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Outdoor Radon Concentration in the Township of Ado-Ekiti Nigeria

OJO T.J[1,*], AJAYI I.R[2]

[1]Department of Science Technology, Federal Polytechnic, P.M.B 5351, Ado-Ekiti, Ekiti State, Nigeria
[2]Department of Physics and Electronics, Adekunle Ajasin University, P.M.B 001, Akungba Akoko, Ondo State, Nigeria
*Corresponding author: talk2ojotj@yahoo.com

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Abstract Solid State Nuclear Track Detectors (CR-39) were used for the measurement of outdoor ^{222}Radon concentration in 30 locations in the township of Ado-Ekiti Nigeria. The annual effective dose of radon and its progenies to the residents was calculated from the results of the measurement. The concentrations of radon varied from 2.22 to 92.50 Bq m^{-3} with an overall mean of 29.57 Bq m^{-3}. The annual absorbed dose was found to range from 0.09 to 3.81 mSv y^{-1} with an average of 1.18 mSv y^{-1}. The estimated annual effective dose to lung ranged from 0.22 to 9.14 mSv y^{-1} with an average of 2.88 mSv y^{-1}. The values measured for Radon concentration were found to fall below the upper limit of the ICRP reference level.

Keywords: *detector, radon, outdoor, absorbed dose, effective dose*

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1. Introduction

Radon is a naturally occurring odourless, colourless, tasteless inert gas which is imperceptible to human sense. It is produced continuously from the decay of naturally occurring radionuclide such as ^{238}U, ^{235} U, ^{232}Th (ICRP, 1993). Worldwide average annual effective dose from ionizing radiation from natural sources is estimated to be 2.4 mSv, of which about 1.0 mSv is due to radon exposure (UNCEAR, 2000). The problem of radon emission has attracted considerable attention worldwide. Nationwide radon surveys and case-control studies on the association of radon with cancer risk have been conducted in many countries. Human exposure to radon and its daughters comprises about 55% of the total dose from natural sources. Therefore, the measurement of environmental radon is significant.

As a result of inhalation, radon progenies may be deposited on the cells lining the airways where the alpha particle emitted by radon and its progenies can damage the DNA and potentially cause lung cancer. When radon gas itself is inhaled, most of it is exhaled before it decays, A small part of the inhaled radon and its progenies may be transferred from the lungs to the blood and finally to other organs, but the corresponding doses and associated cancer risks are negligible compared to the lung cancer risk (WHO, 2009). In developed countries of the world, many research workers are engaged in the measurement of both indoor and outdoor radon levels in the environment for health risk assessments (Mehra et al., 2006; Singh et al., 2001; Sharma et al., 2011; Kumat et al., 2012) The residential radon is regulated by an action level of radon concentration between 200 and 300 Bq m^{3} based on ICRP recommendations (ICRP, 2009). Radon is classified as a human carcinogen by the International Agency for Research Cancer (IARC, 1988). In the past decades, systematic radon surveys in dwellings were carried out in many countries (Rahman et al., 2006) but Nigeria together with many other African countries have not yet formulated national directives to enforce radon limits in the environment. There is no general awareness or factual knowledge about radon and its health hazards. This study tried to estimate the accumulated effective dose due to outdoor exposure of individual from birth to an average school leaving age of 18 years. Age 18 is the average age when most children go outside Ado-Ekiti (the study area) in pursuit of tertiary education. Ado- Ekiti of Nigeria has not been studied for environmental radon so far. Therefore, the present study has been carried out first time in the study area, in order to assess the probable health risks due to outdoor radon among age 18 and below. One- third of the population fall into this group.

2. Method

Each Solid State Nuclear Track Detector (SSNTD) contains a detector element, called foil. When radon atoms decay inside the detector, they release alpha particles. If the alpha particles strike the foil, they make microscopic tracks on the surface of the foil. When the detector is analyzed, the foil is chemically treated to enlarge the alpha tracks. The average number of tracks per unit area gives the concentration of radon. The SSNTD used in this research work were obtained from AccuStar laboratory in the United States. The brand name is AT100. This device is a long term radon detector. The survey of outdoor radon concentration in the township of Ado-Ekiti is to estimate the effective dose to the public from ^{222}Rn and its progenies. The survey was done by randomly choosing 30 locations outdoor to determine the concentration of radon across the entire length of the town. It is noteworthy to say that Radon concentrations depend on meteorological and geological conditions and ways of life of dwellers in an environment.

