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Evaluation of radioactive contamination of radon gas Inside and outside campus buildings

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Abstract:

Radon gas is a major indoor air pollutant, is found inside and outside buildings, and is the main cause of lung cancer. Therefore, determining its concentration levels and the dose resulting from inhalation of this gas is important for the public health of people inside buildings.

The aim of the research includes measuring radon gas concentrations in the air inside and outside the building of the College of Education at Iraqi University using a nuclear trace detector (CR-39). The detector (1x2) cm^2 was exposed for a full month during the winter because this period roughly represents the official working hours at the college. It is clear from the results of the study that the concentrations of radon gas inside buildings are higher than their concentrations outside buildings, and this increase in concentration is due to the fact that the walls of buildings are the main source of radon generation inside buildings, as it was shown that building materials have played an important role in increasing the concentrations of radon gas inside buildings in addition to the age of the buildings and the height above ground level.

The annual equivalent dose values for exposure to radioactive radon gas and its effect on the lungs ranged between 0.43 and 1.34 mSv/y and an average of 0.86 mSv/y. These values are the lowest allowed by ICRP (3-10) mSv/y.

Keywords: radioactive radon, indoor air pollutant, annual equivalent dose, nuclear trace detector, College of Education - Iraqi University.

تقييم التلوث الإشعاعي بغاز الرادون داخل وخارج مباني الحرم الجامعي

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مستخلص:

يُعد غاز الرادون من أهم ملوث الهواء الداخلي، ويتواجد داخل المباني وخارجها، وهو السبب الرئيسي لسرطان الرئة. لذا، يُعد تحديد مستويات تركيزه والجرعة الناتجة عن استنشاقه أمرًا بالغ الأهمية للصحة العامة للأشخاص داخل المباني.

يهدف البحث إلى قياس تراكيز غاز الرادون في الهواء داخل وخارج مبنى كلية التربية في الجامعة العراقية باستخدام كاشف الأثر النووي (CR-39). وقد تم تعريض الكاشف (1×2) سم2 لمدة شهر كامل خلال فصل الشتاء، حيث تُمثل هذه الفترة تقريبًا ساعات الدوام الرسمي في الكلية. ويتضح من نتائج الدراسة أن تراكيز غاز الرادون داخل المباني أعلى من تراكيزه خارجها، ويعود هذا الارتفاع في التركيز إلى أن جدران المباني هي المصدر الرئيسي لتوليد غاز الرادون داخلها، كما تبين أن لمواد البناء دورًا مهمًا في زيادة تراكيز غاز الرادون داخل المباني، بالإضافة إلى عمر المباني وارتفاعها عن مستوى سطح الأرض. تراوحت قيم الجرعة المكافئة السنوية للتعرض لغاز الرادون المشع وتأثيره على الرئتين بين 0.43 و1.34 ملي سيفرت/ سنة، بمتوسط 0.86 ملي سيفرت/ سنة. وتُعد هذه القيم أقل القيم المسموح بها من قِبل اللجنة الدولية للوقاية من الإشعاع (ICRP) (3-10) ملي سيفرت/ سنة.

1. Introduction

One of the major problems with pollution that we currently confront is radon pollution. It is regarded as a radioactive gas since it continuously emits radiation for the duration of its life. Due to its carcinogenic qualities, radon gas is one of the most prevalent indoor air pollutants, and as such, many researchers have recently expressed interest in learning more about its implications on human health. Exposure to radon gas can result in lung cancer, and estimates suggest that 3,000 fatalities are caused by it annually [1]. Radon gas is generated as a result of the spontaneous decomposition of the element radium, which is found in the Earth's crust. The spread of radon from the soil and building materials themselves and its mixing with room air depends mainly on the distribution of the element radium in the soil inside the house. Concentrations of radon and thoron decrease with decreasing distance from the surface due to gases escaping into the air and located above the soil. It was found that the rate of radon release varies with environmental conditions, the most important of which are humidity and pressure. This is due to the effect of humidity and pressure on the recoil of the radon atom resulting from the radioactive disintegration of radium.[2]

The difference in radon concentrations inside buildings depends mainly on the ventilation conditions and air exchange between the rooms of the house. Other human activities, such as opening windows and doors, all affect radon concentrations inside buildings.[3]

UNSCEAR estimates that radon, along with the daughter radionuclides resulting from its decay, contributes about three-quarters of the annual effective dose equivalents received by humans individually from natural terrestrial sources [1].

