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Investigation of Radon Concentration in the Soil in Oduduwa University, Ile-Ife Osun State

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Abstract

Radon which can be found in soil gases is a gaseous highly radioactive element. Radon is a colorless odorless or tasteless chemically unreactive inertgas. Soil gas radon ^{222}Rn concentration was measured at 4 different locations in the Oduduwa University Ipetumodu (OUI), using an active electronic radon detector called RAD7 coupled with a soil gas probe. In each location four different depths were taken for soil gas measurements, starting from (20cm to 80cm) below ground surface. The results suggested that the highest concentration was 16725±2332 Bq/m^3 for 80cm depth at Oyetade hostel, and the lowest concentration was 163±895 Bq/m^3 for 20cm depth at Ramon Adedoyin College of Natural and Applied Sciences (RACONAS). The results obtained from this study indicate that the radon concentration levels in OUI are well below the allowed levels which are range (0.4 to 40) KBq/m^3. The annual effective doses related to the inhalation of radon gas and its progeny which were calculated from the Concentration of emanation in air near ground for each measured depth and it ranged from (0.002395 to 0.158954) mSv/y for depth 80cm, (0.0022429 to 0.057594) mSv/y for depth 60cm, (0.0016822 to 0.052367) mSv/y for depth 40cm, and (0.0015492 to 0.019626) mSv/y for depth 20cm, these results are less than the recommended global average dose from the inhalation of radon from all sources, which is 1mSv/y.

Keywords

Radon, RAD7, Soil, OUI, Annual Effective Dose

1. Introduction

Soil is an important constituent of the earth crust and is one of the fundamental elements for the continued existence of living thing. It is the “membrane of the earth”. Soil is capableof supporting plant life and it is vital to life on earth. Soil is a mixture of organic matter, mineral deposit, gas, liquids, and countless organisms that collectively support life on Earth. Radon which can be found in soil gases is a gaseous highly radioactive element. Radon is a colorless, odorless or tasteless chemically unreactive inert gas [1]. It comes from the natural breakdown of uranium in soil, rock, and water and gets into the air you breathe [1]. In the environment, the elemental normal source of uranium, and also of whatever other antecedentof one of the radon isotopes, is probably going to be the redeposition of tidy particles from the earth [4]. Radon isotopes of natural causes are, independently, ^{222}Rn (with a half life of $t_{1/2}$ = 3.8day), ^{220}Rn (with a half life of $t_{1/2}$ = 55.6s) and ^{219}Rn (with a half life of $t_{1/2}$ = 3.96s) [2]. The density of radon is 9.73g/l at °C [3]. ^{222}Rn exhalation starting from the earliest stage is the principle origin of the presence ^{210}Pb in the air. The decay of radon produces many other shortlived nuclides known as radon daughters Radon progeny can attach to dust and other particles and can be breathed into the lungs. As radon and radon progeny in the air breakdown, they give off radiation that can damage the DNA inside the body's cells [1].

The adverse health effects of exposure to radon are caused primarily by damage due to ionizing alpha particles emitted by the radon progeny or radon decay product which are radiated by the decay of ^{222}Rn in a sequence of radionuclide (Radon decay product) which can damage the cells lining the airways [6]. Exposure to radon in the home and work place isone of the main risks of ionizing radiation causing tens of thousands of deaths from lung cancer each year globally. Epidemiological studies have shown a clear link between breathing high concentrations of radon and incidence of lung cancer [6]. Radon is a contaminant that affects indoor air quality worldwide. Health risk due to inhalation of radon is very low when radon is diluted to very low concentrations with outdoor air. However, it may accumulate up to dangerous concentrations in places such as mines and caves and may pose significant health risk after long term exposure, According to the United States Environmental Protection Agency, radon is the secondmost frequent cause of lung cancer, after cigarette smoking, causing (21,000) lung cancer deaths per year in the United States. About 2,900 of these deaths occur among people who have never smoked [7]. While radon is the second most frequent cause of lung cancer, it is the number one cause among non-smokers, according to EPA estimates [1].

2. Area of the Study

Oduduwa University was established in 2009 and is a private university. It is a private higher education institution located in the large town of Ile Ife with a (population range of 50,000 to 249,999 inhabitants). Oduduwa University is located in Ipetumodu, Ile Ife, Osun State, in the south western part of Nigeria.

