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Determination Of Heavy Metals and Radon Concentration in Soil and Water Samples from Wadi-B Jere Oil Exploration Sites in Maiduguri, Northeast Nigeria

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Abstract

Radon gas and heavy metals are two significant risk factors that can cause lung cancer. Wadi B, a locality in Jere local government of Borno state, is an area where oil exploration is underway. There is a potential health risk of contamination of the drinking water and soil samples in the area. To investigate radon concentration and heavy metal contamination, several samples of water from wells and boreholes, as well as soil samples, were collected for analysis. The analysis was conducted using liquid scintillation (LSC) and atomic absorption spectrometry. The result of radioactivity analysis using LSC shows that water samples have varying levels of radon concentration ranging from 17.77 Bql^{-1} to 22.50Bql^{-1} which exceeded the maximum contaminant levels of 11.1Bq/L set by the USEPA 1999 and the world average value of 10Bq/L set by the World Health Organisation (WHO 2004). The mean annual effective cancer risk of radon intake varied across sampling points, ranging from 0.164, 0.246, 0.287 to 0.130, 0.218, and 0.227 for adults, children, and infants, respectively, with mean values of 0.146, 0.219, and 0.255. The mean values of excess lifetime cancer risk (ELCR) associated with radon inhalation and ingestion for adults, children, and infants were 0.0005110, 0.0007660, and 0.0008930, respectively. Moreover, elevated conductivity and total dissolved solids in water samples suggest potential contamination, exceeding the recommended limits set by the World Health Organization. On the other hand, Heavy metals analysis shows a mean value of ELCR 0.125009 for adults and 0.000063 for infants. Results showed that heavy metal concentrations in soil samples exceeded permissible limits for all metals except chromium and lead, with the order of concentration being Cr < Cd < Pb < Cu < Zn. These findings underscore the need for ongoing monitoring and remediation efforts to mitigate environmental and health risks in Wadi B

Keywords: AAS, Heavy Metals, LSC, Radiation, Radon

INTRODUCTION

Exposure to radionuclides and heavy metals poses significant health risks to humans, with the potential for adverse effects such as cancer and poisoning (Mgbukwu, 2023.; Nduka *et al.*, 2023), While low levels of exposure occur naturally, industrial activities have contributed to increased human exposure to these toxic substances (Mgbukwu, 2023). The accumulation of heavy metals and radon can have toxic effects on various tissues and organs, disrupting cellular processes and causing long-term health issues (Bedassa, 2022; Kalip, 2020; Samuel *et al.*, 2022). Consequently, it is crucial to prioritize measures to mitigate human exposure to radionuclides and heavy metals to protect public health (Usman *et al.*, 2023). Moreover, recent studies have highlighted the detrimental effects of heavy metals on cellular processes such as growth, multiplication, differentiation, and damage-repairing mechanisms (Kalip, 2020). These naturally occurring elements, with atomic weights and densities at least five times greater than water, are used in various industries, agriculture, medicine, and technology, leading to their widespread environmental distribution (Pereira *et al., 2024)*. This widespread distribution has raised concerns about their potential impact on human health and the environment (Samuel *et al.*, 2023)

Furthermore, the presence of radon in drinking water and air, in addition to other sources of exposure, poses a significant hazard to human health (Mgbukwu, 2023). Radon, a type of noble gas, is radioactive and can cause cancer through ingestion and inhalation (Mgbukwu, 2023). Despite being colourless and odourless, it can form compounds and become chemically reactive, adding to its health risks (Mgbukwu, 2023). Measuring radon contamination in groundwater used for drinking is crucial for assessing and mitigating health risks (Mgbukwu, 2023). Addressing the risks associated with radionuclides and heavy metals requires comprehensive strategies to minimize human exposure and protect public health and the environment (Mgbukwu, 2023.; Nduka *et al.*, 2023). Effective management of radiation hazards and heavy metal pollution is essential to ensure the well-being of current and future generations.(Blessing & Usman, 2023; Rilwan, 2023; Shafqat, 2023)

Various research studies have been carried out to investigate the levels of heavy metals and radon present in drinking water, as well as to evaluate the corresponding annual effective cancer risk, both in Nigeria and beyond. A study by (Ajiboye *et al*., 2022) has examined the levels of radon concentration in water in South western Nigeria. Nevertheless, it is important to note that water can contain many other possibly harmful elements, such as cadmium, lead, chromium, arsenic, and selenium, due to usual processes like tectonic activity and erosion, as well as human activities like fossil fuel combustion and industrial (Faweya *et al*., 2018). Even at low concentrations, these elements can generate free radicals that may cause oxidative stress and harm biological molecules and DNA (Jidele *et al*., 2021). Another research was conducted by (Dankawu *et al.* 2021) aiming at estimating the excess lifetime cancer risk and annual effective dose for borehole and well water samples. Their findings suggested that the water in the study area is not safe for domestic purposes and drinking. Despite numerous research articles on radon, there is limited data recorded in the north eastern part of Nigeria. Additionally, there has been no research conducted on radon analysis in water in the study area. Furthermore, many studies are carried out without calculating the annual effective dose and excess lifetime cancer risk due to inhalation and ingestion for different age categories.

This study aims to bridge the existing knowledge gap by examining the levels of radon and heavy metals in the north eastern region of Nigeria, specifically in Wadi-B Jere Local Government, Borno State. Current assessments often fail to consider important factors such as the annual effective dose and excess cancer risk. Thus, this research will focus on analysing carefully selected boreholes and well water sources to determine the concentrations of heavy metals and radon. Through measuring heavy metal levels, evaluating radon concentrations, calculating the annual effective dose from inhalation, and assessing the associated excess cancer risk, this study intends to offer valuable insights into environmental health hazards in the region.