2. Study site

The College of Education is one of the formations of the Iraqi University affiliated with the Iraqi Ministry of Higher Education and Scientific Research. The college was established in 2008. The college is located 40 km north of Baghdad, 33°39′52″N 44°22′26″E. It includes eight departments (4 scientific departments and 4 humanitarian departments). The college building consists of 36 inter-departmental classrooms distributed over two floors built of cement bricks. It also contains laboratories for the Physics, Computer and Biology Departments, which are made of resistant wood caravans. It also contains a one-story building (containing 20 rooms) for the college's administrative divisions, made of cement brick.

3. Materials and Methods

Fifteen samples of the CR-39 nuclear trace detector were deployed inside and outside the halls and laboratories of the College of Education - Tarmiya - Iraqi University. The detector (1x2) cm^2 was exposed for a full month during the winter because this period roughly represents the official working hours at the college. Table (1) shows the locations of the samples taken.

Table (1) Locations for deploying the CR-39 detector inside the building of the College of Education - Iraqi University, sample code and description.

Code of model	Model name	Model description
G1	Classrooms1	ground floor (Building made of cement bricks)
G2	Classrooms2	ground floor (Building made of cement bricks)
G3	Head of the Physics Department	ground floor (Building made of cement bricks)
G4	Biology Department laboratory1	ground floor (Caravan made of sandwich panel material)
G5	Biology Department laboratory2	ground floor (Caravan made of sandwich panel material)
G6	Computer Science Department Laboratory	ground floor (Caravan made of sandwich panel material)
G7	Deanship of the College	ground floor (Building made of cement bricks)
G8	Physics Department Laboratory1	ground floor (Caravan made of resistant wood)
G9	Physics Department Laboratory2	ground floor (Caravan made of resistant wood)
F1	Classrooms4	first floor (Building made of cement bricks)
F2	Classrooms5	first floor (Building made of cement bricks)
F3	Classrooms6	first floor (Caravan made of sandwich panel material)
F4	Classrooms7	first floor (Caravan made of sandwich panel material)
F5	Chemistry Department Laboratory	first floor (Building made of cement bricks)
F6	Chemistry Department Laboratory 2	first floor (Building made of cement bricks)
K1	College garden	Outside the building
K2	College garden	Outside the building
K3	College garden	Outside the building

After the exposure process is carried out, trace reagents are taken to conduct a chemical skimming process using (NaOH) and its standard (6.25N), which is obtained by dissolving (250g) of (NaOH) in one liter of distilled water. The temperature was kept constant (1C°±) during the skimming process. Low temperatures lead to condensation, which affects the solution. Also, temperatures must be prevented from rising to high values because they cause damage to the detector [4].

To detect traces of alpha particles, an optical microscope (400 x) was used. The average number of traces (Nave) for the sample (x) is divided by the calculated unit area (A) to obtain the density of traces using the eq.1

$$(\rho_x) = \frac{N_{ave}}{A} \text{..} (1)$$

Where: ρ_x (*Track/mm*^{2}) density of traces, N_{ave} the rate of total effects within the area (A (mm^2)5]].

4. The Calculations

The technique of counting traces of alpha particles emitted from radon gas was used to calculate the concentrations of radon gas (inside - outside) of the College of Education-Tarmiyah building.

Through comparison with standard samples using Eq. 2, the concentrations of radioactive radon gas were calculated [1].

$$\frac{E_X}{\rho_X} = \frac{E_S}{\rho_S} \text{ ... ... } (2)$$

The CR-39 detector was calibrated by placing it inside a radon monitor box and hanging it inside a room with a size of (21 m^3). It was irradiated with a radium source (Ra-222), which emits radon gas with a radioactive efficacy of (5µCi). The detector was exposed for different periods of time, then the chemical skimming process was carried out at a temperature of (60°C), and the trace density of the standard samples was calculated.

