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Evaluation of radioactive contamination of radon gas inside and outside the building of the College of Education - Iraqi University – Iraq

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Abstract

One major indoor air contaminant that can cause serious health problems, including lung cancer, is radon gas. We used CR-39 detectors to measure radon levels both inside and outside Iraqi University's College of Education. For the purpose of capturing peak exposure periods, measurements were conducted over a full winter month. The study revealed significantly higher radon concentrations inside the building compared to outdoor levels. It was determined that the main sources of indoor radon were building materials, especially those used in construction. The levels of radon were higher in older buildings and those located at lower ground levels. Radon exposure resulted in an annual equivalent dosage that averaged 0.86 mSv/y and varied from 0.43 to 1.34 mSv/y. These values demonstrate the possible health hazards connected to extended exposure, even though they are below the ICRP (3-10) mSv/y. recommended limits. This research contributes to the growing body of knowledge on indoor radon exposure in educational settings.The findings underscore the importance of regular radon monitoring and appropriate ventilation measures to protect the health of students and staff in educational institutions.

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

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].

Study site

The College of Education is one of the formations of the Iraqi University affiliated with the Iraqi Ministry

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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.

EXPERIMENTAL METHOD

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) cm² 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 (1ºC ±) during the skimming process. Low temperatures lead to condensation, which affects the solution. In addition, 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 (400x) 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 eq. 1.

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

Where ρ_x :(Track/mm2) density of traces, Nave the rate of total effects within the area (A (mm^2) [5].

The technique of counting traces of alpha particles emitted from radon gas was used to calculate the concentrations of radon gas (inside and 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].

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

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 m³. It was irradiated with a radium source (Ra-222), which emits radon gas with a radioactive efficacy of (5 µCi). The detector was exposed for different periods of time, and 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/m³.day) and the density of the traces (ρs) in units (Track/mm²), and the relationship was linear as in Figure (1).

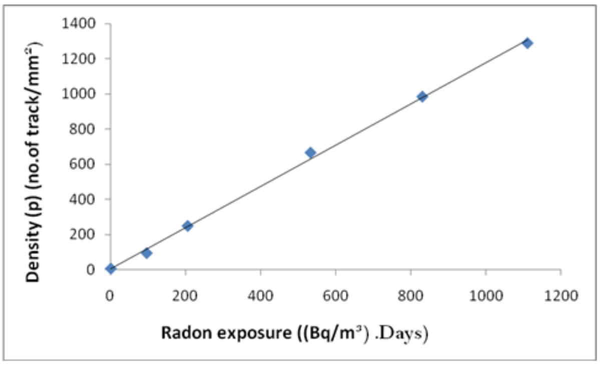

Fig. 1. The relationship between the time rate of exposure to radon and the density of the traces

The regression analysis's R-squared value of 0.9986 indicated a significant positive association between the density and the exposure time rate. The high R-squared value indicates that the model fits the data very well.

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, Cx: 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 the inhalation of radon and its products inside buildings can be calculated through eq. 5 [6].

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

Where: C_{Rn}: Radon gas concentration (Bq/m³),
Q: Occupancy factor in buildings = 0.8, F: the equilibrium factor = 0.4, D: the conversion factor, 7860 = number of hours per year.
The annual lung dose equivalent resulting from radon inhalation can be calculated from Eq. 6 [7].

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

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

RESULTS AND DISCUSSION

The study's findings, which are shown in Table 2 and Figure 2, show a pronounced difference in the levels of radon gas indoors and outdoors in the Iraqi University College of Education buildings. The results show that the radon levels inside the building were consistently higher than those outside. The main source of indoor radon emissions was found to be building materials, which are primarily made of soil and materials derived from rocks, such as bricks and cement. Radon production is facilitated by the naturally occurring radioactive elements uranium and radium found in these minerals. Additionally, these materials' intrinsic permeability permits the eventual release of radon gas into interior spaces [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

