Rafidain Journal of Science

https://rsci.mosuljournals.com

Vol. 32, No. 4, pp. 92- 105, 2023

Determination of Effective Dose Due to Radon Ingestion and Inhalation from Groundwater Across Awe Local Government Areas in Nasarawa, Nigeria

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p-ISSN: 1608-9391
e -ISSN: 2664-2786

Article information

Received:7/ 7/ 2023
Revised: 13/ 9/ 2023
Accepted: 21/ 9/ 2023

DOI: 10.33899/rjs.2023.181268

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ABSTRACT

In Nasarawa State, groundwater is the most often used source of fresh water for daily consumption, but its quality still remains a serious concern due to rising concentrations of radon resulting from activities of mining. This study determined the radon concentration in the sources of water from Awe Local Governments of Nasarawa state in Nigeria using the liquid scintillation detector. Fifteen samples of groundwater were collected, ten samples from the borehole, and five samples from the well. The mean content of radon from water samples of Awe was 18.24 Bq/l. the average ingested and inhaled dose effectiveness annually was 0.093±0.020 mSv/y and 4.6 x10^{-5}mSv/y, respectively. In Awe, the average ingested extra lifetime cancer risk was 3.0 x 10^{-4} and for inhalation was 1.608 x10^{-7}. The Research area's average radon concentration, 18.24 Bq/l, was generally higher than the standard of 11.1 Bq/l set by the SON and USEPA in 2021. Based on the findings of the present work, the concentration of radon is unacceptable, hence, inhabitants should be restricted from using the water until measures are put into place. However further analysis could be carried out in the area to prevent people from cancer risk. To cover the entire zone, additional research should be conducted covering additional sources in the study area. As concentrations of radon in water sources Var with time as a result of dilution by rainfall, more examination may be conducted in dry and rainy periods.

Keywords: Groundwater, Annual Effective Dose, Excess Lifetime, Cancer Risk.

INTRODUCTION

Managing water is a top priority issue that has a significant impact on our lives (Herschy, 2019). The most important natural resource is water (Adebo and Adetoyinbo, 2019). Development requires reliable water sources to be available, which is a crucial need. Due to the lack of water, deserts are uninhabitable (El-Taher and El-Turki, 2016). One of the most crucial environmental and sustainability challenges is the lack of quality and accessible freshwater (UNEPA, 2012; NRC, 2019). Regular groundwater quality inspections are important, particularly those places where water sources and geology together constitute a plausible risk to the community's health (Rilwan *et al*., 2022; Appleton, 2007).

Everywhere there is radon, a naturally occurring radioactive that cannot be detected by human senses and must instead be measured using a detector. Among the radionuclides that contribute to natural background radiation, radon has been one that poses the greatest threat to human health. It accounts for around 55% of the annual dose that the general public receives. Additionally, it has been proven that ^{222}Rn poses a health risk in both mining and non-mining regions. It is the second most prevalent cause of lung cancer in smokers and a significant contributor to lung cancer in non-smokers. Radon is mostly produced by rock and soils that are located in the planet's crust. Radon from subsurface sources can diffuse from rock into the water. Water that contains radon seeps into the atmosphere when it is used for domestic reasons. The quality of the water is important for our daily activities since radon can enter the body by inhalation of radon-containing air or ingestion of radon-containing water (Adebo and Adetoyinbo, 2019; El-Taher *et al*., 2020; Hassan, 2018).

The growing concern about radon (^{222}Rn) as a possible threat to the public's health has prompted calls for more research and an expansion of our understanding of radon in groundwater. Since groundwater is cleaner and easier to control than water from surface, it is used to supply drinkable water in many locations, necessitating the drilling of numerous wells and boreholes. Anthropogenic pollution has contaminated groundwater, and it also naturally includes several chemical components that can cause a variety of health problems (Skeppstrom and Olofsson, 2017; El-Taher., 2012).

The radiation produced when radon enters the body and disintegrates its reserves power to separate molecules of water, creating radicals (free) like OH. Due to their high reactivity, free radicals can harm cells' DNA, which leads to cancer. The bronchial epithelium in the body receives the maximum radiation dosage in a radon-containing environment; however, the extrathoracic airways and the skin may also be exposed to significant doses. Other organs, such as the bone (marrow) and kidney, may also get lower dosages. When someone takes in water with dissolved gasses (radon), their stomach is exposed to it (Edsfeldt, 2021; Cevik *et al*., 2016; Hamoo and Najam, 2020).

Since ^{222}Rn is a proven carcinogen, water with high quantities of it may pose a major hazard to people's health (USEPA, 2019; Khudair, *et al*., 2020).