The SSNTD is a small piece of plastic foil which is enclosed in small cylindrical diffusion chambers. It is round in shape, about 2 cm in diameter, and has a density of 1.30 g cm^{-3}. It is sensitive to tracks of highly ionizing particles such as alpha particles. The detectors were etched in 6.2 M NaOH at 90°C for 2 hours, washed in clean water for 10 minutes, and then air-dried. The tracks on the SSNTD dosimeter were counted with an automatic setup consisting of an optical microscope connected to a display camera controlled by a personal computer. The calibration factor for converting track density to ^{222}Rn concentration was obtained in a calibration experiment performed in the same Laboratory where the detector was manufactured. These procedures were conducted in accordance with US Environmental Protection Authority Quality Assurance/Quality Control documents. (Darby et al., 1998; Asumadu-Sakyi, 2011).

The measurements of ^{222}Rn concentration were performed for a period of 3 months from the time the polythene container was broken open. The dosimeter at each site was hung outdoor of buildings at approximately 2 meters from the floor (breathing zone). After the 3-month period of exposure, the samples were retrieved, sealed in Zip loc polythene bags and taken to laboratory for analysis (Kumar et al., 2010; Gusain et al., 2009).

2.1. Annual Absorbed Dose

In order to estimate the annual absorbed dose received by the population, one has to take into account the conversion co-efficient and the indoor occupancy factor. According to the UNSCEAR (2000) report, the committee proposed 9.0 x 10^6 mSv h^{-1} per Bq m^{-3} to be used as a conversion factor, 0.8 for the equilibrium factor of ^{222}Rn outdoors and 0.6 for the outdoor occupancy factor. Calculating the annual absorbed dose to the population, the equation below is used (ICRP, 1993). At a certain radon concentration C_{Rn} in Bq m^{-3}, the annual absorbed dose D_{Rn} is usually expressed in the unit of mSv y^{-1} from the following relation:

$$D_{Rn}\left(mSvy^{-1}\right) = C_{Rn}.D.H.F.T \qquad (1)$$

where,

C_{Rn} is the measured ^{222} Rn concentration (in Bq m^{-3}),

F is the ^{222} Rn equilibrium factor (0.8)

T is the outdoor occupancy time 24 h ×365 = 8760 h y^{-1}

H is the outdoor occupancy factor (0.6), and

D is the dose conversion factor (9.0×10^{-6} mSv h^{-1} per Bq m^{-3}).

It is, however, apparent that the time spent by individuals outdoor varies widely globally.

2.2. Annual Effective Dose Rate

To calculate the annual effective dose H_E, one has to apply a tissue and radiation weighting factors according to ICRP, 1991. The radiation weighting (W_R) factor for alpha particles is 20 as recommended by ICRP, 1991. With the effective dose, a tissue weighting (W_T) factor is applied. According to ICRP, the tissue weighting factor for lung is 0.12. The annual effective dose is then calculated according to the equation below:

$$H_E\left(mSvy^{-1}\right) = D_{Rn}.W_R.W_T \qquad (2)$$

where,

D_{Rn} = Annual Absorbed dose

W_R = Radiation Weighting Factor for Alpha Particles, 20

W_T = Tissue Weighting Factor for the Lung 0.12.

3. Results and Discussion

The SSNTDs were analyzed and radon concentrations were recorded in Bq m^{-3}. The results for 30 sites were obtained. The variation of radon concentration in the 30 locations surveyed is shown in Table 1. The geometric mean was 24.70 Bq m^{-3}. The arithmetic mean, standard deviation, and variance of ^{222}Rn concentration in the locations were 29.08, 17.96, and 320.27 Bq m^{-3} respectively. The value of the variance is below the upper value of the ICRP reference level of 1500 Bq m^{-3}. (UNSEAR, 2000).

