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Radon Assessment of Drinking Water Sources from Jibia Town, Katsina State, Nigeria

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ABSTRACT
Radon gas, the predominant source of natural occurring radioactive substances is released by natural decay of uranium in the ground. Its half-life is 3.823 days and it can penetrate soils and rocks, contaminating surface and ground water sources. Ingestion (oral) and inhalation leads to a build-up of its daughters ^{218}Po and ^{214}Po in the lungs, whose high-energy alpha and gamma radiation damage cells. This research work aimed to evaluate the health hazards associated with ^{222}Rn in some selected drinking water sources from Jibia Town, Katsina State, Nigeria. Twenty water samples from three different water sources were analyzed using liquid scintillation counter (Model Tri-Carb-LSA1000*)* situated at the Centre for Energy Research and Training of ABU Zaria. The corresponding annual effective doses due to ingestion and inhalation of ^{222}Rn were also estimated. The mean activities concentrations of radon for surface, well and borehole water sources were 1.80±0.01BqL^{-1}, 5.99±0.02 BqL^{-1} and 7.97±0.04 BqL^{-1} respectively, with overall mean value of 5.21±0.03 Bq/L. Similarly, the estimated mean annual effective dose due to inhalation and ingestion of radon were13.14±0.9 µSv/y (for all ages) and 37.95±2.5 µSv/y, 57.08±3.8 µSv/y and 66.59±4.4 µSv/y for adults, children and infants, respectively. Based on the achieved results, the specific activity concentrations of the radon and the estimated annual effective doses due to ingestion and inhalation of ^{222}Rn were all found to be below the World average value of 10Bq/L set by WHO (2011) and recommended limit of 100µSv/y set by WHO (2011), respectively. Hence the radon concentrations were found to pose non-significant hazard to the populace from the drinking water sources.

Keywords:
Radon,
Effective Dose,
Drinking Water,
Jibia.

INTRODUCTION

Water is the predominant substance used by human, occupying about 75% of our daily needs. A part from agriculture, industrial and other domestic uses, human body uses water in all its cell, organs and tissues to help regulate it temperature and maintain other bodily functions (Laskey, 2015). However, as important as water is to man and other living things, it can be a source of ill-health being a common source of disease, bacteria and viruses, radioactive substance and toxic chemicals (WHO, 2008). Some of these contaminants may be harmful if consumed at certain levels while others may be harmless (USEPA, 1992). Radon-222 isamong the most critical harmful contaminants that are considered systematic poisonous even at lower levels of exposure (Tchounwou *et al*, 2012). Radon (^{222}Rn) had been acknowledgedas the main sources of natural occurring radioactive substances in residential area with short live products of ^{218}Po, ^{214}Po, ^{214}Bi and ^{214}Pb each give off either alpha radiation (or beta radiation) and sometimes gamma radiation too (USEPA, 1992).

The presence of radioactive substances in natural drinking water as the major cause of environmental pollution has received considerable attention in recent years, due to their potential risk to human health and ecology (WHO, 2011). This area has therefore been given adequate research backing from all over the world. Frequent studies within Nigeria and other nations have reported different results on the assessment of radioactive substances, status of different drinking water sources and correlate with the maximum permissible limits recommended by different international organizations such as UNSCEAR, WHO, USEPA, IAEA for necessary actions.

A study was conducted by Joseph and his colleagues in

2018 to assess Radon-222 in selected water sources at Dutsin-Ma Local Government of Katsina State, using Liquid Scintillation Counter. The mean radon concentration in the water samples was found to exceed WHO/UNSCEAR recommended value of $10BqL^{-1}$ with 20%. Similarly, the mean annual effective dose was also above the recommended level of $0.1mSvy^{-1}$ by WHO.

Statistical analysis of radon concentration in (borehole) water conducted in Katsina state by Abdulkadir *et al* (2023) showed that the overall average concentration of ^{222}Rn was found to be 69 ± 3 Bql^{-1} which is higher than the world average values of 10 Bql^{-1} set by WHO and 11.1 Bql^{-1} set by USEPA.

