FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 3, March, 2025, pp 45 - 54
DOI: https://doi.org/10.33003/fjs-2025-0903-3343

ASSESSMENT OF RADON CONCENTRATION AND EXCESS LIFE CANCER RISK FOR WATER SAMPLES IN FEDERAL UNIVERSITY DUTSE (FUD), JIGAWA STATE, NIGERIA

[1]Madaki Bello, *[1]Dankawu, U. M., [1]Musa, I. M., [1]David Adamu, G. K., [1]Shuaibu, H. Y., [2]Yakubu Mohammed, [1]Zarma, S. S., [2]Tahir Abdullahi, [3]Nazifi Zubairu, [4]Yusuf Shuaibu and [1]Yakubu, A.

[1]Department of Physics, Federal University Dutse, P.M.B. 7156, Ibrahim Aliyu Bye-pass Dutse, Jigawa State, Nigeria.
[2]Department of Physics, Yobe State University, P.M.B 1144, Damaturu, Yobe State, Nigeria.
[3]Department of Chemistry, (Autoomous), Mumbai University, Mumbai, 400098 Maharashtra, Indian.
[4]Department of Information Technology School: Bayan College of Science and Technology Sudan.

*Corresponding authors' email: umdankawu@gmail.com

ABSTRACT
Radon, a major cause of lung cancer, can be found in groundwater as it emanates from rocks and soil. The risk increases by 16% for every 100 Bq/m³ rise in long-term exposure. Even low radon levels, particularly from groundwater, pose health risks. The WHO estimates radon causes 3% to 14% of lung cancers, with risk rising proportionally to exposure. Six underground water samples (borehole) from within and outside FUD were analyzed using a Liquid Scintillation Counter at CERT in Zaria. Samples were collected from the Senate Building and student hostels. The mean radon concentration was 21.723 Bq/L, below the WHO (2017) and UNSCEAR (2020) limit of 100 Bq/L but above recommended levels of 10-11.1 Bq/L. Annual effective doses for inhalation and ingestion were 0.055, 0.161, 0.237, and 0.278 mSv/year for adults, children, and infants, with ingestion doses exceeding WHO limits. The cancer risk from ingestion exceeded the WHO standard of 2.9E-4, suggesting the water is not safe for drinking without treatment.

Keywords: Radon concentration, Annual effective dose, Excess life cancer risk, Water sample, Liquid Scintillation Counter

INTRODUCTION
The most available and critical commodity that certify the persistence of human lives on earth is water. The cleanliness of water for human use is therefore of very importance. Water is important for life's survival; the scarcity of water for day-to-day activities is dangerous. Nevertheless, maintaining quality of water has to be considered, there is need for extra attention because of potential hazards attached to water. The contaminant that pollutes water include, toxic chemicals, infectious agents and radionuclides (Abdulrasheed *et al 2024*).

A colorless, odorless and tasteless natural radioactive gas called Radon is a naturally occurring radioactive gas with approximate half-life of 3.82 days. Radon gas released from the underlying rock layers moves through the soil via diffusion and is then carried into groundwater, including well water. As radon naturally emanates from uranium-rich rock formations, it travels through porous materials before dissolving into water sources (Chau & Tomaszewska, 2019). Ingested or inhaled radon emits alpha particles that cause significant DNA damage. These particles release high energy over a short range, creating severe and complex DNA damage within cells, including DNA breakage and mutations. While cells attempt to repair this damage, failures can lead to permanent cell damage and genetic instability. Alpha particles can also induce DNA damage indirectly through extracellular factors, affecting even unexposed cells. Breathing in radon gas exposes the lungs to ionizing alpha particles released by the decay products of ^{218}Po and ^{214}Po, which can harm DNA in lung cells. Additionally, drinking water with dissolved radon can deliver a radiation dose to the stomach's inner lining (Baradaran et al., 2014)This process can lead to elevated radon concentrations in wells, posing potential health risks if the water is consumed over extended periods. The radon gas movement is limited by its half-life but can move advance as a solute in water. The concentration of radon gas is primarily increased in areas substrate by granite that is rich in uranium and radium. Radon concentration is dependent on the uranium concentration of the soil and local basal layer (Oluwaseun *et al.,* 2022).

Radon is one of the most dangerous 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. Once inside the lungs, the concentrated energy from radon's alpha particles can damage lung tissue, significantly increasing the risk of lung cancer (Nazir *et al* 2021). Radon is the primary contributor to lung cancer in non-smokers. Prolonged exposure to elevated radon levels has been clearly linked to an increased risk of developing cancer. This is especially concerning because radon is a colorless, odorless gas that naturally emanates from the ground, and individuals who are exposed to high concentrations over time may face significant health risks (Daneall*a et al.,* 2023)

In water, radon is the most significant contaminant which has indirect impression on the general public's health. The risk of lung cancer is increased throughout radon ingested and the short-lived decay products emits it. Radon can travel into the water and increase radon concentrations due to geophysical and geological setting (Samaila *et al.,* 2023). Exploring the geological features of Dutse, particularly its granite formations, highlights the connection between uranium deposits and elevated radon levels. Granite, rich in uranium, naturally emits radon gas as part of the uranium decay process (Dankawu et al., 2024). In Dutse, where granite is widespread, radon concentrations in groundwater and boreholes may be elevated. Prolonged exposure to high radon levels, especially through drinking water, can significantly increase the risk of lung cancer, as radon is a leading cause of the disease. This underscores the importance of monitoring and treating local water sources to mitigate health risks (Dankawu et al., 2022).

