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CANCER HEALTH RISKS ASSESSMENT FROM SELECTED BOREHOLE AND WELL WATER SAMPLES IN DUTSE, JIGAWA STATE, NIGERIA

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ABSTRACT

Radon being one of the major radioactive elements to human health among those contributing to background radiation. Due to its relatively heavy particles, radon's alpha radiation can only travel short distances. While it cannot penetrate the skin, it can be inhaled and accumulate in the lungs. Herein, a total of ten borehole and well water samples was collected across five different selected wards in Dutse, the state capital of Jigawa state and analyze for Radon concentration. Liquid scintillation counter located at Ahmadu Bello University Zaria, Centre for energy research Zaria, was used to analyzed samples. The mean value of Radon concentration for well and borehole water samples was found to be 22.39 and 22.39 Bql^{-1} respectively, which exceeded the acceptable range of 10 Bql^{-1} by WHO (1993), and the world average value of 11.1 Bq/L set by the USEPA (1999); UNSCEAR (1993), and SON (2003). The annual effect tive dose and excess life cancer risk due to inhalation were found to be below the standard recommended value of WHO. However, for the annual effective dose and excess life cancer risk due to ingestion for both well and borehole water samples were found to be above the recommended value set by different standard organization. The finding of this study revealed that water used in these samples location is not safe for drinking and other domestic uses. As such we strongly recommended that the water used in these locations should undergo special treatment before used to avoid any possible health risk associated with water, more especially stomach cancer.

Keywords: Radon Concentration, Health Risk Assessment, Excess Lifetime Cancer Risk (ELCR), Jigawa State, Liquid Scintillation Counting

INTRODUCTION

Water is the most constituent of the Earth's streams, oceans, lakes and the fluid of most of the living organisms. Almost 71% of the Earth surface was covered by water. Water is crucial not only for sustaining life but also for socio-economic development of a country (Abdulrasheed *et al.,* 2025; Dankawu *et al.,* 2022). However, its availability in the right quality remains a great challenge. Water are uses by Humans for various purpose such as power generation, transportation, agriculture as well as other important undeniable domestic activities. Ensuring free contamination of water from microbiological, chemical and radiological is paramount important (Adamoh, 2021; Ajiboye *et al.,* 2022). The total radiation exposure receive by humans are significantly contributed by natural sources. Human exposure to radiation are highly account by natural radiation with Rn decay being the major contributor, despite the highly use of manmade radiation in medical centers, industries and sceintific research establishments. Water is a crucial resource for the existence and survival of mankind and the importance of good quality drinking water cannot be over emphasized. A large portion of the world's population depends on groundwater (i.e. wells, bore holes) for their survival (Daniela *et al.,* 2023; Zarma *et al.,* 2023).

Radon, the heaviest element of the noble gases in the elemental periodic table, Radon is a natural radioactive element which are found in rocks, soils and water (Shuaibu *et al.,* 2024). Radon with atomic number 86, is a naturally occurring radioactive inert gas, with over twenty-six isotopes, the most important isotopes in terms of their radiological significance are: ^{222}Rn (radon) and ^{220}Rn (thoron). Being decay products of the primordial radioactive elements, uranium and thorium, respectively, ^{222}Rn and ^{220}Rn are ubiquitous in all human environments. Most of the radon to which people are exposed emanates from soil and rock. The other sources of significance are building materials, potable water, and natural gas (UNSCEAR, 1993). The link between residential radon and lung cancer among the general public is not unequivocal (Jidele *et al.,* 2021). Dissolved radon is easily released into the air when the water is used for showering, cleaning and other everyday purposes in homes. Only about 1–2 % of radon in the air comes from drinking water. However, breathing radon released to air from tap water increases the risk of lung cancer. Some radon stays in the water; drinking water containing radon also presents a risk of developing internal organ cancers, primarily stomach cancer (Dankawu *et al.,* 2024). However, this risk is smaller than the risk of developing lung cancer from radon released to air from tap water. Based on the report of National Academy of Science, the United States Environmental Protection Agency (USEPA, 1999) estimates that radon in drinking water causes about 168 cancer deaths per year, 89 % from lung cancer caused by breathing radon released to the indoor air from water and 11 % from stomach cancer caused by consuming water containing radon. (USEPA, 2008). Naturally occurring ^{222}Rn, belonging to the ^{238}U decay-series, is an inert gas and thus found at a highly enriched level in ground waters and underground spaces. Since radon and its daughters produce many alpha and beta particles, its inhalation or ingestion may cause cancers in human organs, particularly in the lungs (Kalip *et al.,* 2024). Thus, assessing radon in water, in addition to that in air, is an important step in reducing potential exposure to it. Also, ^{222}Rn has been used as an excellent tool for tracing many environmental and geophysical processes such as gas exchange across the air sea surface (Garba *et al.,* 2017). ^{222}Rn is the most stable and abundant isotope of radon which has a half-life of 3.8 days. It decays by emitting an alpha particle of 5.49 MeV and creates radioactive daughters. In terms of nature, radon is usually found in the air and being soluble in the water in all the water sources on the Earth including lakes, rivers, oceans, underground waters, springs and even in atmospheric precipitation. Radon is a player of a dual role in man's life. On one hand its presence in soil, waters and rocks has been used to predict the earthquake occurrence, volcanic activities, and fault dislocation and in hydrological research, also its presence in high level in indoor environment and drinking water constitutes a major health hazard for mankind because of its carcinogenic effects (Yashaswini *et al.,* 2020).