Density – 100 hectares

Coordinates: 7°22′N4°30′E

Local Government Area Ife North Government

Population (2013 Estimation) •Total 135,000•Density 370/sq mi (144/km^2)

The areas and location for which the experimental works were carried out are Ramon Adedoyin college of natural and applied science (RACONAS) (N07^{0}30.199' E004°26.769'), Oyetade hall (N07°30.278' E004°26.974'), Minimart (N07°30.255' E004°27.206'), College of management and social sciences (CMSS) (N07°30.144' E004°27.159').

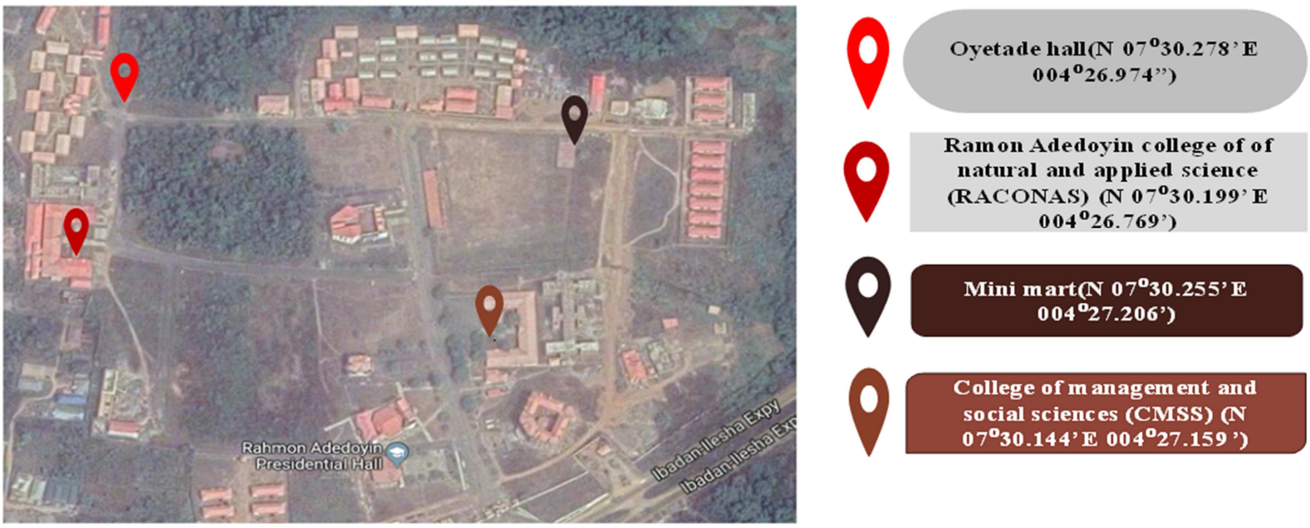


Figure 1. *Satellite view of the location of the area of study.*

3. Materials and Method

Radon activity concentration was measured in four differed locations in OUI using RAD7. RAD7 is recurrent radon measuring device from Durridge Company (USA). The RAD7 is a Sniffer that uses the 3 minute alpha decay of a radon descendant, without intrusion from other radiations, and the instantaneous alpha decay of a thoron daughter [8]. The RAD7 uses silicon as a semiconductor material which converts the energy of (α particles) directly into electrical signals. The measuring range is between (4 to 750000 Bq/m^3). When the radon and thoron daughters deposited on the surface of the detector decays and emits alpha particles of characteristic energy directly into the solid state detector. The RAD7's microprocessor picks up the signal and stores it according to the energy of the particle. When many signals accumulate, they result in a spectrum. The RAD7 groups the spectrum's 200 channels into 8 separate "windows" or energy ranges [4].

The radon gas concentration of the soil was measured at a depth of (20, 40, 60 and 80) cm respectively. A hammer was used to hit a calibrated iron rod so as to drill the point at which the radon was measured (sample point), a stainless steels oil gas probes was used in the carrying out the experimental work. The probe, with a hollow hose and sampling hole close to the tip may well be inserted into the soil, and air drawn up the tube, and directly into the RAD7. In the location, the work was carried out on soils containing few stones were used, tamping down the soil in the region of the probe to prevent the leakage of fresh air into the sample attainment course or down the outside of the probe to sampling point [18]. The soil probeis connected to desiccant which is connected to the RAD7. In each measurement, the moisture was ensured to be below 10% by using the Drierite desiccant which is an important accessory that absorbs the moisture from the soil gas [8].

