ORIGINAL ARTICLE

Assessment of Radon Concentration and its Resulting Radiological Hazards in Jouf University: Girls Campus, Sakaka, KSA

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ABSTRACT

Background The World Health Organization (2016) confirms that humans who are exposed to Radon-222 can significantly suffer from risks of lung cancer. Measuring radon concentrations indoors environment, including houses and workplaces, has become a high priority nowadays.
Aim: To assess the radon exposure risk for students and staff in such locations.
Methods: In this research, radon concentrations were measured inside 14 sites at the Girls' Campus - Jouf University – Sakaka City- KSA by using a RAD7 radon detector for the purpose of estimating the possibility of any risks related to exposure to radon inside these sites.
Results: It has been found that the concentration levels of Radon varied from 13.5 ± 1.8 to 29.2 ± 2.6 Bq/ m^3 representing an average of 19.5 ± 2.5 Bq/m^3. The observed total of effective dose per year caused by radon inhalation was found to range from 0.142 to 0.307 mSv/y, with a mean of 0.21 mSv/y.
Conclusion: The study concluded that the concentration levels of radon and the effective doses per year were lower than the recommended limits. Further, the obtained values of the estimated Excess Life Time Cancer Risk (ELCR) revealed low potential hazards resulting from exposure to radon in the studied sites.
Keywords: Indoor radon levels, RAD7, Annual effective dose, Cancer risk

INTRODUCTION

People normally face the risk of ionizing radiation emitted by natural radiation sources in an indoor environment, as most of the residents spend about 80% of their time indoors[1]. There are two types of radiation exposure. Firstly, the external exposure which comes mainly from gamma radiation emitted during radioactive decay of nuclides in the ^{238}U and ^{232}Th decay chains and of ^{40}K. The second type is the internal exposure attributed mainly to the inhaled radon gas, including the resulted decay products[2]. Radon (^{222}Rn), which is known as a radioactive noble gas with a half-life of 3.82 days, results from the disintegration of radium (^{226}Ra), and it comes, in turn, from the radioactive uranium decay (^{238}U)[3]. So, the substance which contains trace of radium leads to either direct diffusion of radon gas or indirectly as a solution in water up to earth surface[4]. Radon is heavier than air and it exists in different amounts in various environments, including air, soil, and water of various kinds as a gas with no color, odor, or taste[5]. Radon contribution has increased to 55% of all types of exposure in general environment [6].

The World Health Organization considers radon as one of 19 main carcinogens, and the second factor in causing lung cancer in humans after cigarettes[7]. Due to its 3.8 day half-life, a small part of this gas that goes inside the lung area can damage the sensitive DNA tissue of the lung and causes its cancer. Normally most radon atoms leave the body without causing damage, before they decompose[8]. So, the major concern is the short-lived products of radon decay (Po-218, Pb-214, Bi-214, and Po-214), but not radon itself, since such products can attach the aerosol particles that form radioactive aerosols before entering human respiratory tract and reaching the interior according to its grain size[9]. Because of their short half-life period, these products decompose almost entirely in the human respiratory tract producing nuclear radiation. As a result, a great radiation exposure to sensitive cells in the lungs, where much health risk becomes potential[8]. With the possibility of the presence of radon emitters, besides bad ventilation conditions, the radon gas levels are higher indoor than outdoor. To this end, many previous studies were conducted in attempts to investigate and measure both the concentration levels of radon gas and its behavior in indoor environments, on the one hand, and the possible radiological hazards to humans, on the other hand[10-14].

The UNSCEAR (2000) indicates that the weighted average of the global population for radon concentration indoors is 40 Bq·m^{-3} leading to an approximate effective dose of 1.1 mSv·y^{-1} [15]. In line with this trend, the current study was carried out by conducting a series of measurements of radon levels using the Rad7 chamber at different locations within the Girls Campus at Jouf University in the city of Sakaka- KSA. The purpose of this study is to assess the radon exposure risk for students and staff in such locations.

MATERIALS AND METHODS

In this research, a series of measurements were carried out to estimate radon gas concentration in 14 sites within the Girls' Campus of Jouf University – Sakaka- KSA from Nov. 2018 to Apr 2018. They were done to conduct a survey of radon levels. Sakaka is the central city of the Al Jouf region and located in the northwestern of KSA. The Girls Campus is a multi-story campus built of many materials, including metal, brick, concrete, and cement. The measurements were conducted under normal ventilation conditions, as the air conditioner is only turned on during working hours. The site samples were selected from places such as classrooms, laboratories, offices that are normally used by students, staff members, and employees.

