundwater samples were collected in April, 2015 during the dry season, according to standard procedures of [22], from the three senatorial district of Kaduna state in a clean litres container with screw cap. Thirty six water samples were collected from hand-dug wells and thirty six water samples from boreholes all within Zaria, Kaduna and Kafanchan. The sample containers were washed with 20% analytical grade nitric acid and rigorously rinsed with distilled deionized water. Prior to sampling, it was further rinsed with the water sample. Collected samples were preserved by chemical adjustment of the pH < 2, by acidifying with 5 cm^3 of analytical grade nitric acid. The samples were then stored under ice on transit and then refrigerated after arriving at the laboratory at a temperature of (4°C) prior to analysis [23].

2.3 Digestion of Water Samples

The water sample (100 cm^3) was transferred into a beaker and digested using 5 cm^3 of concentrated HNO_3. The beaker was placed on a hotplate and heating continued until the final volume was about 5 cm^3. After heating, the water samples was transferred into a 100 cm^3 volumetric flask and made up to the mark with de-ionised water [24]. Furthermore, the water samples were analysed for (Cu, Cr, Cd, Pb, Ni, Fe and Co) using Buck Scientific an Atomic Absorption Spectrophotometer model 210 VGP series. The digestion was done in order to destroy the organic matrix capable of trapping the trace metals, and thus making them unavailable for the instrumental analysis. Also, prior to metal ion analyses, calibration solutions of the target metal ions were prepared from standard stock by serial dilution.

2.4 Determination of Tds, Ph, Temperature and Electrical Conductivity

These parameters were determined using the HACH complete water laboratory model 44600 and Nahita pH meter model 903 instrument. Water samples of 100 cm^3 were collected in 250 cm^3 Pyrex beaker and the probe of meter dipped into the container. TDS, pH, Temp and electrical conductivity were determined and recorded. This was repeated three times for all the water samples in all the sampled locations.

2.5 Determination of COD

The water sample (50 $cm^{3)}$ was transferred to a 250 cm^3 beaker containing a mixtures of 10 cm^3 of 0.01M $KMnO_4$ and 2 cm^3 of 25% H_2SO_4. The solution was refluxed using a reflux condenser for 1h and allowed to cool at room temperature. Then 1% Ammonium Oxalate $(NH_4)_2C_2O_4.H_2O$ was carefully prepared and added drop wise to the solution until it became colourless. The solution obtained was then titrated with 0.01 M $KMnO_4$ until a pink solution was observed. The

COD of the water samples were calculated as shown below:

$$COD\ (mg/L) = (B - A) \times M \times 16000 \div Volume\ of\ the\ water\ sample$$

Where A is titre value of sample, B is titre value of blank, M = Molarity of $KMnO_4$ and 16000 (Constant).

2.6 Determination of Radioisotopes

The determination of radioisotopes in the water samples was carried out by measuring 100 cm^3 of the water samples using a measuring cylinder. The measured water samples was pre-concentrated by heating in clean beaker on hot plate to the volume of 5 cm^3, de-ionized distilled water (5 cm^3) was used to rinse the concentrated sample into measuring sample cups and analysed for the radioisotopes using ED-XRF instrument [25].

3. RESULTS AND DISCUSSION

All physico-chemical parameters and heavy metal values obtained from well water sources were evaluated using the regulatory standard that was shown below. The results of the physicochemical parameters, heavy metals and radioisotopes analysis for the underground water samples obtained from Zaria, Kaduna and Kafanchan senatorial districts are shown in Tables 1–4.

The mean of the pH results showed that the water samples were below the recommended pH values for drinking water as stated by [26,27]. All the water samples analysed from the well underground source were all acidic except for water samples collected in Goni-Gora and Malali in Kaduna senatorial area, which was within the recommended pH values as shown in Table 1A - B. The increased acidity of the water samples is an indication that there is high level of acidic causing substances in the soil of the area. The low pH values as recorded in some water samples could also be as a result of anthropogenic factors and as such could attack geological materials and leach toxic metals. This may pose a risk for consumption due to metal toxicity [28], reported that acidity in water favours the concentration of heavy metals. The observed trend is similar to values reported by [29,30]. [31], also reported that during dry seasons there may be death and decay of plants due to lack of sufficient water which increases the organic acid content of water. Under a low pH condition, metals tend to go into solution thereby making it readily available for exposure [32]. Although most of the heavy metals investigated in this research were below the recommended permissible limits; there could be retention and accumulation of heavy metals as a result of favourable acidic pH values. Metal corrosion is often the main problem especially when aided by high temperature and low pH leading to corrosion of iron plumbing materials in water systems [33]. Moreover, the bioavailability of heavy metals in soils and sediments must be evaluate, rather than the total concentrations, in order to make a correct assessment of the environmental risks [34-36].

