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Assessment of Excess Life Cancer Risk from Radon Concentration in Borehole water Samples collected from Katagum LGA, Bauchi State, Nigeria

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Abstract

Radon in potable water has turned out to be an issue of public health concerns, specifically when used immediately from supply for domestic purpose and consumption without any pretreatment. In this study, ^{222}*Rn Concentration in 15 water samples collected from ground water sources (borehols) in Katagum local government Bauchi State was determined, using Liquid scintillation counter (Tri-Carb-LSA1000) and the radiological risk was calculated. The study revealed that,* ^{222}*Rn concentration ranges from 28.44 to 49.61* $\mathrm{Bql^{-1}}$ *with mean value of 39.55* $\mathrm{Bql^{-1}}$*. These values were found to be higher than the permissible limits set by WHO, USEPA and UNSCEAR. The mean value of annual effective dose due to ingestion for different age categories (adults, children and infants) are 0.29, 0.43 and 0.51* $\mathrm{mSvy^{-1}}$ *respectively; and for inhalation the mean is 0.1* $\mathrm{mSvy^{-1}}$*. Also, the mean value of excess life cancer risk due to ingestion for different age groups (adults, children and infants) are 0.0010, 0.0015 and 0.0018 respectively while that of inhalation is 0.0003. Thus, this study reveals that borehole water around Katagum Local Government Area Bauchi State is not radiologically safe and there is need for constant monitoring.*

Keywords: Radon, Borehole, water, cancer risk, Katugum

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INTRODUCTION

Water remains the most abundant and critical commodity that guarantees the continuity of human lives on earth. Ensuring cleanliness of water for human consumption is therefore of paramount importance (Abba *et al*., 2020). Water is vital for life's survival, its availability and quality is important for day to day activities (Khaled, 2020). However, preserving the quality of water is not easy, but this needs to be given adequate attention because of potential hazards attached to water. Water can be contaminated with pollutants such as, toxic chemicals, infectious agents and radionuclides (Oni, 2022).

The existence of radionuclides in drinking water gives rise to internal exposure, directly via their decay processes, through ingestion, inhalation, and indirectly, when they are combined as part of the food chain (Duenas *et al*., 1999). Radon ingested in drinking water will deliver a radiation dose to the stomach lining and other internal organs (Hopke, *et al*., 2000). In situations such as showering, washing clothes, and boiling water, some of the dissolved radon is released from the water and mixed with indoor air (Jalili, 2012; Martins et al 2020). Radon is soluble in water and is a naturally occurring radioactive inert gas with a half-life of 3.82 days which is a member of the Uranium decay series (Somlai, 2007). The concentration of Radon in water is due to the decay of Radium-226 associated with rocks and soil (Shilpa, 2017). The radon gas penetrates through soil and rocks and dissolves in water (Xinwei, 2006). Normally, drinking water from groundwater sources has higher concentration of radon than surface water (Ahmad, 2017).

More than 95% of the people in Katagum, Bauchi, Nigeria depends on the ground water that has not undergone any preliminary test to determine its quality for consumption and other activities (Chifu, 2016). From the preceding works, many places in Nigeria are radiologically contaminated. Therefore, studying the degree of radioactivity in water within Katagum local government area of Bauchi State is necessary.

Many researches have been carried out on assessment of radon and annual effective dose within and outside the country. However, despite many works within the country, but yet there is little data recorded in the north eastern part of Nigeria, specifically the study area. Furthermore, most of research is carried out without calculating some important parameters like annual effective dose and excess lifetime cancer risk due to inhalation and ingestion for different age categories (infant, children and adult). Herein, this study determines excess life cancer risk due to inhalation and ingestion of radon. The study also goes further to calculate annual effective dose due to inhalation and ingestion for different age categories (infant, children and adult).

METHODOLOGY

Study Area

Katagum is one of the twenty (20) local government area of Bauchi state, Nigeria. It is located in the northern geophysical zone of Nigeria. It lies between latitude at 11°40′27″N and 10°11′28″E at an elevation of 436 meters. It consists of fifteen (15) wards namely: Nasawa bakin Kasuwa, Tsakuwa kofa Gabas, kafin Kuka, Madangala, Madara, Ragom, Magonshi, Gambaki, Bidir, Chinade, Bulkachuwa, Yayu, Madachi, Gangai and Buskuri. It is bordered by Damban LGA to the east, Misau Local Government to the south, Jama'are Local Government to the west and Itas/Gadau Local Government Area of Bauchi State to the north.