Nigeria faces significant water safety challenges, with an estimated 70 million people lacking access to safe drinking water. This crisis is fueled by inadequate infrastructure, poor investment, and a deficient regulatory environment. Approximately 80 million Nigerians lack access to improved sanitation, contributing to widespread open defecation. As a result, water sources are frequently contaminated, posing health risks. Although the government has launched initiatives such as the National Water Supply and Sanitation Policy and the National Action Plan, progress is impeded by insufficient funding, poor coordination, and corruption. The failure of boreholes and water supply infrastructure is a concerning trend, highlighting the urgent need for a more structured and comprehensive approach to achieve water infrastructure sustainability. Only a small fraction of the population (10%) has access to complete basic water, sanitation, and hygiene services (Yashaswini et al., 2020). Recent studies on radon in Nigeria, particularly in areas such as Sokoto and Zaria, have brought attention to the increasing concerns over radon exposure and its associated health risks. These investigations have mainly concentrated on assessing radon levels in soil, air, and construction materials, offering valuable insights into regional disparities and potential hazards. The results from these locations emphasize the need for further research in other regions, such as the Federal University Dutse (FUD) in Jigawa State. By considering FUD's distinct geographical and geological features, studies at this institution could significantly enhance the understanding of radon distribution nationwide. This would improve Nigeria's ability to address radon-related health concerns and contribute to advancing regional radon research, public education, and safety protocols (Hannafi et al., 2024). Given Nigeria's water safety challenges and regulatory gaps, a study of radon concentrations at Federal University Dutse (FUD) is timely. While radon is typically linked to air and soil, its presence in water sources, particularly groundwater, poses significant health risks. Despite growing awareness of radon exposure, there are still substantial gaps in monitoring and regulation, especially concerning water safety standards. This research could be key in assessing radon levels in water and enhancing regional risk assessments, ultimately supporting stronger policies to protect public health and improve regulatory frameworks for radon in both environmental and water contexts (Bashir et al., 2023).

Several studies have been published on radon analysis in water both within Nigeria and globally. However, there is a noticeable gap in research focused on the health risks associated with radon in borehole water, particularly in the vicinity of Federal University Dutse, Jigawa State, Nigeria. Despite the growing body of research, no studies have specifically addressed the radon concentrations in borehole water used by students and staff at this institution. This study aims to fill that gap by assessing the radon levels in borehole water samples from FUD. Utilizing a well-calibrated Liquid Scintillation Counter, the research will provide valuable insights into potential health risks posed by radon exposure through drinking water in this region. This investigation is essential for understanding local radon levels and developing strategies for mitigating any health impacts associated with radon in borehole water sources.

MATERIALS AND METHODS

Study Area

Federal University Dutse (FUD), Jigawa state, Nigeria is one of the newly twelve (12) created federal University of Nigeria in 2011 by the government of Jonathan Good luck Ebele. FUD offer both undergraduate and postgraduate programmes (PGDE, MSc. as well as PhD). The university is located in Dutse town, the capital city of Jigawa state, Nigeria. Dutse is located between Latitudes 11^0 38' 31"N and 11°46' 16"N and longitudes $9^0$18' 33"E and $9^0$24' 24"E. its bordered by Birnin kudu local government to the south, Jahun and Ringim local government to the north, Gaya and Kiyawa local government to the West and East respectively. (Aminu, 2015). Dutse has an estimated population of 365,818 in 2025 and it's considered as the city with largest area of approximately 1099.60 (Ogunleye *et al*. 2018). Popularly known as "Dutsi" Dutse is derived from the Hausa word meaning rock, the rock reflecting the rocky mapping surface of the area. These rock are mostly igneous in nature. Also, the geology of the area display sedimentary rocks, which was made from the organic materials and deposition of sediments over millions of years. Furthermore, volcanic rocks are also present in Dutse (Dankawu *et al.,* 2023). These rocks were made volcanic activity during the createaceous time and originally composed of andesite and basalt (Dutse 2022). Dutse climate is tropical wet dry climate (Koppen AW) classification, although, around November to February there is slightly cool, however, the temperature is warm to hot throughout the year. The mean monthly temperature values varies from 21 ^{0}C in the coldest months (December/February) and 31 ^{0}C in the hottest months (April/May), while the overall average annual temperature is 26 ^{0}C (Aminu, 2015).

Temporal Bias

The sampling in this study was confined to the rainy season, which may introduce temporal bias by not accounting for seasonal variability in radon concentrations. Radon levels fluctuate based on factors such as soil moisture, temperature, and atmospheric pressure, all of which change between the rainy and dry seasons. As a result, limiting the sampling to only the rainy season may not capture the full range of radon concentrations throughout the year. To address this limitation, future studies should consider sampling across both rainy and dry seasons to better understand seasonal variability in radon levels and assess its potential impact on health risks.

Sample Collection

A total of six (6) borehole water samples were collected from six male and female students' hostels under FUD, Dutse LG, and Jigawa State Nigeria. Four samples were collected within the four available hostel inside the school namely: (Amina J Muhammad Hostel, Rukkayah Hall, and shekarau Aginyu Block), one sample from senate building, while the remaining two samples was collected from the two hostels located outside but near the school (off-campus student's hostels). The samples was collected during raining season between July-August, 2024. A small and clean 100 ml plastic rubber was used as the samples containers. To prevent the ^{222}Rn present from being impure in the samples containers, the containers was washed and rinsed with fresh water. In order to ensure fresh water collections, the borehole water samples was collected after allowing the follow of water for about three to four minutes (3-4 min). To prevent CO_2 from being trap we make sure that the samples containers was filled to the brim and then closed with the cover immediately to prevent ^{222}Rn loss by degassing during the laboratory transport. 10 ml of concentrated nitric acid (HNO_3) was added to the samples to ensure radionuclide stay in the solution, rather absorbing to the walls of containers. The collected samples were transported to the Ahmadu Bello University Zaria, center for energy research and training (CERT) for preparation and analysis. GPS meter was used to measure the coordinates (latitude and longitude).

Table 1: Sample locations, samples ID, coordinates (latitude and longitude)

Sample locations	Sample ID	Latitude	Longitude
Amina J Muhammad Hostel	FUD I	11.705693	9.373373
Rukkayah Hall	FUD II	11.423017	9.226055
Shekarau Aginyu Block	FUD III	11.70154	9.372721
Senate Building	FUD IV	11.0713338	9.372317
IMG Suite	FUD V	11.702544°	9.366612°
Bakwkwato	FUD VI	11.721408°	9.366105°

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 Ahmadu Bello University Zaria, center for energy research and training (CERT) was used to analyzed the preparation samples. The samples were analyzed three hours after preparation, to allow for radioactive equilibrium between ^{222}Rn and its daughter progeny to be established.

Experimental Analysis

The analysis for this study is in four (4) part which include estimation of ^{222}Rn concentration (Bql^{-1}), estimation Annual effective dose from inhalation, estimation of Annual effective dose from ingestion for adult, children and infant, estimation of Excess life cancer risk for different age groups and estimation of total annual effective dose for different age groups.

