International Journal of Scientific Research in Physics and Applied Sciences
Vol.9, Issue.6, pp.86-91, December (2021)

Research Paper

E-ISSN: 2348-3423

Investigation of Radon Concentration in Drinking Water in Some Selected Areas of Sokoto, Nigeria

A.W. Adetoro[1*], A. Bello[2], A. Yakubu[3], S.T. Sununu[4], A. Usman[5], M. Sulieman[6]

[1,2,3,4,5]Kebbi State University of Science and Technology Aliero, Kebbi State Nigeria
[6]Nigeria Atomic Energy Commission Abuja, Nigeria

**Corresponding Author adetorowale@rocketmail.com, +2347060888446*

Available online at: www.isroset.org

Received: 19/Nov/2021, Accepted: 01/Dec/2021, Online: 31/Dec/2021

Abstract**—** Water is one of the most plentiful and important natural resources in the universe. Because of the varying levels of radioactivity in water, the concentration of radon in water needs to be determined for radiation protection. In this study, the radon concentration in groundwater (Borehole and well water) samples were collected in different parts of Sokoto state, Nigeria. Twenty (20) groundwater (6 well water and 14 borehole water) samples were collected and measured using a Liquid scintillation counter (Tri-Carb LSA 1000TR). Most of the values of the radon are below the maximum contamination level (MCL) of 10Bq/L recommended by the World Health Organisation (WHO), “Bello Way” with 22.97Bq/L, and “Gidan Kuka” with 4.08Bq/L having the highest and lowest value of radon concentration respectively. The mean values of radon concentrations were found to be 12.00Bq/L and 10.00Bq/L for Well water and Borehole water source respectively. The values of the estimated annual effective dose were found to be mostly below the recommended reference level of 0.1mSv/yr set by the World Health Organisation (WHO). The mean value of the estimated annual effective dose due to ingestion was found to be 0.087mSv/yr and 0.074mSv/yr for Well water and Borehole water respectively. These results indicate generally that there is no probability of health hazards for the public due to the presence of radon in groundwater and it is safe for consumption.

Keywords**—** Radon, borehole, well water, Effective dose.

I. Introduction

Water has been in existence from the origin of the universe itself. Water covers over 71% of the earth’s surface and it is a very important natural resource. Yet, only 2.5% of the earth’s water is fresh and suitable for consumption [1].

Water is a necessity to man and his environment; it existed long before man came into existence. Skillful management of water bodies is therefore required if they are to be used for diverse purposes. Ninety-five percent 95% of all fresh water on earth is groundwater found in natural rock formations [2]. Water is an essential substance to all living things which include: man, animals, and all that surround them [3].

Water is fundamental to life on earth, and, therefore is one of human most valuable resources. The supply of clean, abundant water sources is a major challenge facing modern civilization. The challenge includes the securing of water supplies in the face of climate changes and population growth and the mitigation of ongoing detrimental effects of the modern world. The use of water cuts across industrial, agricultural, and domestic uses. The two main sources of water are rain and groundwater sources. It is found in rivers, wells, dams, lakes, and streams [4].

Radon (^{222}Rn) is a naturally occurring radionuclide; it is a gas that is formed by a series of radioactive decay of uranium-238. Radium-226 (^{226}Ra) is the parent radionuclide of ^{222}Rn in the decay series, and ^{226}Ra is found in a wide variety of rocks, soil, natural gas, and groundwater [5]. Radon and its decay products called radon daughters or radon progeny emit highly ionizing alpha-radiation. Radon has been classified as a human carcinogen [6]. The half-life of ^{222}Rn is 3.824 days (91.2 hours) and it emits alpha particles. Radon gas always dissolves in water and its density is 7.5 times higher than air [5].

The existence of radionuclides in drinking water gives rise to internal exposure, directly via their decay processes, through ingestion and inhalation, and indirectly, when they are combined as part of the food chain [7].

It has been estimated that lack of clean drinking water and sanitation services leads to water-related diseases globally and between five to ten million deaths occur annually, primarily of small children [8]. Population growth and urbanization have put a lot of pressure on water resources in the world. This has resulted to in adequate public water supply. Drilling of boreholes has now become the norm in most urban areas [9].

Radon is created when uranium, thorium, and radium break down in rocks, soils, and groundwater. Human activities and natural phenomena constantly polluting the sources of water can affect water quality. Water pollution emanates from industries, hospitals, and other activities like farming found in the environment. Water sources such as hand-dug wells and boreholes could be contaminated with Natural Occurring Radioactive Materials (NORMS). These sources of water do not undergo a quality examination concerning natural radiation, which is the leading cause of lung and stomach cancer. Therefore, the need to investigate the concentrations of Radon in the water consumed by the people in the research area was crucial.