The RAD7 can measure radon via 9 different protocols. Theprotocol have been used for the soil gas measurements is called the Grab sample protocol. The RAD7 pumps the soil gas for 5 minutes into the cell of the detector, and then waits for 5 minutes and count only for 5 minutes. ^{218}Po has a half life of 3.05mins and it takes about (3 to 5) half lives for the ^{218}Po activity to reach secular equilibrium, hence, in about (9 to 15) minutes. The decays of the ^{218} Po would then be counted after 10 mins (5 mins of pumping plus 5 mins of waiting), in which 95% of equilibrium would have been reached [8]. Finally, each set of readings includes four (5 mins) cycles that at last takes 30 min.

4. Estimation of the Outdoor Radon Activity and Annual Effective Dose

(C_{so}) is the concentration of emanation in the soil air (Bq/m^3), d is the diffusion constant (cm^2/s), (a) its rate of production within the soil (Bq/m$^{3)}$, which is assumed to be independent of depth and λ is the radon Decay rate of Emanation which is (2.1×10^{-6}).

From the rate of production we can find the concentration of emanation in undisturbed soil air in deeper layers [13]:

$$C_{so} = {}^{a}/_{\lambda} \quad (1)$$

And the exhalation rate (E) is [13]:

$$E = a\sqrt{{}^{d}/_{\lambda}} \quad (2)$$

The constants d and λ are fixed, d=0.05cm^2/sec. Only a fraction of the equilibrium production of emanation escapes intothe soil prior to decay within the soil particles, this fraction is found to be 10%. The concentration of emanation at the ground is given by [13].

$$C_{ao} = C_{so}\sqrt{{}^{d}/_{D}} \quad (3)$$

Where D is the eddy diffusion coefficient (5×10^4cm^2/s). For the estimation of average annual effective dose, AED (mSv/y) received by the public and workers of the studied area due to the outdoor radon and its progeny, Equation (4) was used for the calculation [17]

$$AED\ ({}^{msv}/_{y}) = C_{Rn} \times F \times O \times (DCF) \quad (4)$$

Where;

AED = the annual effective dose,

C_{Rn}= the activity of outdoor radon in Bq/m^3,

F= the global average (0.6) of equilibrum factor for outdoor radon and its descendant,

O= the global average outdoor occupancy factor (1760h/y),

DCF: The dose conversion factor (9nSv/h per Bq/m^3)