^{222}Rn Concentration in Bql^{-1}

The ^{222}Rn concentration in a sample of water was determined using equation 1.

The ^{222}Rn concentration in a sample of water will be determined using equation 1 below. (Abba *et.al.* 2020)

$$Rn(\frac{\text{Bq}}{\text{L}}) = \frac{100\times(R_n\times R_0)\exp(\lambda t)}{60\times 5\times 0.964} \quad (1)$$

Table 2: Nomenclature table for equation (1)

Symbol	Description	Units	Context/Equation
R_n	Sample total count rate	count min^{-1}	Represents the count rate of the sample in counts per minute.
R_0	Background count rate	count min^{-1}	Represents the background count rate, typically measured in the absence of the target isotope.
Rn	^{222}Rn concentration	Bq L^{-1}	Represents the concentration of radon-222 in Bq per liter.
T	Elapsed time between sample collection and counting	Min	Time interval between the collection of the sample and its subsequent counting (4320 min, or 3 days).
Λ	^{222}Rn decay factor	min^{-1}	The decay constant for radon-222, indicating the rate of radioactive decay (1.26 × 10^{-4} min^{-1})
100	Conversion factor from per mL to per liter	-	A factor used to scale the concentration from per milliliter to per liter.
5	Number of emissions per count	-	The number of emissions per count measured, typically used for calibrating the detector.
60	Conversion factor from minutes to seconds (min−1 to S^{-1})	-	A factor to convert the rate from per minute to per second.
0.964	Fraction of 222Rn in the cocktail in a vial of 22 mL total capacity (10 mL cocktail, 10 mL water, 2 mL air)	-	A scaling factor to account for the fraction of radon-222 in the liquid cocktail used in measurement.

where Rn (Bq/L) is ^{222}Rn concentration in Bql^{-1}, R_n is the sample total count rate (count min^{-1}), R_O is the background count rate (count min^{-1}), t is the elapsed time between sample collection and counting (4320 min. (3days), λ is ^{222}Rn decay factor (1.26 × 10^{-4} min^{-1}), 100 is a conversion factor from per ml to per liter (l^{-1}), 5 is the number of emissions per count; 60 is conversion factor from min. to s. (min^{-1} to s) and 0.964 is the fraction of ^{222}Rn in the cocktail in a vial of 22 ml total capacity, assuming it contains 10 ml cocktail, 10 ml water and 2 ml air.

Annual Effective Dose due to Inhalation and Ingestion

The annual effective dose due to inhalation and ingestion of radon in borehole water samples was calculated using the equation 2 and 3 as proposed, by the United Nation Scientific Committee on the Effects of Atomic Radiation (Shuaibu et al., 2024).

$$AED = K \times G \times C \times 1000 \quad (2)$$

$$AED_H = \frac{C_{Rn}\times R_W\times F\times T\times DF}{1000} \quad (3)$$

Table 3: Nomenclature Table for equation two and three (2&3)

Variable	Description	Unit
AED	Annual effective dose due to ingestion	mSv/y
K	Dose coefficient for different age groups (Adults, Children, Infants)	10^{-8}, 2×10^{-8}, 7×10^{-8}
G	Water ingestion rate for different age groups	L/y
C	222Rn concentration in water	Bq/L
1000	Conversion factor from Sv to mSv	-
AEDH	Annual effective dose due to inhalation	mSv/y
CRn	222Rn concentration in water	Bq/L
Rw	Ratio of radon released to air when water is used to radon in water	10^{-4}
F	Equilibrium factor between radon and its product	-
T	Average residence time of an individual indoors	h/y
DF	Conversion dose factor	nSv/(Bq·hm³)

where AED and AED_H are the annual effective dose due to ingestion and inhalation in $mSvy^{-1}$ respectively, K is the dose coefficient (10^{-8}, 2×10^{-8}, and 7×10^{-8}) for Adult, children's and infants (UNSCEAR, 2000), G is the water ingestion rate (730 L/Y, 547.5 L/Y and 182.5 L/Y) for adults, children and infants respectively (UNSCEAR, 1993), C is the ^{222}Rn concentration in water (Bq/L), and 1000 = conversion coefficient of Sv to mSv. C_{Rn} is the ^{222}Rn concentration in water (Bq/l), R_w is the ration 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 in the interior (7000h/y), DF is the conversation dose factor 9 $_n$Sv ($Bqhm^{-3}$).

Excess Life Time Cancer Risk

Excess life cancer risk (ELCR) from inhalation and ingestion for different age categories was calculated from annual effective dose using equation 4, as explain by (Adamoh *et.al* 2021).

$$ELCR = AED \times DL \times RF \quad (4)$$

Table 4: Nomenclature table for equation three (4)

Variable	Description	Unit
ELCR	Excess life cancer risk	-
AED	Annual effective dose from inhalation and ingestion for different age groups	mSv/y
DL	Life expectancy	Years
RF	Fatal risk factor per Sievert	S/v

Where ELCR is the excess life cancer risk, AED is the annual effective dose from inhalation and ingestion for different age groups in $mSvy^{-1}$, DL is the life expectancy 70 years and RF is the fatal risk factor per Sievert (S/v). ICRP-60 uses RF of 0.05 for the public in case stochastic effects.

RESULTS AND DISCUSSION

Table 5: Radon Concentration, Annual Effective Dose due to inhalation and ingestion for different age categories

ID	^{226}Rn (CPM)	^{226}Rn (Bql^{-1})	AED_H ($mSvy^{-1}$)	AED_A ($mSvy^{-1}$)	AED_C ($mSvy^{-1}$)	AED_I ($mSvy^{-1}$)
FUD I	74.88	20.460	0.052	0.149	0.224	0.261
FUD II	65.75	15.019	0.039	0.120	0.164	0.192
FUD III	82.75	25.150	0.063	0.184	0.275	0.321
FUD IV	68.25	16.509	0.042	0.121	0.181	0.211
FUD V	84.57	26.234	0.066	0.192	0.287	0.335
FUD VI	85.8	26.967	0.068	0.197	0.295	0.345
Mean	77.00	21.723	0.055	0.161	0.237	0.278

