Activity Concentration of ^{222}Rn Measured in Drilled and Dug Well Drinking Waters and Resulting Radiation Doses to Population of Ogun State, Nigeria.

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Abstract

Radon studies have been conducted in many countries of the world in indoor air but such studies in drinking waters are sparse. We present the results of ^{222}Rn activity concentration measurements in drilled and dug well drinking waters from three large cities in Ogun State, southwestern Nigeria. The measurements were done suing high-resolution high-purity germanium (HPGe) detector (Canberra Industries Inc.). Measured ^{222}Rn ranged from 0.26±0.01 to 0.88±0.09 Bq l^{-1} and 0.25±0.02 to 0.72±0.10 Bq l^{-1} in the drilled wells and dug wells respectively. The activity concentrations were used with ingested dose conversion factors to estimate annual effective dose rates due to ingestion of ^{222}Rn as a result of the consumption of water from these wells. Estimated annual effective dose rates ranged from1.32±0.11 μSv y^{-1} (in a dug well) to 4.66±0.48 μSv y^{-1} (in a drilled well); 0.11±0.10 to 1.71±0.18 μSv y^{-1} and 0.64±0.05 to 2.25±0.23 μSv y^{-1} for infants (0 – 1y), children (2 – 7y) and adults (≥ 17 y) respectively. All these values fall below the World Health Organisation (WHO) recommended limit of 0.1mSv y^{-1} for public exposure for all ages.

Key Words: drilled and dug well, activity concentration, annual effective dose, ingestion, radon, dose conversion factor.

INTRODUCTION

Radon, one of the noble gases, is a naturally occurring radioactive gas. I
Of its more than twenty isotopes, only ^{222}Rn (radon) and ^{220}Rn (thoron) can be found in significant quantity in our environment and therefore of radiological significance. ^{222}Rn originates from the radioactive decay of ^{226}Ra, a member of the ^{238}U decay series. ^{220}Rn emanates from the ^{232}Th decay series. Both ^{238}U and ^{232}Th are naturally occurring radioactive materials which are present in environmental such as sediments, soils, rocks, ground and surface waters in varying amounts. The amounts of these radioactive materials present in an environmental sample depend on the geological features of a particular location.

Radon (^{222}Rn) has a half life of about 3.82 days. Because it is soluble in water, it dissolves in ground water flowing through or over rocks and soils containing radioactive material and it enters water supplies. Drinking water containing dissolved radon presents health risks like cancer (e.g. stomach or colon cancer) in developing human internal organs. Inhalation of radon released by tap water to the air presents risk of lung cancer. Environmental Protection Agency (EPA) reported that radon in drinking water causes about 168 cancer deaths per year in the United States of America (EPA, 1991, Nikolov et al. 2011). 89% of these deaths are due to lung cancer caused by inhaling radon release from water to the indoor air while the remaining 11% are from stomach cancer caused by ingesting water containing dissolved radon. Radon in drinking water becomes a great concern when the water comes from underground sources like drilled or dug well on an aquifer.

High levels of ^{226}Ra, the immediate precursor of ^{222}Rn were discovered in the untreated water from private dug wells in part of southwestern region of Nigeria in 2005 and promptly reported (Ajayi and Owolabi, 2007). The focus of the present study was therefore to estimate the activity concentrations of ^{222}Rn and consequent natural radiation doses in untreated drilled and dug well drinking waters of some parts of Ogun State, southwestern Nigeria.

MATERIALS AND METHODS

Well water samples were collected from 19 different locations made up of 9 drilled wells and 10 dug wells. The depths of the wells ranged from 5 m to 54 m. Manual procedure was employed to draw water from the dug wells while electric pumping system was used to draw water from all drilled well. The water samples were poured into 2-l plastic bottles that have been previously washed with pure water and rinsed with hydrochloric acid (HCl) to prevent contamination of the samples (Laxen and Harrison, 1981). The samples were acidified with 11 mol of HCl at the rate of 10 ml l^{-1} of sample to prevent the adsorption of radionuclides onto the walls of the containers (IAEA, 1989). About 0.5 l of each sample was poured into a Marinelli beaker and firmly sealed to ensure that radon is not lost. The samples were labeled according to sampling location and kept for about 4 weeks to ensure that a state of secular equilibrium was reached between 222Rn and its decay products - 214Bi and 214Pb.