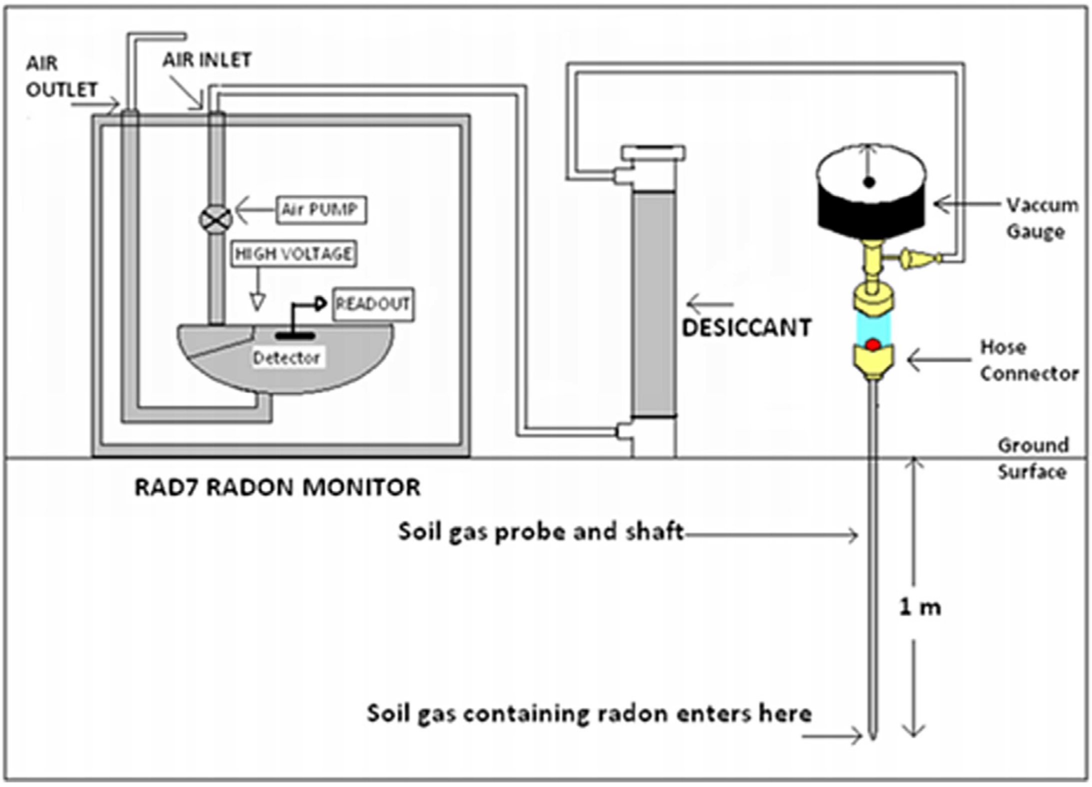


Figure 2. *Schematic diagram of RAD7 soil gas setup [8].*

5. Results and Discussion

The radioactive level of ^{222}Rn of the soil in the study area as shown in Table 1 ranged from 16725±2332 Bq/m^3 at depth 80cm from the ground surface at Oyetade to 163±895Bq/m^3 at depth 20cm from ground surface at RACONAS. For depth 60cm, the radon concentration varied from 6060±1342 Bq/m^3 at Oyetade to 236±407Bq/m^3 at RACONAS, while in depth 40cm, the maximum radon concentration was 2065±825Bq/m^3. From the whole result displayed in the table 1 below, there appear to be linearity between the radon concentration and the depth of the sample point location. However, large variation of radon concentration in soil gas over small depth is also well known. Also from the results obtained it was observed that RACONAS has the minimum radon concentration for most of the depth as compared to other sample location in exception of CMSS in which at depth 80cm, it radon concentration was 252±1543 Bq/m^3. Oyetade had the maximum radon concentration for most of the depth as compared to other location in exception of Minimart in which at depth 40cm, it radon concentration was 5510±1302 Bq/m^3. These concentrations values are well below the allowed levels which is range (0.4 to 40) KBq/m^3 [15-16].

The average Radon concentration in depth 20cm is 893±691 Bq/m^3, in depth 40cm is 2049±725Bq/m^3, in depth 60cm is 2149±755Bq/m^3 and in depth 80cm is 4524±1436Bq/m^3, which also looks as a linear relation with depth as shown in figure 4. The average radon concentration level in those areas, with higher depth, may be due to the presence of Uranium prospect beneath the soil.

These values were used to calculate the ^{222}Rn activity of emanation in air near the ground as shown in table (2 to 5) for all respective depth (80, 60, 40 and 20)cm respectively by using equation (3) with an average value for depth 80cm being (4524Bq/m^3), average value of (2149Bq/m^3) for depth 60cm, average value of (2049 Bq/m^3) for depth 40cm and an average value of (893 Bq/m^3) for depth 20cm. By using equation (1) we were able to calculate the Production rate (a) of emanation in soil with an average value (0.0095004, 0.0045129, 0.0043029, and 0.0018753) for depth (80, 60, 40 and 20cm) respectively and by using equation (2) we calculated the Exhalation rate (E) with an average value (0.014659, 0.0069636, 0.0066395 and 0.0028937) Bq/m^3 for depth (80, 60, 40 and 20cm) respectively. The Soil Radon activity values seem to be safe from the point of view of health hazards because from table (2-5) the values of the Rn activity of emanation in air near the ground were used to calculate the annual effective dose by using equation (4) and ranged from (0.002395 to 0.158954) mSv/y in CMSS and Oyetade for depth 80cm, (0.0022429 to 0.057594) mSv/y for depth 60cm in RACONAS and Oyetade, (0.0016822 to 0.052367) mSv/y for depth 40cm in RACONAS and MiniMart, and (0.0015492 to 0.019626) mSv/y for depth 20cm in RACONAS and Minimart, these results are less than the recommended global average dose from the inhalation of radon from all sources, which is 1mSv/y.