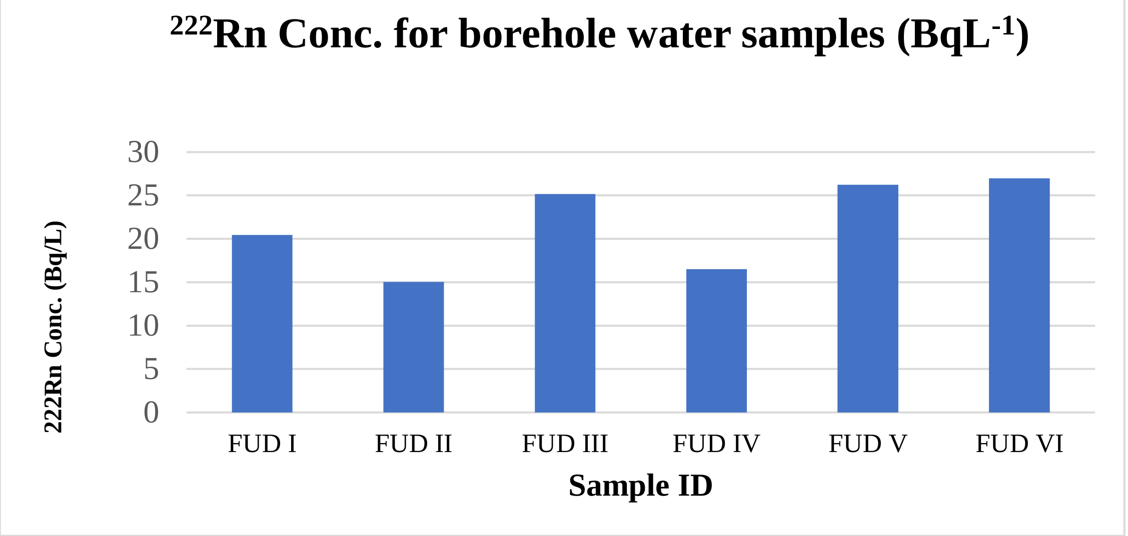

Figure 1: Chart of Radon concentration in Bql^{-1} for borehole water sample

Radon Concentration

Liquid scintillation counter was used to determine the radon concentration of borehole water sample. The radon concentration was found to be in the range of 15.02 to 26.967 Bql^{-1} with mean vale of 19.28 Bql^{-1}. FUD II and FUD VI are the samples locations with minimum and maximum value of radon concentration respectively. The high concentration in the FUD VI sample location may be due to the presences of igneous rock within locations. Igneous rocks, particularly granite, contribute to higher radon levels in FUD VI due to their uranium and radium content. As uranium decays, radon gas is naturally released from these rocks. The high permeability of igneous formations allows radon to escape into the soil and groundwater, leading to elevated concentrations. At FUD VI, this geological makeup increases radon exposure risks, emphasizing the need for regular monitoring to mitigate potential health effects

The results obtained in this study was compared with world standard and other results of similar works within and outside the country, in order to make similar observation. The essence was to establish if there is any correlations between the results obtained with other areas. The first comparison was made between radon concentrations obtained in this study with world standard. The second comparison was made between radon concentrations obtained in this study with the results obtained from other locations within the Nigeria. The third comparison was made between radon concentrations obtained in this study with the results obtained from other country and is presented in tables 6, 7 and 8 respectively.

Table 6: Comparison of ^{222}Rn Conc. From Dutse with 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 Conc. from Dutse with Other Parts of Nigeria

Locations	^{222}Rn Conc. (Bql^{-1})	Sources
Kaduna	10.69	(Garba and Hussaini, 2018).
Zaria	12.43	(Garba et al, 2017).
Sokoto	34.00	(Abba et al, 2020).
Jos	17.00	(Aminu, 2020).
Dutsinma	64.66	(Adams, 2017).
Dutse	83.77	(Dankawu *et al*,, 2021)
FUD	21.723	(Current study, 2021)

Table 8: Comparison of ^{222}Rn Conc. from Dutse with Other Countries

Countries	^{222}Rn Conc. (Bql^{-1})	Sources
India	4.42	(Sudhir, *et al*, 2016).
Malaysia	14.7	(Nasar, *et a*l, 2015).
Iran	1.2	(Malakootian, *et al*, 2017)
Turkey	2.4	(Tabar and Yakut, 2014)
FUD	21.723	(Current study, 2021)

In comparing our results with those of Dankawu et al. (2021), we found a significant discrepancy in the reported 222Rn concentrations for Dutse. While Dankawu et al. reported 83.77 Bq/L, our study observed 21.72 Bq/L. This variation could be due to differences in sampling methods, as both studies may have used distinct techniques or equipment with varying sensitivities. Additionally, seasonal variations in radon concentrations and spatial differences in water sources, such as proximity to radon-emitting geological formations, might explain the discrepancy. Measurement sensitivities and instrument calibration could also contribute. These factors suggest that further studies are needed to clarify the source of this discrepancy."

These values of ^{222}Rn concentration were found to be below the permissible limit of 100 Bql^{-1} set by WHO, (2004) and UNSEAR, (1999). However, all the value was found to be above recommended value of 11.1 and 10 Bql^{-1} set by (WHO 1993; USEPA, 2008 and SON, 2003). In comparison with previous studies carried out within the country (Nigeria), the result obtained in this study is above the previous reported result in Kaduna, Jos and Zaria by (Garba and Hussaini, 2018; Aminu *et al.*, 2020 and Garba *et al.*, 2017) respectively, as all the values obtained by these locations were 2.03, 1.28 and 1.45 lower than the value obtained in this current study respectively. However, the value obtained by this study is 1.57, 2.98 and 3.86 lower than the result obtained in Sokoto, Dutsinma and Dutse (Abba *et al.*, 2020; Adams, 2017 and Dankawu *et al.*, 2021) respectively. This high concentration of ^{222}Rn may be due to the different geological formation of the studies areas, it may also be due to the high presence of both igneous and sedimentary rocks in our study area. Because rocks is one the major source of ^{222}Rn (Dankawu *et al.*, 2021). The result also compared with other reported work outside the country.