The graphic relationship was drawn between the time rate of exposure to radon (Es) in units (Bq/m^3.day) and the density of the traces(ρ_s) in units (Track/mm^2), and the relationship was linear as in Figure (1).

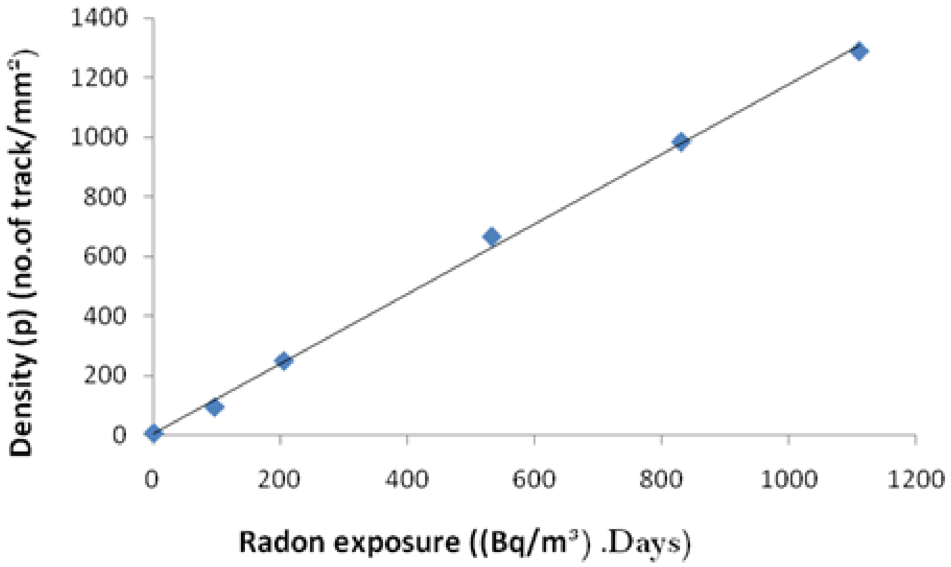

Fig. (1) The relationship between the time rate of exposure to radon and the density of the traces

From the slope of the graph, the radon concentrations for the unknown samples were calculated from the relationships (3) and (4)[1].

$$E_X = (E_s / \rho_s) \times \rho_x = \rho_x / Slope \quad .... \quad (3)$$

$$C_X = \frac{E_X}{t} \quad ....(4)$$

Where Ex: Exposure to radon in unknown samples, C_x: Radon concentration in unknown samples, t: The total time period of samples exposed to radon gas [1].

The amount of annual effective dose resulting from inhalation of radon and its products inside buildings can be calculated through the eq.5 [6].

$$AED({}^{mSv}/_{y}) = C_{Rn} x Q x F x D x 7860 \quad .... (5)$$

Where : C_{Rn} : Radon gas concentration (Bq/m^3) , Q : Occupancy factor in buildings = 0.8 , F: the equilibrium factor = 0.4 , D: the conversion factor = 9x10^{-6} ($mSv/h{\cdot}Bq{\cdot}m^{-3}$), 7860= Number of hours per year.

The annual lung dose equivalent resulting from radon inhalation can be calculated from Eq.6 [7].

$$AED_{Lung}(mSv/y) = AED \times W_R \times W_T \quad .... (6)$$

Where: W_R: Radioactive weight factor for alpha particles emitted by radon gas and its progeny =20, W_T: Lung tissue weight factor = 0.12.[8].

5. Results and Discussion

The results of radioactive radon gas concentrations inside the building of the College of Education - Iraqi University are listed in Table 2. It is noted from the results and Figure 2 that the concentrations of radon gas inside buildings are higher than the concentrations of radon gas outside the buildings. Building materials made of soil and rocks, such as (cement, bricks, etc.) are a source of radon emission inside buildings. These materials contain radioactive materials of natural origin, such as uranium and radium, and thus they generate radon. These materials also have sufficient permeability for the radon generated within them to be released into the external environment [9].