METHODOLOGY

The Study Area

Wadi B is a remote and scarcely populated region, encompassing an area of around 13 square kilometers. The region's population is less than 500, and they have been compelled to leave their homes due to insurgency. Wadi B is situated in a flat terrain with no visible rocks, and the land is covered with dense forestation and dark brown clay soil. The coordinates of Wadi B are latitude N 12°9'30.001'' to N 12°9'40.001'' and longitude E 13°10'27.732'' to E 13°10'30.341''. Additionally, the region experiences an average temperature of about 26.9°C, which remains relatively constant throughout the summer and winter seasons (Magrin & Montclos, 2018).

Table 1: Sample locations and their corresponding co-ordinates in the town

S/N	*Sample location*	*Sample ID*	*Latitude*	*Longitude*
1	Gajiganna	FYM1WW&1BW	12°6'53.25085''N	13°7'19.61945''E
2	Tungushe	FYM2WW&2BW	12°15'25.04001''N	13°6'22.834''E
3	Tuba	FYM3WW&3BW	12°12'17.35898''N	13°9'58.80748''E
4	Lumma	FYM4WW&4BW	12°2'22.13124''N	13°4'10.10448''E
5	Karnowa	FYM5WW&5BW	12°3'59.2829''N	13°4'15.55527''E

Sample collections/preparation

In Wadi B, Jere Local Government Area of Borno State, ten water samples were collected from five different wards. Each ward had two samples collected, one from a borehole and one from a local hand-dug well. Each sample was collected during the dry season and was placed in a clean 750 ml plastic bottle. To ensure no radon was present in the sample, the bottles were washed and rinsed with distilled water. Bailers were used to collect samples from the hand-dug wells, with the stagnant water purged several times to ensure fresh samples were obtained. Samples from the boreholes were operated for at least four minutes before collection to ensure fresh samples were obtained. The bottles were filled to the brim to prevent CO_2 from being trapped and dissolving in water, which could affect the chemical content. The bottles were then immediately closed to avoid loss of radon by degassing during transport to the laboratory. To ensure that radionuclides remained in the solution, rather than adhering to the walls of the container, concentrated nitric acid was added to the water. All samples were taken to Ahmadu Bello University Zaria for analysis at the Centre for Energy Research and Training (CERT). On the other hand, Soil samples were collected from five different locations within the study area, with samples taken from the top surface and 5 cm below the surface at each location. Upon collection, the samples were immediately placed in polyethylene bags, and nitric acid was added to prevent microbial growth and heavy metals loss. Coordinates and unique identifiers (IDs) were recorded for each sampling location. Subsequently, the samples were oven-dried to remove moisture and crushed to a fine consistency for homogeneity. Elemental analysis of soil and water samples was conducted using Atomic Absorption Spectrometry (AAS) at the Soil Science Laboratory, Bayero University Kano, to determine heavy metal concentrations. Dosimeters were employed to measure the background radiation levels at each sampling location to assess natural radiation influences. Data from the elemental analysis and radiation measurements were recorded systematically for further interpretation and reporting.

Sampling technique

Sample analysis for radon

We utilize a well-calibrated Liquid Scintillation Counter (Tri-carb-LSA 1000) located at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria, for sample analysis. It is significant to examine the samples three hours after preparation to institute radioactive equilibrium between ^{222}Rn and its daughter progeny. Calibrate the Liquid Scintillation Counter using IAEA ^{222}Rn standard solutions to maintain accuracy and consistency in measurements (Dankawu *et al.*, 2022).

Sample analysis for heavy metals

Atomic Absorption Spectroscopy (AAS) begins by digesting the sample to liberate metals into a solution. Next, the solution is fed into an AAS instrument, where the metals are vaporized and subjected to light at precise wavelengths. The degree of light absorption by the metals correlates directly with their concentration in the sample. By employing a calibration curve, the metal concentrations are precisely quantified. Rigorous quality control protocols are applied to guarantee result accuracy. In summary, AAS is a highly sensitive and accurate technique for assessing heavy metal levels across diverse sample types (Usman *et al.*, 2023).

Determine the radon concentration

The ^{222}Rn concentration in a sample of water will be determined using Equation 1 (Dankawu *et al.*, 2022)

$$\text{Rn}\ (Bql^{-1}) = \frac{100-(SC-BC)\exp\ (\lambda t)}{60(CF)} \qquad 1$$

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

Annual effective cancer risk

The annual effective cancer risk due to inhalation of radon in water was calculated using equation (2) below as proposed by the United Nations Scientific Committee on the Effects of Atomic Radiation (Janković *et al.*, 2023; Nduka *et al.*, 2023).

$$C_{inh} = \frac{CRn \times RW \times F \times T \times DF}{1000} \quad 2$$

where C_{inh} is the annual effective cancer risk ($mSvy^{-1}$) from inhalation of radon released from water into the air, C_{Rn} is the 222Rn concentration in water (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 (7000h/y), DF is the conversation dose factor 9nSv ($Bqhm^{-3}$), 1000 is the conversation factor micro Sievert to mile Sievert.

Excess Life Cancer Risk

Radiation dose due to ingestion for different age categories was calculated using Equation 2 to determine the annual effective dose.

$$ELCR = AEDE \times DL \times RF \quad 3$$

Where AEDE is the annual effective dose mSv/y, DL is the life expectancy (70 years) and RF is the fatal risk factor per Sievert (Sv). In the case of stochastic effects, ICRP-60 uses an RF of 0.05 for the public

Ingestion of Heavy Metals through

$$ADI_{ing} = \frac{C \times IR \times EF \times ED \times CF}{BW \times AT} \quad 4$$

Where ADIing is the average daily intake of heavy metals ingested in mg/kg-day, IR in mg/day is the ingestion rate, C = conc. of Heavy Metals in mg/kg, EF in days/year is the exposure frequency, ED is exposure duration in years, BW is the body weight of the exposed individual in kg, AT is period, and CF is the conversion factor in kg/mg(Mohammadi *et al.*, 2019).