In Nigeria and here in Northern part, particularly Dutse Jigawa State, lack of safe drinking water is one of the serious threats to the human health as a result, rivers, streams, well and borehole waters are often used as alternative to the scarce pipe-borne water for drinking and other domestic use. Previous study by Dankawu *et al.* (2022) shows that most of the water used in Dutse are radiologically contaminated. Herein this article aim to assess the level of Radon concentration for some selected boreholes and well water samples in Dutse, the state capital of Jigawa state. The study will go further to estimate some important radiological parameters, with regard to human health associated with Radon

MATERIALS AND METHODS

Sample Collection

A total of twenty-two (10) water samples were collected from five (5) different wards in Dutse the state capital of Jigawa state, Nigeria. Six hand-dug well and four borehole water sample were collected across the selected ward. A plastic bottle was used for sample collection and analyzed for ^{222}Rn concentration. The plastic bottle was washed and rinsed with distilled water to avoid radon existence in the sample from being contaminated, the hand dug wells water samples were collected with the aid of bailers, with the stagnant water in the wells first been purged many times by drawing it out and allowing the wells to refill in order to assure that fresh samples were obtained, while boreholes water samples was collected after operating for at least four minutes prior to collection. This is to ensure fresh samples are obtained. The bottles were filled to the brim to avoid CO_2 from being trapped then closed immediately to avoid loss of radon by degassing during transport to the laboratory. 20ml of Concentrated Nitric (V) acid (HNO_3) was added to the water to ensure radionuclides remain in solution, rather than adhering to the walls of the container. All samples were transported to the Center for Energy Research and Training, Ahmadu Bello University Zaria (CERT) for preparations and analysis.

Sample Preparation

About 10 mL of each sample was added into a scintillation vial containing 10 mL of insta-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

A well calibrated Liquid Scintillation Counter (Tri-Carb-LSA1000) located at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria – Nigeria. Were used to analyzed the prepared samples. The samples were analyzed three hours after preparation, to allow for radioactive equilibrium between ^{222}Rn and its daughter progeny to be established.

Equation 1,2,3,4,5 & 6 was used to determined ^{222}Rn concentration, Annual Effective dose due to inhalation and ingestion for different age categories (adult, children and infant), excess life cancer risk inhalation and ingestion for different age groups (adult, children and infant) for boreholes and local hand dug-wells water sample as determine by (Dankawu *et al.,* 2021; Madaki *et al.,* 2024; UNSCEAR, 1993; UNSCEAR, 2000).

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

$$AEDinh = CRn \times RW \times F \times T \times DF \times 1000 \quad (2)$$

$$AEDing = K \times G \times CRn \times 1000 \quad (3)$$

$$ELCRinh = AEDinh \times LE \times RF \quad (5)$$

$$ELCRing = AEDing \times LE \times RF \quad (6)$$

Where:

