Nigerian Journal of Physics (NJP)
ISSN online: 3027-0936
ISSN print: 1595-0611
DOI: https://doi.org/10.62292/njp.v33i2.2024.240
Volume 33(2), June 2024

Annual Effective Dose Estimation from Radon Concentration in Commonly Consumed Bottled Water in Northcentral Nigeria

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ABSTRACT
Radon (^{222}Rn), the heaviest among the noble gas in the periodic table of element, is radioactive nuclide that is naturally available in rocks, soil and water. In this study, a total of ten (10) brands of commonly consumed commercial bottled water in northcentral Nigeria were collected and assigned for their radon concentration using liquid scintillation counter (LSC). The highest radon (^{222}Rn) concentration of 0.073 Bq/l was recorded in C Way bottled water while Mr. V bottled water recorded the lowest ^{222}Rn concentration value of 0.016 Bq/l. These values were below the parametric reference level of 11.1 Bq/l set by United State of America Environmental Protection Agency and lower than the permissible limit of 100 Bq/l by World Health Organization (WHO) and European Union. Computed total annual effective dose due to ingestion and inhalation of waterborne radon recorded the highest mean value of 0.187 μSv/y in C Way Bottled water and lowest value of 0.041 μSv/y in Mr. V bottled water. Mean total annual effective dose recorded for all the bottled water samples were found to be significantly lower than the safety limit of 0.1 mSv/y recommended by WHO. The likelihood of any radiation incidence among the public due to consumption of commercial bottled water is therefore negligible.

Keywords:
Radon,
Bottled water,
Annual effective dose,
Northcentral Nigeria.

INTRODUCTION

Radon is a radioactive, colourless, tasteless and odourless gas, which can be found naturally everywhere on earth. It is generally produced through the radioactive decay of uranium and thorium bearing compounds present naturally in rocks and soil, and moves through pores in soil, fractures in rocks and along other weak zones into water bodies (Isinkaye et al., 2021; Ononugbo et al., Opoku-Ntim et al. 2019; Shuaibu et al., 2021). Three main isotopes of radon has been discovered presently, out of which ^{222}Rn with half-life of 3.8 days is of major concern due to its toxicity and speedy determination in water, indoor and outdoor air. The other two isotopes are however, very short-lived. Human radiation exposure generally occurs through inhalation and/or ingestion of radon dissolved in water that is used domestically on daily basis. Direct ingestion of radon occurs through daily water consumption, while radon inhalation occurs when dissolved radon is released into the air via the usage of water (Isinkaye and Ajiboye, 2017). The disintegration of radon occur through emission of alpha (α) particles to produce its α-emitting daughter nuclei. Two daughter nuclei of radon which are ^{214}Po and ^{218}Po, upon inhalation, deposits their energy into sensitive tissues of the lungs, which results in lung cancer due to the damage done to the DNA. ^{222}Rn has been reported as the principal cause of lung cancer among non-smokers (Isinkaye et al., 2021).

Consumption of bottled water has become an essential part of human diet and indispensable component of modern life in Nigeria (Kolo et al., 2020). Extremely humid, hot and dry climatic conditions, coupled with the dehydrating traffic situations commonly witnessed in virtually all the major cities in Nigeria makes commercial bottled water a readily available source of potable water for majority of Nigerian population. Commercial bottled water has also become very resourceful in the preparation of liquid milk for lactating children, thus, the possibility of increasing population exposure to waterborne radon. United States Environmental Protection Agency however, suggested a maximum contaminant level of 11.1 Bq/l for radon concentration in public water supplies (USEPA, 1991), while the European Commission (EC) recommended 100 Bq/l as the parametric value for radon concentration in potable water, below which no remedial action is required (EU, 2001b).

Information on radon content of commercially consumed bottled water in Nigeria is very scarce in northcentral Nigeria especially among the local people in the region. This study therefore, focuses on the estimation of radon concentration in commercially consumed bottled water in northcentral Nigeria and to estimate the corresponding annual effective dose to human population from its consumption.

MATERIALS AND METHODS

Ten (10) water samples (Figure 1) of commonly consumed commercial bottled water in north central Nigeria were randomly purchased from various super markets and transported to the laboratory for analysis.

Figure 1: Commercial bottled water used for the study

At the laboratory, 10 ml of toluene-based cocktail which act as the liquid scintillator, was transferred into scintillation vials. 10 ml of each water sample was drawn using a syringe and also added into the vials. The vials, as shown in Figure. 2, were then closed tightly and the mixture was shaken thoroughly to release waterborne ^{222}Rn into the organic scintillator. The blank which was used to obtain the background count was prepared in similar fashion by mixing sample of distilled water with 10 ml of the cocktail and stored for about 21 days prior to analysis.

Figure 2: Prepared samples in the sample counting rack

Sample counting and analysis was carried out at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, using a liquid scintillation counter (Tri-carb LSA 1000), shown in Figure 3. The samples and the blank were each counted over a 1 hour period. Before the counting however, the prepared samples were kept undisturbed for at least three (3) hours to allow ^{222}Rn attain radioactive equilibrium with its daughter nuclei. ^{222}Rn activity concentration was computed using the equation (Kalip et al., 2018):

$$C_{Rnw}\,(Bq/l) = \frac{100\times(Sc-Bc)\times ext\,\lambda t}{60\times cf\ x\ D} \qquad (1)$$

where C_{Rnw} (Bq/l) is ^{222}Rn concentration in the samples, SC and BC are the sample and background counts respectively in count min^{-1}, t is elapsed time in minutes, λ is the decay constant (1.26×10^{-4} min^{-1}), Cf is the calibration factor and D is the fraction of ^{222}Rn in the cocktail.