Inhalation of Heavy Metals through

$$ADI_{inh} = \frac{C_s \times IR_{air} \times EF \times ED}{BW \times AT \times PEF} \quad 5$$

Where ADI_{inh} is the average regular intake of heavy metals gasped in mg/kg-day, IR_{air} = is the gasped rate in m^3/day, and C_S is = concentration of Heavy Metals in mg/kg, EF, ED, BW, and AT are defined earlier in Equation 4

Dermal Contact

$$ADI_{dems} = \frac{C_S \times SA \times FE \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \quad \mathbf{6}$$

Where ADI_{dems} is the exposure dose via dermal contact in mg/kg/day, C_S is the concentration of Heavy Metals in mg/kg, SA is the exposed skin area in cm^2, and ABS is the portion of the applied dose enthralled athwart of the skin. EF, ED, BW, CF, and AT are defined earlier in equation 4

Total excess life cancer risk **7**

$$Risk_{total} = Risk_{ing} + Risk_{inh} + Risk_{decimal}$$

Where $Risk_{ing}, Risk_{inh}$ *and* $Risk_{decimal}$ are risk contributions through ingestion, inhalation, and dermal pathways respectively (Mohammadi *et al.*, 2019)

RESULTS AND DISCUSSION

Table 2 Heavy Metal Concentration in collected water samples

Sample ID	Cr(mg/kg)	Cu(mg/kg)	Cd(mg/kg)	Pb(mg/kg)	Zn(mg/kg)
1A	ND	33.31	21.38	24.14	50.3
1B	ND	41.32	21.72	28.49	49.61
2A	ND	29.83	8.47	17.98	44.72
2B	ND	40.13	6.95	9.54	21.99
3A	0.13	77.31	4.05	34.21	119.23
3B	ND	8.25	1.18	ND	10.32
4A	0.06	46.3	2.26	10.01	59.52
4B	0.19	42.22	2.17	10.86	48.23
MIN	0.06	8.25	1.18	9.54	10.32
MAX	0.19	77.31	21.72	34.21	119.23
Mean	**0.126667**	**39.83375**	**8.5225**	**19.31857**	**50.49**

In Table 3, we can see the Total Cancer Risk (TCR) and Annual Dose Intake (ADI) for Adults based on the average values of various heavy metals, ranging from 50.49 Zn to 0.13 Cr. When we consider both ingestion and inhalation, the Annual Dose Intake (ADI) for Adults falls between 1.3×10^{-1} Cr, 4.6×10^{-9} Zn to 5.0×10^{-6} Cd, and 5.3×10^{-12}. The Dermal and Cancer Risk for these heavy metals also vary, with dermal risk ranging between 0.13 to 1.2×10^{-5} and cancer risk ranging between 0.25 to 1.7×10^{-5} with an average of 0.125009. Among these heavy metals, chromium has the highest cancer risk while cadmium has the lowest value see Figure 1. Chromium levels are within recommended limits set by USEPA (Belluck, 2023) USEPA, (1999), 100 for Cr and WHO, (2008), and 50 for Cr respectively. The mean daily intake of heavy metals cancer risk in children exposed is presented in Table 3 as the average daily intake (ADI) in mg/kg/day. The total cancer risk of children ranges from 1.262×10^{-4} to 3.166×10^{-7} with an average value of 0.00006326, exceeding the recommended limits established by the United States Environmental Protection Agency (USEPA) in 2006. The yearly dose intakes resulting from inhalation and ingestion vary from 9.340×10^{-6} and 2.128×10^{-9} to 1.388×10^{-7} and 5.339×10^{-12}, respectively. Furthermore, the dermal effect on the skin ranges from 3.166×10^{-7} to 1.262×10^{-4}. Notably, Figure 2 indicates that children are not affected by chromium.

Table 3 Average daily intake (ADI) Heavy Metals cancer Risk in mg/kg/day for adults and children

RECEPTOR	*PATHWAYS*	*Cr*	*Cu*	*Cd*	*Pb*	*Zn*
ADULT	*Average*	0.127	39.833	8.523	19.319	50.490
	ADI $_{ing}$	0.127	2.339×10^{-5}	5.003×10^{-6}	1.134×10^{-5}	2.964×10^{-5}
	ADI $_{inh}$	5.340×10^{-12}	3.598×10^{-9}	7.698×10^{-10}	1.745×10^{-9}	4.560×10^{-9}
	DERMAL	1.267×10^{-1}	5.792×10^{-5}	1.239×10^{-5}	2.809×10^{-5}	7.341×10^{-5}
	RISK total	**2.533** $\times10^{-1}$	**8.131** $\times10^{-5}$	**1.740** $\times10^{-5}$	**3.943** $\times10^{-5}$	**1.031** $\times10^{-4}$
CHILD	*Average*	0.127	39.833	8.523	19.319	50.490
	ADI $_{ing}$	1.388×10^{-7}	4.365×10^{-5}	9.340×10^{-6}	2.117×10^{-5}	5.533×10^{-5}
	ADI $_{inh}$	5.339×10^{-12}	1.679×10^{-9}	3.592×10^{-10}	8.143×10^{-10}	2.128×10^{-9}
	DERMAL	1.778×10^{-7}	5.592×10^{-5}	1.196×10^{-5}	2.712×10^{-5}	7.088×10^{-5}
	RISK total	**3.166** $\times10^{-7}$	**9.958** $\times10^{-5}$	**2.130** $\times10^{-5}$	**4.829** $\times10^{-5}$	**1.262** $\times10^{-4}$

