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Indoor Radon Levels and Distribution in Occupied and Unoccupied Residential Buildings in Student's Campus at King Saud University, Riyadh, Saudi Arabia

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Abstract. In this work, radon concentrations were measured in four buildings in the Diriyah campus of King Saud University, Riyadh, Saudi Arabia. The closed chamber technique was used employing 2x2 cm^2 sheets of CR-39 detectors. The detectors were kept for periods of about 3-4 months. A total of 270 measurements were taken, 30 of which were found to exceed the EPA limit of 150 Bqm^{-3}. These high concentration values have a range of 156 to 235 Bqm^{-3}, 156 to 254 Bqm^{-3}, 150 to 292 Bqm^{-3} and 152 to 256 Bqm^{-3} in buildings one, two, three and four respectively. The average radon concentration per room in each building is found to be 78 ± 5, 82 ± 5, 50 ± 5 and 58 ± 5 Bqm^{-3} in buildings one, two, three and four respectively.

The effects of factors such as height, ventilation, soil and building materials in this study were investigated. On the basis of this study, no significant radon concentration dependence on height was observed and the influence of ventilation is not significantly observed as expected. Therefore, the ventilation is not the only contributory factor in radon variation. It is concluded that soil and building materials are dominant sources of the measured high values in this study.

Keywords: Radon, Saudi Arabia, Riyadh, Building materials.

1. Introduction

Radon (^{222}Rn) is a radioactive noble gas with a half-life of 3.8 days. It is the immediate daughter of Radium (^{226}Ra) produced in the decay series of Uranium (^{238}U). Radon is the highest contributor, from the natural sources, to the effective dose equivalent in man. The health hazards linked to radon have become a matter of great public concern. If radon "attached to the dust particles" is inhaled, a fraction of radon is dissolved into the lungs fluids by which it is transported to other parts of the body. The radiation damage caused to the lungs due to alpha decay of radon during its transit time within the respiratory tract may cause cancer [1].

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In this study, the indoor radon concentration is measured in the student's residential buildings in King Saud University in Riyadh, Saudi Arabia. The investigated buildings are divided into two categories: occupied and unoccupied. Factors such as building height, ventilation, soil and building materials contribute to the concentration of radon. The objective of this work is to investigate the possible contribution of these factors in addition to measuring indoor radon concentration.

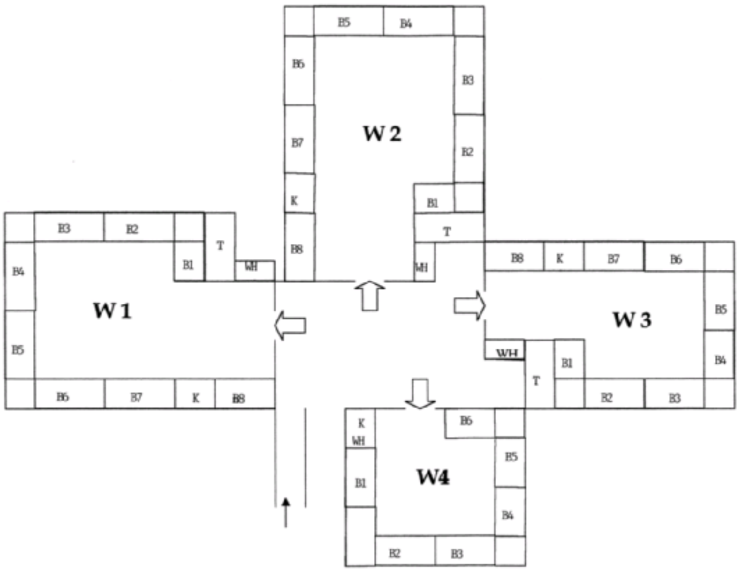

Fig. 1. A typical building plan (W1, W2, W3 and W4 are wings 1, 2, 3 and four respectively).

The studied site (Diriyah) is chosen because it is heavily populated, relatively new and the buildings are made of ready-made concrete. Four identical buildings are studied. Each consisted of five floors and four wings (each wing is built at 90^o to the wing adjacent to it). Each building, in this study, consisted of 28 bedrooms and 12 utility rooms (40 rooms in total) on each floor.

Students occupy two buildings, one building is used for administration and one building has been closed for five years including the period of this study. A typical plan for one of these buildings is shown in Fig. 1. Each building is formed of four wings (W1, W2, W3 and W4), each contains a kitchen, a toilet, a water heater room and a number of bedrooms.