The tested locations were selected randomly at different areas of the town, at about half a kilometer away from one another in the town. The average number of tracks per unit area was taken from the mean of the individual number of tracks per unit area. The study shows that the outdoor radon concentration obtained varied from (2.22 to 92.50) Bq m^{-3} with an overall mean value of 29.57 Bq m^{-3} which is below the recommended ICRP action level of 200-600 Bq m^{-3} (ICRP, 1993). The annual absorbed dose from the corresponding radon concentration in the different locations has been calculated using equation (1). The highest value was observed at Satellite with radon concentration of 92.50 Bq m^{-3} and an annual absorbed dose of 3.81 mSv y^{-1}. The high radon concentration level in the location might be due to the presence of rock and choky pattern of structures used as commercial hostels by the polytechnic students. Also, this could be due to the accumulation of dust in the environment due to the dusty untarred road leading into the place. The lowest value was found in a location at Omisanja (2.22 Bq m^{-3}) with annual absorbed dose of 0.09 mSv y^{-1} which is probably due to free air movement and the presence of river in the area into which small percentage of radon might dissolve (Chauhan, 2010: Kumar and Prasad, 2000). Although most of the outdoor radon concentrations are below the ICRP action level, all the values are lower than the reference level set by the USEPA for the US (148 Bq m^{-3}) (USEPA, 2004) and almost several fractions of the new reference level (100 Bq m^{-3}) set by WHO, 2009 and ICRP, 2007. Also, the average value is below the world average radon concentration of 40 Bq m^{-3} (UNSCEAR, 2000).

The values of annual effective doses thus calculated for radon inhalation by the inhabitants were found to vary in the range 0.22-9.14 mSv y^{-1}, with a mean of 2.88 mSv y^{-1} which is below the recommended ICRP intervention level of (3-10) mSv y^{-1} (ICRP, 1993). These values are far below the mean value of 124.27 mSv y^{-1} that was estimated to be the effective dose due to soil radioactivity in Ondo State, a state in the neighborhood of Ado-Ekiti. Therefore, the risk from radon is found to be lower than that from (outdoor) terrestrial radiation.

Table 1. Measured Radon concentration of the studied location and the resulting annual effective dose

S/N	Location	Radon concentration (Bq m^{-1})	Annual absorbed dose (mSv y^{-1})	Annual effective dose (mSv y^{-1})
1	Omisanjana 1	22.2	0.92	2.21
2	Omisanjana 2	18.5	0.76	1.82
3	Omisanjana 3	14.8	0.61	1.46
4	Omisanjana 4	2.22	0.09	0.22
5	Omisanjana 5	20.0	0.82	1.97
6	Omisanjana 6	21.2	0.87	2.09
7	Omisanjana 7	20.5	0.85	2.04
8	Olaoluwa 1	40.7	1.68	4.03
9	Ola oluwa 2	39.9	1.64	3.94
10	Ola oluwa 3	38.2	1.57	3.77
11	Ola oluwa 4	40.1	1.65	3.96
12	Baptist 1	42.18	1.74	4.18
13	Satelite 1	92.5	3.81	9.14
14	Ekute 1	21.1	0.87	2.08
15	Ekute 2	19.8	0.82	1.99
16	Ekute 3	77.7	3.20	7.68
17	Ekute 4	20.1	0.83	1.99
18	Ekute 5	18.5	0.76	1.82
19	Mattew 1	25.7	1.06	2.54
20	Mattew 2	25.1	1.03	2.47
21	Mattew 3	25.9	1.07	2.57
22	Falegan 1	14. 3	0.61	1.46
23	Falegan 2	29.6	1.22	2.93
24	Falegan 3	14.8	0.61	1.46
25	Fabian 1	25.9	1.07	2.57
26	Fabian 2	28.9	1.19	2.86
27	Fabian 3	29.6	1.22	2.93
28	Irona 1	19.1	0.79	1.90
29	Egbewa 1	25.9	1.07	2.57
30	Agric olope	37	1.53	3.67

Table 2. Accumulated effective dose (mSv y^{-1})

S/N	Locations	Estimated accumulated dose (mSv y^{-1})		
		Pre-primary (0-6 years)	Primary (6-12 years)	Post-primary (12-18 years)
1	Omisanjana 1	13.36	79.56	477.36
2	Omisanjana 2	10.92	65.52	893.12
3	Omisanjana 3	8.76	52.56	315.36
4	Omisanjana 4	1.32	7.92	47.52
5	Omisanjana 5	11.82	70.92	425.52
6	Omisanjana 6	12.54	75.24	451.44
7	Omisanjana 7	12.24	73.44	440.64
8	Olaoluwa 1	24.18	145.08	870.48
9	Ola oluwa 2	23.64	141.84	851.04
10	Ola oluwa 3	22.62	135.72	814.32
11	Ola oluwa 4	23.76	142.56	855.36
12	Baptist 1	25.08	150.48	902.88
13	Satelite 1	54.84	329.04	1974.24
14	Ekute 1	12.48	74.88	449.25
15	Ekute 2	11.94	71.64	429.84
16	Ekute 3	46.08	276.48	1658.88
17	Ekute 4	11.94	71.64	429.84
18	Ekute 5	10.92	65.52	393.12
19	Mathew 1	15.24	91.44	548.64
20	Mathew 2	14.82	88.92	533.52
21	Mathew 3	15.42	92.52	555.12
22	Falegan 1	8.52	51.12	306.72
23	Falegan 2	17.58	105.48	632.88
24	Falegan 3	8.76	52.56	315.36
25	Fabian 1	15.42	92.52	555.12
26	Fabian 2	17.16	102.96	617.76
27	Fabian 3	17.58	105.48	632.88
28	Irona 1	11.4	68.40	410.04
29	Egbewa 1	15.42	92.52	555.12
30	Agric olope	22.02	132.12	792.72

