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The Measurement of Radon Concentration in the Buildings of the College of Education, Al-Qadisiyah University, Iraq Using CR-39 Detector

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ABSTRACT

This research aims to evaluate the concentration of radon gas and the risks involved as a result of exposure to it. The nuclear track detector CR-39 was used to measure radon gas in the buildings of Al-Qadisiyah University's College of Education. For a month, 11 buildings in the college of Education at Al-Qadisiyah University were chosen to measure the radon concentration, with CR-39 reagent placed inside the sponge by two detectors for each building. The highest value of radon concentration was recorded in the CH1 model (270.5±32.9 Bq.m^{-3}), at the building of the Department of Chemistry, and the lowest value was recorded in the Li1 model (96.9±27.7 Bq.m^{-3}), which is the college library building with a concentration rate equal to (168). It is below the acceptable and recommended limit by the International Committee for Radiation Protection (200-300 Bq.m^{-3}).

INTRODUCTION

Radon gas belongs to the noble gases group in the periodic table, and it is seven and a half times heavier than air, therefore it is usually at the bottom, and it mixes virtually homogeneously with the indoor air of residential buildings, where radon gas concentrations are usually 2 to 10 times higher. As a result, radon exposure outside of residential areas is largely neglected (Wehr et al. 1984). The outer medium's two main sources of radon are soil and water, and it produces around 80% of the radon gas emitted to the outer medium from the earth's upper layer. As a result, radon in the soil is caused by the presence of radium 226 and uranium 238 whose concentrations vary depending on the geological nature of the rock, which is commonly concentrated in granitic and phosphate rocks (Matelsky 1968).

As it was found that this matter may occur in rocks with the content of (100 ppm) of uranium hundreds of meters underground, a statistical association between the incidence of earthquakes and the concentration of radon gas in the soil was found (Nougadère et al. 2014). In addition, building materials made of soil and rocks such as cement and bricks contain radioactive materials of natural origin such as uranium and radium and thus generate radon. These materials have sufficient permeability to release the radon generated within them to the outer medium (Abbady et al. 2007). It was found that the rate of radon emission changes with the environmental conditions, the most important of which are humidity and pressure. This is due to the effect of moisture and pressure on the reflux of the radon atom resulting from the radioactive decay of radium (Al-Saif 2009). There are many methods of measuring radon concentration in environmental models.

Solid-state nuclear trace reagents are one of these methods (Obed et al. 2011). Numerous studies have proven that the CR - 39 nuclear trace detector is the most sensitive and can record the effects resulting from protons, even those with low energy, neutrons, alpha minutes, heavy ions, etc. (Al-Khateeb et al. 2012), and it is one of the best detectors recorded for nuclear effects because of its advantage. It is characterized by high sensitivity to radiation, high optical transparency, high analytical power, as well as high uniformity and symmetry (Yamauchi et al. 2003).

MATERIALS AND METHODS

The study was conducted inside the buildings of the College of Education - Al-Qadisiyah University- Iraq. Due to the absence of a previous study to determine the concentrations of radon gas, the study included exposing trace reagents to 22 sites distributed where different rooms from each building were chosen based on where students, employees, and professors spend long periods, as well as places with limited or no ventilation because building materials are one of the most important factors affecting radon gas concentrations after soil. The reagents were distributed in many buildings, which are listed in (Fig .1 and Table 1).

The radioactive trace detectors CR-39 (Columbia Resin-39) with a thickness of 500μ (Tasl Company, UK) were carefully cut with a very sharp cutter with an approximate area of (1 1) cm^2, as shown Fig. 2. By fastening the detectors with a piece of sponge with a thickness of (1.5 cm) and suspending them in the places recorded, we were able to obtain the concentration of radon gas (Table (1), Fig. 3). The detectors were suspended at a height of 150 cm for a month, after that it was removed from the measurement site. We notice that when alpha particles resulting from the decomposition of radon gas fall on these plastic reagents, they create traces on them that are not visible to the naked eye, so these reagents are subjected to chemical treatment with NaOH.

A specific concentration (6.25 $mole.L^{-1}$) was heated at (600°C) for 6 h until alpha particle traces appeared and could be detected using optical microscopy with the proper magnification force (400X). The College of Education, Al-Qadisiyah University deployed 22 detectors in rooms, labs, and classrooms, with two rooms from each building, after which they were collected and prepared for the scraping process.