2. Experimental Methods

The dosemeter used in this work is 2x2 cm^2 sheet of CR-39 detector which was cut into this size from the original sheet of dimensions (25.4x20.3x0.05 cm). The closed chamber technique is used in these measurements. The dosemeter is made with a circular opening (diameter = 1.5 cm) at the center of the chamber's lid and is covered from the inside by a thin sheet (1 cm thick) of soft sponge. The sponge acts as a filter to keep the dust particles outside the chamber allowing radon gas (^{222}Rn) to enter the chamber freely. Since the other two radon gases, ^{219}Rn and ^{220}Rn, have short half lives, 3.96 s and 51.5 s respectively, the sponge acts also to delay these two isotopes allowing them to decay before reaching the detector at the bottom of the chamber (Fig. 2) [2].

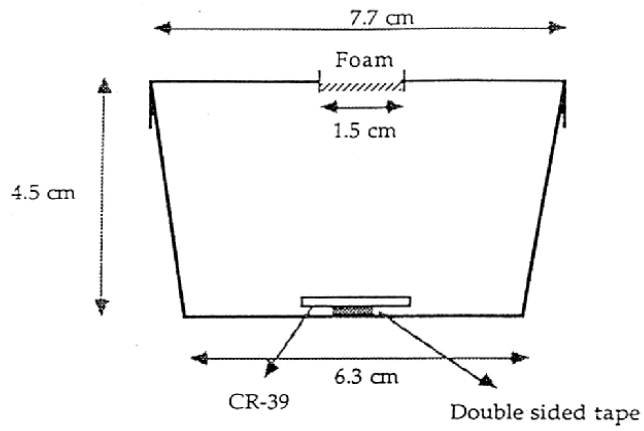

Fig. 2. Schematic diagram of the radon dosemeter.

The dosemeters were prepared for distribution over a period of two days and kept in airtight containers to minimize background radiation. These precautions were taken also during their collection and up to the time of their etching. The detectors were kept for periods of about 3-4 months. The collected CR-39 detectors (270 collected out of 331 distributed) were etched under optimized conditions of temperature (70^{o}C) and in 6N of sodium hydroxide solution, for three hours. The detectors were then removed from the etching bath, washed in water and dried with soft tissue paper.

The track density is determined on each dosemeter by counting the tracks for a number of fields of view (FOV). The number of tracks per cm^2 is then calculated using a calibrated grid which converts the number of tracks observed directly per unit area that is measured in µm^2 into a number of tracks given per cm^2.

Thirty radon dosemeters were sent to the National Radiological Protection Board (NRPB) in the UK for calibration. Three groups, each consisted of eight detectors, were used for calibration and a group of six detectors was used for background measurement during the transit period.

The passive radon detectors were placed in the radon chamber in the indicated groups and were exposed to a number of different known radon doses. The tracks density for each irradiated group was determined after subtracting the background track density of the transit detectors. The calibration factor was found to be 5.2 ± 0.5 Tracks/cm^{2}kBq.m^{-3}h. The radon concentration is determined in units of Bq.m^{-3} by dividing the measured values by this factor.

3. Results and Analysis

In this study, 30 high values were found that exceeded the limit set by the United States Environmental Protection Agency (EPA) which is 150 Bqm^{-3} [3] (Table 1). The high concentration values are found to be random in all buildings and floors, but mainly on the first floor in each building (Table 1). These high concentration values have a range of 156 to 235 Bqm^{-3}, 156 to 254 Bqm^{-3}, 150 to 292 Bqm^{-3} and 152 to 256 Bqm^{-3} in buildings one, two, three and four respectively. It can be also seen that the average of each value (last row of Table 1) in all buildings is higher than the accepted level within three standard deviations. The high values measured in these buildings are possibly due to soil and building materials [4, 5].

Table 1. Indoor radon concentration exceeding the EPA limit in each floor for each building and the average radon concentration

Radon concentration (Bqm^{-3})			
Building 1	**Building 2**	**Building 3**	**Building 4**
223(F1)	254(F1)	150(F1)	152(F1)
156(F1)	162(F1)	150(F1)	163(F1)
179(F1)	167(F1)	156(F1)	219(F1)
188(F1)	173(F1)	162(F1)	256(F1)
156(F2)	156(F3)	162(F1)	152(F5)
156(F3)	X	211(F1)	X
235(F3)	X	212(F1)	X
279(F3)	X	292(F1)	X
212(F4)	X	286(F1)	X
235(F5)	X	X	X
212(F5)	X	X	X
Average = 203 ±10 Bqm^{-3}	182 ±10 Bqm^{-3}	198 ±5 Bqm^{-3}	188 ±7 Bqm^{-3}

3.1. Radon concentration dependence on height

The average radon concentration per room on each floor is calculated and the result is listed against floor number (height) for each building (Table 2).

