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ASSESSMENT OF RADON CONCENTRATIONS IN WATER SOURCES FROM SABON GARI LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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ABSTRACT

Radon concentration in water is one of the major problems of radiation protection in recent years. This work assessed the radon concentration in water sources from Sabon Gari, local government area, Kaduna State. The water samples were collected and analyzed using Liquid scintillation counter (Tri-Carb-LSA1000). The overall mean radon concentration of the waters samples was found to be 14.9 BqL^{-1}, which is higher than the maximum permissible limit of 11.1 BqL^{-1} by USEPA and the world average value of 10 BqL^{-1} by UNSCEAR and WHO. The overall Annual effective dose (AED) due to inhalation of radon is calculated to be 37.6 μSvy^{-1}. This value is less than the permissible limit of 100 μSvy^{-1} set by WHO. Also, the overall AED due to ingestion is estimated as 109.0, 154.2, and 180.4 μSvy^{-1} respectively for both Adult, children and Infant, which is slightly higher than the WHO permissible limit of 100 μSvy^{-1} for adults and less than the permissible limit of 200 μSvy^{-1} for children. This result shows that the inhabitants of Sabon Gari local government are safe from any radiological health related effects that may result from the inhalation of radon gas. Also, both Children and Infant are safe from any immediate radiological health risk, but for Adults, consuming any of the water sources (Well, Borehole and Surface) over a prolong period of time is not completely safe and may result in radiological health hazard.

Keywords: Radon, Effective dose, Sabon Gari, Liquid Scintillation Counter

INTRODUCTION

Water is the major constituent of the Earth's streams, lakes, oceans and the fluid of most living organisms. It covers about 71% of the Earth surface. It is vital for all known forms of life especially humans. Humans uses water for various reasons such as transportation, power generation, agriculture and other domestic activities. Hence, its availability and quality with regards to radiological, microbiological, chemical and any other form of contamination is a delicate and vital issue (Garba *et al.,* 2008). Unfortunately, access to clean and potable drinking water in most developing countries such as Nigeria is a major challenge, hence leading most people to rely heavily on untreated surface and ground water sources for consumption (Garba *et al.*, 2008).

Radon (^{222}Rn) is an odorless, colorless and tasteless naturally occurring radioactive inert gas that is soluble in water, having a half-life of 3.82 days. It is a member of the Uranium decay series that contributes the largest proportion of the total radiation from natural sources (Somlai, 2007). Studies have shown that ^{222}Rn and its progeny contribute about 50% of the total effective dose equivalent from natural sources. The concentration of ^{222}Rn in water is due to the decay of Radium (^{226}Ra) associated with rocks and soil (Shilpa *et al.*, 2017). Radon gas can easily penetrate through soil and rocks and dissolves in water, with a higher concentration in drinking water from groundwater sources than those from surface water (Xinwei, 2006). The exposure of a population to high concentration of Radon and its daughters for a long period has significant health effects ranging from respiratory functional changes, cancer of the lungs, stomach and gastrointestinal tract cancer, etc. (Kendel *et al.*, 2002; BEIR, 1999).

In the last decade, Radon concentration in water sources has become one of the major problems of radiation protection (Xinwei, 2006; Shilpa *et al.*, 2017). Reports have shown that high activity concentration of ^{222}Rn is associated with areas rich in granite (David *et al.*, 1989). Also, studies reveal that the entire Kaduna State is underlain by a basement complex of igneous and metamorphic rocks, and since rocks and soil contain radium that decays to form radon, both underground water and surface water should contain the dissolved gas (Garba *et al.,* 2012). As such, the level of radon in water sources should be investigated. Sabon Gari Local Government Area is one of the largest Local Government Areas in Kaduna State, Nigeria, whose majority of population consisting of both humans and animals lack access to portable sources of water. As such, majority rely on untreated surface and ground water sources (well, borehole streams etc.) for consumption, agricultural and other domestic uses respectively. Hence, this study is aimed at assessing the ^{222}Rn concentration in different water sources within Sabon Gari Local Government Area Kaduna State, Nigeria. The liquid scintillation counter at the Centre for Energy Research and Training, Ahmadu Bello University was used in this study due to its simplicity and accessibility. The counter was first calibrated using standard procedure in 2011 (Garba *et al.*, 2012), which make it possible for many studies to be carried out with it within the country.