Human development (both mental and physical takes place between ages 0 and 18 years). Children are exposed to preliminary trainings (learning mother tongues, domestic chores and pre-tertiary training). This is also the period to develop into puberty (development of critical sexual parts). This stage is the most critical stage in man's life. Genetic mutation and developmental aberration could be linked to radiation in general (radon inclusive) in most cases (Kumar et al., 2007; Gupta et al., 2011). For each developmental stage, estimated accumulated effective dose was calculated (Table 2). For a person who spends nearly all his entire school age in Ado-Ekiti. Before his tertiary education, he would have accumulated an effective dose of about 689.95 mSv y^{-1} on the average.

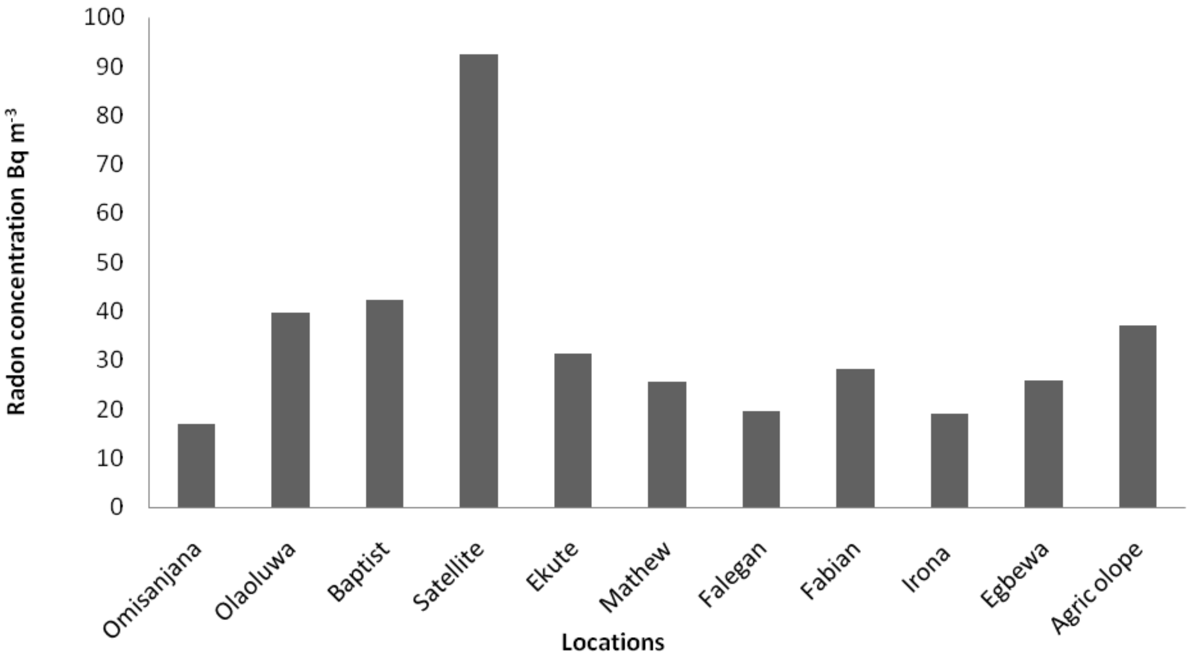

Figure 1. Radon concentration in the studied locations

4. Conclusion

Radon concentrations were found to be very low in most of the surveyed locations probably due to the fact that Ado-Ekiti is located on a plane topography with few numbers of rocks around it. This could also be attributed to lateral development because of the presence of plane land (skyscrapers block free air flow which give rise to still air). Moreover, buildings are widely separated apart. Absence of factories giving off effluents which could obstruct free air movement might be another contributory factor to low radon values obtained in most of the locations.

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