Rn = Concentration of radon in Bq/L, SC = Count rate of the sample (counts/min), BC = Count rate of the background (counts/min), t = Time elapsed between sample collection and analysis, in minutes, 0.964 = Fraction of ^{222}Rn in the cocktail in a 22 mL total capacity vial, consisting of 10 mL of the sample, 10 mL of cocktail, and 2 mL of air, 5 = Number of emission per count, CRn = Concentration of 222Rn in water (Bq/L), T = Average residence time of an individual indoors (7000 hours per year), F = Equilibrium factor between radon and its decay products (0.4), RW = Ratio of radon released to air from water use to radon concentration in water (10^{-4}), G = Water ingestion rate (547.5 L/year for children, 182.5 L/year for infants, and 730 L/year for adults), K = Dose coefficient (2×10^{-8} for children, 7×10^{-8} for infants, and 1×10^{-8} for adults), 1000 = Conversion factor from Sv to mSv DF = Conversation dose factor 9nSv $(Bqhm^{-3})^{-1}$; AED_{inh} and AED_{ing} denote the annual effective dose in mSv per year due to the inhalation and ingestion of radon emitted from water, respectively, $ELCR_{inh}$ and $ELCR_{ing}$ are the excess life cancer risk for inhalation and ingestion, AEDinh and AEDing correspond to the annual effective doses from inhalation and ingestion for various age groups, LE indicates a life expectancy of 70 years, and RF represents the fatal risk factor of 0.05 per Sievert (S/v).

RESULTS AND DISCUSSION

Table 1: ^{222}Rn concentration in Bql^{-1} and annual Effective dose due to inhalation and ingestion in mSv/y for well water samples

S/N	Samples ID	Rn (Bq^{-1})	AED_{inh} (mSvy^{-1})	$AED_{Ing(A)}$ (mSvy^{-1})	$AED_{Ing(c)}$ (mSvy^{-1})	$AED_{ing(I)}$ (mSvy^{-1})
1	WLMW 1	24.95	0.06	0.18	0.27	0.32
2	WLMW 2	20.02	0.05	0.15	0.23	0.26
3	WKCH 3	25.06	0.06	0.18	0.27	0.32
4	WKCH 4	22.51	0.06	0.16	0.23	0.29
5	WDR 5	20.46	0.05	0.15	0.22	0.26
6	WDR 6	21.31	0.05	0.16	0.23	0.27
	Mean	22.39	0.06	0.16	0.24	0.29

A total of six (6) hand-dug well water samples were collected from three (3) different selected wards in Dutse, with aim of examining the level of Radon concentration and other important parameters. The study revealed that the radon concentration range from 20.02 Bql^{-1} to 25.06 Bql^{-1} with mean value of 22.39 Bql^{-1} see Table 1 and Fig. 1. The annual effective dose due to inhalation and ingestion for different age groups (infant, children and adult) are found to be 0.05, 0.15, 0.23 and 0.26 mSvy^{-1} to 0.06, 0.18, 0.27 and 0.32 mSvy^{-1}, with mean value of 0.06, 0.16, 0.24 and 0.29 mSvy^{-1} respectively. The minimum value of this study was obtained from WLMW 2 sample location while the maximum value was obtained at WKCH 3

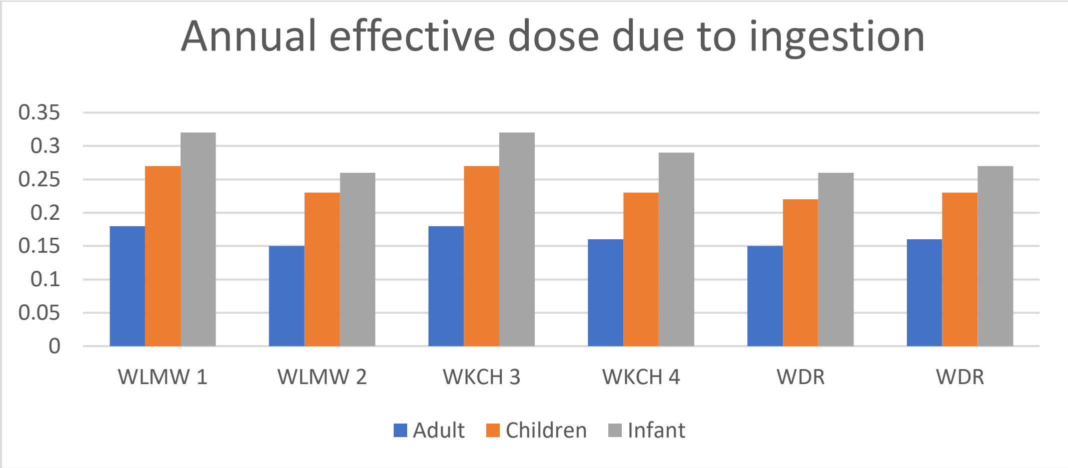

Figure 1: Annual effective dose due to ingestion for different age groups for well water samples