A researchperformed by Garba *et al* (2013) to assess Radon in ground water sources from Zaria and Environs using Liquid Scintillation Counter showed that, the radon concentration in borehole sources is higher than the hand – dug well water sources and both concentration were higher than the World average value of 10 BqL^{-1} set by WHO (1996) and UNSCEAR (1993). The high concentration of radon in the area was believed to be due to natural processes, industrial activities and other human activities.

Zakari *et al* (2015) used Liquid Scintillation Analysis to measure radon concentration in water sources around Ririwai Artisanal Tin mine Kano State, Nigeria. The research revealed that the annual effective dose due to the ^{222}Rn concentration is higher in ground water than in surface water. However, the mean ^{222}Rn concentration obtained in this work is lower than 10.00Bq/L recommended by WHO and UNSCEAR. Also in this study the annual effective dose obtained is lower than the maximum permissible limit of 0.1mSv/year recommended by UNSCEAR.

According to records of investigation of this field, it can be assumed that the level of radon concentration in ground water sources is higher than surface water sources. This research work meant to assess the activity concentration of ^{222}Rn and estimate the annual affective dose due to the ingestion and inhalation of ^{222}Rn from drinking water.

Study Area

The access to safe and treated drinking water remained one of the major challenges for most people especially in rural areas due to persistent portable water shortage. Among such areas were Jibia, Kagamada and Magama communities of Jibia Local Government, Katsina State. Where secured, treated and potable drinking water is an everyday challenge, especially during dry season (Mohammed *et al,* 2020). The land of these communities was degraded and deserted such that some of the water sources dried off, thereby pressuring the populace to rely heavily on untreated water sources for drinking and other domestic uses and it may be possible that the water they use contains a higher than permissible contamination limits of Radon and heavy metals; whose accumulation in the body overtime may lead to several types of cancer and other health effects. Jibia is located at an approximate distance of 43Km west of Katsina, situated on the extreme part of Northern Nigeria. It lies between Latitude 13º5´37´´N and Longitude 7º13´34´´E.The population of the LGA was about 167,435 (as at the 2006 census) and 226,000 according to 2016 estimation. Jibia have total land area of about 1037 km². It is bordered with Niger Republic to the North, Katsina and Kaita to the North East, and to the South by Batsari and Batagarawa (NPC, 2010 and 2016).

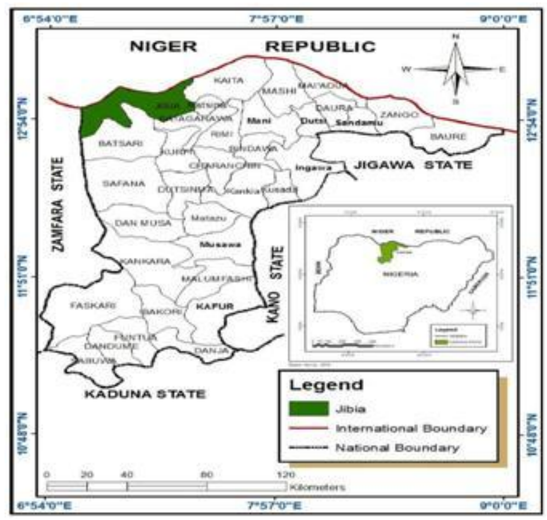

Figure 1. Administrative Map of The Study Area
(Source: Geology Dept, ABU Zaria)

MATERIALS AND METHODS

The materials used to carry out this research are those described by ASTM (1999) and USEPA (1988, 2002a).The materials used include; plastic sample bottles (100ml), disposable hypodermic syringes, hypodermic needles, surgical gloves, distilled water, scintillation vial (22 ml capacity) with seal cap, scintillation cocktails, concentrated NHO_3, ink, masking tape, tissue paper and beaker.