The highest temperature of 28.4°C and the lowest temperature value of 25.2°C with a mean value of 26.7°C were observed in the water samples as collected during the dry season. These values were however lower than the recommended temperature value of 30 – 35°C as stated WHO (2011) but higher than NIS (2007) value of 25°C. The increasing water temperature during the dry season could be attributed to decrease in depth of water resulting in light rays penetrating the water and heating up the ground hence consequently raising the water temperature [37]. [38], stated that cool waters are generally more potable for drinking purposes, because high water temperature enhances the growth of micro-organisms and hence, taste, odour, colour, and corrosion problems may increase. The electro-conductivity value of all the water samples were all below the permissible limit of 250 mS/cm as recommended by NIS and WHO. The highest EC value was 0.78 mS/cm, while the lowest EC was 0.14 mS/cm and the mean EC was 0.48 mS/cm. Conductivity indicates the presence of dissolved solids and contaminants especially electrolytes but does not indicate the presence of specific chemicals. Hence, for most aqueous solutions, the higher the concentration of dissolved salts, the higher the conductivity value. The low EC values as observed in the result indicates the low concentration of dissolve electrolyte. [39], stated that low EC could be as a result of low solute dissolution generally in the groundwater, rapid ion-exchange between the soil and water, or basically a poor and rather insoluble geologic rock and mineral types.

Table 1 (A). The result of physicochemical parameters determination in the well water samples from three senatorial (Zaria, Kaduna and Kafanchan) during dry season

ID No	Location of sample	Temperature (0°C)	pH	Conductivity (mS/cm)	TDS (g/L)	COD (mg/L)
WW 01	WUSASA- ZA	28.3±1.60	5.9±1.2	0.76±0.28	0.38±0.12	20.48±3.83
WW 02	KOFA DOKA- ZA	28.1±1.40	5.3±0.6	0.41±0.07	0.20±0.06	20.48±3.83
WW 03	KONGO- ZA	28.2±1.50	5.1±0.4	0.61±0.13	0.30±0.04	15.56±1.09
WW 04	SABO GARI- ZA	28.2±1.50	5.4±0.7	0.31±0.17	0.15±0.11	16.00±0.65
WW 05	EMANTO- ZA	28.4±1.70	5.6±0.9	0.44±0.04	0.22±0.04	27.52±10.87