Table 2: Result for excess life cancer risk due to inhalation and ingestion for different age categories (Adult, child and infant) for well water samples

S/N	SAM ID	$ELCR_{(INH)}$	$ELCR_{(ING)A}$	$ELCR_{(ING)C}$	$ELCR_{(ING)I}$
1	WLMW 1	2.20 E-3	6.38 E-3	9.56 E-3	1.12 E-3
2	WLMW 2	1.77 E-3	5.12 E-3	7.67 E-3	8.95 E-3
3	WKCH 3	2.21 E-3	6.40 E-3	9.60 E-3	1.12 E-3
4	WKCH 4	1.99 E-3	5.75 E-3	8.63 E-3	1.01 E-3
5	WDR 5	1.80 E-3	5.23 E-3	7.84 E-3	9.15 E-3
6	WDR 6	1.88 E-3	5.44 E-3	8.17 E-3	9.53 E-3
	Mean	1.97 E-3	5.72 E-3	8.58 E-3	5.15 E-3

The excess life cancer risk due to inhalation and ingestion for different age categories (infant, child and Adult) for well water samples, from the corresponding annual Effective dose due to inhalation and ingestion were varies from 1.77, 8.95 E-3, 7.67 E-3, and 5.75 E-3 to 2.21 E-3, 1.12 E-3, 9.60 E-3, and 6.40 E-3 with mean value of 1.97 E-3, 5.15 E-3, 8.58 E-3 and 5.72 E-3 respectively. The minimum and maximum values were found at WLMW 2 and WKCH 3 respectively see Table 2.

Table 3: ^{222}Rn concentration in Bql^{-1} and annual Effective dose due to inhalation and ingestion in mSv/y for well water samples

S/N	Samples ID	Rn (Bq^{-1})	AED_{inh} (mSvy^{-1})	$AED_{Ing(A)}$ (mSvy^{-1})	$AED_{Ing(c)}$ (mSvy^{-1})	$AED_{ing(I)}$ (mSvy^{-1})
1	BKD 25	19.74	0.05	0.14	0.22	0.25
2	BKD 26	29.54	0.07	0.22	0.32	0.38
3	BCC 23	22.80	0.06	0.17	0.25	0.29
4	BCC 24	17.25	0.05	0.13	0.19	0.22
	Mean	22.33	0.06	0.17	0.24	0.29

Four (4) borehole water samples were collected from two (2) different selected wards in Dutse Kudai and Duru ward, with aim of assessing the level of Radon concentration and other important parameters. The study revealed that the radon concentration range from 17.25 Bql^{-1} to 29.54 Bql^{-1} with mean value of 22.33 Bql^{-1} see Table 3 and Fig. 2. The annual effective dose due to inhalation and ingestion for different age groups (infant, children and adult) are found to be 0.05, 0.22, 0.19 and 0.13 $mSvy^{-1}$ to 0.07, 0.38, 0.32 and 0.22 $mSvy^{-1}$, with mean value of 0.06, 0.29, 0.24 and 0.17 $mSvy^{-1}$ respectively. The maximum value of this study was obtained from BKD 26 sample location while the minimum value was obtained at BCC 24.