Figure 3: Experimental setup of the LSC and the Printer

Estimation of Annual Effective Dose (AED)

Waterborne radon can enter the human body through the two principal metabolic pathways of ingestion and inhalation. The annual effective dose incurred through the two routes were computed using the equation (Ajiboye et al., 2018; Kalip et al., 2018; UNCEAR 2000):

$$AED_{ing} = C_{Rnw} \times W_{CR} \times DCF_{ing} \quad (2)$$

$$AED_{inh} = C_{Rnw} \times R_{aw} \times Ef \times 0T \times DCF_{inh} \quad (3)$$

where AED_{ing} and AED_{inh} are annual effective dose from ingestion and inhalation of radon in water respectively in mSv/y, C_{Rnw} is ^{222}Rn concentration in water given in Bq/l, W_{CL} is the water consumption rate per year (730L), with assumption that an average adult take 2 L of water per day, DCF_{ing} and DCF_{inh} are the dose conversion factors for ingestion and inhalation which are given as 3.5 nSv/Bq and 9 nSv/h Bq/l respectively, R_{aw} (=10^{-4}) is the ratio of radon released to air when water is used to radon in water, EF is equilibrium factor between radon and its progeny given as 0.4, and 0T is the average indoor occupancy factor of 7000 h/y.

RESULTS AND DISCUSSION

Results of ^{222}Rn concentrations in ten commercially consumed bottled water products are presented in Table 1. ^{222}Rn concentrations in the water products varied between 0.016 and 0.073 Bq/l, with C Way bottled water recording the highest concentration of 0.073 Bq/l and Mr. V bottled water had the lowest ^{222}Rn concentration of 0.016 Bq/l. The results presented shows that ^{222}Rn concentrations in commercially consumed bottled water in northcentral Nigeria are extremely low when compared with the parametric reference level of 11.1 Bq/l set by United State of America Environmental Protection Agency for public safety. Furthermore, ^{222}Rn concentration in all the investigated samples are extremely lower than the upper boundary limit of 100 Bq/l recommended by the European Union above which any remedial action can be taken (EU, 2001b; Oni et al., 2016).

Table 1: Activity concentration, ingestion, inhalation and total annual doses from ^{222}Rn in commercially consumed bottled water in northcentral Nigeria

S/no	Bottled water sample	Sample ID	^{222}Rn conc (Bq/l)	Annual effective dose (µSv/y)		
				ingestion	Inhalation	total
1	Bimcap table Water	BTW	0.060	0.153	0.0001512	0.153
2	C way Water	CWW	0.073	0.187	0.000184	0.187
3	Dudu premium Water	DPW	0.036	0.092	9.072E-05	0.092
4	DJE Water	DJW	0.023	0.059	5.796E-05	0.059
5	Eva	EVW	0.055	0.141	0.0001386	0.141
6	Faro	FRW	0.034	0.087	8.568E-05	0.087
7	G. Kas	GKW	0.041	0.105	0.0001033	0.105
8	Gurara	GRW	0.031	0.079	7.812E-05	0.079
9	J. Firs	JFW	0.023	0.059	5.796E-05	0.059
10	Mr. V	MVW	0.016	0.041	4.032E-05	0.041
	Min	MVW	0.016	0.041	4.032E-05	0.041
	Max	CWW	0.073	0.187	0.000184	0.187

Annual effective doses due to ingestion and inhalation of radon from the commercial bottled water samples were estimated using equation 1 and the results presented in Table 1. The ingestion dose obtained for C Way bottled water was 0.187 μSv/y, while the inhalation dose was 0.000184 μSv/y, which resulted in total effective dose of 0.1872 μSv/y. Mr. V bottled water recorded the lowest ingestion and inhalation doses of 0.041 and 4.03×10^{-5} μSv/y respectively, resulting in total effective dose of 0.041 μSv/y. The obtained results shows that the total effective doses for all the sampled commercially consumed bottled water were less than the recommended safety limit of 0.1 mSv/y (WHO, 2004). This implies that the doses obtained in this study are negligible and therefore, the sampled commercial bottled water are save for drinking and other domestic activities from the perspective of radiation protection.

CONCLUSION

Radon concentration in commercially consumed bottled water in northcentral Nigeria was measured using a Tri-carb LSA 1000 liquid scintillation counter. The results obtained in this study were far below the 11.1 Bq/l safety threshold set by United State of America Environmental Protection Agency. Total annual effective dose incurred by the public from the consumption of commercial bottled water is lower than the recommended safety limit of 0.1 mSv y^{-1}. Therefore, commercial bottled water sold in northcentral Nigeria are safe for consumption. However, periodic check of commercial bottled water and other potable water supplies for human consumption in northcentral Nigeria is recommended in order to ensure their safety from the point of view of radiation protection.

ACKNOWLEDGMENT

The authors appreciate the staff of Centre for Energy Research and Training (CERT), A. B. U. Zaria, for their cooperation and assistance.

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