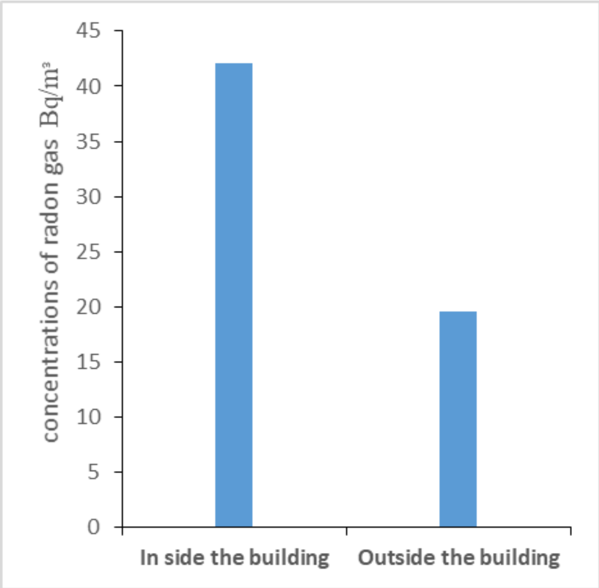

Fig. 2. A comparison between the results of radon gas concentrations inside and outside the building of the College of Education - Iraqi University.

Although it may seem counterintuitive that radon concentrations would be higher on higher floors given its density, our results, as shown in Table 2 and Figure 3, bear this out. This discrepancy merits further investigation, especially given the prevailing understanding that radon, which is seven times denser than air, should dissipate with increasing height [10]. The discrepancy suggests that there are underlying mechanisms that facilitate radon transport upward within the building structure, which may involve factors such as air pressure differences, ventilation systems, or building materials

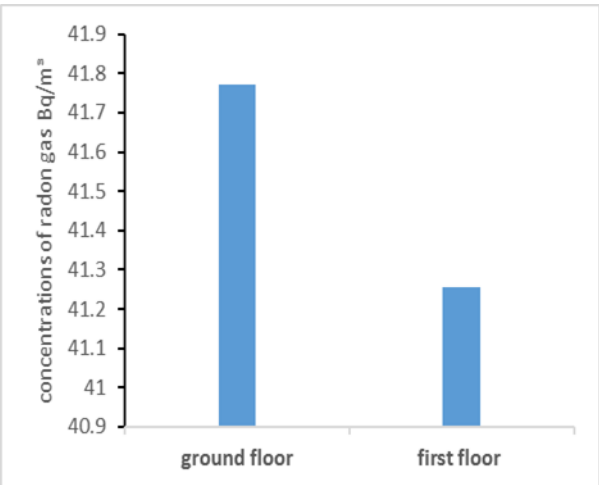

Fig. (3) A comparison between the levels of radon gas concentrations in the upper floors of the building and the lower floors

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]. 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	$AED\left({}^{mSv}/_{y}\right)$	$AED_{Lung}(mSv/y)$
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

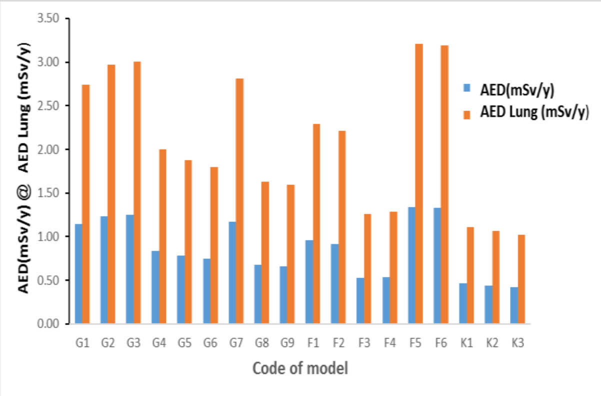

Fig. (4) the annual equivalent dose of exposure to radioactive radon gas and its effect on the lungs.

CONCLUSION

From the results obtained, we conclude the following:

Compared to outside structures, radon gas concentrations inside buildings are higher. Compared to the building's ground levels, the upper stories have lower amounts of radon gas. The amounts of radon gas within the structures were influenced by the type of building materials used and the length of time occupants spent within. The levels of radon gas within the College of Education building at Iraqi University were found to be within the internationally allowed limits. Although our findings highlight the importance of building materials in causing indoor radon exposure, more research is necessary to pinpoint the precise processes controlling radon transport in these buildings and to evaluate the possible health effects on inhabitants. Furthermore, investigating cutting-edge building materials and construction methods that reduce radon emissions may yield insightful information for creating successful mitigation plans.

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