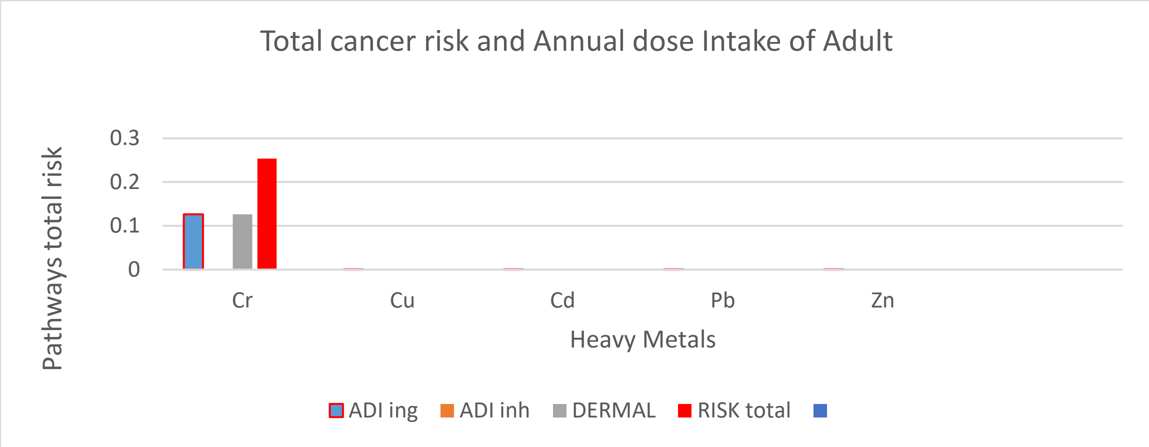

Figure 1 Total Cancer Risk (TCR) and Annual Dose Intake (ADI) for Adults

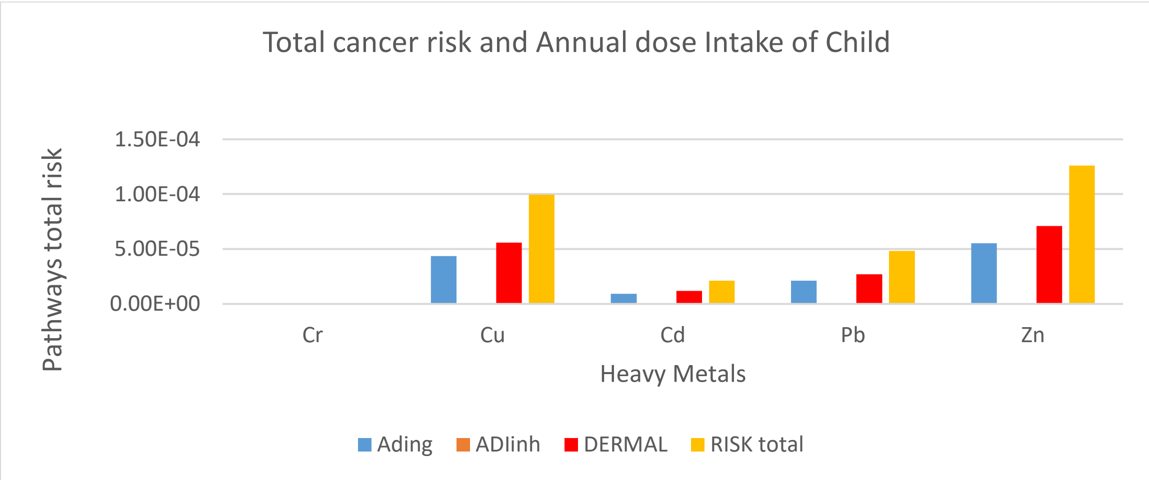

Figure 2 Total cancer risk (TCR) and Annual Dose Intake (ADI) for children

Table 4 The analysis of radon concentration in water samples collected from various locations in Wadi B town, Jere local government area, Borno state, revealed noteworthy findings, as depicted in Table 4. The concentration of $^{222\,\text{radon}}$ ranged from 22.50 to 17.77 Bq/L, with a mean value of 20.00 Bq/L, as illustrated in Figure 4.8. The highest concentration was recorded at FYM1 BW, while the lowest concentration was observed at FYM4 BW, as indicated in Figure 4.6. Of significance is the observation that all values obtained from the samples exceeded the maximum contaminant levels of 11.1 Bq/L set by the USEPA, (1999) and the world average value of 10 Bq/L established by the World Health Organisation (WHO 2008). However, it's noteworthy that despite these exceeding, the mean concentration of ^{222}Rn remained below the recommended guideline of 100 Bq/L, as established by the WHO in 2008. This analysis underscores the urgency for further investigation and remedial action to address the elevated levels of radon in the water sources of Wadi B. It highlights the importance of ongoing monitoring and regulatory measures to ensure compliance with established guidelines and protect public health in the region.

Table 4: Results Of ^{222}Rn (Bq/L) and their corresponding Water Sample Identity, AEDs (mSv/y) to Ingestion for both Adult, Child, and Infant.

SAM ID	*Rn.Con*	*Rn(Bq/l)*	*AED_{inh}*	*$AED_{Ing(A)}$*	*AED_{IngI}*	*$AED_{ing(I)}$*
FYM1 ww	77.33	21.91971722	0.055237687	0.160013936	0.240020904	0.280024387
FYM2 ww	76.67	21.52641017	0.054246554	0.157142794	0.235714191	0.27499989
FYM3 ww	71.55	18.4753009	0.046557758	0.134869697	0.202304545	0.236021969
FYM4 ww	71.65	18.53489288	0.04670793	0.135304718	0.202957077	0.236783257
FYM5 ww	74.05	19.96510035	0.050312053	0.145745233	0.218617849	0.255054157
FYM1 BW	78.30	22.49775941	0.056694354	0.164233644	0.246350465	0.287408876
FYM2 BW	74.92	20.48355055	0.051618547	0.149529919	0.224294879	0.261677358
FYM3 BW	71.90	18.68387282	0.04708336	0.136392272	0.204588407	0.238686475
FYM4 BW	70.37	17.77211556	0.044785731	0.129736444	0.194604665	0.227038776
FYM5 BW	74.02	19.94722275	0.050267001	0.145614726	0.218422089	0.254825771
MIN	70.37	17.77211556	0.046557758	0.129736444	0.218422089	0.227038776
MAX	78.30	22.49775941	0.056694354	0.164233644	0.246350465	0.287408876
MEAN	**74.076**	**19.98059**	**0.050351**	**0.145858**	**0.218788**	**0.255252**