MATERIALS AND METHODS

Study Area

The study area is Sabon Gari Local government of Kaduna State, Nigeria. It is located in the Northwest geophysical zone of Nigeria. It lies between latitude 11.056^0 and 11.36^0 north and longitude 7.08^0 and 7.72^0. It has distinct wet and dry season and is within the northern Guinea Savannah zone and part of the Sahel savannah zone of Nigeria. Eighteen locations within Sabon gari Local Government Areas have been selected for the research. They include, Samaru, Palladan, Basawa etc.

Geology of the Study Area

The entire Kaduna State is underlain by basement complex of igneous and metamorphic rocks. The basement complex rocks are essentially granites, gneisses migmatites, schist, quartz (Benett, 1979). The topographical relief is relatively flat, having an elevation of between 600-650 meters in large areas of local government. It is over 650 meters above mean sea level (a.m.s.l) in some places and below 500 meters in places that slope downward toward the river (Saleh, 2015).

Sample Collection

Samples were collected in a clean sample collection battles with tight covers, surface water were collected with the aid of bailer, the ground water in the well were first purged by drawing it out severally to ensure fresh samples were obtained. The borehole water samples were collected after evacuating the existing water in the pipe. The containers were rinsed with the water to be collected and later with concentrated Nitric acid. To avoid contamination, the water was preserved with concentrated Nitric Acid to minimize precipitation and adsorption of particles in the water on container walls. The bottles were also brimmed without any head space to prevent Carbon dioxide from being trapped, as it can easily dissolve in water resulting to a different chemistry (Kamunda *et al*., 2017). In order to achieve accuracy, samples were transferred to the laboratory immediately and analyzed within a period of three days so as to maintain the sample composition. A sample, containing one of the selected water sources (stream, well and borehole water) was taken from each of the eighteen sampling locations (Table 1). During sampling, a Global Positioning System (GPS) was used to mark the geographical locations on the earth surface of the sample collection points.

Sample Preparation

The sample preparation procedures reported by Garba *et al*., (2012) was used in preparing the samples for analysis. Plastic sample bottles were used for sample collection of ground and surface water sample from each of the villages. The samples were transferred to the laboratory at Centre for Energy Research and Training, A.B.U Zaria, for analysis. Liquid scintillation vials were prepared containing 10 ml of liquid scintillation solution. 10 ml of each sample was carefully drawn from the sample bottle into a disposable syringe in order to minimize out-gassing the sample by aeration. The samples in the hypodermic syringes were immediately transferred to the liquid scintillation vials containing 10 ml scintillation solution by injecting the sample at the bottom of the vial, below the immiscible scintillation solution. The hypodermic needle was thereafter carefully removed from the vial and the cap of the vial was immediately closed tightly. The vial was shaken vigorously for ^{222}Rn to be extracted from the water phase to the organic scintillant solution due to its greater solubility in organic liquids. The vials were left for about 3 hours to allow for in growth of the short-lived decay products of ^{222}Rn and also for attainment of secular equilibrium. The background samples were prepared by dissolving 10 ml of the scintillation solution in 10 ml of distilled water. Similarly, the calibration solution was prepared by dissolving 10ml of IAEA standard ^{226}Rn sample in 10 ml distilled water.

Sample Analysis

The procedures reported by (ASTM, 1999; Garba *et al.,* 2012; Kamba *et al*. 2016 and Aruwa *et al*., 2017) was used for the analysis. Prepared samples were analyzed using liquid scintillation counter (Tri-Carb-LSA1000) located at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. Calibration of the liquid scintillation counter was made prior to the analysis using IAEA ^{226}Ra standard solution. The background, calibration and sample solutions were measured over the same spectral range and for the same counting period of 60 mins. The background and sample count rate (counts.min^{-1}) were recorded. ^{222}Rn and its short-lived daughters emit a total of 5 radioactive particles (3 α and 2 β) per every disintegration of ^{222}Rn. Since, secular equilibrium was established between ^{222}Rn and these decay daughters, all the five emissions were used to detect and quantify ^{222}Rn in water. Therefore, the total efficiency of detection is 500%. ^{222}Rn activity concentrations was evaluated by considering sample volume, total and background count rates, decay time (time between sample collection and counting) and efficiency of detection. The ^{222}Rn concentration in the water samples was then determined using the equation 1. (ASTM, 1999 and Garba *et al.,* 2012):

$$R_n = \frac{100 \times (N_S - N_B)e^{\lambda t}}{60 \times 5 \times 0.964} \qquad (1)$$