WW 06	SAMARU- ZA	28.2±1.50	6.0±1.2	0.14±0.34	0.07±0.19	17.28±0.63
WW 07	DUTSE- ZA	28.3±1.60	5.1±0.4	0.76±0.28	0.38±0.12	20.48±3.83
WW 08	BASSAWA- ZA	28.1±1.40	5.4±0.7	0.41±0.07	0.20±0.06	18.56±1.91
WW 09	CHIKA- ZA	28.2±1.50	5.6±0.9	0.61±0.13	0.30±0.04	16.00±0.65
WW 10	GRACELAND- ZA	28.3±1.60	5.3±0.6	0.44±0.04	0.15±0.11	20.48±3.83
WW 11	TUDUN WADA- ZA	28.2±1.50	5.9±1.2	0.31±0.17	0.30±0.04	18.56±1.91
WW 12	U/GODO- KD	28.2±1.50	5.1±0.4	0.61±0.13	0.07±0.19	15.00±1.65
WW 13	NARAYI – KD	25.2±1.50	5.1±0.3	0.67±0.19	0.33±0.07	19.20±2.55
WW 14	TELEVISION- KD	25.3±1.40	5.0±0.3	0.40±0.08	0.20±0.06	16.64±0.01
WW 15	GONIGORA- KD	25.7±1.00	6.5±1.8	0.78±0.30	0.39±0.13	16.0±0.65
WW 16	C/ MARKET-KD	25.4±1.30	5.3±0.6	0.55±0.07	0.27±0.01	14.72±1.93
WW 17	MANDO-KD	25.7±1.00	3.9±0.8	0.27±0.21	0.13±0.13	13.44±3.21
WW 18	H/ DAMANI- KD	25.7±1.00	3.9±0.8	0.27±0.21	0.13±0.13	14.70±1.95
WW 19	KAWO- KD	25.4±1.30	5.3±0.6	0.40±0.08	0.27±0.01	13.44±3.21
WW 20	MALALI- KD	25.7±1.00	6.5±1.8	0.78±0.30	0.78±0.52	14.72±1.93
WW 21	TUDUNWADA- KD	25.4±1.30	5.0±0.3	0.55±0.07	0.55±0.29	16.00±0.65
WW 22	KAKURI- KD	25.2±1.50	5.1±0.3	0.27±0.21	0.27±0.01	16.40±0.25
WW 23	HAYAN BAKIN- KD	25.7±1.00	5.1±0.3	0.67±0.19	0.33±0.07	16.44±0.21
WW 24	SABO- KD	25.7±1.00	5.0±0.3	0.78±0.30	0.39±0.13	14.72±1.93
WW 25	ADWANI I- KF	25.4±1.30	4.9±0.2	0.35±0.13	0.17±0.09	17.28±0.63
WW 26	U/RIMI	26.4±0.30	5.5±0.8	0.77±0.29	0.38±0.12	11.52±5.13
WW 27	GARAJI ROAD- KF	26.6±0.10	2.4±2.3	0.24±0.24	0.12±0.14	13.44±3.21
WW 28	KATSIT- KF	27.2±0.50	4.4±0.2	0.60±0.12	0.30±0.63	17.28±0.63
WW 29	MADAKIA- KF	27.0±0.30	2.1±2.6	0.45±0.03	0.22±0.56	17.21±0.56
WW 30	TAKAU – KF	27.3±0.60	2.2±2.4	0.19±0.29	0.09±2.55	19.20±2.55
WW 31	ADWANI II- KF	25.4±1.30	2.4±2.3	0.19±0.29	0.30±0.63	17.28±0.63
WW 32	KANIKON –KF	26.4±0.30	5.5±0.8	0.45±0.03	0.12±3.21	13.44±3.21
WW 33	FASAN – KF	26.4±0.30	4.9±0.2	0.60±0.12	0.30±5.13	11.52±5.13
WW 34	LOKO- KF	27.3±0.60	2.0±2.6	0.45±0.03	0.30±0.60	17.25±0.60
WW 35	U/FARI –KF	25.4±1.30	2.4±2.3	0.45±0.30	0.22±1.93	14.72±1.93
WW 36	U/BAKI –KF	26.4±0.30	2.8±1.8	0.19±0.29	0.09±0.21	16.44±0.21
	MEAN	**26.7±1.23**	**4.7±1.3**	**0.48±0.20**	**0.26±0.14**	**16.65±3.01**