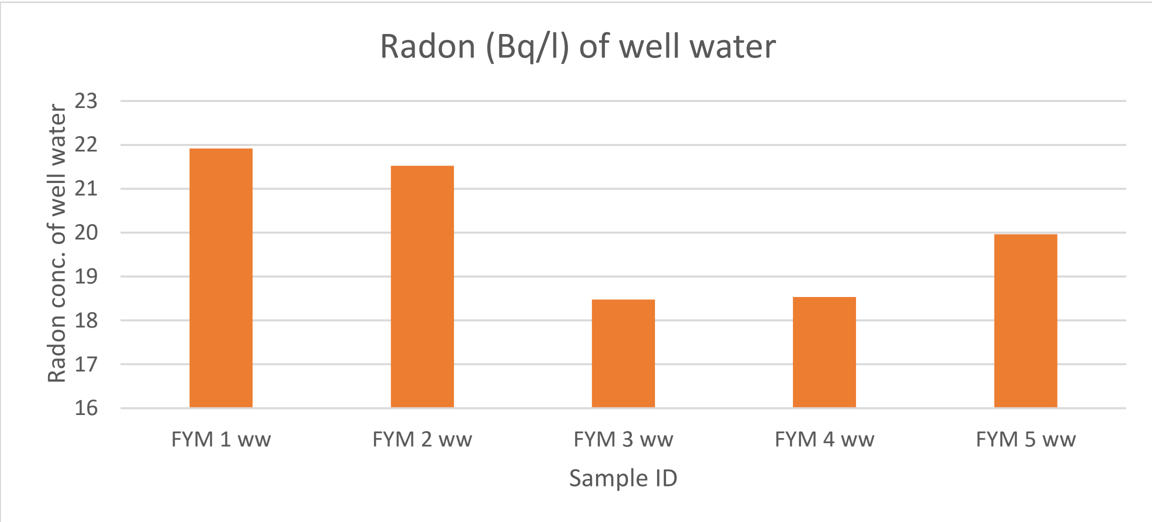

Figure 3: Represents a bar chart showing the sample location of well water with corresponding Radon concentration

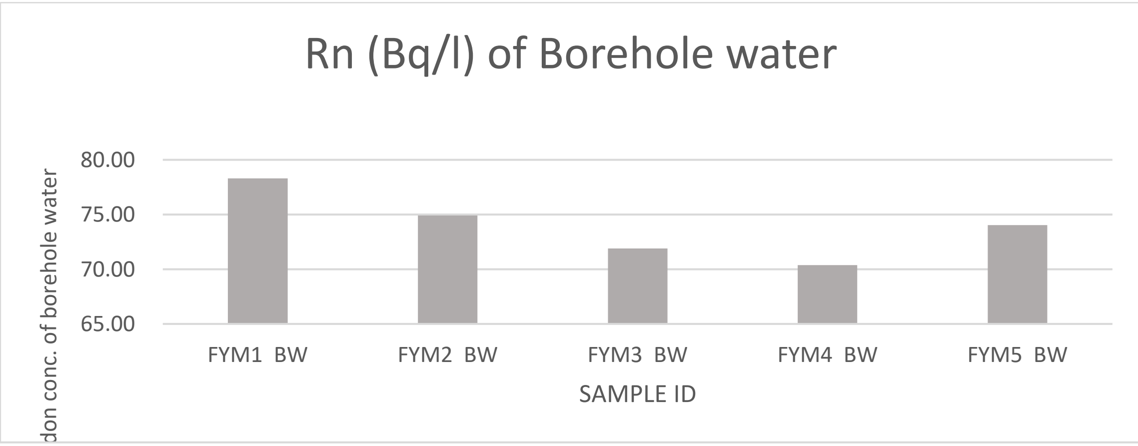

Figure 4: Bar chart showing the sample location of Borehole water with corresponding Radon concentration

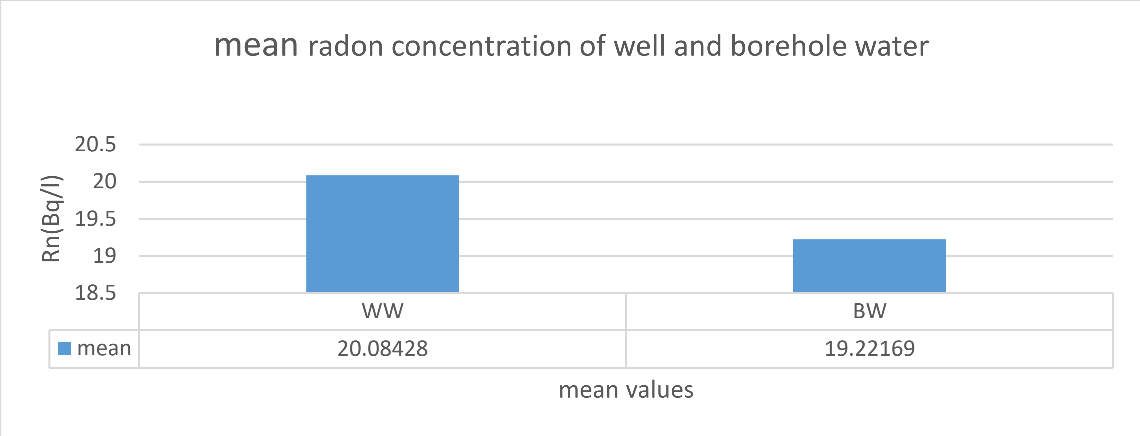

Fig 5: Comparison between the mean value of radon concentrations of well and borehole water samples.