Using a RAD7 detector, Oni *et al*. (2016) researched the measurement of radon concentration in drinking water in Ado-Ekiti, Ekiti State, Nigeria. With RAD7, groundwater samples from Ado-Ekiti were collected and evaluated. Oni et al discovered that none of the water samples tested for radon concentration were suitable for household use or human consumption when the result was compared to 0.1 Bq/l established by SON. In another research, Groundwater samples from chosen boreholes and wells in Idah, Nigeria, were utilized to estimate the concentration of radon (^{222}Rn) using the Liquid Scintillation Counter (LSC) in an investigation conducted by Aruwa *et al*. (2017). Aruwa *et al.* found that 80% of the samples surpassed 11.1 Bq/l. All effective dose levels in Aruwa *et al's*. study fell below the ICRP's 3–10 mSvy^{-1} intervention level recommendation.

This study assessed the level of concentration of radon in Awe local government of Nasarawa state, and also evaluating the effective dose through ingestion and inhilation in both adults and children as well as their future cancer risk.

Study Area

The senatorial district of Nasarawa South located at north-central Nigeria is among the origin of Benue's low plains. Many cones of volcanic weathered composing the primary sandstone enveloping the community that mines salt in Awe. However, separate synclinal zones created by localized folding surround the salt-producing areas of the Awe Local Governments. (Table 1) lists the GPS coordinates for the sample codes and Fig. (1) displays the research area's map (Ishaya *et al*., 2018).

Table 1: Sampling ID and G.P.S Points of Awe

Type of Sample	Name of Points	Sampling ID	N° Coordinate	E° Coordinate
Borehole	Market	AWB1	8.1112	9.1401
Borehole	Emir Palace	AWB2	8.1201	9.1524
Borehole	Alh. Bako Compound	AWB3	8.1121	9.1441
Borehole	General Hospital	AWB4	8.1311	9.1521
Borehole	Mal. Ladan Compound	AWB5	8.1131	9.1444
Borehole	Haruna Hospital Azara	AWB6	8.3579	9.3104
Borehole	Azara Motor Park	AWB7	8.3583	9.3098
Borehole	Ang. Waje Azara	AWB8	8.3588	9.3086
Borehole	Tudun Wada Azara	AWB9	8.3608	9.3171
Borehole	Ang. Lungu Azara	AWB10	8.3609	9.3074
Well	Police Station	AWW1	8.1244	9.1422
Well	Mugunji	AWW2	8.1124	9.1532
Well	Alh. Bako Compound	AWW3	8.1202	9.1401
Well	Emir Palace	AWW4	8.1311	9.1512
Well	Mal. Yahaya Compound	AWW5	8.1101	9.1401

AWB = Samples from Borehole Water
AWW = Samples from Well Water

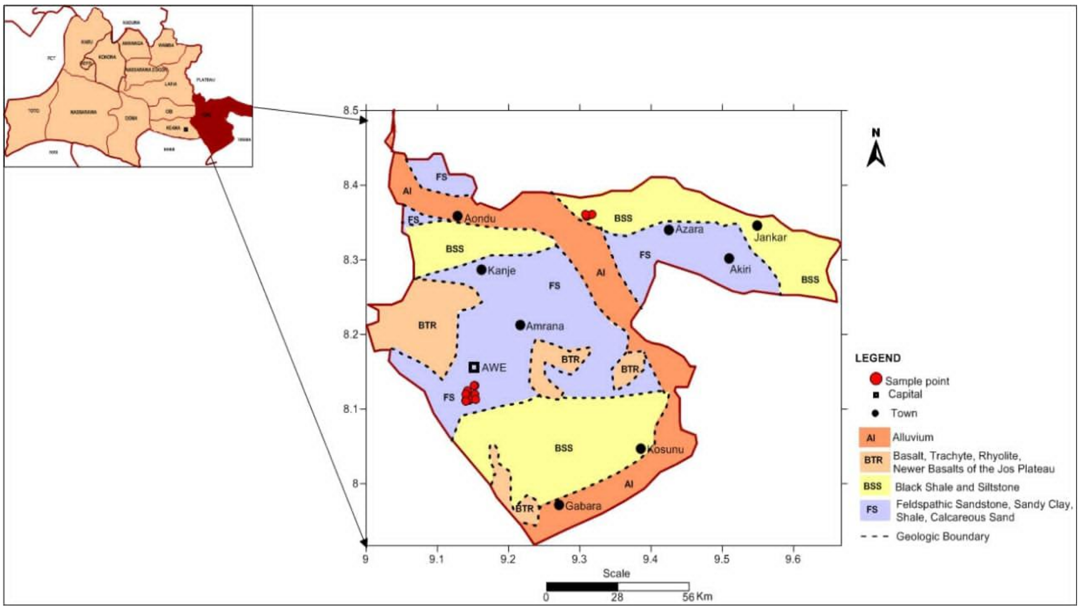

Fig. 1: Study area map indicating sampling points

METHODOLOGY

Five (5) samples from well water and ten (10) samples from borehole water were collected in plastic containers with covers. To prevent radon in the samples from being polluted, the containers were cleaned and rinsed with water (distilled).

