Assessment of Indoor Radon Levels in Student Lecture Halls in Umm Al Qura University, Makkah, KSA

R. A. Hassan[1, 2]

[1]Department of Physics, Faculty of Applied Sciences, Umm Al-Qura University, Makkah, Saudi Arabia
[2]Department of Nuclear physics, National Cancer Institute, Cairo University, Cairo, Egypt

***Abstract:** Radiation and radioactive isotopes form part of our natural environment. Elevated levels of these radioactive isotopes in the environment can pose a threat to our health. One of naturally occurring radioactive gas is Radon (^{222}Rn). Radon is a colorless, odorless, and tasteless gas. ^{222}Rn is the second leading cause of lung cancer after smoking, and may pose a significant long-term risk for student, who spend long time in class and halls. In the current work, radon concentrations were measured for one day run in 28 student lecture halls at Umm Al-Qura University-Makkah, Saudi Arabia. Radon was measured with a portable Radon counter (Rad 7 Instrument, Durridge-USA), which was placed on the middle of student halls at a height of about 0.85 m. ^{222}Rn gas levels were registered in Becquerels (Bq/m^3). The measured concentration of radon in the air of halls ranged from 15.6 ± 8.65 Bq/m^3 to 24.8 ± 10.4 Bq/m^3 with a mean of 19.8 ± 2.919 Bq/m^3, while that of the progeny of radon varied from 0.00173 to 0.00276 WLM Y^{-1} (average: 0.00213). The mean indoor concentration of radon was considerably less than the lower levels prescribed by EPA (148 Bq/m^3), EEC (400 Bq/m^3), WHO (100 Bq/m^3), ICRP (200–600 Bq/m^3) and NRPB (200 Bq/m^3). The mean annual effective dose calculated 0.012 mSv y^{-1}, which is less than the UNSCEAR and WHO recommended global lower average dose value of 1 mSv/y. The hazard indices (PAEC, and CPPP) values were lower than the permissibility limit value.*

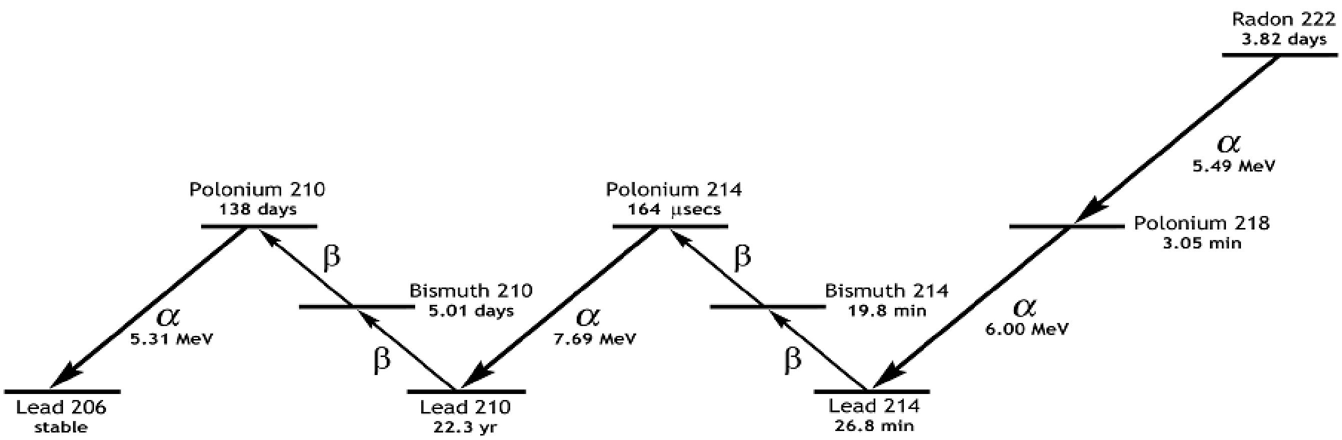
Keywords: indoor radon; Umm Al Qura University; student halls; Rad 7

1. Introduction

When the earth was formed, many of years ago, there were probably many radioactive elements included in the mix of material that became the earth. Three of this radioactive, have survived to this day, namely uranium-235 (^{235}U), uranium-238 (^{238}U), and thorium-232 (^{232}Th). Each has a half-life measured in billions of years, and each stand at the top of a natural radioactive decay chain. All three of these natural decay chains include isotopes of radon. Radon-219 (^{219}Rn), or "actinon", is a link in the uranium-235 chain. We will probably never encounter actinon in indoor air, due to its scarcity and short half-life. Radon-220 (^{220}Rn), or "thoron", is part of the ^{232}Th decay chain. We will sometimes encounter thoron in indoor air, particularly near radon entry points, and, more often, in soil gas [IAEA, 2015-Health Canada, 2008].