Table 1. *Radon concentration in different depth for four sample point in OUI.*

LOCATION	LONGITUDE	LATITUDE	Radon gas conc in Bq/m^3 for different depth from ground surface			
			20cm	40cm	60cm	80cm
RACONAS	N 07^{0}30.199'	E004^{0}26.769'	163±895	177± 343	236± 407	472± 472
Oyetade	N 07^{0}30.278'	E004^{0}26.974'	2064± 825	2227± 857	6060± 1342	16725± 2332
MINI MART	N 07^{0}30.255'	E004^{0}27.206'	713± 537	5510± 1302	1842± 803	650± 1400
RACMASS	N 07^{0}30.144'	E004^{0}27.159'	633± 509	284± 400	461± 469	252± 1543
MINIMUM			163±895	177± 343	236± 407	252± 1543
MAXIMUM			2064± 825	5510± 1302	6060± 1342	16725± 2332
AVERAGE			893±691	2049±725	2149±755	4524±1436

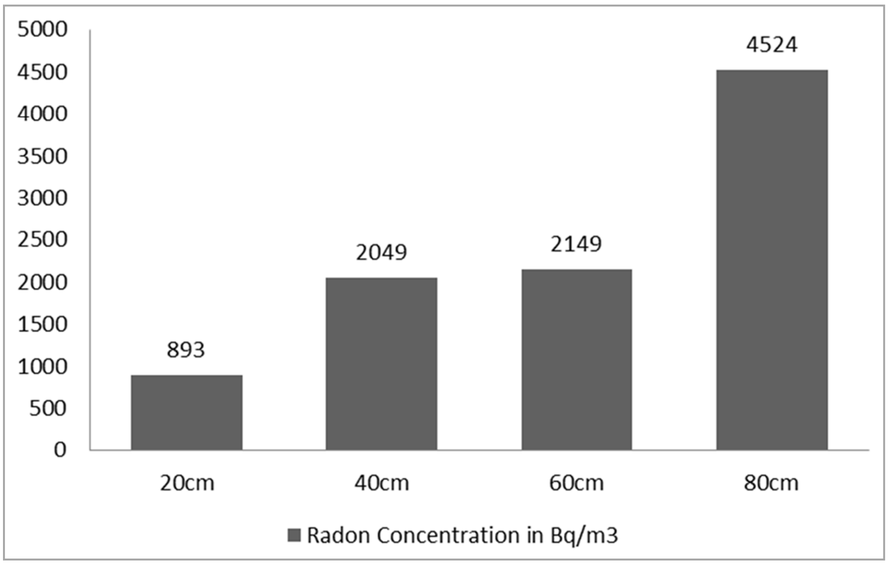


Figure 3. *Radon concentration in Bq/m^3 as a function of the depth from the ground surface.*