The aim of this research is to investigate the radon concentration in drinking water in some selected areas of Sokoto metropolis.

II. Related Work

Preliminary studies on ^{222}Rn concentration in groundwater from Zaria, Nigeria was carried out [10]. Water samples from various sources in the city and surrounding area of Zaria were analyzed for their Radon concentration. The results obtained in this study indicate that the ^{222}Rn concentration was in the range of 2.42–16.60 Bq/L and 3.11–21.31 Bq/L for wells and borehole water samples, respectively. Mean concentrations were measured as 7.18 ± 1.11 Bq/L for wells and 7.41 ± 2.04 Bq/L for boreholes. While the average values are within the maximum concentration limit of 11.1 Bq/L sets by USEPA and the world average value of 10 Bq/L set by WHO, several incident values from well and borehole sites exceeded these values.

Radon concentration in ground water of Dhaka city, Bangladesh was investigated [5]. It was found that the radon concentrations of maximum samples were below the USEPA limit. Only two or three values of radon concentration were found slightly high than the USEPA limit of 11.1 Bq/L. The calculated annual effective doses to an individual for ^{222}Rn due to intake of ground water for all samples were below the WHO limit. Therefore these results also indicate that there is no probability of health hazards for public due to presences of radon in ground water and it is safe for consumption in the study area.
Measurement of radon concentration in drinking water of Ado-Ekiti, Nigeria were analyzed [11]. The result obtained in this study were in the range of 3.09±1.30 Bq/L to 32.03±2.32 Bq/L with an average value of 13.59 Bq/L. The recorded value of radon concentrations is within the recommended safe limit of 4-40 Bq/L suggested by the United Nations Scientific Committee on the Effect of Atomic Radiation. All the radon concentration values were found to be below the recommended action level of 100 Bq/L set by the European Commission for drinking purposes. The US Environment Protection Agency has proposed that the allowed maximum contamination level (MCL) for radon concentration in water is 11 Bq/L in which about 53% of samples were above the maximum contamination level. The higher value of radon concentration was ascribed to the nature of basement rock in the study locations and also could be linked to the hilly nature of the area.

III. Materials and Methods

Study Area

The study area is located in Sokoto State North-Western part of Nigeria, which is situated between latitudes 13°00.160′N to 13°04.188′N and longitude 005°11.172′E to 005°15.537′E with an estimated area of 59,570 km². Sokoto area has a population of about 427,760 according to the 2006 census. The investigation would be limited to the underground water sources (boreholes and well water) used by the people in the study area.

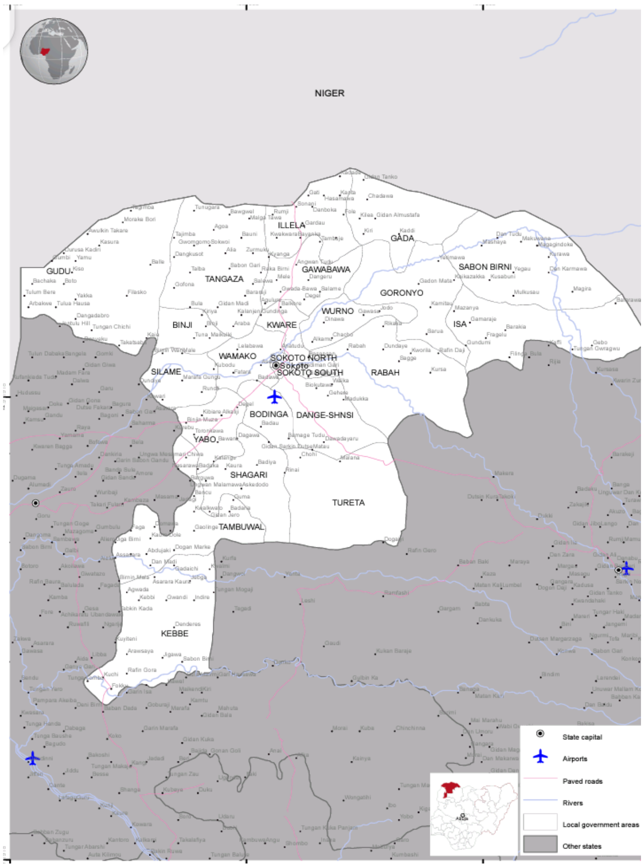

Figure (1) Map of Sokoto state, Nigeria.