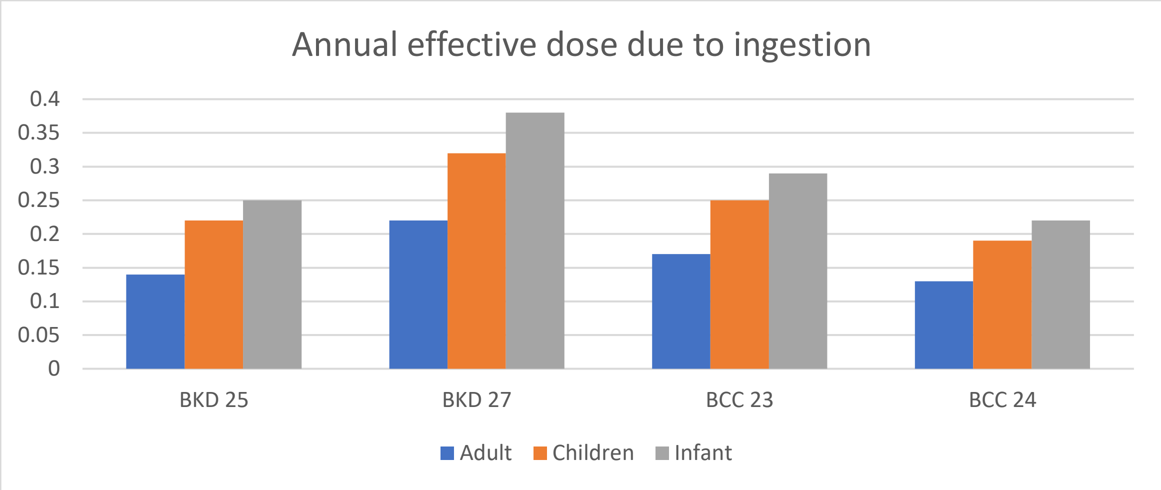

Figure 2: Annual effective dose due to ingestion for different age groups for borehole water samples

Table 4: Result for excess life cancer risk due to inhalation and ingestion for different age categories (Adult, child and infant) for well water samples

S/N	SAM ID	$ELCR_{(INH)}$	$ELCR_{(ING)A}$	$ELCR_{(ING)C}$	$ELCR_{(ING)I}$
7	BKD 25	1.74 E-3	5.04 E-3	7.56 E-3	8.83 E-3
8	BKD 26	2.61 E-3	7.55 E-3	1.13 E-2	1.32 E-2
9	BCC 23	2.01 E-3	5.82 E-3	8.74 E-3	1.02 E-2
10	BCC 24	1.52 E-3	4.41 E-3	6.61 E-3	7.71 E-3
	Mean	1.97 E-3	5.71 E-3	6.01 E-3	4.72 E-3

The excess life cancer risk due to inhalation and ingestion for different age categories (infant, child and Adult) for borehole water samples, from the corresponding annual Effective dose due to inhalation and ingestion were varies from 1.52 E-3, 7.71 E-3, 6.61 E-3, and 4.41 E-3 to 2.61 E-3, 1.32 E-2, 1.13 E-3, and 7.55 E-3 with mean value of 1.97 E-3, 4.72 E-3, 6.01 E-3 and 5.71 E-3 respectively. The maximum and minimum values were found at BKD 26 and BCC 24 respectively see Table 4.

Discussion

Ten (10) different water samples consisting of six well and four borehole water samples was collected and analyzed for Radon concentration across five different wards see Table1 and Table 3. The maximum value of this study was obtained from BKD 26 sample location while the minimum value was obtained at BCC 24 all corresponding to borehole water sample. The highest value obtained at BKD 26 sample location, may be as a result geological formation of the sample location, especially igneous rock Madaki et al., 2025. The mean Radon concentration for borehole and hand-dug well water samples were calculated to be 22.39 and 22.33 Bql^{-1} respectively. All the radon concentration values from both borehole and well water samples were found to be above 10 and 11.1 Bql^{-1} which is the accepted value set by WHO 1993; USEPA, 2008 and SON, 2003. But below the recommended value of 100 Bql^{-1} set by WHO, 2004 and UNSEAR, 1999 as shown in table 7. The finding of this study is also not in accordance with similar work carried out in India, Turkey, Iran as well as Malaysia as there are within the permissible limit (Sudhir, *et al*, 2016; Tabar and Yakut, 2014; Malakootian, *et al*, 2017; Nasar, *et a*l, 2015) as presented in Table 8. In comparison with previous work carried out within country Nigeria, this research is in line with study carried out Zaria, Lagos, Sokoto, Jos, Abeokuta, Dutsinma, Dutse as well as FUD as all the values were found to be above recommended value see Table 5. However, the study is not in agreement previous work conducted at Kaduna with value below the WHO standard.

All the values of annual effective dose due to inhalation were found to be far below the standard value set by WHO, 2004. Indicating that the water being used by the people of these communities are safe from long cancer according to Dankawu et al., 2022. However, all the values of annual effective dose due to ingestion for infant children and adult were found to be higher than the accepted value set by the WHO, 2008. However, the values of annual effective dose due to inhalation are far lower than the permissible limit set by WHO, 2004, except BCC 24 and BKD 25 sample location. Indicating that the water need proper treatment before used in order avoid any possible health risk, particularly stomach cancer. The finding of annual effective doses due to inhalation and ingestion for different age groups is in agreement with previous study carried out in Sokoto and FUD by Abba et al., 2020 and Madaki et al., 2024 respectively. However, the study is not in line with the previous study carried out in Dutse by Dankawu et al., 2021, as the value is almost 2.1 times higher than the accepted value as clearly seen in Table 8.