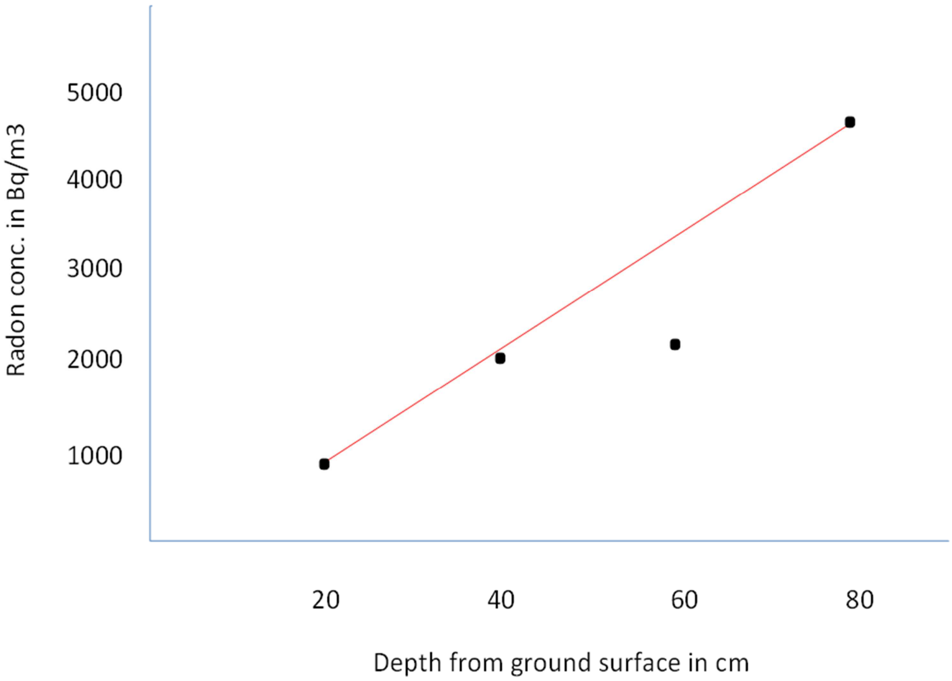
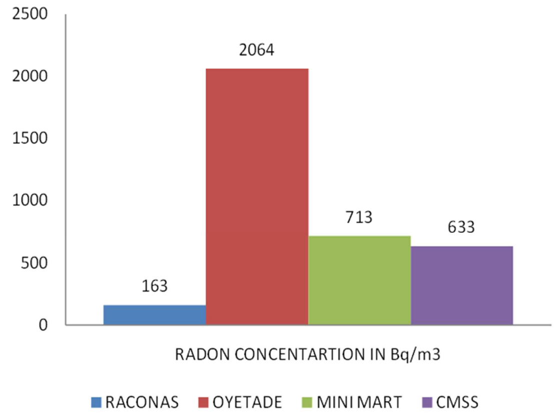
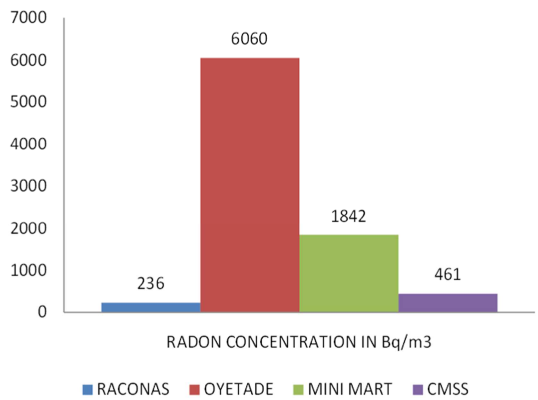


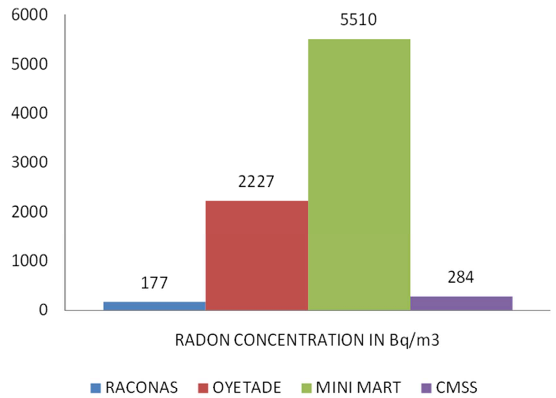
Figure 4. *A graph of radon concentrations in Bq/m^3 against depth from ground surface for all area of study.*



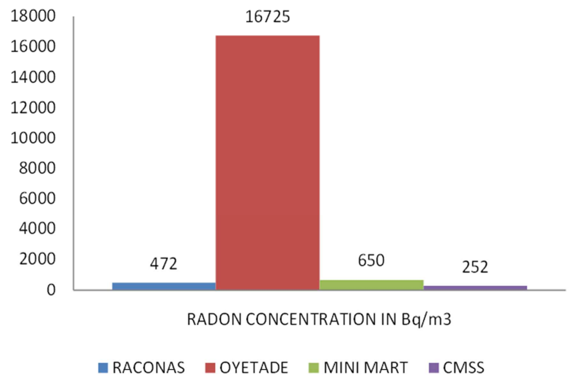
a)Average radon concentration in Bq/m3 in soil of depth 20cm



b)Average radon concentration in Bq/m^3 in soil of depth 40cm



(c) Average radon concentration in Bq/m^3 in soil of depth 60cm



(d) Average radon concentration in Bq/m3 in soil of depth 80cm

Figure 5 *(a-d.) Average radon concentration in Bq/m^3 in soil for all the measured depth.*