Radon-222 (^{222}Rn), or familiar "radon", is part of the ^{238}U decay chain. We will usually be able to detect ^{222}Rn in indoor air, outdoor air, and soil gas. The radon isotope is the first element, in each of the decay chains, that is not a metal. It is, in fact, an inert, or “noble”, gas. Therefore, it can escape any chemical compound its parent (radium) was in, and diffuse into the air.

To focus on these inert gases, the thoron and radon decay chains, shown below, are those parts of the ^{232}Th and ^{238}U decay chains that include just these radioactive gases and their short-lived progeny.



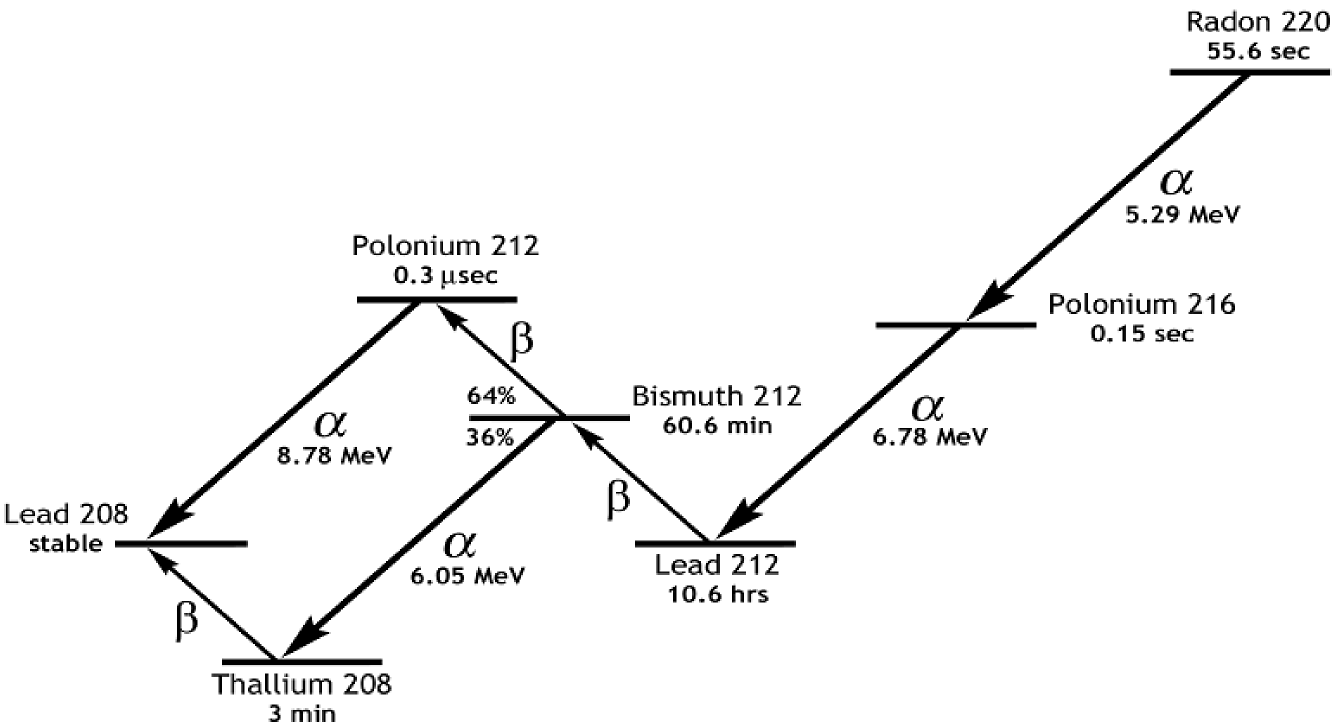


Figure 1: Radon-220, Radon-222 decay chain

About 90% of indoor radon comes from cracks on the floor and wall, and the rest comes from building material such as gypsum board, monazite, and cement [Timothy, 2003]. Inhalation of radon can damage DNA and enhance the risk of lung cancer by depositing alpha particles emitted during the radioactive decay of radon in lung epithelium [National Research Council 1999]. In 1988, the International Agency for Research on Cancer (IARC), and cancer research institute of the World Health Organization, declared radon to be carcinogenic for humans and classified it as a proven human carcinogen [International Agency for Research on Cancer 1988]. Other studies have also provided information on the risks of exposure to lower levels of radon [Lubin and Boice 1997; NRC 1999]. Despite other perceptions, such as those described in several studies, and such as those presented by Cohen (1995), Becker (2004), Thompson et al. (2008), Dobrzy ´nski et al. (2018), or even Pylak et al. (2021), where the authors differed with the generalized opinion about the connection between low Radon concentration and lung cancer. Lung cancer is the number one cancer killer worldwide afflicting the lives of 1.8 million annually [IARC-2012]. In Saudi Arabia, lung cancer is on the rise increasingly claiming lives of many peoples [Saudi Ministry of Health 2018].