Gamma spectrometry measurements were carried out with a high purity germanium (HPGe) detector with about 50% relative counting efficiency and energy resolution of 2.4 keV at 1.33 MeV gamma rays of ^{60}Co. Shielding, energy and efficiency calibration techniques are described in Ajayi and Achuka (2009)

Each sample and background was counted for 86,400 s to achieve minimum counting error. The detection limit (DL) of the measurement system was obtained as described in Ajayi and Achuka (2009). Activity concentrations of 222Rn in the water samples were estimated from gamma ray peak of 609.3 keV for ^{214}Bi and 351.9 keV for ^{214}Pb on the assumption that both had attained secular equilibrium before gamma ray analysis was done. Annual effective doses to an individual due to the consumption of ^{222}Rn present in the well waters was done by using (Alam et al. 1999).

$$A_E = A_C A_I C_F \qquad \ldots \qquad (1)$$

where A_C is the activity concentration of ^{222}Rn in the well water (Bq l^{-1}), A_I is the annual intake of drinking water (l y^{-1}) and C_F is the age-dependent ingested dose conversion factor for ^{222}Rn. The ingested dose conversion factors 2.3x10-8, 5.9x10-9 and 3.5x10-9 Sv Bq^{-1} for infants (<1 y), children (2 – 7 y) and adults (≥17 y) respectively were taken from United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR, 2000). The annual average water intake values of 230, 330 and 730 l for infants, children and adults respectively were taken from World Health Organisation (WHO, 1988, 2003)

RESULTS AND DISCUSSION

The data generated through activity concentration measurements and calculation of annual effective doses for different age groups are displayed in Table 1.

Table 1. ^{222}Rn activity concentrations and annual effective doses

Well location	Activity concentration	Annual effective dose µSv y^{-1}		
		Infants	Children	Adults
Awujale	0.88±0.09	4.66±0.48	1.71±0.18	2.25±0.23
Ibara	0.26±0.01	1.38±0.05	0.51±0.02	0.66±0.03
Molipa	0.37±0.02	1.96±0.11	0.72±0.04	0.95±0.05
Oyingbo	0.36±0.01	1.90±0.05	0.70±0.02	0.92±0.03
Ita Osun	0.57±0.05	3.02±0.27	0.11±0.10	1.46±0.13
Ake	0.51±0.37	2.70±1.96	0.99±0.72	1.30±0.95
Abeokuta	0.55±0.06	2.91±0.32	1.07±0.12	1.41±0.15
Fidipote	0.55±0.05	2.91±0.27	1.07±0.10	1.41±0.13
Isaga	0.31±0.03	1.64±0.16	0.60±0.06	0.72±0.08
Kenta	0.26±0.02	1.38±0.11	0.51±0.04	0.66±0.05
Elega	0.32±0.01	1.69±0.05	0.62±0.02	0.82±0.03
Saboid	0.53±0.04	2.80±0.21	1.03±0.08	1.35±0.10
Penpe	0.30±0.02	1.59±0.11	0.58±0.04	0.77±0.05
Elekute	0.45±0.02	2.38±0.11	0.88±0.04	1.15±0.05
Totoro	0.36±0.05	1.90±0.27	0.70±0.10	0.92±0.13
Alagbon	0.72±0.10	3.81±0.53	1.40±0.20	1.84±0.26
Alapora	0.70±0.25	3.70±1.32	1.36±0.49	1.79±0.64
Ita Oshin	0.65±0.01	3.44±0.05	1.27±0.02	1.66±0.02
Sabo	0.25±0.02	1.32±0.11	0.49±0.04	0.64±0.05
Range	0.25 – 0.88	1.32 – 4.66	0.11 – 1.71	0.64 – 2.25
Mean	0.47	2.48	0.91	1.20
Standard deviation	0.18	0.96	0.35	0.46

The activity concentration values varied from 0.25±0.02 to 0.88±0.09 Bq l^{-1} with an average value of 0.47 Bq l^{-1} and a standard deviation of 0.18 Bq l^{-1}. Water from the well at Awujale has the highest 222Rn activity concentration while the one located at Sabo has the lowest value. These activity concentration values are comparable with reported values from different parts of the value as shown in Table 2.

Table 2. Comparison of 222Rn activity concentration values (Bq l^{-1})

Country	Range of values	Reference
Turkey	5.3 – 18.5	Cevik et al. 2006
Kenya	0.8 – 4.7	Otwoma and Mustapha, 1998
Algeria	2.6 – 14.0	Amrani, 2002
Egypt	0.07 – 2.33	Abbady et al. 1995
Portugal	16.7	Gans, 1985
Yugoslavia	0.0002 – 0.63	Kobal et al. 1979
Pakistan	2.0 – 7.9	Manzoor et al. 2008

The activity concentration values obtained in this work are much lower than the action levels of 11.1 Bq l-1 and 100 Bq l-1 proposed by United States Environmental Protection Agency (USEPA, 199) and World Health Organisation (WHO, 1993) respectively. The calculated annual effective doses due to ingestion of 222Rn dissolved in these drinking waters vary from 1.32±0.11 to 4.66±0.48 μSv y^{-1}, 0.11±0.10 to 1.71±0.18 μSv y^{-1} and 0.64±0.05 to 2.25±0.23 μSv y^{-1} for infants, children and adults respectively. The values are much lower than those obtained by Muhammad et al. (2011) which are 3 – 48, 1 – 18 and 2 – 23 μSv y^{-1} for infants, children and adults respectively in the investigation they carried out on domestic water sources in Penang, Malaysia.

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