In order to minimize the absorption of radon on container walls, samples of water were stored in a 20 ml of non-dilluted HNO_3 in liter of water. Every sample of water was splited into ten mill (10 ml) portions and put into twenty mill (20 ml) vial of scintillation glass along ten mill (10 ml) cocktail of scintillation insta-gel, tightly closed and Shaked for over two minutes to extract radon-222 in the phase of water to the scintillate (organic).

The analysis followed procedures outlined by (ASTM, 2019; Garba *et al*., 2012; Kamba *et al*., 2016; Aruwa *et al*., 2017). The prepared samples underwent evaluation utilizing a liquid scintillation counter (Tri-Carb-LSA1000) stationed at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. Calibration of the liquid scintillation counter occurred before the analysis employing the IAEA ^{226}Ra standard solution. Over the course of a 60-minute counting period, both the background and calibration solutions, as well as the sample solutions, were measured across the same spectral range. The count rates (counts.min-1) of the background and sample were recorded.

Given that ^{222}Rn and its short-lived daughters emit a cumulative total of 5 radioactive particles (3 α and 2 β) per disintegration of ^{222}Rn, their emissions were harnessed for the detection and quantification of ^{222}Rn in water due to the established secular equilibrium between ^{222}Rn and these decay daughters. This approach yields a total detection efficiency of 500%. To determine the ^{222}Rn activity concentrations in the water samples, various factors such as sample volume, total and background count rates, decay time (time elapsed between sample collection and counting), and detection efficiency were taken into account. The equation 1, as defined by (ASTM, 2019; Garba *et al*., 2012), was employed to calculate the ^{222}Rn concentration in the water samples (ASTM, 2019; Garba *et al*., 2012; Forte *et al*., 2016; Jacek *et al*., 2017).

This counter is obtained from Ahmadu Bello University's Centre for Energy Research and Training in Zaria, Nigeria and can be shown in Plate 1.

Plate 1: Counter for scintillation of liquid

Theory

The concentration (Bq/l), effectiveness dosage annually (mSv/y) to both children and adults, the extra aged risk to cancer were obtained by the use of equation 1 to 4 and the outcome are compared with previous works and industries standards. Concentration of Radon-222 (Bq/l) was gotten from Equation 1 according to Aruwa *et al*. (2017) as:

$$Rn(Bq/l) = \frac{100 \times (C_S - C_B)e^{-\lambda t}}{60 \times 5 \times 0.964} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

According to Aruwa *et al*. (2017), Rn represents the ^{222}Rn concentration at the time of sample collection (Bq/l). NS stands for the total count rate of the sample (count/min.), NB indicates the background count rate (count/min.), t signifies the time that has elapsed between sample collection and counting (4320 mins), λ denotes the decay factor of ^{222}Rn (1.26 x 10^{-4} min.$^{-1}$). The value 100 acts as a conversion factor from per 10 ml to per liter (l^{-1}). The value 60 serves as a conversion factor from minutes to seconds, the factor 5 (500%) represents the number of emissions per disintegration of ^{222}Rn (3 α and 2 β, assuming a 100% detection efficiency for each emission). The factor 0.964 signifies the fraction of ^{222}Rn in the cocktail within a vial of total capacity 22 ml, assuming the vial contains 10 ml of cocktail, 10 ml of water, and 2 ml of air.