Materials

The following are some of the materials used for the radon measurement;

i. Plastic containers (1Litres)
ii. Gloves
iii. Distilled water
iv. Scintillation cocktail (Reagent)
v. Scintillation vial
vi. Marker pen and Masking tape
vii. Liquid Scintillation Counter (LSC) (tri-carb-LSA 1000TR).
viii. Syringe and needles
ix. Global positioning system (GPS)

Method

The international standards organization procedure (ISO13164) for the measurement of the concentration of radon in water is to be employed in this analysis. The methods are stipulated below;

To adjust the water flow to avoid turbulence and air bubbles at the outlet of the tap and in the sampling container.

The sampling container was filled without air bubbles below the cap after closing the container.

Sample Collection

A total number of twenty (20) groundwater samples were collected across the state metropolis from both boreholes and well water. Samples were collected in clean 1litre plastic containers with tight covers.

The plastic bottles were first washed cleaned and rinsed with distilled water to avoid radon present in the samples from being contaminated or absorbed. The water samples were collected after the water was allowed to run for a few minutes.

The samples were taken to the laboratory immediately after collection without allowing them to stay long (three days maximum) for analysis. This is done to achieve maximum accuracy and not to allow the composition of the sample to change.

Sample Analysis and Counting

The prepared samples are to be analyzed using Liquid Scintillation Counter (Tri-Carb LSA 1000TR) model located at the center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria.

The counting was carried out immediately after the prepared samples were brought to the laboratory. The counting vial was placed in the liquid scintillation counter (LSC) and each vial was counted for 60 minutes. It was ensured that the vials were not shaken to avoid disturbing the state of equilibrium between ^{222}Rn and its short-lived daughters in the organic scintillate. The time and date of counting were all noted.

The ^{222}Rn concentration is to be calculated using the following equation [12].

$$Rn(Bq/L) = \frac{100\times(SC-BC)\exp(\lambda t)}{60(CF)\times(D)} \qquad (1)$$

Where

Rn = Concentration of Radon

SC = Sample count

BC = Background count

CF = Calibration Factor

D = Decay correction factor.

t = Elapsed time (time taken from sample collection to counting)

λ = Decay constant found using the equation

$$\lambda = \frac{ln2}{T_{1/2}}$$

The annual effective dose is to be calculated using the below equation [13].

$$E = Rn \times D \times L \qquad (2)$$

Where

E = Annual effective dose by ingestion (mSv/yr)

Rn = Concentration of Radon

D = Dose coefficient (10^{-5}mSv/yr)

L = Annual water consumption, 2 L/d (730L/yr).

IV. RESULTS AND DISCUSSION

In each of the study areas, the source of groundwater is randomly located. The boreholes and the well water samples were not collected along any profile line. Despite the random locations of the source of water samples, the exact location of the sample on the surface of the earth was taken by the Global positioning system (GPS).

A total of twenty (20) groundwater samples comprising of fourteen (14) borehole sources and six (6) well water sources were collected from some selected areas of Sokoto metropolis and analyzed using Liquid Scintillation Counter. The radon activity concentrations from all the samples collected were evaluated through equation (1).

The results of the analysis obtained are shown in the table.

Table (1) Radon concentration and the annual effective dose from the study area

S/N	Sample Location	Sample type	Latitude (N)	Longitude (E)	Rn(Bq/L)	AED (mSv/yr)
1	Tudun Faila	W	13°04.188′	005°11.949′	**5.12**	**0.037**
2	Gidan Igwe	W	13°04.280′	005°12.446′	**6.87**	**0.050**
3	Arkilla Gandu	W	13°01.802′	005°11.172′	**14.36**	**0.10**
4	Polo Club	W	13°00.731′	005°13.786′	**12.31**	**0.090**
5	Tamaje	W	13°00.463′	005°15.431′	**21.91**	**0.16**
6	Rijia Doruwa	W	13°02.929′	005°14.652′	**11.26**	**0.082**
7	Gidan Kuka	B	13°03.905′	005°12.417′	**4.08**	**0.030**
8	Sama Road	B	13°00.770′	005°14.243′	**7.56**	**0.055**
9	Runjin Sambo	B	13°03.984′	005°13.067′	**10.28**	**0.075**
10	Bafarawa Estate	B	13°00.160′	005°14.340′	**13.86**	**0.10**
11	Danbuwa	B	13°00.293′	005°15.092′	**8.29**	**0.061**
12	Gidan Dare	B	13°03.235′	005°12.610′	**8.56**	**0.062**
13	Offa Road	B	13°00.596′	005°15.537′	**8.07**	**0.059**
14	City Campus	B	13°02.407′	005°14.747′	**9.50**	**0.069**