Sample Collection

The selection of the sampling points was based on accessibility to water sources at the site by the public. The factors considered during the sampling were; random strategic sampling, whereby each sampling point was selected independent of the other points, such that all points were given equal chance to be selected. Representative Sampling such that the samples taken were delegate of the different sources from which water is obtained by the public or enters the system as a whole (USEPA 1989 and WHO 2000). During the sample collection, the water sources were allowed to flow freely for a couple of minutes without aeration before being sampled and the plastic sample bottles were filled to the brim without any head space to prevent CO_2 from being trapped because it could dissolve in the water samples and affect the chemistry (Suomela, 1993). Twenty (20) samples were collected which comprises of 6 surface water, 5 borehole water and 9 well water sources. During the sampling, Global Positioning System (GPS) was used to mark the geographical locations of the sample collection points on the earth surface. In order to achieve accuracy, the samples were transferred to the laboratory immediately after collection and analyzed within 6 hours, so that the sample compositioncouldnot change (WHO, 2000).

Sample Preparation

The sample preparation procedure reported by Suomela (1993) was used for the samples preparation,as follows;the samples were prepared by adding 10ml of each sample into a 22ml scintillation vial that contains 10ml of the instagel scintillation cocktail using hypodermic syringes, in order to minimize out-gassing the sample by aeration. After that, the vials were sealed tightly and shaken for about two minutes so as to extract Radon-222 into the organic scintillator solution due to its greater solubility in organic liquids. The vials were then left for about 3 hours to allow for in growth of the short-lived decay products of radon-222 and the attainment of secular equilibrium (Huda *et al*, 2010). The background samples were prepared by dissolving 10ml of the scintillation solution in 10ml of distilled water. Similarly, the calibration solution was prepared by dissolving 10ml of IAEA standard Radium-226 sample in 10ml distilled water.

Sample Analysis

The samples prepared were analyzed using Liquid Scintillation Counter (Model Tri-Carb-LSA1000) situated at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria. The quality of the analytical data was guaranteed through the implementation of laboratory quality assurance and quality laboratory methods, including the use of standard operating procedures and calibration with standards.

Activity of Radon Concentration

The activity of ^{222}Rn was computed using Equation 1 as provided UNSCEAR (1989 and 2000)

$$A_{Rn} = \frac{100 \times (SC - BC)e^{(\lambda t)}}{60 \times 5 \times 0.964} \quad (1)$$

whereby; A_{Rn} is the activity concentration of radon in Becquerel per litre (Bq/L), 100 is the conversion factor from per 10ml to per litre, SC is the sample count rate (Count/min), BC is the background count rate (Count/min), λ is the decay constant of ^{222}Rn (1.26×10^{-4} Min^{-1}), t is the elapse time (Min) between sampling to counting, 60 is the conversion factor from min to sec, 5 is the number of emission per disintegration of Radon-222 (3α and 2β) assuming 100% detection efficiency for each and 0.964 is the fraction of Radon-222 in cocktail in 22ml total capacity vial.

Annual Effective Dose

The corresponding annual effective doses (μSvy^{-1}) due to ingestion and inhalation of ^{222}Rn were estimated using Equations (2) and (3), respectively (UNSCEAR, 1993 and WHO, 2004).

$$AED_{(Ing)} = A_{Rn} \times DCF_{Ing} \times W_C \times T_S \times 10^6 \quad (2)$$

Where $AED_{(Ing)}$ is annual effective dose due to ingestion of radon in water, A_{Rn} is the measured radon concentration in water (BqL^{-1}), $DCF_{Ing}$is dose conversion factor due to ingestion of radon and its progeny = 1×10^{-8}, 2×10^{-8} and 7×10^{-8}SvBq^{-1}for adults, children and infants, respectively. W_C water consumption rate = 2, 1.5 and 0.5 Lday^{-1} for adults, children and infants, respectively. T_S is the time span of water consumption (365 days) and 10^6 is the conversion factor from Svy^{-1} to μSvy^{-1} (UNSCEAR, 2000 and WHO, 2004)

$$AED_{(Inh)} = A_{Rn} \times DCF_{Inh} \times R \times F \times T \times 10^{-3} \quad (3)$$

where $AED_{(Inh)}$ is annual effective dose due to inhalation of radon gas in water, A_{Rn} is the measured radon concentration in water (BqL^{-1}), $DCF_{Inh}$is dose conversion factor due to inhalation of radon = 9nSvh^{-1} per Bq/m^3, R is ratio of radon in air to radon in water = 10^{-4} Bqm^{-3} per BqL^{-1}, F is the indoor equilibrium factor between radon and its progeny = 0.4, T is the indoor time = 7000hy^{-1} and 10^{-3} is the conversion factor from nSvy^{-1} to μSvy^{-1} (ICRP, 1993 and UNSCEAR, 2000).