Katagum is underlain by undifferentiated rocks of the basement complex which have been subjected to weathering that produced a fairly deep regolith (Kogbe, 1976). The rocks are of Precambrian origin and consist of metamorphic and igneous rock types common among which are the granite descriptions; migmatite, gneisses and Phillies. The granite dominates the structures, hence, is refered to as the Older Granites (Carter, 1963). In most areas underlain by the Basement complex is a thin, discontinuous mantle of weathered rocks. Previous geological studies of Katagum are few. However, Carter (1963) has described aspects of the geology of the Upper Benue Trough, and the hydrogeology of parts of Bauchi State. The stratigraphic succession the upper Benue Trough consists of folded Cretaceous sediments called the Bima Sandstones unconformable overlying the Precambrian to Paleozoic Basement. This is succeeded by the Cretaceous Gombe sandstones which pass upwards into the Tertiary sands of the Kerri-Kerri Formation. The sequence is terminated by the Quaternary Chad Formation .

Materials

The materials used in this research are plastic sample bottles, disposable hypodermic syringe (20, 10, and 2 ml capacity) with 38 mm (1in) hypodermic needle, surgical globe, distill water, Scintillation vial (20 ml capacity) with polyethylene inner seal cap liners, Scintillation cocktail, indelible ink and masking tape, Liquid scintillation counter (Packard Tri-Carb LSA 1000TR).

Sample Collection

A total of fifteen (15) borehole water samples were collected from fifteen different wards in the study area. 750 ml plastic pop cola bottles were used as sample containers. The sample containers were washed and rinsed with ionized water before the collection of the water samples. To ensure fresh samples are collected, the borehole water samples were collected after operating it for at least three (3) minutes prior to the collection. The sample containers were filled to the brim to prevent CO_2 from being trapped and dissolved in water (which may likely affect the chemical content) and were tightly closed immediately to prevent Radon gas from escaping during transportation to the laboratory. Masking tape was used to mark and label all the collected samples. GPS metre was used to measure the coordinate (latitude and longitude) of the sample collection points (Table 1). All the collected samples were transported immediately to the Center for Energy Research and Training (CERT) Zaria, for preparation and analysis.

Table 1: Name of Sample Location, Sample ID, Longitude and Latitude

S/N	Sample Location	Sample ID	Longitude	Latitude
1	Tsakuwa kofar Gabas	AB01	10°11'51.27"	11° 40'38.64"
2	Kafin kuka	AB02	10°11'29.46"	11° 40'16.32"
3	Nasarawa Bakin Kasuwa	AB03	10°11' 33.52"	11° 40'42.24"
4	Madangala	AB04	10° 9'05.15"	11° 38'44.52"
5	Madara	AB05	10° 9'11.00"	11° 46'28.56"
6	Ragom	AB06	10° 6'10.08"	11° 44'30.48"
7	Magonshi	AB07	10° 7'41.16"	11° 44'18.96"
8	Gambaki	AB08	10° 21'46.44"	11° 35'12.12"
9	Bidir	AB09	10° 12'08.28"	11° 37' 27.12"
10	Chinade	AB10	10° 25'01.20"	11° 31'19.20"
11	Bulkacuwa	AB11	10° 30'47.52"	11° 38'51.72"
12	Yayu	AB12	10° 30'47.52"	11° 38'51.72"
13	Madachi	AB13	10° 25'37.92"	11° 29'50.64"
14	Gangai	AB14	10° 30'26.64"	11° 32'56.76"
15	Buskuri	AB15	10° 19'13.08"	11° 38'56.76"

Sampling Preparation

About 10 ml of each sample was added into a scintillation vial containing 10 ml of install gel scintillation cocktail. The vials were tightly sealed and then shaken thoroughly for three minutes to extract ^{222}Rn in the water phase into the organic scintillator.

Sample Analysis

The prepared samples were analyzed using liquid scintillation counter (Tri-Carb-LSA1000) located at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. The samples were analyzed after they were allowed to stay for three hours after preparation, to allow for radioactive equilibrium between ^{222}Rn and its daughter progeny to be established. Calibration of the liquid scintillation counter was made prior to the analysis using IAEA ^{226}Ra standard solution. For the calibration, the ^{226}Ra standard samples were counted for 60 min. For background, background count measurements were also made for same period (60 min).

The Radon concentration in Bq/L for borehole water samples was determined using equation 1. (Garba, 2018; Dankawu *et al.,* 2021).

$$\mathrm{Rn}\ (\mathrm{Bql}^{-1}) = \frac{100\times(SC-BC)\exp\,(\lambda t)}{60(CF)\times(D)} \tag{1}$$

where, Rn = Radon concentration in Bql^{-1}, SC = Sample count rate (count/min), BC is Background count rate (count/min), t = Elapsed time from sampling to testing given in minutes, CF = Calibration factor and D is Decay time.