15	Minanata	B	13°02.681′	005°15.434′	**9.44**	**0.069**
16	Kantin Daji	B	13°03.361′	005°13.063′	**11.41**	**0.083**
17	Bello Way	B	13°02.833′	005°13.934′	**22.97**	**0.18**
18	Bado Uku	B	13°00.524′	005°11.331′	**9.92**	**0.072**
19	J Allen	B	13°02.745′	005°13.767′	**7.25**	**0.053**
20	D Daji House	B	13°02.533′	005°13.812′	**8.88**	**0.065**

From the results obtained, most of the values of Radon-222 are below the maximum contamination level (MCL) of 10Bq/L, “Bello Way” with 22.97Bq/L, and “Gidan Kuka” with 4.08Bq/L having the highest and lowest value of Radon concentration respectively. The mean values of Radon-222 concentrations were found to be 12.00Bq/L and 10.00Bq/L for Well water and Borehole water source respectively.

Activity Concentration of Radon (^{222}Rn)
Well waters
The results of the analysis of radon concentration for the six (6) well water samples collected at different locations as presented in Table 4.1 above revealed that the concentration of radon varies from 5.12Bq/L to 21.91Bq/L with a mean value of 12.00Bq/L. The minimum radon concentration was obtained to be 5.12Bq/L at Tudun Faila, while the maximum radon concentration was found to be 21.91Bq/L at Tamaje as shown in figure (2) below, the high concentration in the water consumed in Tamaje pose a threat to the health of the consumers which is as a result of the geology of the area and also being a construction site (block molding factory).

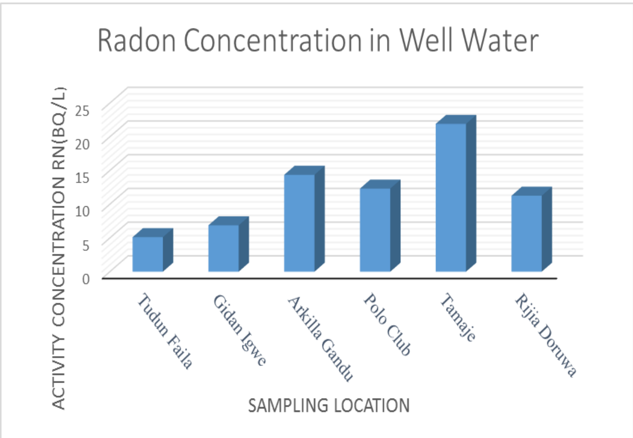

Figure (2) Bar graph of radon concentration in well waters

Borehole
The results of the analysis of radon concentration for the fourteen (14) borehole water samples collected at different locations as presented in Table (1) below revealed that the concentration of radon varies from 4.08Bq/L to 22.97Bq/L with a mean value of 10.00Bq/L. The minimum radon concentration was obtained to be 4.08Bq/L at Gidan Kuka, while the maximum radon concentration was found to be 22.97Bq/L at Bello way as shown in figure (3) below, the high concentration of radon in the water consumed in Bello way pose a threat to the health of the consumers which is due to the geology of the area and also, as it is a mechanical workshop.

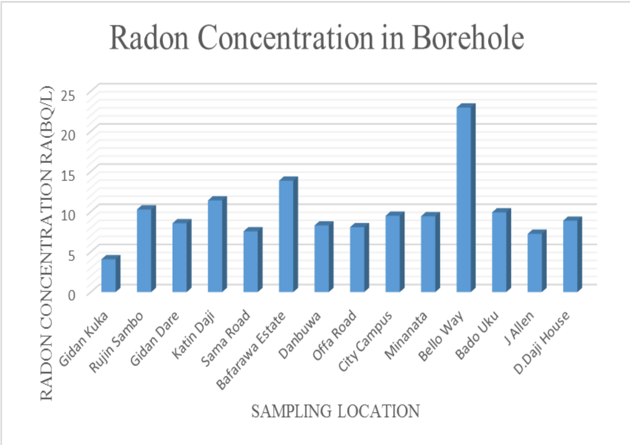

Figure (3) Bar graph of radon concentration in boreholes

Variations of radon content in all water samples may be due to variations in meteorological parameters (temperature, pressure, and humidity). Other reasons for Well water samples can be the aeration or cooling processes [14].