Table 6 is a comparison between the concentration of ^{222}Rn in Wadi B Jere Local Government Area, Borno State, Nigeria, and other regions of the country is presented in Table 6 and Figure 6. Based on the findings of this study, it can be inferred that the concentration of ^{222}Rn in Wadi B Jere is similar to that in Nasarawa, 1.7 times lower than in Sokoto, 4.2 times lower than in Jigawa, and 2.6 times higher than in Ota.

Table 6: Comparison of ^{222}Rn concentration from Wadi B with other parts of Nigeria.

Location	*^{222}Rn concentration(Bq/L)*	*references*
Nasarawa	19.62	Rilwan, 2023
Dutse	83.77	Dankawu *et al.*, 2022
Ota	7.70	Jidele *et al.*, 2020
Sokoto	34.00	Abba *et al.*, 2020
Wadi B	20.14	current study, 2024

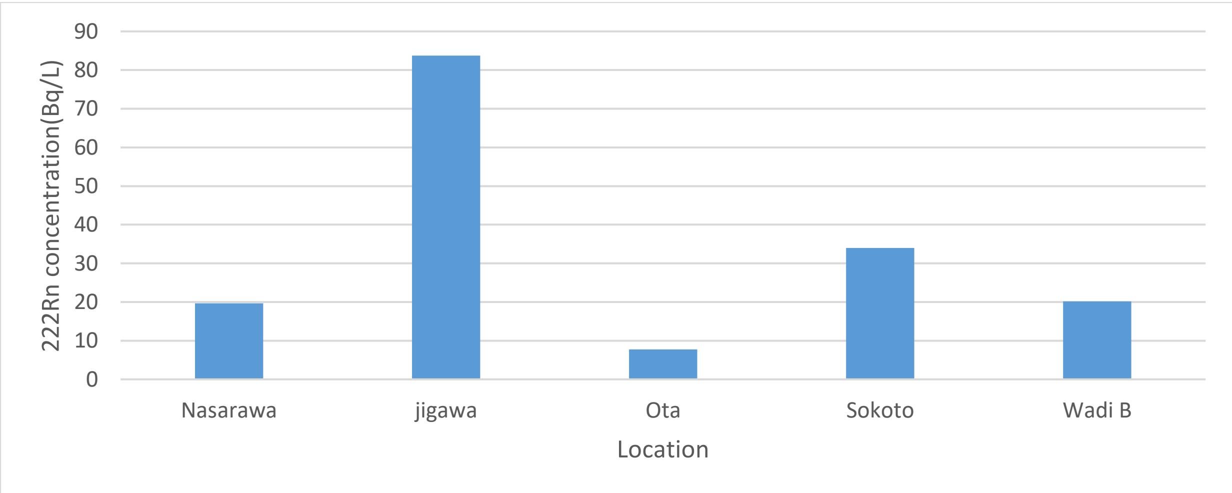

Figure 6: the relationship between ^{222}Rn concentrations from Wadi B with other parts of Nigeria.

Table7 a comparison of ^{222}Rn concentrations from Wadi B Jere Local Government Area in Borno State, Nigeria with other countries is presented in Table 7 and Figure 7. The findings of this study reveal that the concentration of 222Rn obtained in this study is lower than all the compared values, except for Ikogosi, which is 100.7 times less. Specifically, the value obtained in this study is 18.9 times lower than that of Saudi Arabia, 4.6 times lower than that of India, and 1.7 times lower than that of Kirkuk City.

Table 7: Comparison of ^{222}Rn concentration from Wadi B with other parts of the World.

Location	*222Rn concentration(Bq/L)*	*reference*
Saudi Arabia	381.05	El-Araby *et al*., 2021
Ikogosi	0.2	Faweya *et al*., 2018
India	93.22	Nayak *et al*., 2021
Kirkuk City	33.89	Kareem *et al*., 2019
Wadi B	20.14	current study, 2024