The annual effective dose due to inhalation and ingestion and total annual effective dose for different age groups (adult, children and infant) was determined equation 2, 3 and 4. (Abba *et al.,* 2020; Dankawu *et al.,* 2021).

$$\mathrm{AED}_{\mathrm{inh}} = \frac{CRn\times RW\times F\times T\times DF}{1000} \tag{2}$$

$$\mathrm{AED}_{\mathrm{ing}} = K\times G\times C\times 1000 \tag{3}$$

$$T_{\mathrm{AED}} = \mathrm{AED}_{\mathrm{inh}} + \mathrm{AED}_{\mathrm{ing}} \tag{4}$$

where, $\mathrm{AED}_{\mathrm{inh}}$ and $\mathrm{AED}_{\mathrm{ing}}$ is the annual effective dose in mSvy^{-1} due to inhalation ingestion of radon release from water, CRn & C is the concentration of ^{222}Rn in water in Bql^{-1}, RW is the ratio of radon released to air when water use to radon in water (10^{-4}), F is the equilibrium factor between radon and its product (0.4), T is the average residence time of individual in the interior (7000 h/yr), DF is the conversation dose factor 9nSv (Bqhm^{-3})$^{-1}$, 1000 is the conversation factor micro Sievert to mile Sievert. K & G is the dose coefficient and water ingestion rate (7×10^{-8}, 2×10^{-8}, and10^{-8}) and (182.5, 547.5 and 730 ly^{-1}) for infants, children's and Adult respectively, (UNSCEAR, 2000). TAED is the total annual effect dose in (mSv/y), AEDinh and AEDing are the annual effective dose due to inhalation and ingestion for Infant, children and adult respectively.

The excess life cancer risk due to inhalation and ingestion was calculated using equation 5 and 6 (Dankawu *et al.*, 2021; Adamoh *et al.,* 2021).

$$\mathrm{ELCR}_{\mathrm{inh}} = \mathrm{AED}_{\mathrm{inh}} \times \mathrm{LE} \times \mathrm{RF} \tag{5}$$

$$\mathrm{ELCR}_{\mathrm{ing}} = \mathrm{AED}_{\mathrm{ing}} \times \mathrm{LE} \times \mathrm{RF} \tag{6}$$

where $\mathrm{ELCR}_{\mathrm{inh}}$ and $\mathrm{ELCR}_{\mathrm{ing}}$ are the excess life cancer risk for inhalation and ingestion, $\mathrm{AED}_{\mathrm{inh}}$ and $\mathrm{AED}_{\mathrm{ing}}$ are the annual effective dose for inhalation and ingestion for different age groups, LE = life expectancy 70 years and RF is the fatal risk factor per Sievert (S/v).

RESULT AND DISCUSSION

Results

The results obtained for the Radon concentration in borehole water samples are presented in Table 2. The Annual Effective Dose for inhalation and ingestion were also estimated together with total annual effective dose in mSvy^{-1} and the excess life cancer risk for inhalation and ingestion were estimated.

Table 2. Results for ^{222}Rn Concentration and Annual Effective Dose due to Inhalation and ingestion and total annual effective dose

S/N	SAM ID	^{222}Rn conc. (Bql^{-1})	AED$_{inh}$ (mSvy^{-1})	AED$_{Ing(A)}$ (mSvy^{-1})	AED$_{Ing(c)}$ (mSvy^{-1})	AED$_{ing(I)}$ (mSvy^{-1})	TAED$_{(A)}$ (mSvy^{-1})	TAED.$_{(C)}$ (mSvy^{-1})	TAED$_{(I)}$ (mSvy^{-1})
1	AB01	39.0047	0.10	0.2847	0.4271	0.498286	0.383027	0.52394	0.59658
2	AB02	40.7925	0.10	0.2978	0.44668	0.521124	0.400582	0.549475	0.62392
3	AB03	49.6121	0.13	0.3622	0.54325	0.633795	0.487191	0.668275	0.75882
4	AB04	35.906	0.09	0.2621	0.39317	0.458699	0.352596	0.483653	0.54918
5	AB05	48.897	0.12	0.3569	0.53542	0.624659	0.480169	0.658643	0.74788
6	AB06	46.6921	0.12	0.3409	0.51128	0.596492	0.458516	0.628943	0.71416
7	AB07	33.1051	0.08	0.2417	0.3625	0.422918	0.325092	0.445926	0.50634
8	AB08	29.3091	0.07	0.214	0.32093	0.374424	0.287816	0.394794	0.44828
9	AB09	47.1688	0.112	0.3443	0.5165	0.602582	0.463198	0.635364	0.72145
10	AB10	48.897	0.12	0.3569	0.53542	0.624659	0.480169	0.658643	0.74788
11	AB11	30.2924	0.07	0.2211	0.3317	0.386985	0.297471	0.408038	0.46332
12	AB12	43.7721	0.11	0.3195	0.4793	0.559189	0.429842	0.58961	0.66949
13	AB13	28.445	0.07	0.2076	0.31147	0.363385	0.27933	0.383155	0.43507
14	AB14	39.6602	0.10	0.2895	0.43428	0.50666	0.389464	0.534224	0.6066
15	AB15	31.6332	0.08	0.2309	0.34638	0.404114	0.310638	0.426099	0.48383
MEAN		39.54582	0.10	0.288673	0.433025	0.505198	0.38834	0.532682	0.604853