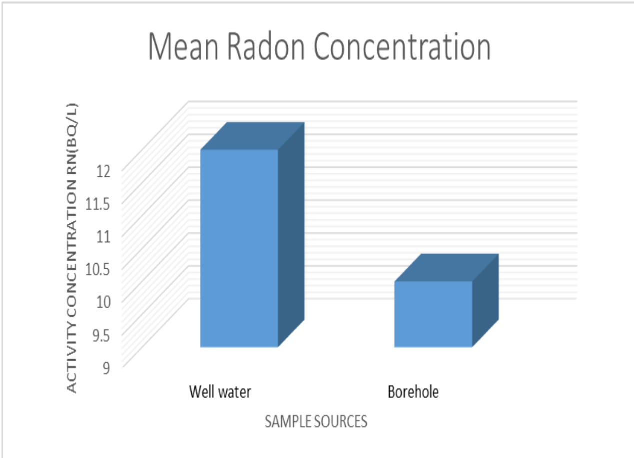

Figure (4) Bar graph of the mean radon concentration

Annual Effective Dose (AED)
The values of the estimated annual effective dose were found to be mostly below the recommended reference level of 0.1mSv/yr. “Bello Way” with 0.18mSv/yr and “Gidan Kuka” with 0.030mSv/yr have the highest and lowest value of the estimated annual effective dose respectively. Also, it was found that the mean value of the estimated annual effective dose due to ingestion be 0.087mSv/yr and 0.074mSv/yr for Well water and Borehole water respectively. These results show that the mean value of radon-222 concentration in Well water and that of Borehole water both do not exceed the recommended value of 0.1mSv/yr set by the World Health Organisation [15].

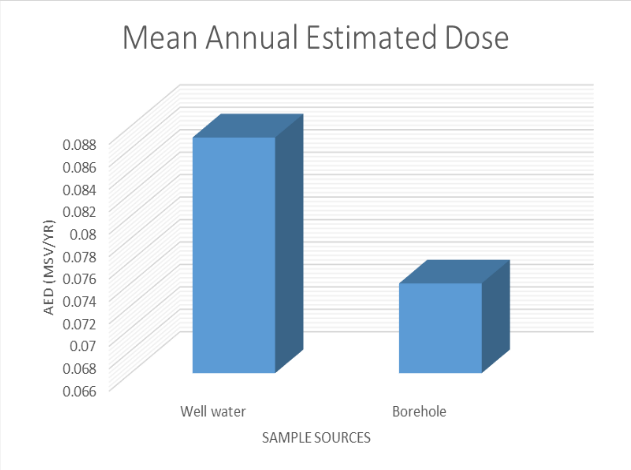

Figure (5) Bar graph of the mean Annual estimated dose.

Table (2) Comparison of radon concentration in groundwater from Sokoto with other parts of the world

Location	Radon concentration Bq/L	Reference
India	11.16	[16]
Egypt	0.49	[17]
Turkey	0.091	[18]
Ghana	0.195	[19]
Zaria, Nigeria	14.9	[12]
Katsina, Nigeria	12.37	[13]
Gadau, Nigeria	38.32	[20]
Idah, Nigeria	13.77	[21]
Sokoto, Nigeria	10.60	Present study

V. Conclusion and Future Scope

This research determines the radon activity concentration and its corresponding annual effective doses in the samples from the available water resources used for drinking and domestic purposes in some selected areas of Sokoto metropolis. The study showed that 60% of the recorded values of Radon concentration in the groundwater samples have been observed to be below the maximum limit set by World Health Organization (WHO). The findings from this study suggest that no serious radiological hazard due to Radon concentration in water uses for drinking and other domestic purposes in the area.

This was the first study of such type of radon measurement in groundwater samples in Sokoto metropolis using this technique. So it's demanding larger and more comprehensive studies of all areas of the city. The results obtained from this study would serve as baseline data for research on the measurement of Radioactivity from the research area and beyond.

Acknowledgment

The authors wish to express their gratitude to all those who contributed to this research and whose work served as reference literature during this study. Special gratitude goes to the staff of the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria for the laboratory works.

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AUTHORS PROFILE

ADETORO, Abdulkadir Wale is a lecturer at the department of physics, Kebbi state university of science and technology, Aliero. His area of interest is nuclear physics and nuclear energy.

BELLO, Abdullahi is a senior lecturer at the department of physics, Kebbi state university of science and technology, Aliero. His area of interest is nuclear physics and quantum mechanics.

YAKUBU, Abubakar is a senior lecturer at the department of physics, Kebbi state university of science and technology, Aliero. His area of interest is telecommunication.

SUNUNU, Sanusi Tanko is a lecturer at the department of physics, Kebbi state university of science and technology, Aliero. His area of interest nuclear physics.

USMAN, Ahmed Usman is a lecturer at the department of physics, Kebbi state university of science and technology, Aliero. His area of interest is geology and geophysics.

SULIEMAN, Mudassir is a technologist with the Nigeria atomic energy commission Abuja. His area of interest is nuclear technology.