Where; R_n is ^{222}Rn concentration at the time of sample collection (BqL^{-1}), N_S is the sample total count rate (count min.$^{-1}$), N_B is the background count rate (count min^{-1}), t is the elapsed time between sample collection and counting (4320 mins), λ is ^{222}Rn decay factor (1.26 x 10^{-4} min.$^{-1}$), 100 is a conversion factor from per 10 ml to per liter (l^{-1}), 60 is conversion factor from min. to sec, 5 (500%) is number of emissions per disintegration of ^{222}Rn (3 α and 2 β, assuming 100% detection efficiency for each) 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.

Assessment of Effective Dose Due to Radon in Drinking Water

The average annual effective dose from ingestion and inhalation of Radon in water were estimated using equations 2 and 3 provided by UNSCEAR as reported by (Khattak *et al.*, 2011; Tabar and Yakut, 2014). According to the world health organization (WHO) and the council of European Union (EU), the average annual effective dose of Radon in drinking water has a permitted value of 0.1 mSvy^{-1} (100 μSvy^{-1}) (Bem, 2014).

Annual Effective dose due to ingestion

$$E_{w\cdot I_g}\ (nSvy^{-1}) = C_{Rn} \times C_w \times EDC \qquad (2)$$

Where; $E_{w\cdot I_g}$ = effective dose for ingestion, C_{Rn} = measured Radon concentration in water (BqL^{-1}), C_w = Water consumption rate and EDC= effective dose coefficient for ingestion (3.5 $nSvBq^{-1}$).

Annual Effective dose due to inhalation

$$E_{w\cdot I_h}\ (nSvy^{-1}) = C_{Rn} \times R_{a.w} \times F \times O \times \mathrm{DCF} \qquad (3)$$

Where; $E_{w\cdot I_h}$= effective dose for inhalation, C_{Rn} = measured Radon concentration in water (BqL^{-1}), $R_{a.w}$ = ratio of Radon conc. in air to tap Water $(10^{-4}), F$ = equilibrium factor between Radon and its progeny, O = global average indoor occupancy factor (7000hy^{-1}), DCF = Dose conversion factor (9$nSvh^{-1}(Bqm^{-3})^{-1}$) UNSCEAR (2000)

RESULTS AND DISCUSSION

Radon Concentration and the Resulting Annual Effective Dose

Table 1 shows the coordinates, radon concentration (BqL^{-1}) and the annual effective dose (μSvy^{-1}) of the study area (Sabon Gari Local government). There are eighteen (18) sampling locations comprising of five (5) wells, Six (6) surface and seven (7) boreholes water sample. The overall mean radon concentration of the waters samples is found to be 14.9 BqL^{-1}, with boreholes having a mean concentration of 14.0 BqL^{-1}, Surface water 15.7 BqL^{-1} and wells 15.1 BqL^{-1}respectively. A4 GRA Sabon Gari with well water sample type recorded the highest radon concentration of 22.4 BqL^{-1}, while Mammy market Basawa with borehole water sample type recorded the least value of 13.1 BqL^{-1}. All the eighteen (18) sample types had radon concentration above the maximum permissible limit of 11.1 BqL^{-1} (USEPA, 2003) and the world average value of 10 Bq/L (UNSCEAR, 1993 and WHO, 2004).