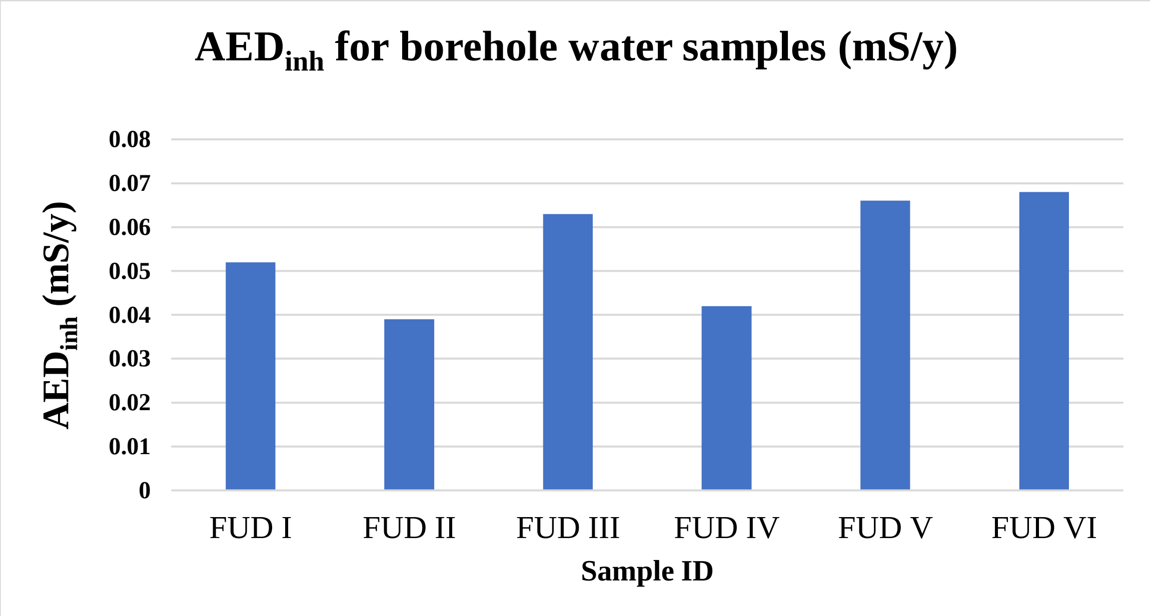

Figure 2: Chart of Annual effective dose due to inhalation for borehole water sample

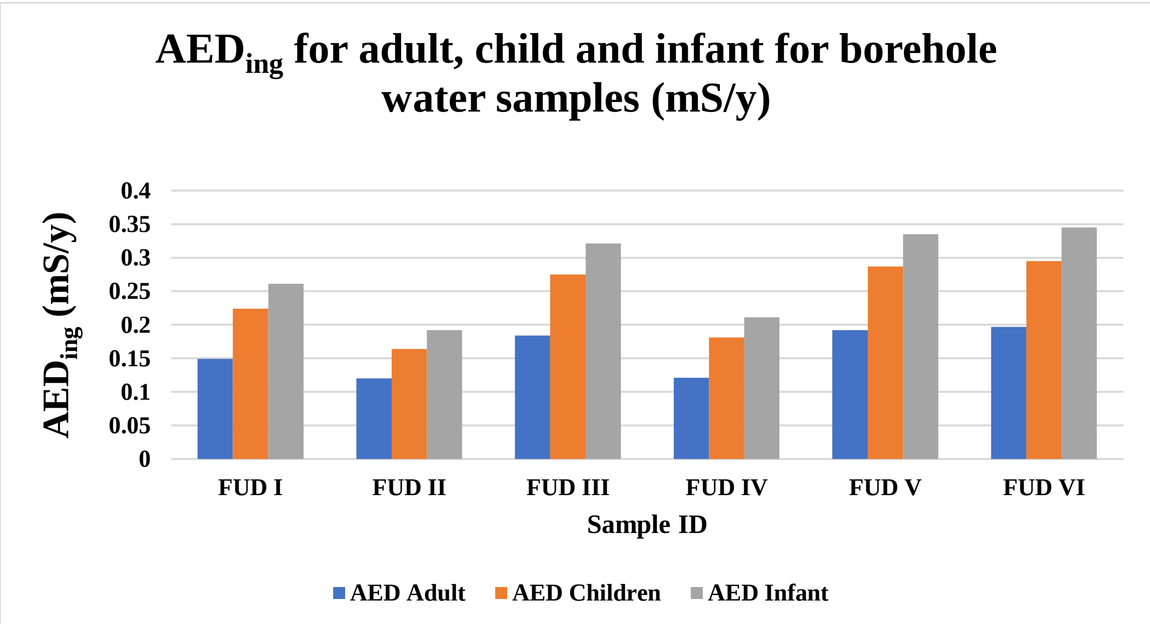

Figure 3: Chart of Annual effective dose due to Ingestion for Different Ages Categories (Adult Children and Infant) for borehole water sample

Annual Effective Dose due to Inhalation and Ingestion

The annual effective dose due to inhalation and ingestion for different ages categories (adult children and infant) from the corresponding radon concentration were varies from 0.04, 0.11, 0.16, and 0.19 to 0.068, 0.197, 0.295, 0.345 $mSvy^{-1}$, with mean values of 0.055, 0.161, 0.237 and 0.278 respectively. FUD II is the sample locations with lowest value of annual effective dose due to inhalation while FUD VI is the sample location with highest value. For ingestion, FUD II and FUD VI are the samples locations with lowest and maximum values for adult children and infant respectively. All the value of annual effective dose due to inhalation were found to be within the acceptable limit of 0.1 $mSvy^{-1}$ as recommended by WHO, 2004. However, all the value of the annual effective dose due to ingestion for adult children and infant were found to be above the permissible limit set by the WHO, 2008. Comparison was made between annual effective doses obtained with other previous reported research within the country. The study revealed that the annual effective dose due to inhalation and ingestion obtained in this study is in accordance with research carried out in Dutse and Jos (Dankawu et al., 2021 and Aminu, 2020), but not in agreement with conducted in Sokoto and Dutsinma (Abba *et al.,* 2020 and Adams, 2017) respectively, as their values are far above the current study.