Table 2. *The Rn activity of emanation in air near the ground a.E,AED in soil at depth 80cm.*

Location	Production rate (a) of emanation in soil in (Bq/m³.s)	Exhalation rate (E) (Bq/m³)	Rn activity of emanation in air near the ground	The annual effective dose mSv/y
Oyetade	0.0351225	0.054195194	16.725	0.1589544
Minimart	0.001365	0.00210624	0.65	0.0061776
RACONAS	0.0009912	0.00152946	0.472	0.0044859
CMSS	0.0005292	0.00081657	0.252	0.002395
Min	0.0005292	0.00081657	0.252	0.002395
Max	0.0351225	0.05419519	16.725	0.1589544
Average	0.0095004	0.014659	4.524	0.042996

Table 3. *The Rn activity of emanation in air near the ground a.E,AED in soil at depth 60cm.*

Location	Production rate (a) of emanation in soil in (Bq/m³.s)	Exhalation rate (E) (Bq/m³)	Rn activity of emanation in air near the ground	The annual effective dose mSv/y
Oyetade	0.012726	0.0196366	6.060	0.57594
Minimart	0.0038682	0.0059687	1.842	0.017506
RACONAS	0.0004956	0.00076478	0.236	0.0022429
CMSS	0.0009681	0.0014938	0.461	0.0043813
Min	0.0004956	0.00076478	0.236	0.0022429
Max	0.012726	0.0196366	6.060	0.57594
Average	0.0045129	0.0069636	2.149	0.020424

Table 4. *The Rn activity of emanation in air near the ground a.E,AED in soil at depth 40cm.*

Location	Production rate (a) of emanation in soil in (Bq/m³.s)	Exhalation rate (E) (Bq/m³)	Rn activity of emanation in air near the ground	The annual effective dose mSv/y
Oyetade	0.0046767	0.0072163	2.227	0.021172
Minimart	0.011571	0.0178544	5.510	0.052367
RACONAS	0.0003717	0.00057355	0.177	0.0016822
CMSS	0.0005964	0.000920265	0.284	0.002699
Min	0.0003717	0.00057355	0.177	0.0016822
Max	0.011571	0.0178544	5.510	0.052367
Average	0.0043029	0.0066395	2.049	0.019474

Table 5. *The Rn activity of emanation in air near the ground a.E,AED in soil at depth 20cm.*

Location	Production rate (a) of emanation in soil in (Bq/m³.s)	Exhalation rate (E) (Bq/m³)	Rn activity of emanation in air near the ground	The annual effective dose mSv/y
Oyetade	0.0043365	0.0066914	2.065	0.019626
Minimart	0.0014973	0.00231038	0.713	0.0067764
RACONAS	0.0003423	0.00052818	0.163	0.0015492
CMSS	0.0013293	0.00205115	0.633	0.006016
Min	0.0003423	0.00052818	0.713	0.0067764
Max	0.0043365	0.0066914	2.065	0.019626
Average	0.0018753	0.0028937	0.893	0.008487

6. Conclusion

According to the range of the radon concentration measured for the different areas under investigation shows that these areas under investigation as different radon concentration. From the range of the radon concentration measured for each area of study it can be deduced that all the results of radon concentrations that were obtained in this study are well below the allowed levels and standard limit which is range from (0.4 to 40) KBq/m^3, also the average radon concentration of the soil for each depth has a linear relationship with respect to the depth. The Production rate (a) of emanation in soil, the Exhalationrate (E) and the radon activity of emanation in air near the ground were estimated using the soil radonactivity. The annual effective dose that has been calculated from the Rn activity of emanation in air near the ground were lesser than 1mSv/y; the recommended global average dose from the inhalation of radon from all sources. In addition, the average radon concentration of the soil for each depth has a linear relationship with respect to the depth. The results found from this work, together with permeability of soil, can be helpful in compiling new radiation protection regulation to estimate health hazard index due to radiation exposure in Nigeria

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