Table (2) The results of radioactive radon gas concentrations inside the building of the College of Education - Iraqi University

Code of model	density of traces (*Track/mm²*)	concentrations of radon gas (Bq/m³).
G1	4116.793 ± 4.6	50.42
G2	4463.8055 ± 3.2	54.67
G3	4515.32665 ± 1.9	55.301
G4	3012.885 ± 4.1	36.9
G5	2821.824 ± 3.9	34.56
G6	2695.2665 ± 3.7	33.01
G7	4222.1215 ± 2.8	51.71
G8	2452.766 ± 3.5	30.04
G9	2395.611 ± 4.77	29.34
F1	3448.0795 ± 8.1	42.23
F2	3319.0725 ± 6.5	40.65
F3	1893.4635 ± 9.8	23.19
F4	1932.6555 ±1.6	23.67
F5	4818.983 ± 3.8	59.02
F6	4799.387 ± 9.6	58.78
K1	1669.7425 ±1.6	20.45
K2	1598.707 ± 4.5	19.58
K3	1535.8365 ± 3.6	18.81

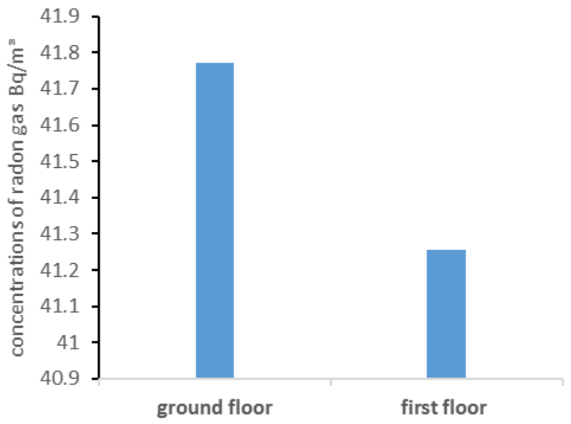

Fig. (2) A comparison between the results of radon gas concentrations inside and outside the building of the College of Education - Iraqi University.

As can be seen from Table 2 and Figure 3, the concentrations of radon gas in the upper floors are higher than the ground floors of the building. Radioactive radon gas is seven times heavier than air, and therefore its spread after its emission from the soil decreases with increasing altitude [10]. The highest concentration of radon gas is in the form (F5, F6) because chemistry laboratories contain a number of chemical materials that may contain radioactive elements.The choice of the type of building material played an important role in determining the levels of radioactive radon gas concentrations. It is noted in Table 2 that the level of radon gas concentration in rooms made of wood (G8,G9) is lower than in rooms made of cement brick. Wood contains the lowest concentration of radon gas [1].

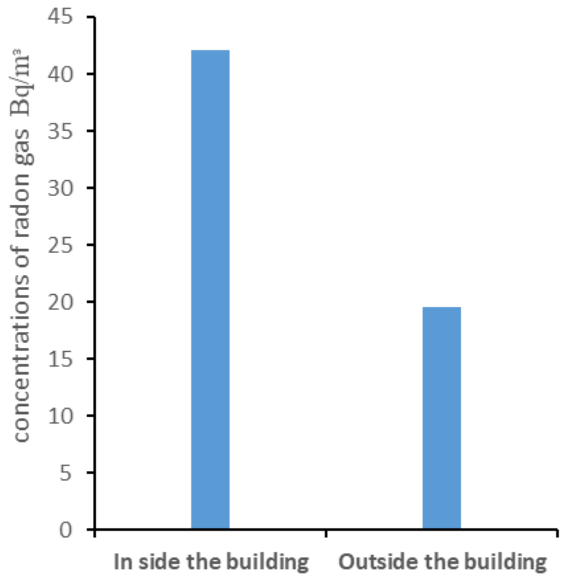

Fig. (3) A comparison between the levels of radon gas concentrations in the upper floors of the building and the lower floors.