To evaluate the Ra-222 effects & risks we need to calculate;

1-The annual effective dose (AED) in units mSv/y were calculated by using following equation [Hamidawi A 2012]

$$AED\ (m\ Sv/y) = C_{Rn} * F * H * T * D \qquad \dots(1)$$

Where, C_{Rn} is the radon concentration in Bq.m^{-3}, F is the equilibrium factor, F= (0.4), H: is the occupancy factor, H = (0.02) [UNSCEAR United Nations Scientific Committee 2000]. T: is the time in one year in hours, T= (8760 h/y). D: is the dose conversion factor [D = 9*10^{-6} m Sv / (Bq.h.m^{-3})].

2-Exposure to radon progeny (EP) in term of WLM Y^{-1} units were calculated using the following equation [ICRP 2009]:

$$EP\ (WLM\ Y^{-1}) = 8760 * n * F * C_{Rn} / 170 * 3700 \quad \dots (2)$$

n: is the fraction of time spent halls n = (0.02). Where the number of hours per year is (8760) and is the number of hours per working month (170) [UNSCEAR United Nations Scientific Committee 2000].

3- The evaluation of exposure to Rn and the decay products must thus take account of the actual activity concentrations of the various alpha-emitting radionuclides in the two series in the air that breathed. This consideration, as well as the fact that it is the total alpha particle energy yet to be released by, or following, the decay of inhaled radionuclides that is important in determining dose, has led to the definition of radon exposure rate in terms of potential alpha energy concentration (PAEC) with unit of J m^{-3} or of working level (WL). The PAEC in units (WL) were calculated using the following equation [Ismail, A2010, Kansal 2009, and UNSCEAR United Nations Scientific Committee 2000]:

$$PAEC\ (WL) = F * C_{Rn} / 3700 \qquad \dots (3)$$

4- The number of lung cancer cases per year per million people in each AED (CPPP) was calculated using a conversion factor of 18 mSv^{-1} y, as recommended by the International Commission on Radiological Protection-ICRP (Quarto et al., 2015). The lung cancer cases per year per million person (CPPP) was calculated using the following equation [Ismail, A2010, Abdullah, and A2013]:

$$(CPPP) = AED * (18*10^{-6}\ mSv^{-1}.y) \qquad \dots (4)$$

2. Materials & Methods

As shown in Figure 2, RAD7 detector was used to measure the indoor radon concentration. The RAD7 is able to detect radon concentration in the range of 0.1 pCi/L to 20,000 pCi/L with the relative uncertainty of ± 5 % [Durridge Company Inc2009].

The study was carried out at the student lecture halls of Faculty at Applied Science Abdia campus- Umm Al Qura University- Makkah, Saudi Arabia. The RAD7 able to make the continuous measurement. Our measurements were made based on the U.S Environmental Protection Agency (U.S. EPA) protocols [EPA 1992]. Before each measurement, the Rad 7 was purged more than 10 minutes to discharge the remaining radon gas including thorium inside the RAD7. After purging, the air inlet nozzle of the RAD7 was positioned 0.85 m above the floor, considering the breathing region of a setting student. The indoor radon concentration was continuously measured for 24 hours each measurement is done at the center of the halls, there was no forced air-conditioning except natural ventilation through the entrance door opened and closed by visitors. The measurement data were recorded and analyzed by using the program embedded already in RAD7.

In addition, these devices measure and track additional environmental parameters above and beyond the radon concentration such as relative humidity, and temperature.