Key: ZA - Zaria, KD – Kaduna, KF-Kafanchan. WW01 – WW36: Well water sample of dry season

Table 1 (B). Comparison of observed values of the physicochemical parameters of well water samples in Kaduna State during dry season with Nigeria and World health Organisation (WHO) standards

Parameters	NIS (2007)	WHO (2011)	Minimum	Maximum	Mean
Temperature (°C)	25	30-35	25.2	28.4	26.7
pH	6.8-8.5	6.5-9.2	2.06	6.56	4.74
Conductivity (mS/cm)	250	250	0.14	0.78	0.48
TDS (mg/L)	500	500	0.07	0.78	0.26
COD (mg/L)	10	10	11.52	27.52	16.65

Table 2(A). Concentrations (mg/L) of heavy metals in the well water samples of the three Senatorial Districts (Zaria, Kaduna and Kafanchan) of Kaduna state during dry season

Location samples	ID No.	Cu	Cr	Cd	Pb	Ni	Fe	Co
WUSASA- ZA	WW01	0.0020	0.0005	0.0002	0.0040	0.0008	0.0060	0.0011
KOFA DOKA- ZA	WW02	0.0040	0.0006	0.0000	0.0013	0.0025	0.0010	0.0040
KONGO- ZA	WW03	0.0018	0.0056	0.0007	0.0005	0.0036	0.0010	0.0040
SABO GARI- ZA	WW04	0.0058	0.0012	0.0028	0.0005	0.0020	0.0010	0.0001
EMANTO- ZA	WW05	0.0011	0.0010	0.0020	0.0004	0.0048	0.0010	0.0001
SAMARU- ZA	WW06	0.0012	0.0019	0.0003	0.0023	0.0005	0.0060	0.0001
DUTSE- ZA	WW07	0.0018	0.0006	0.0001	0.0014	0.0008	0.0000	0.0001
BASSAWA- ZA	WW08	0.0012	0.0005	0.0002	0.0040	0.0025	0.0001	0.0001
CHIKA- ZA	WW09	0.0040	0.0018	0.0007	0.0040	0.0020	0.0050	0.0001
G/LAND- ZA	WW10	0.0088	0.0056	0.0025	0.0035	0.0048	0.0060	0.0014
T/ WADA- ZA	WW11	0.0015	0.0014	0.0026	0.0050	0.0036	0.0050	0.0010
U/GODO- KD	WW12	0.0000	0.0010	0.0020	0.0011	0.0018	0.0040	0.0001
NARAYI – KD	WW13	0.0560	0.0009	0.0001	0.0016	0.0011	0.0080	0.0012
TELEVISION- KD	WW14	0.0026	0.0012	0.0025	0.0080	0.0006	0.0040	0.0012
GONIGORA- KD	WW15	0.0086	0.0026	0.0023	0.0018	0.0008	0.0050	0.0013
C/ MARKET-KD	WW16	0.0006	0.0018	0.0018	0.0010	0.0002	0.0900	0.0012
MANDO-KD	WW17	0.0340	0.0017	0.0002	0.0010	0.0006	0.0050	0.0001
H/ DAMANI- KD	WW18	0.0006	0.0018	0.0011	0.0012	0.0006	0.0050	0.0012
KAWO- KD	WW19	0.0026	0.0016	0.0023	0.0016	0.0010	0.0050	0.0011
MALALI- KD	WW20	0.0006	0.0009	0.0006	0.0011	0.0011	0.0500	0.0013
T/WADA- KD	WW21	0.0340	0.0026	0.0024	0.0018	0.0011	0.0900	0.0013
KAKURI- KD	WW22	0.0340	0.0024	0.0025	0.0018	0.0008	0.0600	0.0012
H/ BAKIN- KD	WW23	0.0080	0.0022	0.0018	0.0016	0.0006	0.0400	0.0012
SABO- KD	WW24	0.0066	0.0018	0.0022	0.0018	0.0004	0.0900	0.0001
ADWANI I- KF	WW25	0.0004	0.0038	0.0010	0.0017	0.0002	0.0040	0.0001
U/RIMI	WW26	0.0036	0.0009	0.0028	0.0010	0.0032	0.0120	0.0013
G/ ROAD- KF	WW27	0.0022	0.0012	0.0028	0.0006	0.0011	0.0040	0.0014
KATSIT- KF	WW28	0.0020	0.0022	0.0023	0.0005	0.0020	0.0030	0.0001
MADAKIA- KF	WW29	0.0066	0.0005	0.0010	0.0010	0.0009	0.0001	0.0001
TAKAU – KF	WW30	0.0014	0.0012	0.0010	0.0040	0.0035	0.0001	0.0001
ADWANI II- KF	WW31	0.0012	0.0010	0.0010	0.0040	0.0032	0.0001	0.0001
KANIKON –KF	WW32	0.0022	0.0012	0.0028	0.0016	0.0011	0.0028	0.0001
FASAN – KF	WW33	0.0066	0.0012	0.0040	0.0056	0.0020	0.0040	0.0014
LOKO- KF	WW34	0.0018	0.0022	0.0040	0.0050	0.0008	0.0040	0.0001
U/FARI –KF	WW35	0.0036	0.0009	0.0024	0.0010	0.0018	0.0024	0.0014
U/BAKI –KF	WW36	0.0000	0.0038	0.0001	0.0005	0.0000	0.0001	0.0001
Mean		0.0070	0.0017	0.0016	0.0021	0.0016	0.0145	0.0008

Key: ZA - Zaria, KD – Kaduna, KF-Kafanchan. WW01 – WW36: Well water sample of dry season

Table 2 (B). Comparison of observed values of the concentration of selected heavy metals in the well of the three senatorial district (Zaria, Kaduna and Kafanchan) during dry season with Nigeria and World health Organisation (WHO) standards

	NIS (2007)	WHO (2011)	Minimum	Maximum	Mean
Cu (mg/L)	1.0	1.0	0.0000	0.0560	0.0070
Cr (mg/L)	0.01	0.05	0.0005	0.0056	0.0017
Cd (mg/L)	0.01	0.003	0.0000	0.0040	0.0016
Pb (mg/L)	0.10	0.01	0.0004	0.0080	0.0021
Ni (mg/L)	0.01	0.001	0.0000	0.0048	0.0016
Fe (mg/L)	1.0	0.3	0.0000	0.0900	0.0145
Co (mg/L)	0.01	0.05	0.0001	0.0040	0.0008