Table 9: Comparison of annual effective doses due to inhalation and ingestion from Dutse with others related research

Locations	Einh	$E_A$ing	$E_C$ing	$E_I$ing	References
Sokoto	0.04 $mSvy^{-1}$	2.48 $mSvy^{-1}$	3.72 $mSvy^{-1}$	4.34 $mSvy^{-1}$	(Abba *et al.*, 2020).
Dutsinma	-	0.47 $mSvy^{-1}$	0.944 $mSvy^{-1}$	3.304 $mSvy^{-1}$	(Adams, 2017).
Dutse	0.237 $mSvy^{-1}$	0.69 $mSvy^{-1}$	1.030 $mSvy^{-1}$	1.202 $mSvy^{-1}$	Dankawu *et al*,, 2021
Jos	-	0.12 $mSvy^{-1}$	-	-	(Aminu, 2020).
FUD	0.055	0.161	0.237	0.278	Current study

Table 10: Excess Life Cancer Risk due to inhalation and ingestion for different age categories

ID	$ELCR_H$	$ELCR_A$	$ELCR_C$	$ELCR_I$
FUD I	1.8E-4	5.2E-4	7.8E-4	9.2E-4
FUD II	1.3E-4	3.8E-4	5.8E-4	6.7E-4
FUD III	2.2E-4	6.4E-4	9.6E-4	1.1E-3
FUD IV	1.4E-4	4.2E-4	6.3E-4	7.4E-4
FUD V	2.3-E4	6.7-E4	1.0-E3	1.2-E3
FUD VI	2.4-E4	6.9-E4	1.0-E3	1.2-E3
Mean	1.9E-4	5.5E-4	5.3E-4	4.5E-4

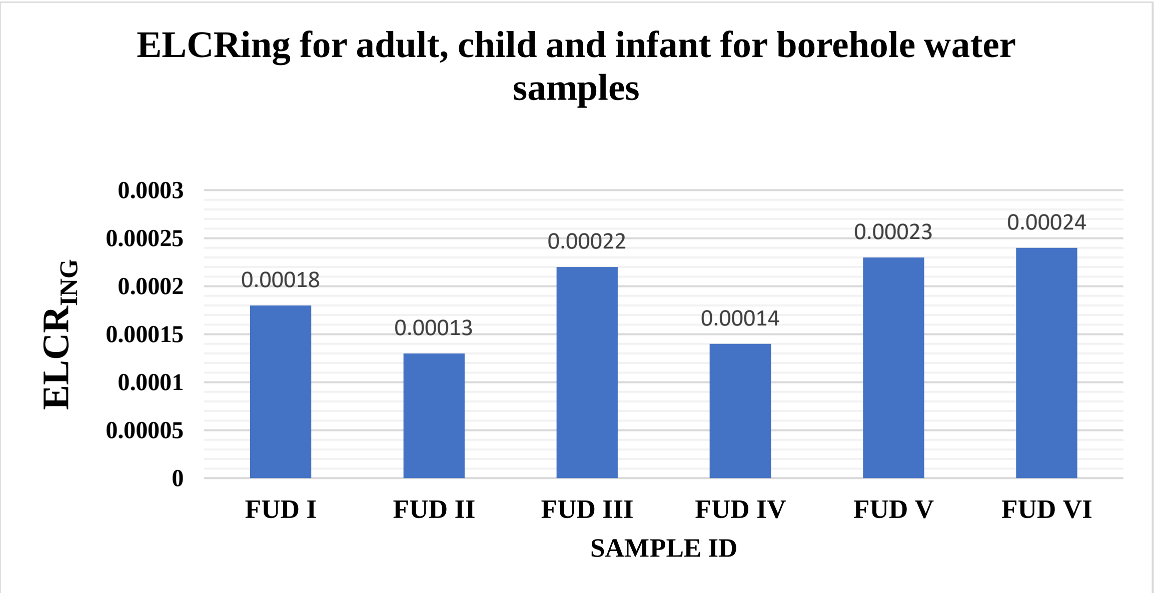

Figure 4: Chart for Excess life cancer risk due to ingestion for adult, children and infant for borehole water sample

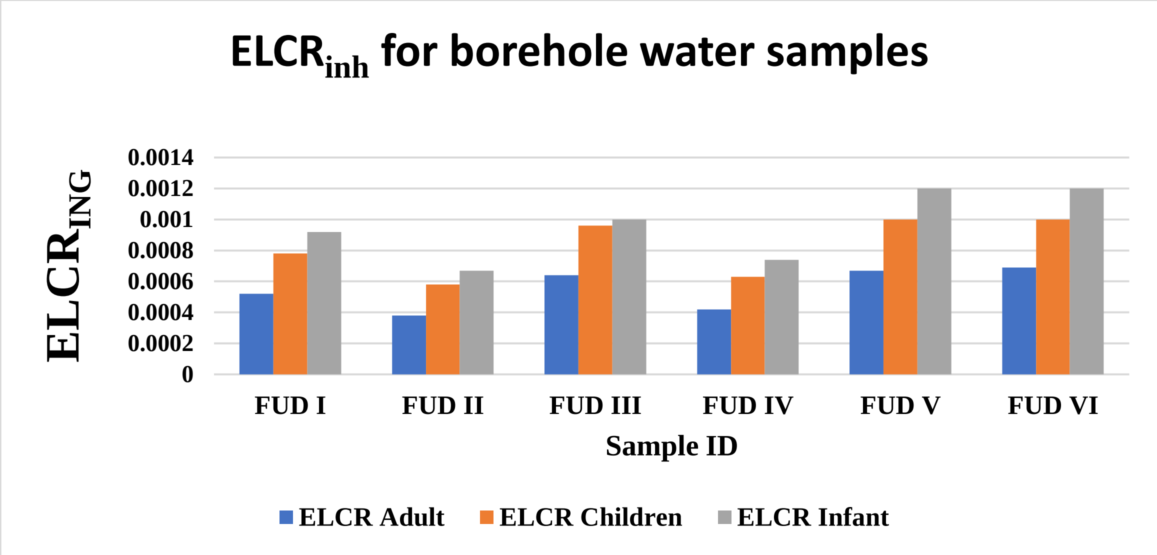

Figure 5: Chart for Excess life cancer risk due to inhalation for borehole water sample