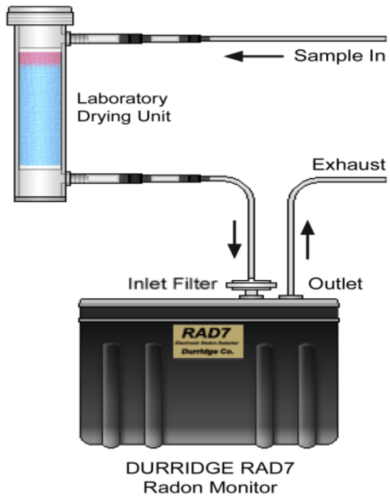


Figure 2: RAD7 Professional Electronic Radon Detector

3. Results & Discussion

Indoor radon measurements were carried out in 28 different student lecture halls, the mean, the maximum and minimum value of radon concentration were 19.8 ± 2.919 Bq/m^3, 24.8 ± 10.4 Bq/m^3,15.6 ± 8.65 Bq/m^3, respectively (table 1). The highest values were observed in the halls 8 (24.8 Bq/m^3) which located at the ground level and where air ventilation was poor. Figure 3 shows the histogram of radon concentrations. As can be seen, all the measured values are below 148 Bq/m^3, which the recommended level issued by EPA. All values below 24.5 Bq/m^3. However, just in one case, halls 8, the value exceeded the level of 24.5 Bq/m^3 and thus the high ventilation is recommended. The implementation of a proper ventilation system or even taking benefit of the natural air exchange by opening windows and door occasionally can avoid accumulation of radon. Based on radon concentration and the time spent in a hall, the annual effective dose (AED) due to exposure to radon and progenies were calculated (mean 0.0122 mSv/y). As stated in Tab.1 all the calculated values of annual effective dose were below the ICRP recommended level of 1 mSv per year.

The highest value of EP was found in halls 8 which was equal to 0.00276 WLM.Y^{-1}, while the lowest value of EP was found in halls 25 which was equal to 0.00174 WLM.Y^{-1}, with an average value 0.0021 WLM.Y^{-1}. Which is lower than the recommended range 1-2 WLMY^{-1}.

The highest value of PAEC was found in halls 8 which was 0.0027 WL, while the lowest value of PAEC was found in halls 25 which was 0.00169 WL with an average value 0.00206 WL, which is less than the recommended value 0.0533 WL. Also, from Table-1, it can be noticed that the highest value of CPPP was found in halls 8 which was equal to 2.8 x 10^{-7}, while the lowest value of CPPP was found in halls 25 which was equal to 1.8 x 10^{-7} with an average value 0.22.

Table 1: Details of measured halls radon concentrations, gamma dose rates and calculated annual effective dose

Lab.	Floor	Ventilation Rate (low, medium, high)	T (C)	RH(%)	Mean	SD	High	Low	AED (m Sv/y)	EP (WLM Y^-1)	PAEC(WL)	CPPP
1	2	Low	25	4	16	8.18	32.9	0	0.01009	0.001783	0.00173	1.8E-07
2	2	High	22	4	16.6	6.54	37.4	5.33	0.01047	0.001849	0.001795	1.9E-07
3	2	High	22.5	4	15.7	7.65	37.7	0	0.0099	0.001749	0.001697	1.8E-07
4	2	High	23.1	3	16.7	7.36	33.6	0	0.01053	0.001861	0.001805	1.9E-07
5	Ground	High	21.9	4	15.7	6.97	32.3	5.39	0.0099	0.001749	0.001697	1.8E-07
6	Ground	High	21.7	3	18.3	7.52	35.7	5.49	0.01154	0.002039	0.001978	2.1E-07
7	Ground	High	22.3	4	16.8	6.4	27.8	2.67	0.0106	0.001872	0.001816	1.9E-07
8	Ground	Low	23.5	4	24.8	10.4	52.1	5.72	0.01564	0.002763	0.002681	2.8E-07
9	Ground	Medium	20.4	4	21.1	8.64	40	5.33	0.01331	0.002351	0.002281	2.4E-07
10	Ground	Medium	23.1	3	19.7	7.69	37.5	0	0.01243	0.002195	0.00213	2.2E-07
11	Ground	High	23.4	4	17.1	8.71	43.1	2.69	0.01079	0.001905	0.001849	1.9E-07
12	Ground	High	21.8	4	17.5	7.35	35.8	2.1	0.01104	0.00195	0.001892	2E-07
13	Ground	Medium	24.6	4	22.7	9.87	53.9	2.69	0.01432	0.002529	0.002454	2.6E-07
14	Ground	High	23.2	4	17.9	7.13	34.7	0	0.01129	0.001994	0.001935	2E-07
15	Ground	High	20.3	5	18.5	7.45	45.3	2.4	0.01167	0.002061	0.002	2.1E-07
16	Ground	Medium	22.6	4	22.9	6.33	28.7	3.5	0.01444	0.002551	0.002476	2.6E-07
17	Ground	Low	23.1	4	24.4	8.65	33.6	2.3	0.01539	0.002719	0.002638	2.8E-07
18	Ground	Medium	21.9	4	23.2	9.41	45.3	0	0.01463	0.002585	0.002508	2.6E-07
19	Ground	High	23.2	4	21.7	10.2	51.3	5.7	0.01369	0.002418	0.002346	2.5E-07
20	Ground	High	23.1	4	22.8	8.39	44.6	4.6	0.01438	0.00254	0.002465	2.6E-07
21	Ground	High	22.7	4	18.6	6.84	28.8	3.56	0.01173	0.002072	0.002011	2.1E-07
22	Ground	High	21.5	4	17.6	8.21	38.9	1.52	0.0111	0.001961	0.001903	2E-07
23	Ground	High	22.5	4	19.6	7.41	33.5	3.78	0.01236	0.002184	0.002119	2.2E-07
24	2	Medium	23.6	3	22.3	9.35	40.3	5.13	0.01407	0.002485	0.002411	2.5E-07
25	2	High	24.1	5	15.6	8.65	46.5	2.45	0.00984	0.001738	0.001686	1.8E-07
26	2	High	23.2	3	16.9	6.11	35.7	0	0.01066	0.001883	0.001827	1.9E-07
27	2	Medium	24.5	4	17.1	9.42	38.6	3.2	0.01079	0.001905	0.001849	1.9E-07
28	1	Medium	22.3	4	16.4	10.24	34.3	1.34	0.01034	0.001827	0.001773	1.9E-07
	average		22.75	3.8929	19.08	8.1096	38.57	2.75	0.01203	0.002126	0.002063	2.2E-07