The measurement was carried out within each location by the use of a solid-state alpha detector RAD7

(Durridge, USA), which is a continuous real-time Rn detector (Fig. 1). The instrument was calibrated by the manufacturer. As RAD7 sensitivity decreases at high humidity, the desiccant tube that contained a desiccant (CaSO4) was used to keep the RAD7 relative humidity below 10%. Normally, a high electric field is used by the RAD7 along with a detector of silicon semiconductor at ground potential in order to catch the positively charged polonium daughters, $^{218}Po^{+}$ (T1/2 = 3.10 min) and $^{214}Po^{+}$ (T1/2 = 164 μs), which were then computed to find out the ^{222}Rn activity measure in the air. Radiation equilibrium between ^{218}Po and ^{222}Rn would be reached within just 15 minutes; however, because of the intermediate ^{214}Pb and ^{214}Bi daughters, ^{214}Po would need around 3 hours for equilibrium[16].

Fig. 1: RAD7 electronic radon detector

RAD7 was purged with fresh air for 10 minutes by attaching the drying unit in a closed loop with RAD7. The device is set to 24-hour mode, recording a half-hour reading of 48 readings per location. During pump operation for five minutes, radon is extracted from the air and delivered to the measurement chamber at RAD7, followed by five minutes to reach the equilibrium state. Then, it is repeated for four cycles for five minutes per cycle, and thus the total test duration is 30 minutes. The detector air inlet was placed above the ground at one meter height. In the meantime, no mechanical ventilation had been used. Then, the data which was stored in the RAD7 was computed after being transferred using a capture software that provided rich options of graphing and data analysis. It also allowed the correction of both the moisture values and the counts spillover, which happened between adjacent windows of the RAD7. Then, the collected data was processed using the Microsoft Office program.

RESULTS

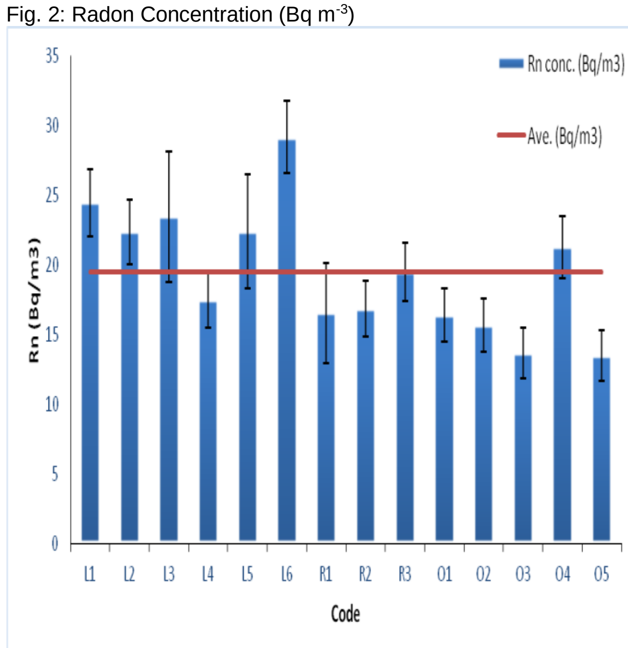
The obtained values of indoor ^{222}Rn activity concentrations for 14 sites at Jouf University Girls' campus in Sakaka city, which included student laboratories, classrooms, and offices, are listed with their identification codes in Table-I. Furthermore, the values of temperature and humidity which were recorded by Rad7 are listed in Table-I below. Table-I and Fig. 2 showed that the radon concentration results, at all measurement points, ranged from 13.5 ± 1.8 Bq/m^3 (O5) to 29.2 ± 2.6 Bq/m^3 (L6) with a mean of 19.5 ± 2.5 Bq/m^3.