CALCULATION

After preparing the nuclear trace detectors (CR-39) for measurement, the average number of N_{avg} traces formed was calculated using an optical microscope to then calculate the density of the traces in units ($Track.mm^{-2}$) from the following equation (Aswood et al. 2017, Al-Hamzawi et al. 2019):

$$\rho = \frac{N_{avg}}{A} . \quad ...(1)$$

Where A is the area of a square and is equal to 0.07 mm^2.

Then the radon concentration was measured in the surrounding air unit ($Bq.m^{-3}$), where the radon concentration

Table 1: Coordinates the study area.

No.	Location	Sample	Coordinates X	Coordinates Y
1	Student Club for the College of Education	SC1	32°0'9.6228"	44°52'57.2988"
2	Student Club for the College of Education	SC2	32°0'9.2736"	44°52'57.6544"
3	Library	Li1	32°0'10.2744"	44°52'55.7796"
4	Library	Li2	32°0'10.6236"	44°52'56.4132"
5	Department of Psychological and Educational Sciences	PE1	32°0'11.4408"	44°52'54.2136"
6	Department of Psychological and Educational Sciences	PE2	32°0'12.4092"	44°52'51.7008"
7	Department of Physics	PH1	32°0'10.71"	44°52'53.8392"
8	Department of Physics	PH2	32°0'11.5956"	44°52'51.0996"
9	Department of Mathematics	Ma1	32°0'9.54"	44°52'53.6016"
10	Department of Mathematics	Ma2	32°0'10.3716"	44°52'50.5452"
11	Department of Arabic Language	AR1	32°0'8.1396"	44°52'50.8024"
12	Department of Arabic Language	AR2	32°0'8.7876"	44°52'49.7892"
13	Department of Biology	Bi1	32°0'6.2028"	44°52'48.6192"
14	Department of Biology	Bi2	32°0'5.5656"	44°52'47.3844"
15	Department of History	Hi1	32°0'4.1544"	44°52'47.856"
16	Department of History	Hi2	32°0'3.2076"	44°52'46.5312"
17	Deanship of the College of Education	DC1	32°0'1.3032"	44°52'51.7404"
18	Deanship of the College of Education	DC2	32°0'0.9396"	44°52'52.5072"
19	Department of English Language	EN1	32°0'2.8728"	44°52'56.2188"
20	Department of English Language	EN2	32°0'3.42"	44°52'54.9048"
21	Department of Chemistry	CH1	32°0'6.7536"	44°53'0.3264"
22	Department of Chemistry	CH2	32°0'6.282"	44°52'58.4364"

Fig. 1: Map of the selected buildings and the distribution of reagents in them.

in buildings was determined by the following equation (Obayes 2020, Oudah & Al-Hamzawi 2020):

$$C_{Rn}(\text{Bq}.m^{-3}) = \frac{1}{k}\left(\frac{\rho}{t}\right) \quad ...(2)$$

Where (k) represents a calibration factor of the detector and its value (0.169 Track.m^{-3} /Bq.day.mm^{-2}), (t) represents exposure time (30 d) .

RESULTS AND DISCUSSION

After distributing the nuclear detectors (CR-39) in the buildings of the College of Education, Al-Qadisiyah University- Iraq for 30 days, the detectors were collected and chemically skimmed off using the basal solution. The prepared (NaOH) at a caliber of (6.25) for 6 h and the density of traces were calculated using a light microscope, according to the concentration of radon (Rn), using equation (2), where the results of the radon gas concentrations and the intensity of the traces are shown in Table 2. Inside the buildings, the lowest value of radon concentration in the air was recorded for the Student Club, which is around (106±20.8) Bq.m^{-3} in the SC1 model, while the highest value was (119.5±21.6) Bq.m^{-3} in the SC2 model. As for the College Library, the lowest value for radon concentration was recorded in air and was (96.9±27.7) Bq.m^{-3} in the Li1 model, while the highest value was (120.3±14.6) Bq.m^{-3} in the Li2 model. The lowest value for radon concentration in the air for the Department of Psychological and Educational Sciences was (121.4±16.8) Bq.m^{-3} in the PE2 model, while the highest value was (140.3±17.9) Bq.m^{-3} in the model PE1. As for the Department of Physics, the lowest value of the radon concentration in the air was (264.9±32.0) Bq.m^{-3} in the PH2 model, while the highest value was 267.4±30.9) Bq.m^{-3} in the PH1 model. The lowest value for radon concentrations in the air for the Department of Mathematics was (136.9±27.9) Bq.m^{-3} in the Ma2 model, the highest value was (144.6±27.6) Bq.m^{-3} in the Ma1 model. The lowest value for radon concentration in the air for the Department of Arabic Language was (101.4±23.9) Bq.m^{-3} in the AR2 model and the highest value was (111.0±15.3) Bq.m^{-3} in the AR1 model. The lowest value for radon concentration in the air for the Department of Biology was (248.3±33.9) Bq.m^{-3} in the Bi2 model. The highest value was (259.2±31.1) Bq.m^{-3} in the Bi1 model. The lowest value for the Department of History was (186.8±18.8) Bq.m^{-3} in the Hi1 model. The highest value was (193.0±23.3)