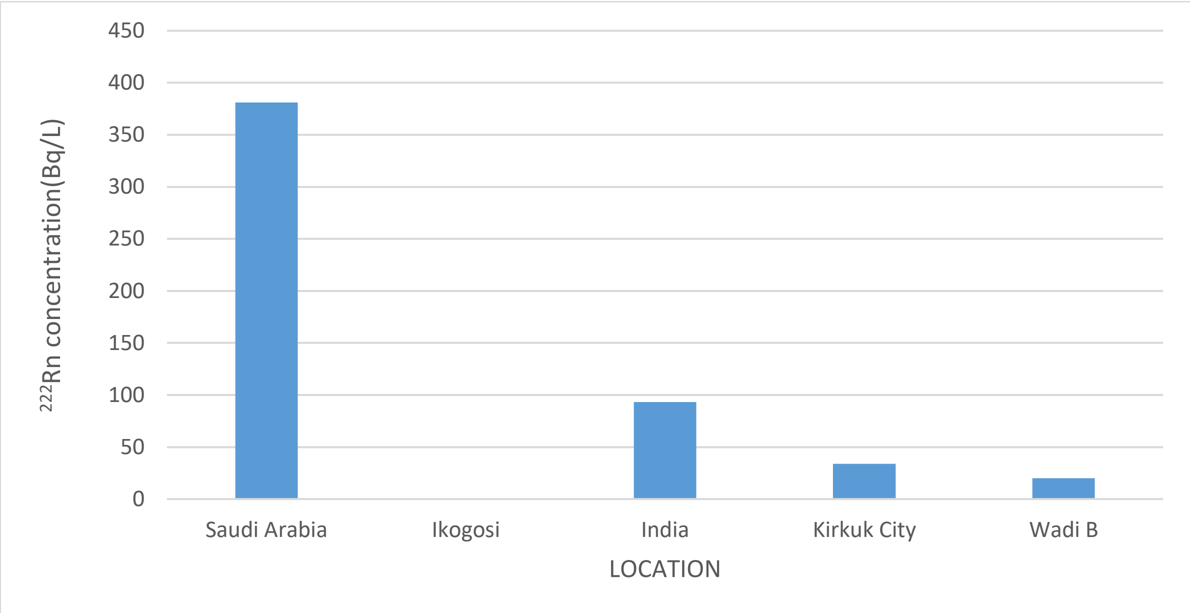

Figure 7: Relationship between ^{222}Rn concentrations from Wadi B Jere Local Government Area Borno State Nigeria with other countries

Table 8 displays the annual effective doses resulting from ^{222} radon intake in Well and Borehole Water samples at various locations in Wadi B town, Jere local government area, Borno state. The results demonstrate that the annual effective doses range from (0.160014-0.13487) mSv/y, (0.240021-0.202305) mSv/y, and (0.280024-0.236022) mSv/y, with mean values of 0.146615, 0.219923, and 0.256577 for adults, children, and infants in mSv/y, respectively and borehole water samples, the corresponding annual effective doses range from 0.164234-0.129736 mSv/y to 0.287409-0.227039 mSv/y, with mean values of 0.145101, 0.217652, and 0.253927 for adults, children, and infants, respectively. FYM1 WW and FYM4 BW represent the maximum and minimum annual effective doses, respectively, for all three age categories. The average mean values for both well and borehole water samples are 0.145858, 0.218788, and 0.255252 for adults, children, and infants, respectively.

It is important to note that all estimated annual effective doses exceeded the recommended reference level of 0.1mSv/y for radionuclide intake in water set by WHO (2004).

Table 8: Annual Effective cancer risk (mSv/y) Due to Ingestion for Adult (A), Child(C), and Infant (I)

SAM ID	AED_{inh}	$AED_{Ing(A)}$	$AED_{Ing(c)}$	$AED_{ing(I)}$
FYM 1 ww	0.055238	0.160014	0.240021	0.280024
FYM 2 ww	0.054247	0.157143	0.235714	0.275
FYM 3 ww	0.046558	0.13487	0.202305	0.236022
FYM 4 ww	0.046708	0.135305	0.202957	0.236783
FYM 5 ww	0.050312	0.145745	0.218618	0.255054
FYM1 BW	0.056694	0.164234	0.24635	0.287409
FYM2 BW	0.051619	0.14953	0.224295	0.261677
FYM3 BW	0.047083	0.136392	0.204588	0.238686
FYM4 BW	0.044786	0.129736	0.194605	0.227039
FYM5 BW	0.050267	0.145615	0.218422	0.254826
MIN	0.044786	0.129736	0.194605	0.227039
MAX	0.056694	0.164234	0.24635	0.287409
MEAN	**0.050351**	**0.145858**	**0.218788**	**0.255252**

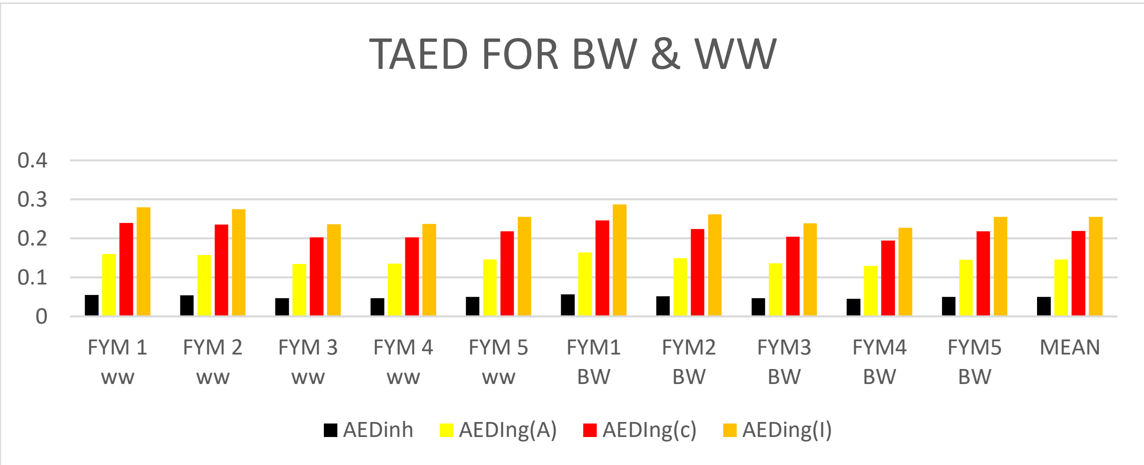

Figure 8: Total Annual Effective Cancer Risk Due to Ingestion (Adults, Children & Infants) for Boreholes and Well Water samples