Table 3 (A). Concentrations (mg/L) of radioisotopes in the well water samples of the three Senatorial Districts (Zaria, Kaduna and Kafanchan) of Kaduna state during dry season

Location samples	ID No.	Uranium	Thorium
WUSASA- ZA	WW01	ND	ND
KOFA DOKA- ZA	WW02	ND	ND
KONGO- ZA	WW03	ND	ND
SABO GARI- ZA	WW04	ND	ND
EMANTO- ZA	WW05	ND	ND
SAMARU- ZA	WW06	ND	ND
DUTSE- ZA	WW07	ND	ND
BASSAWA- ZA	WW08	ND	ND
CHIKA- ZA	WW09	ND	ND
G/LAND- ZA	WW10	ND	ND
T/ WADA- ZA	WW11	ND	ND
U/GODO- KD	WW12	ND	ND
NARAYI – KD	WW13	ND	ND
TELEVISION- KD	WW14	ND	ND
GONIGORA- KD	WW15	ND	ND
C/ MARKET-KD	WW16	ND	ND
MANDO-KD	WW17	ND	ND
H/ DAMANI- KD	WW18	ND	ND
KAWO- KD	WW19	ND	ND
MALALI- KD	WW20	ND	ND
T/WADA- KD	WW21	ND	ND
KAKURI- KD	WW22	ND	ND
H/ BAKIN- KD	WW23	ND	ND
SABO- KD	WW24	ND	ND
ADWANI I- KF	WW25	ND	ND
U/RIMI	WW26	ND	ND
G/ ROAD- KF	WW27	ND	ND
KATSIT- KF	WW28	ND	ND
MADAKIA- KF	WW29	ND	ND
TAKAU – KF	WW30	ND	ND
ADWANI II- KF	WW31	ND	ND
KANIKON –KF	WW32	ND	ND
FASAN – KF	WW33	ND	ND
LOKO- KF	WW34	ND	ND
U/FARI –KF	WW35	ND	ND
U/BAKI –KF	WW36	ND	ND
Mean		ND	ND

Key: ZA - Zaria, KD – Kaduna, KF-Kafanchan. WW01 – WW36: Well water sample of dry season.

Table 4. Correlative matrix results of the physico-chemical parameters of the well water

	Temp	Cond	TDS	pH	COD
Temp	1				
Cond	-0.00344	1			
TDS	-0.12257	0.72061	1		
pH	0.186552	0.484348	0.266218	1	
COD	0.530266	-0.05519	0.044159	0.104599	1

Low TDS values were observed in all the water samples as they were within the permissible limits as recommended by the regulatory agents above. This also correlate with the low conductivity value observed above the TDS results show that there are low concentrations of dissolved inorganic salts in the sampled water.

The effect of low EC is its insipid flat taste and this may not be acceptable for consumers [40]. High TDS levels (>500 mg/litre) result in excessive scaling in water pipes, water heaters, boilers, and household appliances such as kettles and steam irons [41]. From the total dissolved solids examination in all the sampling locations, it was obvious that the total dissolved solids were similar from one location to another and from well to well. This is an indication of the similarity of the types of soil and rock that the ground water passes through and the concentrations of dissolved inorganic salts in the sampled areas. High COD values were observed in all the water samples as shown in Table 1A. The minimum COD value recorded in the various water samples was 11.52 mg/L, the maximum value was 27.52 mg/L and the mean values of all the COD values was 16.65 mg/L. All the sampled water had COD values that were higher than the recommended WHO/NIS value of 10 mg/L for COD in drinking water. The COD corresponds to the amount of oxygen required to oxidize the organic fractions of the sample [42]. High chemical oxygen demand has an impact on the people and industries reliant on water, it kills natural vegetation, the water becomes unsuitable for livestock and on farm supplies. It reduces crop yields; it makes the land unsuitable for agricultural purposes [43].

The concentration of copper in the underground well water in the three senatorial areas were low and were within the recommended limits set by [27,26]. Copper is a transition metal and excessive intake of copper via drinking water could be harmful to the consumer. Contamination of drinking water with high level of copper may lead to chronic anaemia. Studies have shown that ingesting copper may also be implicated in coronary heart diseases and high blood pressures although coronary heart diseases have also been linked to copper deficiency [42]. Presences of cadmium were observed in all the water samples except for water obtained in Kofa – Doka in Zaria senatorial area. However the concentration s of cadmium metal in the various water samples were below the permissible limit.