Fig. 2: CR-39 detector.

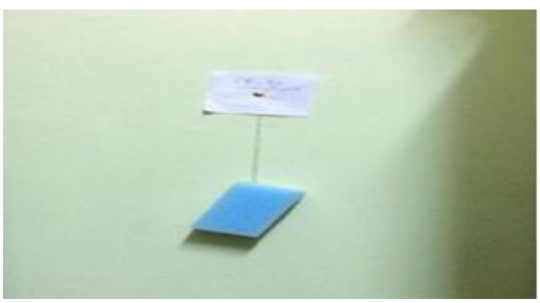

Fig. 3: Method of deployment of detectors.

Table 2: The intensity of effects and the concentration of radon using the CR-39 detector in the buildings of the College of Education, Al-Qadisiyah University.

No.	Sample	Track number [Track.mm^{-2}]	C_{Rn} [Bq.m^{-3}]
1	SC1	540.0	106.5± 20.8
2	SC2	605.7	119.5±21.6
3	Li1	491.4	96.9±27.7
4	Li2	610.0	120.3±14.6
5	PE1	711.4	140.3±17.9
6	PE2	615.7	121.4±16.8
7	PH1	1355.7	267.4±30.9
8	PH2	1342.9	264.9±32.0
9	Ma1	732.9	144.6±27.6
10	Ma2	694.3	136.9±27.9
11	AR1	562.9	111.0± 15.3
12	AR2	514.3	101.4±23.9
13	Bi1	1314.3	259.2±31.1
14	Bi2	1258.6	248.3±33.9
15	Hi1	947.1	186.8±18.8
16	Hi2	978.6	193.0±23.3
17	DC1	697.1	137.5±23.0
18	DC2	647.1	127.6±22.6
19	EN1	804.3	158.6±25.4
20	EN2	847.1	167.1±17.6
21	CH1	1371.4	270.5±32.9
22	CH2	1125.7	222.0±35.5