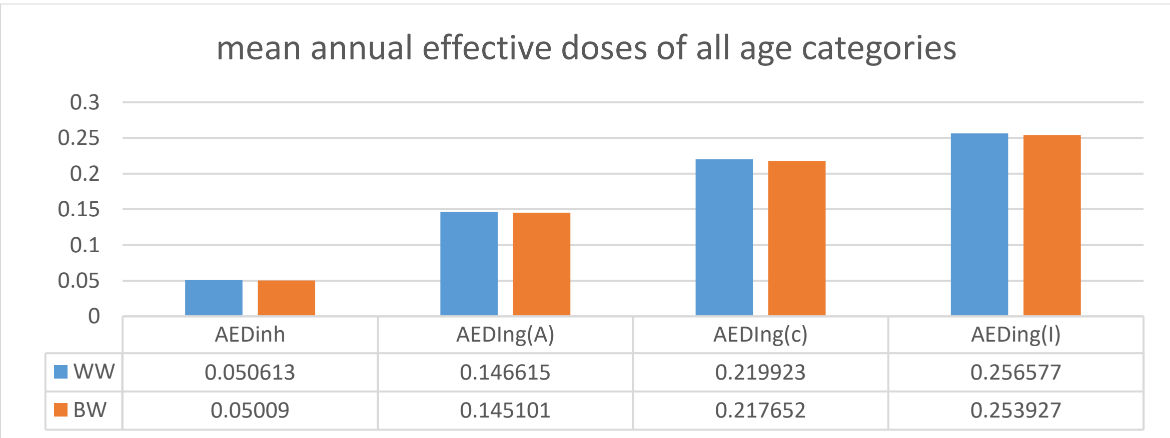

Figure 9: Bar graph of mean annual effective cancer risk (Adults, Children & Infants) for Boreholes and Well Water samples

Table 9 is the annual effective cancer risk caused by inhalation of water samples was analysed, and the results showed the cancer risk at points FYM3 WW and FYM1 BW ranged from 0.000198-0.000163. The mean value was 0.0001760. The cancer risk from ingestion was also evaluated and found to vary depending on age groups. For adults, the range was 0.0005748-0.0004541, for children, it was 0.0008622-0.0006811, and for infants, it was 0.0010059-0.0007950. The mean values for adults, children, and infants were 0.0005110, 0.0007660, and 0.0008930, respectively.

Table 9 Excess Life Cancer Risk Due to Ingestion and Inhalation

SAM ID	*$ELCR_{(INH)}$*	*$ELCR_{(ING)A}$*	*$ELCR_{(ING)C}$*	*$ELCR_{(ING)I}$*
FYM1 WW	0.0001933	0.00056	0.0008401	0.0009801
FYM2 WW	0.0001899	0.00055	0.000825	0.0009625
FYM3 WW	0.000163	0.000472	0.0007081	0.0008261
FYM4 WW	0.0001635	0.0004736	0.0007103	0.0008287
FYM5 WW	0.0001761	0.0005101	0.0007652	0.0008927
FYM1 BW	0.0001984	0.0005748	0.0008622	0.0010059
FYM2 BW	0.0001807	0.0005234	0.000785	0.0009159
FYM3 BW	0.0001648	0.0004774	0.0007161	0.0008354
FYM4 BW	0.0001568	0.0004541	0.0006811	0.0007946
FYM5 BW	0.0001759	0.0005097	0.0007645	0.0008919
MIN	0.000163	0.0004541	0.0006811	0.000795
MAX	0.0001984	0.0005748	0.0008622	0.0010059
MEAN	0.000176	0.000511	0.000766	0.000893

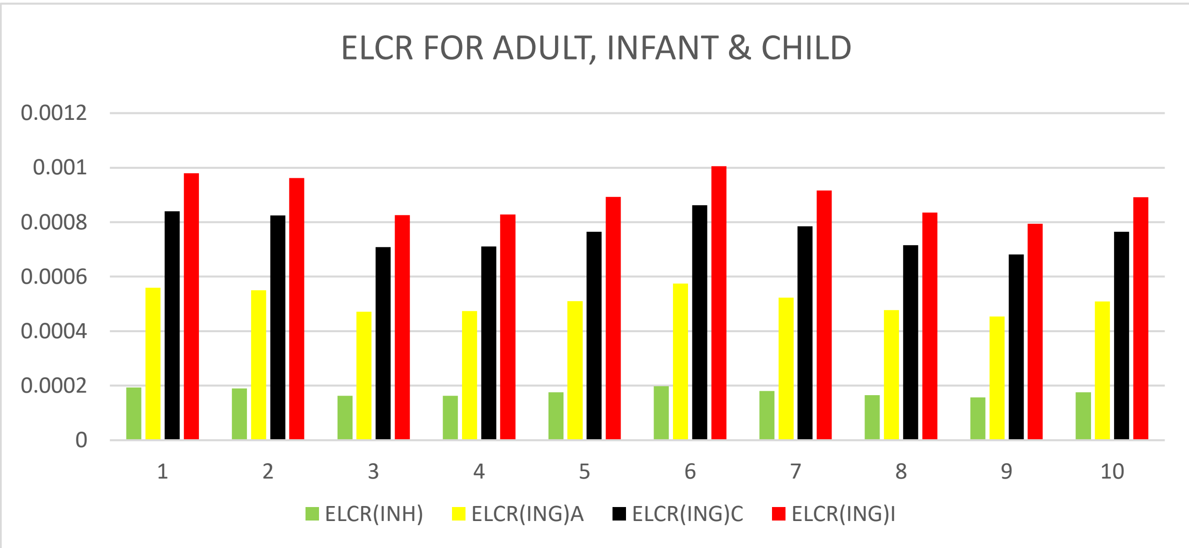

Fig 10: Excess life cancer risk due to ingestion and inhalation

CONCLUSION

The findings from the investigation in Wadi B, Borno state, underscore the significant environmental and health risks associated with radon gas and heavy metal contamination in both water and soil. The detected radon concentrations in water samples, along with the calculated annual effective cancer risk and excess lifetime cancer risks, highlight the potential health hazards faced by residents, particularly vulnerable groups such as children and infants. Moreover, the elevated levels of conductivity and total dissolved solids in water samples exceeding WHO limits indicate compromised water quality. The presence of heavy metals in soil and water samples further accentuates the environmental challenges, necessitating urgent interventions to mitigate pollution and safeguard public health and the ecosystem.

Continuous monitoring and strict regulatory enforcement are imperative to address these issues effectively and ensure the sustained well-being of the community in Wadi B.

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