RESULTS AND DISCUSSION

The sampling collection points, sample codes, the category of water sources and the geographical locations of the samples collection points on the earth surface are presented.

Table 1: Sampling Collection Points and Coordinates

S/N	Sample Code	Sample Description	Coordinates		Sources Category
			Latitude (°)	Longitude (°)	
1	JSW 1	Jibia Surface (Dam) Water 1	13.086600	7.222101	Surface Water
2	JSW 2	Jibia Surface (Dam) Water 2	13.086649	7.228727	
3	JSW 3	Jibia Surface (Dam) Water 3	13.082375	7.235652	

4	JSW 4	Jibia Surface (Pump) Water 4	13.089851	7.219013	
5	JSW 5	Jibia Surface(Pump) Water 5	13.098731	7.227532	
6	JSW 6	Jibia Surface (Pump) Water 6	13.106155	7.214230	
7	JWW 1	Jibia Well Water 1	13.099022	7.216024	Well Water
8	JWW 2	Jibia Well Water 2	13.098780	7.232414	
9	JWW 3	Jibia Well Water 3	13.102759	7.222002	
10	KWW 1	Kagadama Well Water 1	13.103521	7.240530	
11	KWW 2	Kagadama Well Water 2	13.100746	7.246289	
12	MWW 1	Magama Well Water 1	13.116543	7.261113	
13	MWW 2	Magama Well Water 2	13.111969	7.257447	
14	MWW 3	Magama Well Water 3	13.102390	7.256733	
15	MWW 4	Magama Well Water 4	13.098795	7.261756	
16	JBW 1	Jibia Borehole Water 1	13.091307	7.228474	Borehole Water
17	MBW 1	Magama Borehole Water 1	13.109312	7.261791	
18	MBW 2	Magama Borehole Water 2	13.103063	7.267050	
19	MCBW1	Magama (Custom) Borehole Water 1	13.121027	7.262621	
20	MFBW 1	Magama Farfaru Borehole Water 1	13.081435	7.222595	

The overall mean specific activity of radon concentration recorded for the twenty samples collected from the three drinking water sources was 5.21±0.03 Bq/L, with minimum and maximum values of 0.13 Bq/L and 12.07 Bq/L, respectively. The ranges of the radon specific activity were 0.13 – 2.91 BqL^{-1}, 3.06 – 9.57 $BqL^{-1}$and 3.19 – 12.07 BqL^{-1} with mean values of 1.80±0.01 BqL^{-1}, 5.99±0.02 BqL^{-1} and 7.97±0.04 BqL^{-1} for surface, well and borehole water sources, respectively. The average specific concentrations of the radon for both surface, well and borehole, and their overall mean values were all recorded lower than the World average value of 10Bq/L set by (WHO, 2004).

The overall mean annual effective dose due to inhalation (all ages) of radon in the drinking water sources was found to be 13.14±0.9 µSv/y, with minimum and maximum of 0.318 and 30.416 µSv/y, respectively. In similar perspectives, the overall mean annual effective doses due to ingestion of radon were 37.95±2.5 µSv/y, 57.08±3.8 µSv/y and 66.59±4.4 µSv/y with ranges of 0.92-88.11, 0.92-88.11 and1.61-154.19 µSv/y for adults, children and infants, respectively. The mean annual effective doses due to ingestion and inhalation of ^{222}Rn were found to be within the recommended limit of 100µSv/y as set by (WHO, 2004).