The excess life cancer risk due to inhalation and ingestion for adult, children and infant for borehole water sample was calculated from the corresponding annual effective dose. The result shows that the lowest and highest value of excess life cancer risk due to inhalation varies from 1.3E-4 obtained from FUD II location to 2.4E-4 obtained from FUD VI sample locations with mean value of 1.9E-4. The excess life cancer risk due to ingestion for adult, children and infant are found to be 3.8E-4, 5.8E-4 and 6.7E-4 to 6.9E-4, 1.0E-3 and 1.2E-3, with mean value of 5.5E-4, 5.3E-4 and 4.5E-4 respectively. The maximum value of excess life cancer risk due to ingestion for children and infant was found in FUD V and FUD VI samples location. These value were found to be above the world average value of 2.9 x 10^{-4} as proposed by (Ibikunle *et al* 2018). In comparison with previous research within the country, this study indicates that, the result is in-line with research carried out (Dankawu *et al.,* 2021; Abdulrasheed *et al.,* 2024)

CONCLUSION

This study evaluates the radon activity concentration, annual effective doses from inhalation and ingestion for different age groups (adults, children, and infants), and the excess life cancer risk due to radon in groundwater used for drinking and domestic purposes at Federal University Dutse (FUD) and surrounding communities in Dutse Local Government Area, Jigawa State, Nigeria. Liquid scintillation analysis revealed that the mean radon levels at FUD exceeded the Maximum Contaminant Level (MCL) of 11.1 Bq/L set by the USEPA (1999), the world average value of 10 Bq/L by WHO (1993) and UNSCEAR (2002), and the value of 11.1 Bq/L set by SON (2003), but were below the 100 Bq/L limit established by WHO (2008) and the EU (2001). However, the mean annual effective doses from inhalation and ingestion for all age categories were above the maximum limits recommended by UNSCEAR, WHO (2004), and EU (1998). The excess life cancer risk from these doses also exceeded the world average value of 2.9 x 10^-4 as proposed by Ibikunle et al. (2018). he Excess Lifetime Cancer Risk (ELCR) measures the increased likelihood of cancer over a person's lifetime due to exposure to a carcinogen, expressed as a probability (e.g., 1 in a million). ELCR values help assess the potential health risk and inform regulatory decisions about whether action is needed to reduce exposure. An ELCR below 1 in 1 million is generally considered an acceptable or negligible risk, while values between 1 in 1 million to 1 in 100,000 are still acceptable but may warrant further monitoring or mitigation. ELCR values between 1 in 100,000 to 1 in 10,000 suggest moderate risk and may trigger actions such as additional controls or regulations. Values greater than 1 in 10,000 indicate an unacceptable or hazardous risk, requiring immediate intervention such as stricter regulations or exposure elimination to protect public health. These findings suggest that the drinking water resources at FUD and nearby communities are not safe due to increased radiological hazards from radon gas. Additionally, seasonal variations in radon levels, with higher concentrations during the dry season, highlight the need for FUD to focus radon monitoring efforts on the dry months (October to April). Studies from Nigeria and Ghana show significantly higher radon levels in the dry season, such as in Ogbomoso, where soil-gas radon levels were 1.90001 Bq/L in the dry season compared to 0.71181 Bq/L in the wet season. By prioritizing monitoring during the dry season, FUD can better assess peak radon levels and improve risk mitigation strategies. Based on the finding of this study it is here by recommended that: Continues studies with larger sample size and different sampling methods might be required to better highlight the exposure levels and risk on the students, staffs and Jigawa state people in general to be examined at least quarterly. Preliminary and further extensive studies should be done on large scale by initiating further detailed investigation of all Local Government Areas of the state for radon contamination, so as to increase awareness and mitigate possible health hazards due to radon gas concentration in the drinking water. Attention of the Local Government chairman and State Governor should be drawn to take preventive measures and community awareness that could reduce the exposure level of radon and risk on the population in Dutse Local Government Area and Jigawa state in general.

ACKNOWLEDGMENT

The Tertiary Education Trust Fund (TETFund), Nigeria, provided financial support for the 2024 Intervention program of the Institutional Based Research (IBR). The authors acknowledged this assistance

REFERENCES

Abba, L, Nasiru, R, Garba, N. N. and Ahmed, Y. A, (2020). Assessment of Annual Effective Dose Due to Inhalation and

Ingestion of Radon in Water Samples from the Cement Industrial Area Of Sokoto, North-Western Nigeria. *FUDMA journal of science Vol. 4 No., pp 615– 619.*

Adamoh Nojeeb Oyeyemi (2021) risk impact assessment of natural occurring radioactive materials (NORMS) from operation activities in uke gold mine in karu Nasarawa. *Int. J. Environ. Sci. 11:493–508.*

Adams S. (2017). Assessment of radon-222 in some selected water sources at dutsin-ma town, Dutsin-ma local government area, katsina state. *FUDMA journal of science Vol. 6 No., pp 147 – 153.*

Abdulrasheed A, J. Muhammed, Abba Alhaji Bala, U.M Dankawu, N. Zubairu, H.Y Hafeez (2024) Assessment of Excess Life Cancer Risk from Radon Concentration in Borehole water Samples collected from Katagum LGA, Bauchi State, Nigeria" *Dutse Journal of Pure and Applied Sciences (DUJOPAS),* Vol. 10 No. 1c 2024

Aminu Kalip, (2020). Measurement of Radon Concentration in Borehole and Well Water, and Estimation of Indoor Radon Levels in Jos, Plateau State, Nigeria. *International Journal of Pure and Applied Science Vol. 19 No.9*

Aminu S. Z (2015), land use land cover changes in Dutse (1986-2014), Jigawa state, Nigeria. (Master's thesis). Department Of Geography, Faculty of Science Ahmadu Bello University, Zaria Nigeria

Aruwa, A., A. A. Kassimu, P. M.Gyuk, B. Ahmadu and J. O. Aniegbu (2017) Studies on Radon Concentration in Underground Water of Idah, *Nigeria ©International Journal of Research – Granthaalayah Vol.5 (Iss.9*). Http://www.granthaalayah.com

Baradaran, S., Maleknasr, N., Setayeshi, S., & Akbari, M. E. (2014). Prediction of lung cells oncogenic transformation for induced radon progeny alpha particles using sugarscape cellular automata. *Iranian Journal of Cancer Prevention*, *7*(1), 40–47

Chau, N. D., & Tomaszewska, B. (2019). Mineral and Bottled Water as Natural Beverages. In *Bottled and Packaged Water*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-815272-0.00001-5

Dankawu, U. M., Adamu, G. D., Mahraz, M. N., Benedict, J. N., Yakubu, A. and Uzair. M.(2021).Determination of Radon Concentration and The Annual Effective Dose DueInhalation for Some Borehole and Well Water Supply in Dutse, Jigawa State Nigeria. *Journal of Science, Technology, Mathematics and Education (JOSTMED)*, Vol. 16 pp 22-24.