According to Aruwa *et al*. (2017), Equation 2, as proposed by the United Nations Scientific Committee on the Effects of Atomic Radiation, can be used to determine the annual effective dose of ^{222}Rn through drinking water (λ_{ings}) in mSv/y:

$$\lambda_{ings} = K \times G \times C \quad \text{.......................................(2)}$$

Where C is the concentration of ^{222}Rn (Bq/l), G is the daily consumed water for both adults and children (4 L/d = 1460 L/y), K is the conversion coefficient concentration of ^{222}Rn (3.5×10^{-9} Sv/Bq) for ingestion. According to Equation 3 as employed by Adeola *et al*. (2017) and Jibril *et al*. (2021), the yearly effective dosage of ^{222}Rn via inhalation (λ_{inh}) in mSv/y is given as:

$$\lambda_{inh} = C \times F \times T \times R \times P \quad \text{..................................(3)}$$

C is the radon concentration (Bq/l), F is the factor for equilibrium (0.4), T is the indoor occupancy duration (7000 h/y), and R is the ratio of radon concentration in air to borehole water (10^{-4}) and P is the Dose conversion factor (9nSv/h/(Bq/m^3) Using Equation 4 as reported by Bako *et al*. (2023), the increased lifetime cancer risk was calculated as follows:

$$\alpha = \lambda \times \mu \times \eta \times 10^{-3} \quad \text{.......................................(4)}$$

where α is the extra risk of cancer for lifetime. In the determination of radon concentration in groundwater from Awe local government areas in Nasarawa, Nigeria, certain parameters are crucial in assessing the associated health risks. These parameters include the annual effective dose equivalent (λ), the average duration of life (μ) (approximately 70 years), and the Risk Factor (η) (0.05 Sv^{-1}) expressed as the fatal cancer risk per Sievert.

RESULTS AND DISCUSSION

Results

Using liquid scintillation analysis (LSA), the information regarding the Rn-222 concentrations in the CPM of the groundwater samples has been determined. In total, fifteen water samples were taken at random from various locations throughout Awe, Nasarawa, Nigeria. A total of fifteen (15) water samples (ten (10) from boreholes and five (5) from wells) were tested, and the results are shown in (Table 2).

To assess the potential health risks associated with radon exposure, we translated the results from (Table 2) into concentrations measured in Becquerels per liter (Bq/l). These concentrations were then utilized to calculate the annual effective dose for both adults and children, estimate the excess lifetime cancer risk, and compare our findings with industry norms and the research outcomes of other investigators. (Tables 3 and 4) present the comprehensive results of these analyses.

Table 2: Concentrations of Radon-222 (Bq/l) in samples of water from Awe

Sample ID	Rn ± SD (CPM)	Rn ± SD (Bq/l)
AWB1	108.40±7.60	20.46±1.599
AWB2	118.87±0.87	22.67±0.183
AWB3	133.85±0.86	25.82±0.181
AWB4	88.620±0.53	16.30±0.112
AWB5	130.63±0.73	25.14±0.154
AWB6	82.080±0.02	14.93±0.004
AWB7	80.080±0.79	14.51±0.166
AWB8	94.100±0.12	17.46±0.026
AWB9	90.950±0.83	16.79±0.175
AWB10	81.350±0.83	14.77±0.175
AWW1	113.07±0.06	21.45±0.013
AWW2	81.330±0.02	14.77±0.003
AWW3	80.930±0.71	14.69±0.149
AWW4	86.270±1.51	15.80±0.319
AWW5	96.630±2.65	17.99±0.558
Mean	**97.81±18.58**	**18.24±3.909**
Min	**80.080**	**14.51**
Max	**133.85**	**25.82**
SE	**4.7976**	**1.009**

AWB = Samples from Borehole Water; AWW = Samples from Well Water; Rn = Radon Concentration; SE = Standard Error.

According to (Table 2), the concentrations of Rn-222 in Awe borehole water samples ranged from 14.51±0.166 to 25.82±0.181 Bq/l (AWB7 to AWB3), with a mean of 18.89±4.331 Bq/l and standard error of 1.37 Bq/l, while those in well water samples ranged from 14.69±0.149 to 21.45±0.013 Bq/l (AWW3 to AWW1), with a mean of 16.94±2.851 Bq/l and standard error of 1.28 Bq/l. It was discovered that the mean radon concentration for borehole and well water in Awe was 18.24±3.909 Bq/l.

Effective Dose per Year of Ingestion

The computation of annual effective dosage was carried out using Equation 2, taking into account the data provided in (Table 2). The obtained results have been presented in (Table 3).