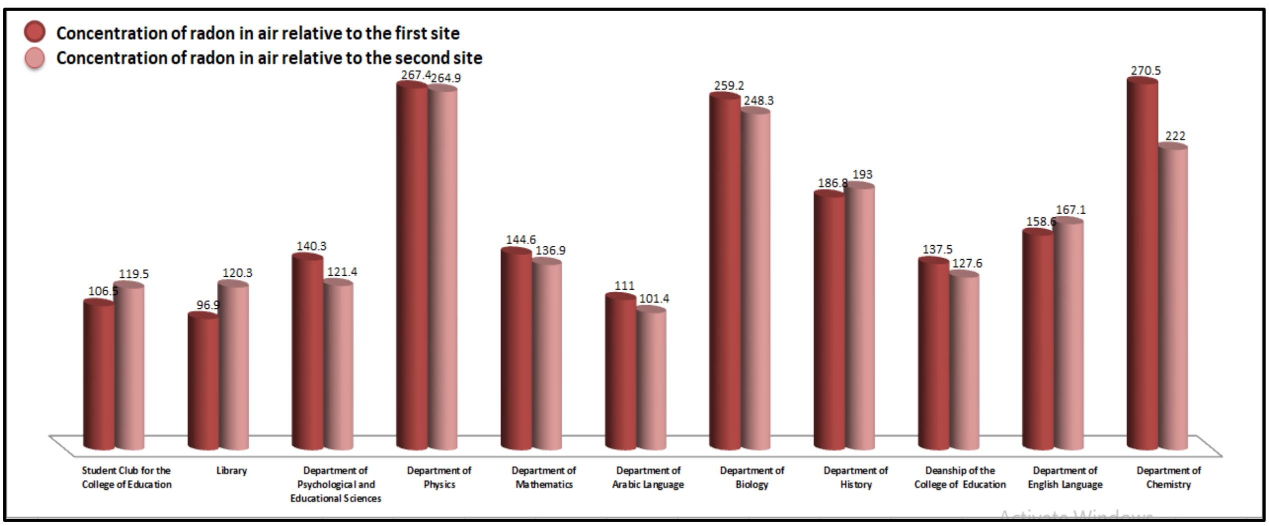

Fig. 4: Radon concentration levels inside the buildings of the College of Education, University of Al-Qadisiyah using CR-39 detector.

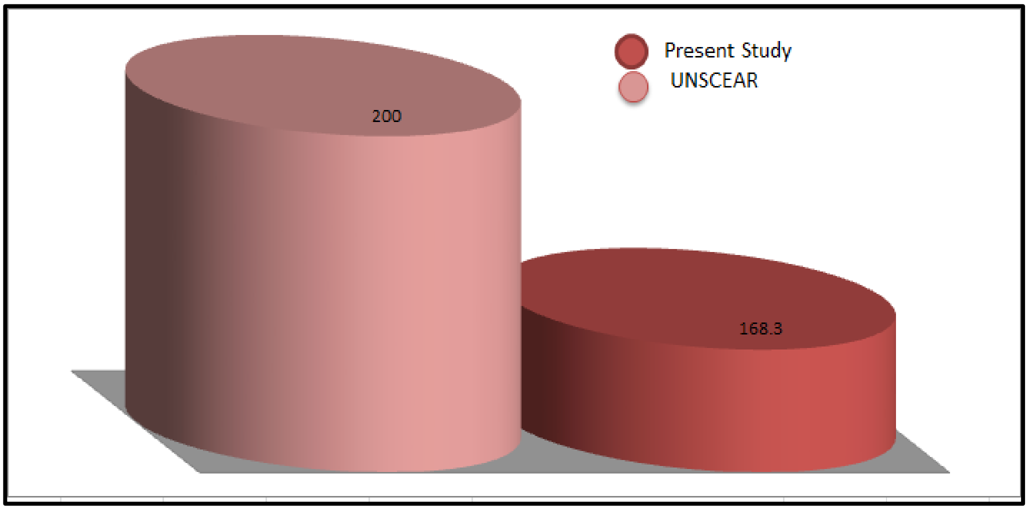

Fig. 5: Comparison of the radon concentration value of the current study with the value recommended by the International Committee for Radiation Protection.

$Bq.m^{-3}$ in the Hi2 model. The lowest value for the building of the College of Education was (127.6±22.6) $Bq.m^{-3}$in the model DC2, while the highest value was (137.5±23.0) $Bq.m^{-3}$ in the model DC1. The lowest value for the Department of English Language was (158.6 ± 25.4) $Bq.m^{-3}$ in the model EN1 and the highest value (167.1±17.6) $Bq.m^{-3}$ in the model EN2. The lowest value for radon concentration in the air for the Department of Chemistry was (222.0±35.5) $Bq.m^{-3}$ in the model CH2 and the highest value was (270.5±32.9) $Bq.m^{-3}$ in the model CH1. Fig. 4 shows the highest and lowest radon concentration value for the same site, and Fig. 5 shows a comparison between the current study and the internationally accepted limit for radon concentration by the International Committee for Radiation Protection.

CONCLUSION

Through the results obtained for the radon concentrations recorded using the solid-state nuclear trace detector CR-39, we conclude that these results were within the acceptable level or less than the acceptable level recorded by (ICRP 2020) which is equal to (200-300) $Bq.m^{-3}$ (UNSCEAR 1986). Except for the Departments of Physics, Chemistry, and Life Sciences, all of the results are within the permitted range, albeit at high concentrations. As a result, we conclude that the sites that recorded results near to permissible values, owing to the fact that they are buildings with poor ventilation or the nature of the building materials used in them. Covering the walls with materials that can limit the spread of radon gas, as well as constructing a ventilation system to increase ventilation.

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