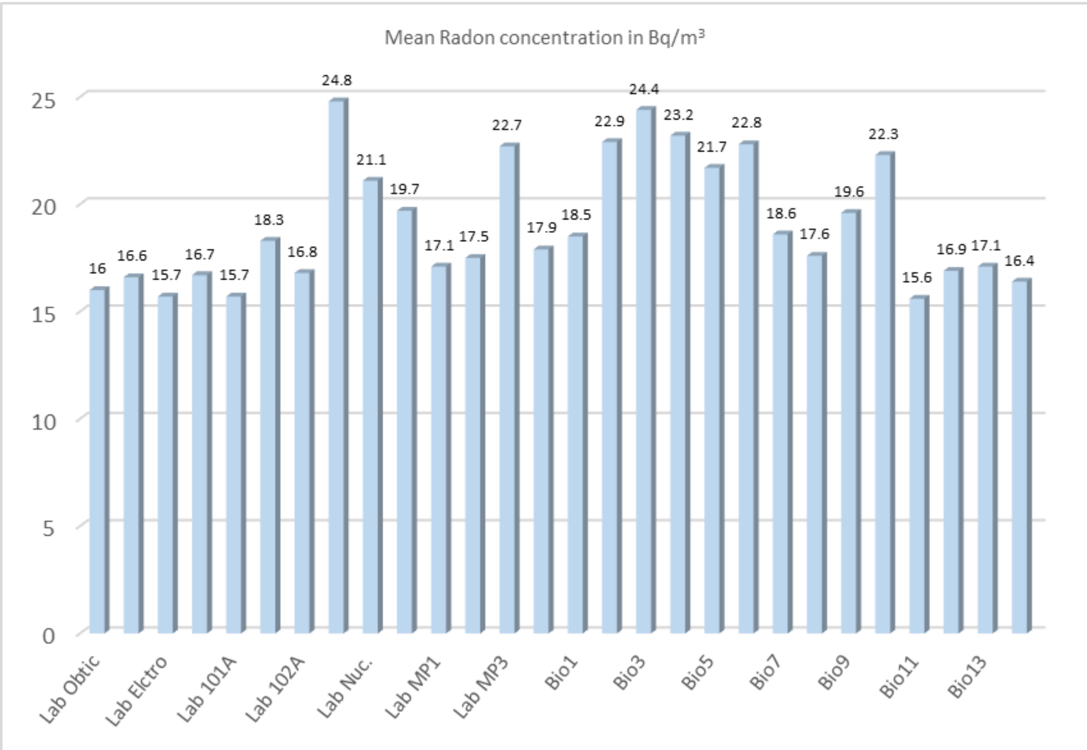


Figure 3: Mean Radon concentration in Bq/m^3

4. Conclusions and Future Perspective

Long-term exposure to radon can increase the risk of lung cancer. Therefore, public awareness about adverse health effects of radon should be increased and systematic measurement plans should be considered to identify environments where individuals are exposed to elevated radon levels. In this research, student lab radon concentrations have been measured simultaneously based on the standard testing procedure. The most important point observed here was that using ventilation systems or even improving natural ventilation can effectively reduce radon levels. This can be an economic and a preliminary solution for increased radon levels, however, for the sites space with significantly high concentration, the implementation of a remediation action is recommended.

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