^{222}Rn concentration (Bql^{-1}) for borehole water samples was obtained as in Table 2. The results reveal that the ^{222}Rn concentration varies from 28.45 to 49.61 Bql^{-1}, with mean value of 39.55 Bql^{-1}. All the values are found to be within the accepted value of 100 Bql^{-1} as recommended for public water supplies (WHO, 2008; EU, 2001). However, these values were higher than accepted value of 11.1 and 10 Bql^{-1} set by USEPA (1999) and SON (2003), world average value of 10 Bql^{-1} set by WHO (1993). The highest concentration of ^{222}Rn may be attributed to the fact that radon readily dissolves in water under pressure which lead to the radon accumulation in groundwater (Cho, 2004). The mean value of ^{222}Rn concentration obtained in this study is far above that in the study carried out by Farai et al., (2023); Kolo et al., (2023); Mostafa et al., (2022); Jideli et al., (2021); Abdullahi et al., (2020); Garba et al., (2017) and Garba & Hussaini, (2018), who found the ^{222}Rn concentration to be 14.3, 17.3, 18.8, 7.7, 2.4, 12.43 and 10.69 Bql^{-1} respectively. However, the results is slightly in accordance with study carried out by Abba et al., (2020) and Ajiboye et al., (2022) who found the mean ^{222}Rn concentration to be 34.7 and 35.9 Bql^{-1} respectively; but below the study conducted by Dankawu et al., (2021) and Adams (2017) with mean ^{222}Rn concentration of 83.77 and 64.66 Bql^{-1} respectively (Table 4).

The annual effective dose due to inhalation was found to be in the range 0.07 mSvy^{-1} to 0.13 mSvy^{-1} with the mean value of 0.10 mSvy^{-1}. The lowest value was obtained from AB13 while the highest value was obtained from AB03 sample. The annual effective dose due to ingestion for adults, children and infants was found to be from 0.21, 0.31 and 0.36 mSvy^{-1} to 0.36, 0.54 and 0.63 mSvy^{-1}, with mean value of 0.29, 0.43 and 0.50 mSvy^{-1}. All the values of annual effective dose due to inhalation were found to be lower than the maximum concentration value of 0.1 mSvy^{-1}, while that of ingestion were found to be above the accepted value of 0.1 and 0.2 mSvy^{-1} for adult and children as set by UNSEAR, (2008); WHO (2004) and EU (1998). The results show that annual effective dose due to inhalation decreases compared with the annual effective dose due to ingestion. Infants suffer high radon exposure compared to the children and Adults. This current result is in agreement with the result obtained for similar studies by Dankawu *et al.,* (2021) and Abba *et al.,* (2020).

Table 3. Excess Life Cancer Risk for Adults, Children and Infants for Borehole Water Samples.