Table 2. Average indoor radon concentration (Bqm^{-3}) on each floor

Floor/Building	Building 1	Building 2	Building 3	Building 4
Floor 1	79 ± 10	104 ± 11	113 ± 19	85 ± 13
Floor 3	94 ± 14	56 ± 7	48 ± 8	45 ± 6
Floor 5	97 ± 33	112 ± 13	46 ± 7	38 ± 8

From Table 2, one can see that the average radon concentration values in the first two buildings are distributed randomly, indicating no height dependence. The average radon concentration values in buildings three and four follow the expected decrease with height with values on floor one being significantly different from those measured on the upper floors. The large error in the average radon concentration value in building one, floor five is due to the two values of 212 and 235 Bqm^{-3} which gave large spread in the distribution.

3.2. Average radon concentration in each building

The average radon concentration in all floors in each building is calculated to compare the average radon concentration of the four buildings. The measured values in buildings one to four are: 78 ± 5, 82 ± 5, 50 ± 5 and 58 ± 5 Bqm^{-3} respectively. The results are presented in Table 3.

Table 3. Average indoor radon concentration (Bqm^{-3}) in each building

Building number	Average indoor radon concentration (Bqm^{-3})
Building 1	78 ± 4
Building 2	82 ± 5
Building 3	50 ± 5
Building 4	58 ± 5

The average radon concentration is the highest in building two, followed by building one and four respectively and the lowest average is measured in building three. These overall values remained within the internationally acceptable concentration level of 150 Bqm^{-3}. The average radon concentration in building two (occupied) is slightly higher than that in building one (unoccupied). This further shows that the building material contribution might be significant.

The frequency distribution of indoor radon concentrations (Bqm^{-3}) measured in the four buildings is found to be skewed to the right (Fig. 3). The mean value is 75 Bqm^{-3} lower than the safe limit set by the EPA. The measured concentrations values ranged from about 3 Bqm^{-3} to 292 Bqm^{-3}, hence the distribution is right tailed.

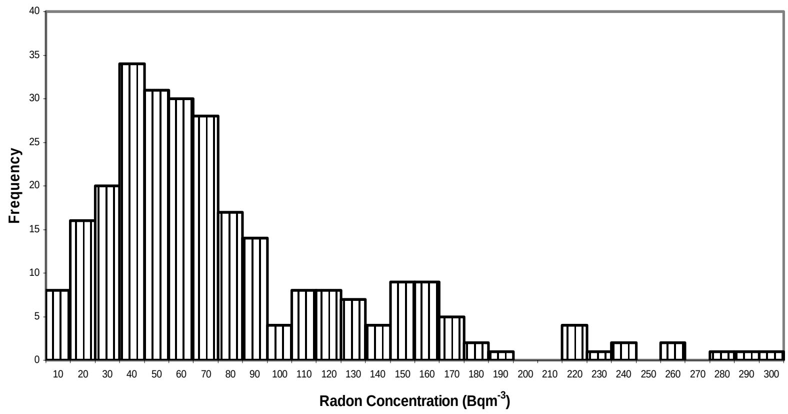

Fig. 3. Radon concentration distribution in Direyah site.

4. Discussion

Radon's behavior is far more affected by physical conditions (atmospheric pressure, temperature, wind velocity, rainfall, moisture, etc.) than by chemical processes (inert gas). However, these conditions were assumed constant in this study [6]. Different studies have suggested that the soil itself can give different radon exhalation. Consequently, elevated levels of radon resulting from soil gas are found mainly in basements and at ground floors [4, 5].

In this study, basements were not investigated. However, elevated levels of radon concentration were observed on the ground floor of all buildings but significantly in building three (Table 1), hence the soil and the building materials might be a major contributor. Indoor radon concentration also depends on building materials and on ventilation. It is reported that the use of latex and epoxy paints reduce radon emanation while the use of color painted wall papers indicate a high activity of radon and its daughters inside buildings [7].