Table 3: Ingested Effective Dosage Annually and Cancer Risks of Water Samples from Awe

Sample ID	λ_{ing}	λ_{inh} x10^{-5}	α_{ing} x10^{-4}	α_{inh} x10^{-7}
AWB1	0.105	5.157	3.7	1.805
AWB2	0.116	5.712	4.1	1.999
AWB3	0.132	6.506	4.6	2.277
AWB4	0.083	4.108	2.9	1.438
AWB5	0.128	6.335	4.5	2.217
AWB6	0.076	3.762	2.7	1.317
AWB7	0.074	3.656	2.6	1.280
AWB8	0.089	4.399	3.1	1.540
AWB9	0.086	4.232	3.0	1.481
AWB10	0.075	3.723	2.6	1.303
AWW1	0.110	5.404	3.8	1.891
AWW2	0.075	3.722	2.6	1.303
AWW3	0.075	3.701	2.6	1.295
AWW4	0.081	3.984	2.8	1.394
AWW5	0.092	4.533	3.2	1.587
Mean	**0.093**	**4.600**	**3.0**	**1.608**
Min	**0.074**	**3.656**	**2.6**	**1.280**
Max	**0.132**	**6.506**	**4.6**	**2.277**
SE	**0.005182**	**0.254**	**0.18**	**0.089**

AWB = Samples from Borehole Water; AWW = Samples from Well Water; λ_{ing} = Annual Effective Dose by Ingestion; λ_{inh} = Annual Effective Dose by Inhalation; α_{ing} = Excess Lifetime Cancer Risk due Ingestion; α_{inh} = Excess Lifetime Cancer Risk due Inhalation; SE = Standard Error.

The determination of the annual effective dose by ingestion was performed for the Awe area using the relevant data from Table 3 and the corresponding measured radon concentrations. The results indicate that, in the case of ingestion, the annual effective dose by ingestion from borehole water samples ranged from 0.074 to 0.132 mSv/y (AWB7 to AWB3), with a mean value of 0.096±0.022 mSv/y and standard error of 0.00703 mSv/y. Similarly, for well water samples, the range was 0.0750to 0.1100 mSv/y (AWW2 to AWW1) with a mean value of 0.0866 mSv/y and standard error of 0.006623 mSv/y. The annual effective dose by ingestion has overall mean for both borehole and well water as 0.093mSv/y.

The annual effective dose by inhalation for the Awe area was estimated based on the measured radon concentrations, as also presented in (Table 3). The analysis revealed that for borehole water samples, the annual effective dose by inhalation ranged from 3.666 $x10^{-5}$ to 6.506 $x10^{-5}$ mSv/y (AWB7 to AWB3) with a mean value of 4.760 $x10^{-5}$±0.000 mSv/y and standard error of 0.345 $x10^{-5}$ mSv/y. In the case of well water samples, the range was 3.70 $x10^{-5}$ to 5.40 $x10^{-5}$ mSv/y (AWW2 to AWW1) with a mean value of 4.27 $x10^{-5}$ mSv/y and standard error of 0.006623 mSv/y. The mean value for the entire Awe Local Government area was calculated as 0.321 $x10^{-5}$ mSv/y. The annual effective dose by inhalation has overall mean for both borehole and well water as 4.6 $x10^{-5}$ mSv/y.

Based on (Table 3), excess lifetime cancer risks due to ingestion for borehole water were found to range from 2.60 $x10^{-4}$±0.000 to 4.60 $x10^{-4}$±0.000 (AWB7 to AWB3) with a mean of 3.38 $x10^{-4}$ and standard error of 0.245 $x10^{-4}$. For well water, excess lifetime cancer risks ranged from 2.60 $x10^{-4}$ to 3.80 $x10^{-4}$ (AWB7 to AWB3) with a mean of 3.03 $x10^{-4}$ and standard error of 0.228 $x10^{-4}$. The excess lifetime cancer risks due to ingestion has overall mean for both borehole and well water as 3.0 $x10^{-4}$ mSv/y.

Lastly, according to Table 3, excess lifetime cancer risks due to inhalation for borehole water were found to range from 1.280 $x10^{-7}$ to 2.277 $x10^{-7}$ (AWB7 to AWB3) with a mean of 1.666 $x10^{-7}$ and standard error of 1.20764 $x10^{-8}$. For well water, excess lifetime cancer risks ranged from 1.295 $x10^{-7}$ to 1.891 $x10^{-7}$ (AWB7 to AWB3) with a mean of 1.494 $x10^{-7}$ and standard error of 0.112 $x10^{-7}$. The excess lifetime cancer risks due to inhalation have an overall mean for both borehole and well water as 1.608 $x10^{-7}$ mSv/y.

Comparison to Other Researchers and the Standard

The findings of this investigation were contrasted with safety requirements and other researchers' studies (Tables 4 to 6)

Table 4: Comparison of Concentration of Radon of Groundwater Samples for the Current work with Regulatory Bodies.