The annual effective dose (AED) in (μSvy^{-1}) for inhalation and ingestion of Radon from the water sources was estimated using equation (3) and (4) respectively. The overall AED due to inhalation of Radon is calculated to be 37.6 μSvy^{-1} with well, surface and borehole water type having an average of 38.2, 39.6 and 38.2 μSvy^{-1} respectively. This value is less than the permissible limit of 100μSv/year set by WHO (WHO, 2004). Also, the overall AED due to ingestion of Radon in the water sources is calculated to be 109.0, 154.2, and 180.4 μSvy^{-1} respectively for both Adult, children and Infant. For consumption of well water only, the average AED is 110.81, 166.2 and 193.9 μSvy^{-1} respectively for adults, children and infants, As for Surface water only, 114.9, 172.4 and 201.2 μSvy^{-1} respectively were the AED while for the consumption of borehole water only, the average AED for adults, children and infants were 102.9, 154.2, and 180.4 μSvy^{-1} respectively. These values are higher than the WHO permissible limit of 100 μSv/year for adults and less than the permissible limit of 200 μSvy^{-1} for children.

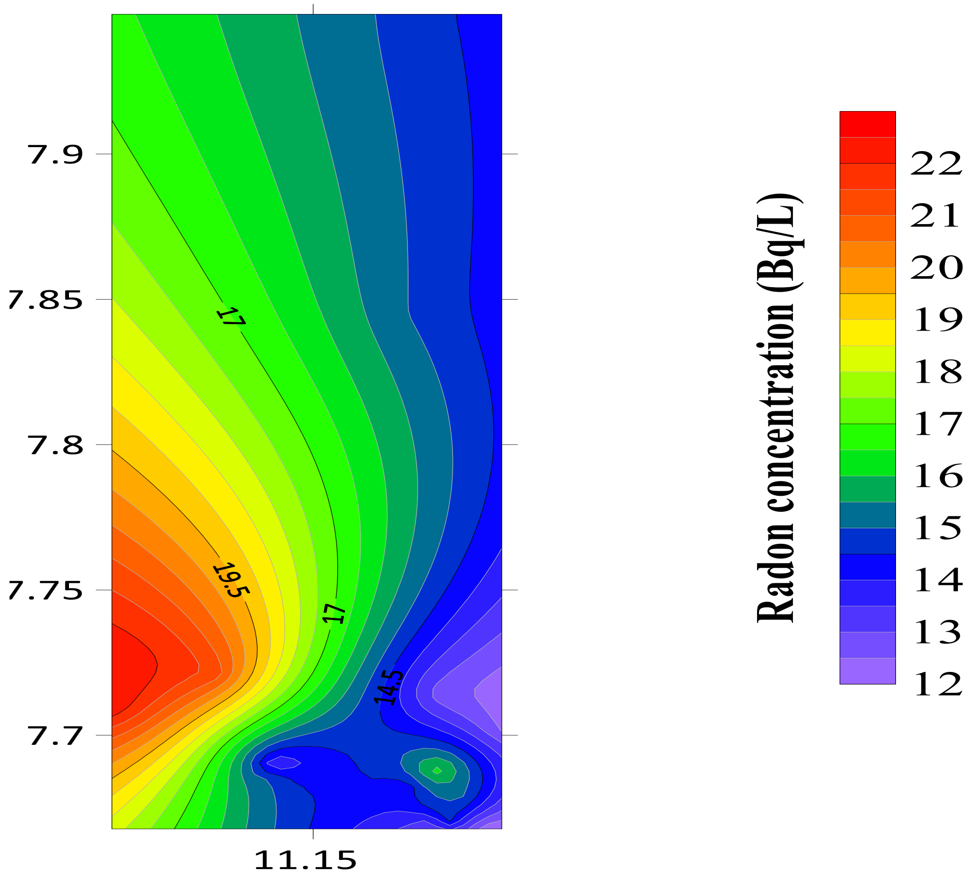

Fig. 1: 2D plot showing the Radon Concentration in (Bq/L) within the study area.

Generally, it is observed that the radon level was higher in the well water samples as compared to the boreholes water samples. This can be attributed to the fact that radon readily dissolve in water under pressure, leading to radon accumulation in ground water (Cho *et al*., 2004). Another reason may be due to human activities such as farming and other natural phenomena such as weathering and volcanic actions (Oni *et al.*, 2016). Also, the average AED of 37.6 µSvy^{-1} obtained due to inhalation implies that the inhabitant of Sabon gari local government are safe from any radiological health related effect that could result from the inhalation of radon gas. As for ingestion, the results show that both Children and Infant are safe from any radiological health risk, but for Adults, consuming any of the water sources (Well, Borehole and Surface) over a prolong period of time is not completely safe and may result in radiological health hazard.