Chromium metal was observed in all the water samples analysed from the three senatorial areas. The concentration of chromium however, was below the permissible limits as recommended by [27,26]. Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Low-level exposure can irritate the skin and cause ulceration, while long-term exposure can cause kidney, liver, circulatory and nerve tissue damage. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium [44]. Lead metal concentration in all the water samples collected from the three senatorial areas were within the permissible limits as recommended. The presence of lead in the drinking water should be taken seriously, although detected in minute concentrations, lead affects children by leading to the poor development of the grey matter of the brain, thereby resulting in poor intelligence quotient (IQ) [45]. Nickel metal was detected in all the water samples collected from the three senatorial areas except for U/Baki in Kafanchan senatorial area. Some of the water samples had nickel concentrations that were above the [27], limit but below the [26] limit. The affected water samples with nickel metal concentrations that were above the limits were considered unsafe for consumption as far as WHO is concerned.

The primary source of nickel in drinking water is leaching from metals which are in contact with drinking water, such as pipes and nickel may also be present in some ground water as a consequence of dissolution from nickel ore bearing rocks [46]. The various toxic effects of nickel in the human body either via ingestion or inhailing of dust are toxic embryo toxic effect, allergic reactions, nephrotoxic effects and contact dermatitis due to nickel pollution [46].

Iron concentration was detected in all the water samples except in Dutse sampling site in Zaria senatorial area. The concentration of iron was however within the recommended value as stated by [27, 26]. The non-availability of iron in water samples collected from Dutse sampling location will lead to a deficiency of iron in the drinking water. Iron in well water usually does not present a health problem. In fact, iron is needed to transport oxygen in the blood. The human body requires approximately 1 to 3 additional milligrams of iron per day (mg/day) [47]. However, consuming large amounts of iron can lead to a condition known as iron overload;

this condition is usually the result of a gene mutation that afflicts about one million people in the United States. Left untreated, iron overload can lead to hemochromatosis, a severe disease that can damage the body's organs. The concentration of cobalt in the drinking water observed in all the three senatorial areas were within the permissible limits as recommended by [27,26]. Small amounts of cobalt are naturally found in most rocks, soil, water and plants. Cobalt has both beneficial and harmful effects on human health. Cobalt is beneficial to humans because it is part of vitamin B_{12}, which is essential to maintain human health. Cobalt (0.16–1.0 mg/kg of body weight) has also been used as a treatment for anaemia (less than normal number of red blood cells), including in pregnant women, because it causes red blood cells to be produced. Cobalt also increases red blood cell production in healthy people, but only at very high exposure levels. Cobalt is also essential for the health of various animals, such as cattle and sheep [48].

There is no significant difference in the values of the parameters determined from one sampling location to another (p-values are greater than 0.05). The correlative matrix result as shown in Table 4 shows that there is weak correlation between the physico-chemical parameters.

Thorium and Uranium radioisotopes were not detected in the water samples collected from the three senatorial areas as shown in Table 3. This shows that there concentration is below the detection limit. Radioisotopes of natural origin are normally present in different amounts in drinking water. They are released from rocks and minerals which form the aquifer as happens with other cations and anions. The processes of erosion and dissolution bring radioactive elements from rocks into the water [49].

[21], reported a Rn concentration in borehole sources is higher than that of well water sources in Zaria and were both greater than the maximum concentration limit (MCL) of 11.1 Bq/L set by USEPA. Onoja et al., 2013 also reported a potassium-40 concentration in the water samples ranging from 0.124 and 0.849 Bq/L, respectively. Also, uranium-238 and thorium-232 investigated in the samples gave mean concentration of 0.0011 and 0.00006 Bq/L, respectively. The results obtained from their analysis showed that samples have radioisotopes activity concentrations that were below the recommended value for the radioisotopes.

4. CONCLUSION

The physico-chemical results show that some of the drinking water had a low pH value and all the water samples had high COD value that were not acceptable when compared with the WHO/NIS regulatory standards. This is an indication of water contamination through anthropogenic factors, is a potential health risk for consumers. The heavy metals concentration results showed that all the metals were within the permissible limits except for Ni, and Cd whose concentrations in some of the water samples were evident of water contamination above the limits. It is therefore, observed that the water sources from the studied area have lot of potentials for wide applications by the people if only they can be subjected to further treatments that will reduce drastically, the concentration of the few identified elements that may pose some health risks to the society. The well water underground source could be kept safe from dust and contamination, if properly covered and the body properly cemented, plastered and raised up to avoid waste water from entering it.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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