Regulatory Bodies	Concentration of Radon (Bq/l)	Sources
United Nation Scientific Committee on the Effect of Atomic Radiation (UNSCEAR)	22	Aruwa *et al.* 2017
United States Environmental Protection Agency (USEPA)	11.1	Aruwa *et al.* 2017
European Commission for Drinking Water Purposes (ECDWP)	100	Aruwa *et al.* 2017
World Average (WA)	10	Garba *et al*. (2013)
Standard Organisation of Nigeria (SON)	11.1	Aruwa *et al.* 2017
Present Study	**18.24**	Present Study

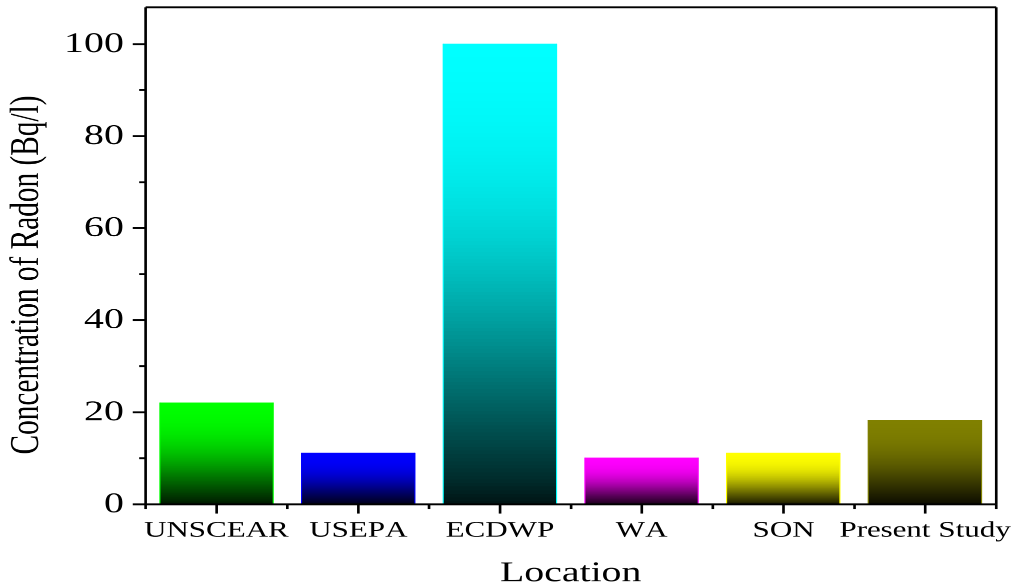

Fig. 2: Comparison of Concentration of Radon of Groundwater Samples for the Current work with Regulatory Bodies

According to (Table 4) and Fig. (2), the radon concentration values in this investigation were found to be a bit higher than the safe limits prescribed by authoritative bodies such as the, the United States Environmental Protection Agency (USEPA), and the global average (WA) and Standard Organization of Nigeria. Even though found lower than that prescribed by European Commission for Drinking Water Purposes (ECDWP) and United Nation Scientific Committee on the Effect of Atomic Radiation (UNSCEAR).

Table 5: Comparison of Concentration of Radon of Groundwater Samples for the Current work with other Places in Nigeria.

Location	**Radon Concentration (Bq/l)**	**Reference**
Ekiti State	13.59	Oni *et al.* (2016)
Kogi State	13.77	Aruwa *et al.* (2017)
Kaduna State	11.80	Garba *et al.* (2013)
Ondo State	35.54	Adeola *et al.* (2017)
Present Study	**18.24**	Present Study