Past studies to measure indoor radon concentration were carried out in Saudi Arabia. The radon concentration measured in houses in the Eastern Province is found to have a value between 25 and 58 Bqm^{-3}. The difference in these values was suggested to be due to ventilation where the lower concentration values were measured in rooms of higher ventilation [8]. In another study, it was found that the radon levels in buildings made of ready-made concrete (6 ± 2 Bqm^{-3}) was lower than that measured in buildings made of ordinary bricks (24 ± 2 Bqm^{-3}). The reason suggested, for the difference of the lower radon exhalations from the ready-made concrete, was because it has significantly less voids than ordinary bricks, hence the radon emanation from ready-made concrete is expected to be lower [9]. In our study, the average indoor radon levels are much higher than the above value measured for the same type of building with the lowest being that measured in building three (50 ± 5 Bqm^{-3}) (Table 3). These values may indicate a stronger contribution to the radon level from the paint used in these buildings than that from the concrete.

Other studies in Riyadh City and Al-Qasim Province were carried out as well. Measurement conditions such as weather, location, building materials and building's conditions in these studies were different [10, 11]. In the western part of Riyadh, the average radon concentrations in summer was 39 Bqm^{-3} and in winter was 14 Bqm^{-3} [10]. These values were found in the staff's accommodation of King Saud University and King Abdulaziz City for Science and Technology. They are relatively lower than the values obtained in this study in the same location (west), but in the student's residential buildings in Diriyah, at King Saud University.

In the present study, the average radon concentration measured in buildings one, two, three and four are 78 ± 5 Bqm^{-3}, 82 ± 5 Bqm^{-3}, 50 ± 5 Bqm^{-3}, 58 ±5 Bqm^{-3} respectively. High concentration values found in the occupied buildings indicate that poor ventilation in the unoccupied building is not a significant contributory factor to the radon levels. Hence, the high radon concentrations found, in all buildings and on different floors other than the ground floor, indicates that the contribution from the building materials is dominant. These buildings are made of ready-made concrete which has significantly smaller number of voids than the ordinary bricks, hence a lower radon emanation is expected [9]. Based on this idea, it might be suggested that the major sources of radon levels are the paint and the inner surface of the concrete block.

It is well known that relatively high radon concentrations are produced by soil having significant quantities of uranium and radium. The high values measured on the ground floor in all buildings may indicate that the soil contribution is also significant.

5. Conclusion

The study showed no height dependence of the radon concentration. In this study, the influence of ventilation is not significantly observed as expected in the unoccupied building. Therefore, ventilation is not the only contributory factor in radon variation. It has been concluded that the soil and building materials might be the major sources of radon gas in these buildings.

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قياسات مستويات وتوزيع الرادون الداخلي ا با ا أهولة والغ مأهولة سكن طلاب جامعة ا لك سعود مدينة الرياض, ا ملكة العربية السعودية

سفر بن ساعد الغامدي, وغادة بنت أ د خوة , وه زا ر ت بيك

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(قدم للنشر في ٢٤/١٠/١٤٢٦هـ؛ وقبل للنشر في ٢٩/١٢/١٤٢٦هـ)

ملخص البحث. قيس في هذا البحث تراكيز الرادون داخل أربع مباني سكنية في جامعة الملك سعود في الدرعية بمدينة الرياض في المملكة العربية السعودية. استخدم في هذا البحث طريقة الحجرة المغلقة باستخدام شرائح ($2x2\ cm^2$) من كاشف الـ CR-39 حيث وزعت على المباني وتركت مدد تراوحت بين ٣-٤ أشهر تقريبا. كان مجموع القياسات ٢٧٠ تعدى منها ٣٠ قياس مستوى الرادون المحدد (١٥٠ بيكريل/م٣) من قبل هيئة الحماية البيئية الأمريكية (EPA). وقد تراوح مدى تلك القياسات ما بين ١٥٦ و ٢٣٥ بيكريل/م٣، ١٥٦ و ٢٥٤ بيكريل/م٣، ١٥٠ و ٢٩٢ بيكريل/م٣، ١٥٢ و ٢٥٦ بيكريل/م٣ في البنايات الأولى والثانية والثالثة والرابعة على التوالي. وقد وجد كذلك أن معدل تركيز الرادون في كل غرفة يساوي ٥٨±٥، ٥٢±٥، ٨٢±٥، ٧٨±٥ بيكريل/م٣ في البنايات الأولى والثانية والثالثة والرابعة على التوالي. وقد درست عوامل الارتفاع والتهوية والتربة ومواد البناء ولم يوجد اعتماد كبير لتراكيز الرادون على الارتفاع، أما أثر التهوية فلم يتضح في هذه الدراسة كما كان متوقعا وبالتالي فإنه ليس العامل المساهم الوحيد في تغير مستويات الرادون. استنتج كذلك أن المصدران الرئيسيان للتراكيز العالية هما التربة ومواد البناء.

كلمات مفتاحية: الرادون، الرياض، مواد البناء.