The mean values of the excess life cancer risk due to inhalation and ingestion for different age categories (infant, child and Adult) for borehole and well water samples, from the corresponding annual Effective dose were found to be 1.97 E-3, 4.72 E-3, 6.01 E-3 & 5.71 E-3 and 1.97 E-3, 5.15 E-3, 8.58 E-3 and 5.72 E-3 respectively. The maximum and minimum values were found at BKD 26 and BCC 24 respectively, corresponding to borehole water sample. However, all these values are below the permissible limit of unity as previously documented by Shuaibu *et al*., 2023, Madaki *et al.,* 2024 and Dankawu *et al*., 2022. This study is in agreement with previous study carried out by Abdultrashid et al., 2024, Shuaibu *et al*., 2024, Madaki *et al.,* 2024 and Dankawu *et al*., 2022, as all the findings were above the acceptable ranges of WHO standard of 2.9E-4.

Table 5: Comparison of ^{222}Rn Concentration obtained with previous Nigerian study

Locations	^{222}Rn Conc. (Bql^{-1})	Sources
Kaduna	10.69	(Garba and Hussaini, 2018).
Zaria	12.43	(Garba et al, 2017).
Lagos	18.8	(Mostafa et al., 2022)
Sokoto	34.00	(Abba et al, 2020).
Jos	17.00	(Aminu, 2020).
Abeokuta	14.3	Farai et al., 2023
Dutsinma	64.66	(Adams, 2017).
Dutse	83.77	(Dankawu *et al*,, 2021)
FUD	21.723	(Madaki et al., 2025)
Ogun	7.7	(Jidele et al., 2021)
Niger	17.3	(Kolo et al., 2023)
Ondo	35.9	(Ajiboye et al., 2022)
Dutse	22.33	Current study, 2025

Table 6: Comparison of ^{222}Rn Concentration obtained with world Standard

^{222}Rn Conc. (Bql^{-1})	Standards
10	UNSCEAR,1993; WHO, 2004
11.1	(USEPA, 2003)
11.1	SON
4.0-40.0	UNSCEAR, 1993
100	EU, 2001
21.723	(Current study, 2021)

Table 7: Comparison of ^{222}Rn Concentration obtained with Other Countries

Countries	^{222}Rn Conc. (Bql^{-1})	Sources
India	4.42	(Sudhir, *et al*, 2016).
Turkey	2.4	(Tabar and Yakut, 2014)
Iran	1.2	(Malakootian, *et al*, 2017)
Malaysia	14.7	(Nasar, *et a*l, 2015).
Dutse	22.33	Current study, 2025

Table 8: Comparison of annual effective doses due to inhalation and ingestion from Dutse with others related research

Locations	Einh (mSvy^{-1})	$E_A$ing (mSvy^{-1})	$E_C$ing (mSvy^{-1})	$E_I$ing (mSvy^{-1})	References
Sokoto	0.04	2.48	3.72	4.34	(Abba *et al.,* 2020).
Dutsinma	-	0.47	0.944	3.304	(Adams, 2017).
FUD	0.06	0.161	0.237	0.278	Madaki et al., 2024
Dutse	0.24	0.69	1.030	1.202	Dankawu *et al*,, 2021
Jos	-	0.12	-	-	(Aminu, 2020).
Dutse	0.06	0.16	0.24	0.29	Current study, 2025

CONCLUSION

A total of ten borehole and well water samples was collected across five different selected wards in Dutse, the state capital of Jigawa state and analyze for Radon concentration. The five selected wards are Limawa, Kachi, Duru, Kudai and Chaichai. The samples was analyze at Ahmadu Bello University Zaria, Centre for energy research Zaria, using liquid scintillation techniques. The mean value of Radon concentration for well and borehole water samples was found to be 22.39 and 22.39 Bql^{-1} respectively, which exceeded the acceptable range of 10 Bql^{-1} by WHO (1993), and the world average value of 11.1 Bq/L set by the USEPA (1999); UNSCEAR (2002), and SON (2003). The annual effective dose and excess life cancer risk due to inhalation were found to be below the standard recommended value of WHO. However for the annual effective dose and excess life cancer risk due to ingestion for both well and borehole water samples were found to be above the recommended value set by different standard organization. The finding of this study revealed that water used in these samples location is not safe for drinking and other domestic uses. As such we strongly recommended that the water used in these locations should undergo special treatment before used to avoid any possible health risk associated with water, more especially stomach cancer,.

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