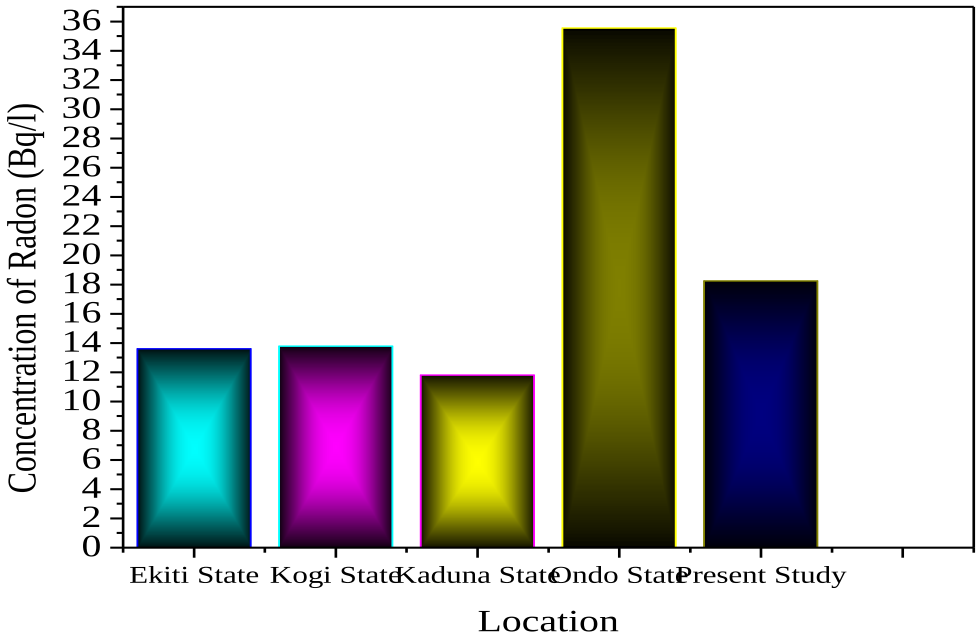

Fig. 3: A Chart Showing a Comparison of Radon Concentration of the Present Study and other parts of Nigeria

From (Table 5) and Fig. (3), it can be shown that the radon levels in the groundwater samples from the current study are higher than those from Ado-Ekiti in Ekiti State, Zaria in Kaduna State, Idah in Kogi State but lower than that of Ondo State.

Table 6: Comparison of Radon Concentration of Groundwater Samples from Nasarawa South with other parts of the World.

Location	**Radon Concentration (Bq/l)**	**Reference**
India	2.63	Oni *et al.* (2016)
Turkey	9.28	Oni *et al.* (2016)
Romania	15.40	Oni *et al.* (2016)
Lebanon (many locations)	11.30	Oni *et al.* (2016)
United States of America	5.20	Oni *et al.* (2016)
Present Study	**18.24**	Present Study

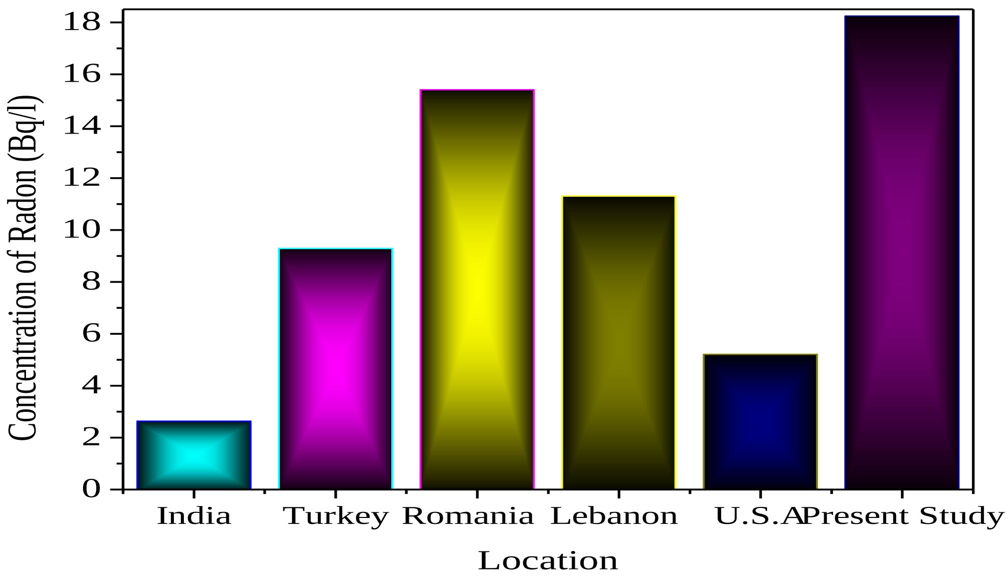

Fig. 4: A Chart Showing Comparison of Radon Concentration of the Present Study and other parts of the World

Based on the findings presented in (Table 6) and Fig. (4), the radon concentrations observed in the groundwater samples from this study were comparatively lower than those reported in countries such as Algeria and specific areas in Northern Venezuela, Romania, Jordan, the outer Himalayas, Finland, Turkey, Lebanon and United States and India.

DISCUSSION OF THE RESULTS

According to the work's findings, Awe had a mean radon content of 18.24 Bq/l. This value fell above the benchmarks 0f 11.1 Bq/l set by the Standard Organization of Nigeria (SON) and the United States Environmental Protection Agency, the value was also above the world average limit of 10 Bq/l. The value fell below 100 Bq/l prescribed by the European Union Commission for Drinking Water Purposes and 22 Bq/l set by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR).