Table 1: Radon Concentrations and their Corresponding Annual Effective Doses in (µSv/y) for water samples at some selected areas within the study area.

Sample ID	Sources	Location	Latitude	Longitude	Rn (Bq/L)	Inhalation	AED (µSv/y)		
							Ing (A)	Ing (C)	Ing (I)
SSG1	Surface	Samaru	11.1730555	7.84527778	14.90	37.55	108.77	163.16	190.35
BSG2	Borehole	T/ Muntsira Bsw	11.1813888	7.94805556	14.50	36.54	105.85	158.78	185.24
WSG3	Well	Shubee Bsw	11.1833333	7.67138889	13.90	35.03	101.47	152.21	177.57
BSG4	Borehole	Mk Skd RD	11.191666	7.70222222	12.40	31.25	90.52	135.78	158.41
SSG5	Surface	Basawa/Palladan	11.1625	7.68055556	14.50	36.54	105.85	158.78	185.24
BSG6	Borehole	Hayin Dogo Pld	11.1416666	7.6875	14.80	37.30	108.04	162.06	189.07
SSG7	Surface	A/Rimi Stream	11.1830555	7.6783333	15.00	37.80	109.50	164.25	191.63
BSG8	Borehole	PHC Basawa	11.1772222	7.6883333	16.30	41.08	118.99	178.49	208.23
BSG9	Borehole	Mammy Bsw	11.1761111	7.66972222	13.20	33.26	96.36	144.54	168.63
WSG10	Well	A/Fulani Plldn	11.141666	7.6883333	13.10	33.01	95.63	143.45	167.35
BSG11	Borehole	Staff Qtrs NARICT	11.1719444	7.6775	14.50	36.54	105.85	158.78	185.24
BSG12	Borehole	NARICT Admn Block	11.170277	7.6816667	14.00	35.28	102.20	153.30	178.85
BSG13	Borehole	Gangare Bsw	11.179444	7.6711111	14.90	37.55	108.77	163.16	190.35
WSG14	Well	Gidan Yara Bsw	11.1786111	7.67138889	14.50	36.54	105.85	158.78	185.24
SSG15	Surface	Basawa	11.1880555	7.6677778	12.10	30.49	88.33	132.50	154.58
SSG16	Surface	Sakadadi	11.1780555	7.71416667	12.70	32.00	92.71	139.07	162.24
WSG17	Well	GRA	11.1055555	7.70944444	22.40	56.45	163.52	245.28	286.16
SSG18	Surface	Dogarawa	11.1286111	7.72111111	21.30	53.68	155.49	233.24	272.11
Mean						**37.66**	**109.09**	**163.64**	**190.92**
SD						**6.88**	**19.93**	**29.89**	**34.87**

NB: Ing (A), Ing (C) and Ing (I) = ingestion by adults, Children and infants respectively.

CONCLUSION

The assessment of radon concentration in water sources from Sabon Gari, local government area, Kaduna State, Nigeria has been carried out using Liquid Scintillation Counter. It was observed that the radon concentration for all the three-water sample type (Well, Borehole and surface) is higher than the permissible level of 11.1 Bq/L set by USEPA. The overall AED due to inhalation of Radon in the water sources is found to be less than the permissible limit of 100μSv/year set by WHO. Also, the overall AED due to ingestion of Radon is found to be higher than the WHO permissible limit of 100 μSv/year for adults and less than the permissible limit of 200 μSvy^{-1} for children. Therefore, the inhabitant of Sabon gari local government are safe from any radiological health related effect that may result from the inhalation of radon gas. As for ingestion, the results show that both Children and Infant are safe from any radiological health risk, but for Adults, consuming any of the water sources (Well, Borehole and Surface) over a prolong period of time is not completely safe and may result in radiological health hazard.

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