Table-I: Indoor radon concentrations of the studied sites

Location	Code	Radon Conc.	% of Int. Limit^c		Temp.	Humidity
		(Bq/m^3)	WHO	ICRP	(C°)	%
Laboratories	L1	24.5±4	25%	12%	20.2	3.13
	L2	22.4±2.3	22%	11%	20.5	2.85
	L3	23.5±4.7	24%	12%	19.5	3.27
	L4	17.5±2	18%	9%	20.2	2.25
	L5	22.4±4.1	22%	11%	20.8	2
	L6	29.2±2.6	29%	15%	21.3	2
Rooms	R1	16.6±3.6	17%	8%	24.5	3.59
	R2	16.9±2	17%	8%	25.8	2.98
	R3	19.5±2.1	20%	10%	24.6	2.45
Offices	O1	16.4±1.9	16%	8%	25.8	2.67
	O2	15.7±1.9	16%	8%	24.9	2.5
	O3	13.7±1.8	14%	7%	25.3	3.1
	O4	21.3±2.2	21%	11%	26.3	2.83
	O5	13.5±1.8	14%	7%	24	3
Average		19.5±2.5	20%	10%	23.1	2.76
Maximum		29.2±2.6	29%	15%	26.3	3.59
Minimum		13.5±1.8	14%	7%	19.5	2.0

^{c}Radon concentration percentage relative to international limits

Fig. 2: Radon Concentration (Bq m^{-3})



It is found that compared with other studies, the values of indoor radon in the area under investigation were lower than or within the corresponding values of other regions worldwide, as listed in Table-II.

The instantaneous change in the levels of radon concentration was also investigated and presented in Fig. 3 for one room (R2), as an example. Fig. 3 shows that the concentration of radon was approximately constant during the working hours because the workers used the site where the ventilation levels were fixed. Then, the level of radon rose after 4 pm by the end of the work and the closure of the room. This led to the accumulation of radon with low ventilation rate, and thus, increased over time until it reached a maximum value at 8 am. After that, the focus was sharply broken due to the reopening of the room on the following day. This emphasizes the importance of ventilation as an important and essential factor in reducing indoor radon levels.

The annual effective dose value that is normally received by an individual in indoor sites was calculated through the following relationship[15].

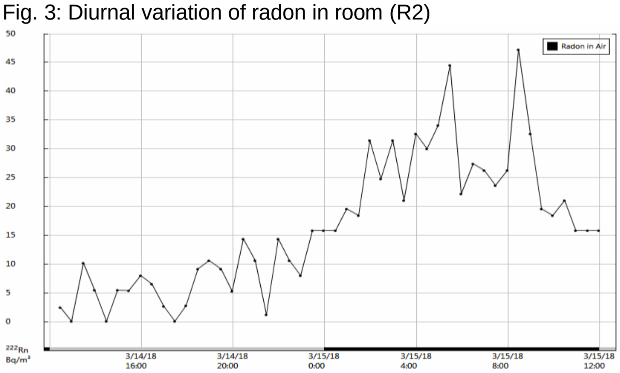
$H_y = C_{Rn} \times F \times T \times D$ (1)

Where, H_y refers to the annual dose resulted from inhaled radon, C_{Rn} refers to radon concentration indoor, F represents the equilibrium factor between radon and its decay products (0.4), T refers to the average occupancy time indoor for a person (hour 8 x 365 days) and D represents the conversion factor from Bq to mSv (9×10^{-6} $mSvh^{-1}$ /Bqm^{-3}).

Table-II: Comparison of Rn concentrations indoor inside the studied area with different regions worldwide

Regions	Mean concentration (Bq/m^3)	References
Al Jouf, Saudi Arabia	19.5±2.5	Present study
Riyadh, Saudi Arabia	24.7	19
Valencia, Spain	24	20
Megalopolis, Southern Greece	52	21
Irbid (Jordan)	44	5
Brisbane, Australia	10.5 ± 11.3	14
Xi'an, China	66.7	22
All over the world	40.0	15

Fig. 3: Diurnal variation of radon in room (R2)



The obtained values correspond to the annual effective dose ranged from 0.142 to 0.307 mSv/y, with a mean of 0.21 mSv/y, as shown in Table-III and Fig. 4. The ELCR was calculated for each year in addition to every 4 years to give information about the total risk to which the student was exposed during the study period, which measures to 4 years as shown in Fig. 5. The following equation was used to calculate the Excess Lifetime Cancer Risk (ELCR)[23]:

$ELCR = H_y . RF. T$ (2)

Table-III: Annual effective dose and excess lifetime cancer risk caused by indoor radon in the studied sites

Code	Annual effective dose	Excess lifetime cancer risk % (ELCR)	
	(mSy/y)	/year	/4years
L1	0.258	0.014	0.057
L2	0.235	0.013	0.052
L3	0.247	0.014	0.054
L4	0.184	0.010	0.040
L5	0.235	0.013	0.052
L6	0.307	0.017	0.068
R1	0.174	0.010	0.038
R2	0.178	0.010	0.039
R3	0.205	0.011	0.045
O1	0.172	0.009	0.038
O2	0.165	0.009	0.036
O3	0.144	0.008	0.032
O4	0.224	0.012	0.049
O5	0.142	0.008	0.031
Average	0.21	0.01	0.05
Maximum	0.31	0.02	0.07
Minimum	0.14	0.01	0.03