S/N	Sample ID	$ELCR_{inh}$	$ELCR_{ingA}$	$ELCR_{ingC}$	$ELCR_{ingI}$
1	AB01	3.44×10^{-4}	9.97×10^{-4}	1.50×10^{-3}	1.74×10^{-3}
2	AB02	3.6×10^{-4}	1.04×10^{-3}	1.56×10^{-3}	1.82×10^{-3}
3	AB03	4.38×10^{-4}	1.27×10^{-3}	1.90×10^{-3}	2.212×10^{-3}
4	AB04	3.17×10^{-4}	9.17×10^{-4}	1.38×10^{-3}	1.61×10^{-3}
5	AB05	4.31×10^{-4}	1.25×10^{-3}	1.87×10^{-3}	2.19×10^{-3}
6	AB06	4.12×10^{-4}	1.19×10^{-3}	1.79×10^{-4}	2.09×10^{-4}
7	AB07	2.92×10^{-4}	4.6×10^{-4}	1.27×10^{-3}	1.48×10^{-3}
8	AB08	2.59×10^{-4}	7.49×10^{-4}	1.12×10^{-3}	1.31×10^{-3}
9	AB09	4.16×10^{-4}	1.21×10^{-3}	1.81×10^{-3}	2.11×10^{-3}
10	AB10	4.31×10^{-4}	1.25×10^{-4}	1.87×10^{-3}	2.19×10^{-3}
11	AB11	2.67×10^{-4}	7.74×10^{-4}	1.16×10^{-3}	1.35×10^{-3}
12	AB12	3.86×10^{-4}	1.12×10^{-3}	1.68×10^{-3}	1.96×10^{-3}
13	AB13	2.51×10^{-4}	7.27×10^{-4}	1.09×10^{-3}	1.27×10^{-3}
14	AB14	3.5×10^{-4}	1.013×10^{-3}	1.52×10^{-3}	1.77×10^{-3}
15	AB15	2.79×10^{-4}	8.08×10^{-4}	1.21×10^{-3}	1.41×10^{-3}
Mean		$\mathbf{3.49} \times 10^{-4}$	$\mathbf{1.01} \times 10^{-3}$	$\mathbf{1.52} \times 10^{-3}$	$\mathbf{1.77} \times 10^{-3}$

Table 3, shows that the excess life cancer risk due to inhalation for borehole water sample varies from 2.51×10^{-4} as the minimum value obtained from AB13 to 4.38×10^{-4} as the maximum value obtained from the AB03 with mean value of 3.49×10^{-4}. These values were found to be above the world average value of 2.9×10^{-4}, except the values of five (5) locations namely: AB07, AB08, AB11, AB13 and AB15. The excess life cancer risk due to ingestion for different age categories were found to be from 7.27×10^{-4}, 1.09×10^{-3} and 1.27×10^{-3} to 1.27×10^{-3}, 1.90×10^{-3} and 2.22×10^{-3} with mean value of 1.01×10^{-3}, 1.52×10^{-3} and 1.77×10^{-3} . All the value were found to be higher than the world average value of 2.9×10^{-4}, (Ibikunle et al., 2018).

Table 4 presents a comparisons of Radon concentration in ground water obtained in this study with other locations within Nigeria.

Table 4 Comparison of ^{222}Rn Concentration(Bql^{-1}) with nearby Locations

Location	Sources	^{222}Rn (Bql^{-1})	Reference
Jigawa	Ground Water	83.7	Dankawu, *et al.*, 2021.
Niger	Well and Borehole	17.3	Kolo, *et al.*, 2023.
Abeokuta	Ground Water	14.3	Farai, *et al.*, 2023.
Ondo	Ground Water	35.9	Ajiboye, *et al.*, 2022.
Lagos	Ground Water	18.8	Mostafa, *et al.*, 2022.
Ogun	Ground Water	7.7	Jidele, *et al.*, 2021.
Kano	Ground Water	2.4	Abdullahi, *et al.*, 2020.
Katagum	Borehole	39.55	Current study

CONCLUSION

In conclusion, the ^{222}Rn concentrations for water samples in Katagum Local Government, Bauchi State, Nigeria, was studied. The study covered radon concentration, estimation of annual effective dose from ingestion and inhalation for infant, children and adult, estimation of excess life cancer risk due to ingestion and inhalation for infant, children and adult.

The mean ^{222}Rn concentrations of water samples were found to be 39.5458 Bql^{-1}, which are above the accepted value of 11.1 Bql^{-1} as set by USEPA (1999), world average value of 10 Bql^{-1} (WHO, 1993; and UNSCEAR, 2002). The mean annual effective dose from inhalation and ingestion for different age categories (adults, children and infants) were found as 0.0997 mSvy^{-1} for inhalation and 0.2888, 0.4330 and 0.5051 mSvy^{-1} for ingestion respectively. All the values of the annual effective doses due to ingestion were found to be above the accepted value as set by the UNSCEAR (2008) and WHO (2004), however that of inhalation were within the acceptable range. The mean value of Excess life cancer risk due to inhalation and ingestion for different age categories (Adult, children and infant) from the corresponding annual effective dose for borehole were found above the world average of value of 2.9×10^{-4}. Most of the locations exceeded the guidelines for the intake of radionuclides in water of value 0.1 mSvy^{-1}. It is concluded that most of the sample locations are radiologically contaminated. Therefore, it is recommended that, the water from these locations should be treated before consumption and use for other domestic activities and further extensive studies should be done on large scale by initiating further detailed investigation of whole command area completely for radon contamination, to increase awareness and mitigate possible hazards.

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