The level of radon concentrations and the resulting annual effective doses due to ingestion and inhalation reported from the studied area corroborate with the values reported in some regions of Ririwai of Kano State, Nigeria by (Zakari *et al*, 2015) and Idah, Nigeria by (Aruwa *et al*, 2017). However, the values reported in this work were lower than the values reported in in Dutsin-Ma town of Katsina State by (Joseph *et al*, 2018), Statistical analysis of radon concentration in (borehole) water in Katsina state by Abdulkadir *et al* (2023), Zaria of Kaduna State by (Garba NN, 2011) and cement industrial area of Sokoto, North-Western Nigeria by (Abba *et al*. 2020).

The specific activity concentrations of radon (A_{Rn}) and the resulting annual effective doses (AED) due to ingestion and inhalation of ^{222}Rn from surface, well and borehole water sources across the study area were presented in Table 2.

Table 2: Average radon concentration and resulting annual effective doses.

S/N	Sources	No Of Samples	Statistical Factor	A_{Rn} (Bq/L)	AED_{Ing} Adults (µSv/y)	AED_{Ing} Children (µSv/y)	AED_{Ing} Infants (µSv/y)	AED_{Inh} All Ages (µSv/y)
1.	Surface	6	Range	0.13-2.91	0.92-21.22	1.38-31.83	1.61-37.140	0.32-7.33
			Mean±SD	1.80±0.01	13.13±0.90	19.69±1.30	22.97±1.60	4.53±0.30
2.	Well	9	Range	3.06-9.57	22.37-69.83	33.55-104.74	39.14-122.19	7.72-24.10
			Mean±SD	5.99±0.02	43.27±1.80	65.24±2.70	76.11±3.20	15.01±0.60
3.	Borehole	5	Range	3.19-12.07	23.29-88.11	34.93-132.17	40.75-154.19	8.04-30.42

		Mean±SD	7.97±0.04	58.16±2.70	87.24±4.00	89.78±4.70	20.08±0.90
All (Overall)	20	Range	0.13-12.07	0.92-88.11	1.38-132.17	1.61-154.19	0.32-30.42
		Mean±SD	5.21±0.03	37.95±2.50	57.08±3.80	66.59±4.40	13.14±0.90

With reference to Figures 2 and 3, the specific activity of the radon concentration and the resulting annual effective doses due to inhalation and ingestion from the studies area, increases simultaneously with depth of the water sources; borehole water sources have the highest depth hence the highest concentration, while surface water sources have the lowest concentration due to its shallow depth. In general, the concentration level was higher in ground water (borehole and well) sources compared to the surface water sources. The associated increasing trend in the radon concentration and the resulting annual effective doses corroborated with that of the previous studies such as Abba *et al*, (2020), Kalip *et al*, (2018) and Bello (2019). This observation could be related to diffusional losses and perennial aeration to the atmosphere by the surface water sources (Bello, 2019 and Abba *et al.* 2020).