The matching measured radon concentrations from Awe resulted in a mean annual effective exposure by consumption and breathing (Table 3) of 0.093±0.020 mSv/y and 4.6 x10^{-5}±0.000 mSv/y respectively.

The Standard Organization of Nigeria (SON) has endorsed the World Health Organization’s (WHO) recommended reference level of 0.1 mSv/y for the intake of radionuclides in water, as well as the International Commission on Radiological Protection’s (ICRP) recommended intervention level of 3-10 mSv/y for radionuclide intake. In the case of present study conducted in Awe, the corresponding observed radon concentrations yielded a mean annual effective by ingestion and inhalation dose lower than the above-mentioned standards. Importantly, all the recorded values for annual effective inhalation dose remained below the threshold of 1 mSv/y, which is advised as safe for the general public. The extra risk of cancer over lifetime from borehole and well water samples by ingestion and inhalation in Awe was 3.0 x 10^{-4}±0.000 and 1.608 x 10^{-7} ±0.000. Water samples from Awe Local Governments had excess lifetime cancer risk values for ingestion that were slightly higher than the global average of 2.9 x 10^{-4} while that of inhalation were far lower than the global average of 2.9 x 10^{-4} (Ibikunle *et al*., 2018; Aljomaily *et al*., 2021).

CONCLUSION

According to the findings, the groundwater samples used in the current investigation had radon concentrations beyond than the maximum limit of 11.1 Bq/l reported by US-EPA and agreed by SON, making them non-suitable for utilization at home by human. This spike in radon concentration of the study area may be attributed to the illegal mining activities going on in the area. If major restriction could be placed on the local miners, the magnitude of radionuclide excavation from beneath the soil to the top surface of the soil may be reduced to the bearest minimal, which may in turn go a long way in reducing the quantity of radon gas coming from those excavated radionuclides to people's environment. With that, the future cancer risk can be minimized, even though the annual effective dose is low. As a result, the information from this study could be applied to the study area because it was the first to determine the presence of radon in the groundwater there. To fully cover the zone, additional research involving additional boreholes and wells in the study area should be conducted. As concentrations of radon in ground-water varies with time as a result of dilution from rainwater, more examination may be carried out in the dry and rainy seasons.

ACKNOWLEDGMENT

The initial author expressed gratitude to the other authors for their constructive comments, which improved and brought freshness to the work.

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تقدير تركيز الرادون في المياه الجوفية من مناطق اوى في ولاية نصراوة، نيجيريا

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الملخص

تعد المياه الجوفية في ولاية نصراوة المصدر الأكثر استخدامًا للمياه العذبة للشرب والري والاستخدامات المنزلية الأخرى، لكن جودتها لا تزال مصدر قلق كبير بسبب ارتفاع تركيزات الرادون الناتجة عن أنشطة التعدين. حددت هذه الدراسة تركيز الرادون في المياه الجوفية في منطقة اوى في ولاية نصراوة، نيجيريا باستخدام الكاشف الوميضى السائل. تم جمع خمسة عشر (15) عينة من المياه الجوفية. بلغ متوسط محتوى الرادون في عينات المياه منطقة اوى 2.44 بيكريل في اللتر حسب النتائج. بالنسبة للبالغين والأطفال في منطقة اوى، كان متوسط الجرعة الفعالة السنوية عن طريق الابتلاع 0.018 و 0.030 ميللي سيفرت في السنة، على التوالي وكان متوسط خطر الإصابة بالسرطان مدى الحياة هو 6.21×10^{-5} للبالغين و 10.22×10^{-5} للأطفال. كان متوسط تركيز الرادون في منطقة البحث 2.44 بيكريل فى اللتر أقل من 11.1 بيكريل في اللتر الذي حددته منظمة المعايير النيجيرية ووكالة حماية البيئة الأمريكية في عام 1991. من نتائج هذه الدراسة، فإن تركيز الرادون آمن لذلك، يمكن للناس الاستمرار في زراعتهم وأنشطتهم الأخرى. ومع ذلك، يمكن إجراء مزيد من التحليل في المنطقة لمنع الناس من خطر الإصابة بالسرطان. لتغطية المنطقة بأكملها، يجب إجراء بحث إضافي يغطي مصادر إضافية في منطقة الدراسة. نظرًا لأن تركيزات الرادون في المياه الجوفية تتغير بمرور الوقت بسبب التخفيف عن طريق التغذية من الأمطار، يجب إجراء المزيد من الفحوصات خلال الموسمين الجاف والرطب.

الكلمات الدالة: المياه الجوفية، الرادون، الجرعة الفعالة السنوية، مخاطر الإصابة بالسرطان مدى الحياة.