Fig. 4: Annual effective dose (mSv/y)

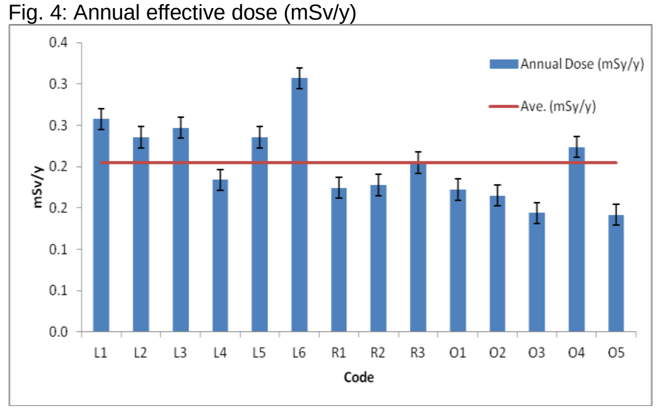
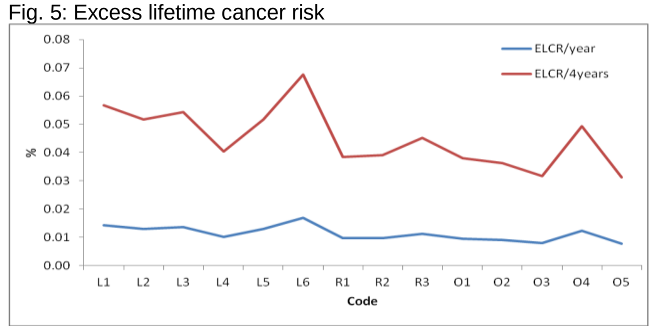


Fig. 5: Excess lifetime cancer risk



Where H_y denotes the annual dose, RF refers to the risk related to fatal cancer for each Sievert (5.5×10^{-2} Sv^{-1}) as per the recommendation of the ICRP, and T is the duration time[24].

The results showed that the annual risk ranged from 0.008 to 0.017, with an average of 0.01. During the four years, the risk coefficient was found to range from 0.031 to 0.068, with an average of 0.05.

DISCUSSION

The average levels of radon concentration indoors were below their world counterpart of 40 Bqm^{-3} [15]. It was noted that the highest radon concentration levels were in the laboratories, followed by classrooms and administrative offices. This can be attributed to the levels of ventilation which were higher in offices than in laboratories. The high levels of ventilation in offices come as a result of human activity and the relevant opening of rooms at higher rates than in laboratories. So, the air inside is frequently renewed, and the concentration of radon gas is reduced. In light of the World Health Organization's limit (100 Bq/m^3)[17], all readings were below that limit and did not exceed 29.2% of it at the highest level, which was measured. While, according to ICRP limits of 200 Bq/m^3, the highest recorded value represents only 15% of the allowable level[18]. This indicated that all observed values of radon in the selected sites were significantly lower than the levels allowed by the concerned international bodies. Therefore, these sites are safe for all users, including students or employees. The estimated values of annual effective dose is sharply lower than the global average (1 mSv for radon and its decay products)[15]. It was also found that laboratories represented the highest value of the annual effective dose, while the lowest value was in the offices consistently with the radon concentrations described before. The values of excess lifetime cancer risk were found to be extremely low. Therefore, the findings proved a low degree of cancer risk among students during their study in the studied areas.

CONCLUSION

This research estimated the concentration levels of indoor radon in 14 sites at Girls Campus of Jouf University using the RAD7 radon detector, which was manufactured by Durridge Company Inc. The main value of the measured radon was 19.5 ± 2.5 Bq/m^3 within all selected sites. Higher radon concentration values were found to be at laboratories in comparison to rooms and offices at the same location. All obtained measured indoor radon values were less than the values recommended by the international organizations. Levels of radon concentration were lower at working hours than other timings. This was attributed to the increase in the ventilation rate caused by human activities at working hours. The mean value of the annual effective dose from radon of the studied sites was 0.21 $mSv\ y^{-1}$ and, therefore, below the recommended safe limit. Furthermore, the excess lifetime cancer risk (ELCR) values were negligible. Therefore, it can be confirmed that the studied sites did not show any significant health hazards to humans associated with radon.

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