Regarding the limits of exposure to radon, ICRP set the exposure level for residents (200 Bq/m³) and for workplaces (400 Bq/m³) [10, 11]. We conclude that the radon concentrations of the selected models are within internationally permissible limits.

The results of the annual equivalent dose of exposure to radioactive radon gas and its effect on the lungs are shown in Table 3 and Figure 4. The values ranged between (0.43-1.34) mSv/ y and an average of (0.86) mSv/ y and these values are the least permitted by ICRP (3-10) mSv/ y [12].

Table (3) the annual equivalent dose of exposure to radioactive radon gas and its effect on the lungs.

Code of model	AED (mSv/y)	AED_{Lung} (mSv/y)
G1	1.14	2.74
G2	1.24	2.97
G3	1.25	3.00
G4	0.84	2.00
G5	0.78	1.88
G6	0.75	1.79
G7	1.17	2.81
G8	0.68	1.63
G9	0.66	1.59
F1	0.96	2.29
F2	0.92	2.21
F3	0.52	1.26
F4	0.54	1.29
F5	1.34	3.21
F6	1.33	3.19
K1	0.46	1.11
K2	0.44	1.06
K3	0.43	1.02

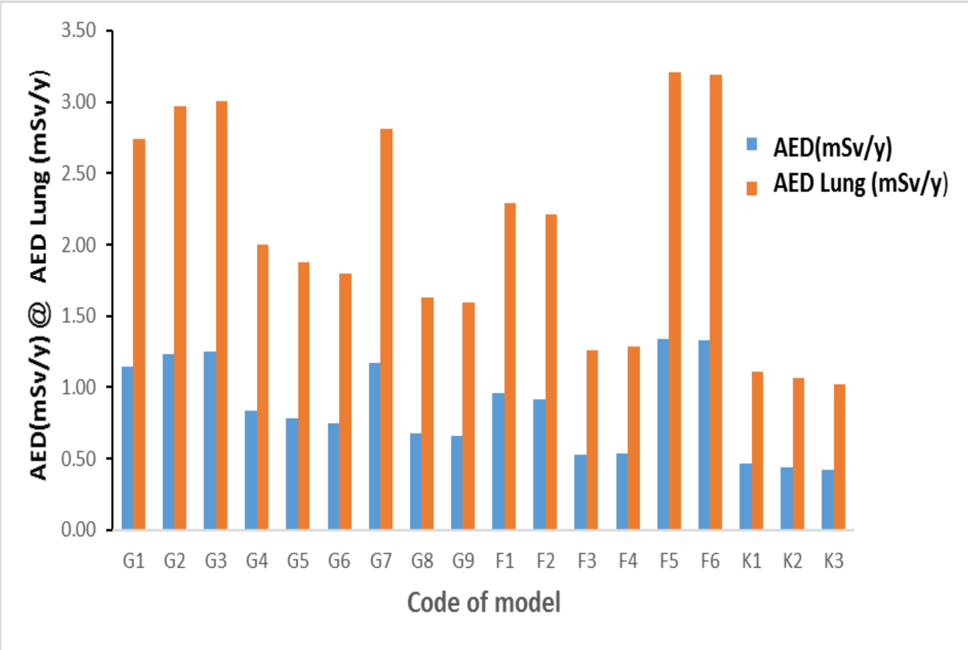

Fig.(4) the annual equivalent dose of exposure to radioactive radon gas and its effect on the lungs.

Conclusions

From the results obtained we conclude the following

1. Radon gas concentrations inside buildings are higher than radon gas concentrations outside buildings.

2. Radon gas concentrations in the upper floors are lower than the ground floors of the building.

3. The choice of the type of building materials and the duration of people's presence inside the buildings played a role in determining the concentrations of radon gas inside the buildings.

4. The results of radon gas concentrations inside the building of the College of Education - Iraqi University were within the internationally permitted limits.

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