Daniela Pacella, Filomena Loffredo, Maria Quarto (2023). Knowledge, risk perception and awareness of radon risks: A Campania region survey" Journal of Radiation research and applied science 16 10072

Dankawu, U. ., Ghosh, D., Naskar, A. ., David, G. ., Sharfaddeen, M. ., Salihu, A. . M., Shuwa, H. ., Yakubu, A., Isyaku, S., Olabimtan, S. ., Abdulrasheed, A., & Zarma, S. . (2024). Assessment of outdoor gamma exposure levels at some borehole and well sites in Dutse, Nigeria. *Dutse Journal of Pure and Applied Sciences*, *9*(4b), 11–22. https://doi.org/10.4314/dujopas.v9i4b.2

Dankawu, U. M., Shuaibu, H. Y., Maharaz, M. N., Zangina, T., Lariski, F. M., Ahmadu, M., Zarma, S. S., Benedict, J. N., Uzair, M., Adamu, G. D., & Yakubu, A. (2022). Estimation of excess life cancer risk and annual effective dose for boreholes and well water in Dutse, Jigawa State Nigeria. *Dutse Journal of Pure and Applied Sciences*, *7*(4a), 209–218. https://doi.org/10.4314/dujopas.v7i4a.22

EU. (2001). (European Commission) Commission recommendation of 20th December 2001 on the Protection of the public against exposure to radon in drinking water. 2001/982/Euratom, L344/ 85. Official Journal of the European Commission.

Garba N. N., N. Rabi'u, B. B. M. Dewu, U. Sadiq, H.A. Kutama, (2017). Annual Effective Dose Due To 222Rn Concentration in Well and Borehole Water Source of Zaria and Environs, Nigeria. Yusuf Maitama Sule University, Kano Faculty of Science *3rd Annual International Conference*

Garba, Z. N. and Hussaini, A. R. (2018), Assessment of Radon Concentration in Underground Well Water from Selected Parts of Kaduna Metropolis. *Chem Search Journal 9(2): 8 – 12,*

Ibikunle, S. B., Arogunji, A. M. & Ajayi, S. O. (2018). Characterization of radiation dose and Excess life cancer risk due to natural radionuclides in soil from some cities in South western Nigeria. *Journal of forensic and Criminal Investigation, 10(4), 8.*

Malakootian M, and Y. Soltani Nejhad ID, (2017). Determination of radon concentration in Drinking water of Bam villages and evaluation of the annual effective dose. *International Journal of Radiation Research, Volume 15, No 1*

Nisar A, Mohammad S. J, Mohammed S. A, (2012). Study of radon Concentration and toxic Elements in drinking and irrigated water and its implications In Sungai Petani, Kedah, Malaysia *Journal of Radiation Research and Applied Sciences 8 294e299.* http://www.elsevier.com/locate/jrras

Nazir, M. U., Yasin, I., & Tat, H.H (2021). Destination image's mediating role between perceived risk, perceived constraints and behavioral intention. *Heliyon, 7,* Article e07613

Oluwaseun G. Dosunmu, Augustine Kolapo Ademola, Pauline A. Jidele, Kayode F. Ajayi and Inioluwa O Olowofila: Measurements of Radon and estimation of excess lifetime cancer risk in water well sample along Iwajara-Ifewara fault southwestern Nigeria. pp. 120-124 August 2022.

Shuaibu, H. Y., Shuaibu, Y., Dankawu, U. M., Yakubu, A., Olaide, A. A., Isyaku, S., Adamu, G. K. D., & Usman, M. (2024). *Assessment of Radon Concentration in some selected water sources at Kiawa town, Kiyawa, Jigawa state Nigeria*. 40–48.

Samira Sherafat, Sepideh Nemati Mansour, Mohammad Mosaferi, Mayyereh Aminisani Zabihollah Yousefi, Shahram Maleki "First indoor radon mapping and assessment excess life cancer risk in Iran" MethodsX 6(2019) 2205-2216.

Sudhir M, Asha R, & Rohit M. (2016) Estimation of radon concentration in soil and Groundwater Samples of Northern Rajasthan, India, *Journal of Radiation Research an Applied Sciences, 9:2, 125-130,* https://doi.org/10.1016/j.jrras.2015.10.006.

SON, (2003). Standard Organization of Nigeria (Inorganic constituents for drinking water Quality).

Tabar, E. and H. Yakut, (2014). Radon measurements in water samples from the thermal springs Of Yalova basin, Turkey. *J Radioanal Nucl Chem 299:311–319*

UNSCEAR, (1993). United Nations Scientific Committee on the Effects of Atomic Radiation: Sources and effects of ionizing radiation, UNSCEAR report to the General assembly with Scientific annexes, Volume II. New York: United Nations.

UNSCEAR, (1999). United Nations Scientific Committee on the Effects of Atomic Radiation: Sources and effects of ionizing radiation, UNSCEAR report to the General assembly with Scientific annexes, Volume II. New York: United Nations;

USEPA, (1999). (United States environmental protection agency) Health risk reduction and cost Analysis for radon in drinking water. Federal Register, Washington D.C. 64(38), 9559. Washington

USEPA. (2008). (United States environmental protection agency) federal register 40 parts 141 and 142: National primary drinking water regulations; radionuclides: Proposed rule. U.S. Government Printing Office, Washington D.C. EPA/570/991/700.

WHO. (1993). World Health Organization. (1993). Guidelines for drinking-water quality. Vol.1, 2nd edn. World Health Organization, Geneva.

WHO. (2004). (World health organization) guidelines for drinking water quality (3rd ed., vol. 1).

World Health Organization.WHO, (2008) World health organization guidelines for drinking water quality. Incorporating first
And second Addenda 3rd ed. WHO press, Geneva. Switzerland.

Yashaswini, T., Ningappa, C., Niranjan, R. S., & Sannappa, J. (2020). Radon Concentration Level in Ground and Drinking Water around Kabini River Basin, Karnataka. *Journal of the Geological Society of India*, *95*(3), 273–278. https://doi.org/10.1007/s12594-020-1425-0

©2025 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via https://creativecommons.org/licenses/by/4.0/ which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.