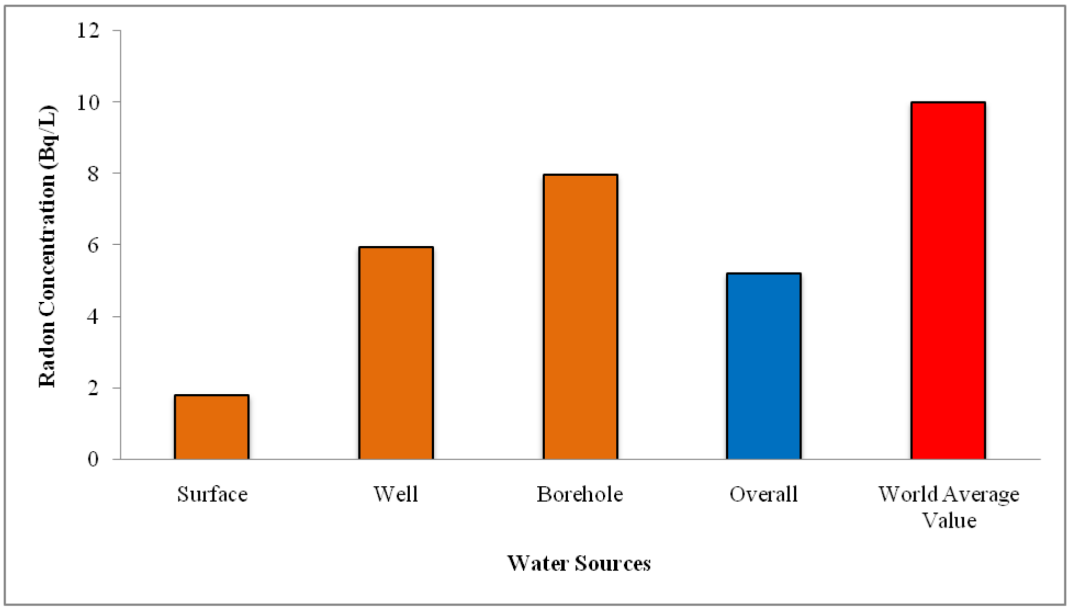

Figure 2: Average Specific Activity of Radon Concentration

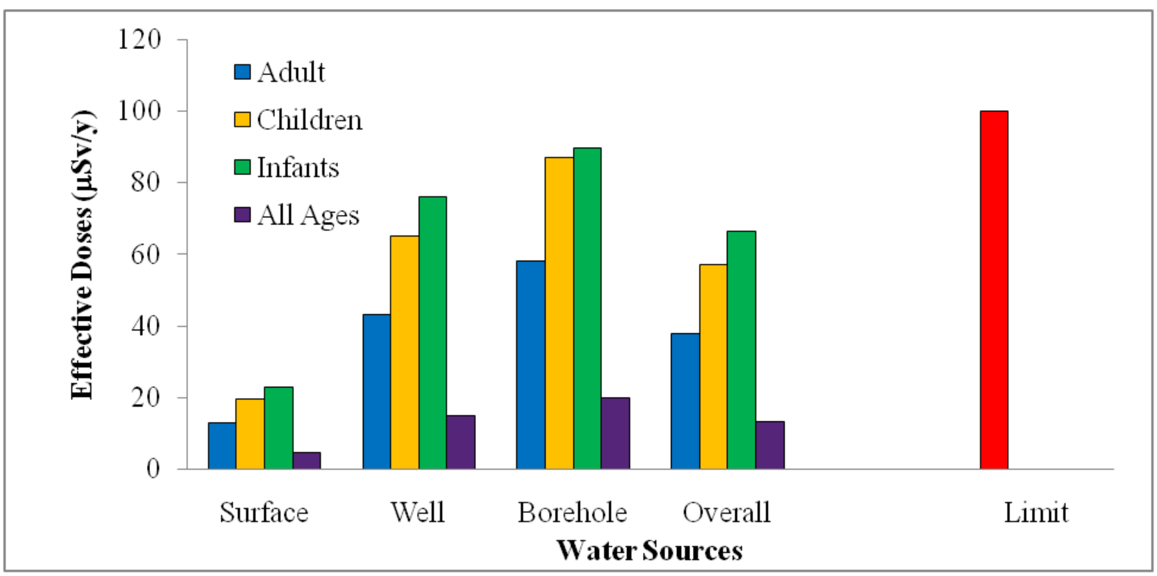

Figure 3: Annual Effective Doses due to ingestion and Inhalation

CONCLUSION

The mean specific activity of concentration of radon 5.21±0.03 Bq/L and the estimated average annual effective doses due to ingestion of radon37.95±2.5 µSv/y, 57.08±3.8 µSv/y and 66.59±4.4 µSv/y for adults, children and infants respectively; and inhalation 13.14±0.9 µSv/y (for all ages) from the three water sources (surface, well and borehole) were found to be within the maximum contamination level of 10Bq/L and 100µSv/y set by WHO for drinking water guidelines. In view of the above, the drinking water sources of the study area may not pose serious radiological health hazards due to the low level of radon concentration. However, while significant health risks have not been recorded for the analysis, it is still advisable that a good ventilation of bathroom, and kitchen areas should be ensured in order to prevent the build-up of airborne radon coming from the water sources. This is because showering, washing dishes, and laundering can disturb the water and release radon gas into the breathing air.

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