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Determining the Level of Radon Gas in the Classrooms of Diyala Governorate Schools

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Abstract. In this research, radon gas concentration was measured for a number of schools located in Diyala Governorate, Iraq, using the CR-39 detector, which is from Solid State Nuclear Track Detectors (SSNTDs). In a number of classrooms, the detector was set at a distance of 160 cm from the earth's surface, for a period of time, these detectors were exposed (30 days). Where the results showed that the concentration of radon gas ranged from the lowest value which is equal to(8.528)Bq/m^3 for the sample (D5) in (Alshumue) school to the greatest value, which was (50.395)Bq/m^3 for the sample (A4) that was in (Alandalusia) school. , where the average radon gas concentration was equal to (25.257)Bq/m^3, and the lung cancer cases per year per 10^6 person (CPPP) was also calculated, Where the results ranged from (3.873 to 22.885), with a rate equal to (11.470). After comparing the results obtained with the global results, it was found that they are much less than the permissible limits, which were recorded through ICPR (200-300) Bq/m^3.

Keyword: radon concentration, CR-39 detector, effective dose, Diyala.

INTRODUCTION

Friedrich Ernst Dorn, a scientist, discovered radon in 1900. The inert gas radon has the attributes of being odorless, colorless, and tasteless. The atomic radius is (1.3×10^{-10}m), it weighs approximately eight times as much as air. Because it is a monatomic gas (not a molecule), it can easily permeate leather, paper, most paints, low-density plastic, and constructing concrete block, as well as materials such as gypsum board, wood panel, and most insulations, and mortar. According to this emitter, radon has a strongly neutron-rich nucleus, making it a radioactive element having a 3.8-day half-life [1]. Radon is a naturally occurring radioactive source, and (Rn-222) is one of the isotopes of uranium that has an impact on the environment (U-238). Radium and uranium are naturally occurring elements in rocks and soils. Because radon seeps through the soil, it is one of the most common indoor sources. Following testing, another supply including well water and building materials was given the same weight[2]. The most important and variable source of public radiation exposure is radon, the yearly effective dose of radon and its offspring inhaled through the air is estimated to be approximately (55 percent) of the normal dosage rate of public exposure, lung cancer can be caused by long-term exposure to high amounts of radon. [3]. Natural radioactive Radon is made up of three unstable isotopes from each of the three natural radioactive disintegration series (Uranium, Thorium and Actinium)[4]. To differentiate it from the other two natural isotopes, Thoron (Rn-220) and Actinon (Rn-222), the (Rn-222) isotope is given the name Radon (Rn-219), which come from the Thorium and Actinium families, respectively. The gas Radon, Rn222, has a half-life of 3.82 days; the gas Thoron, (Rn-220), has a half-life of 55.6 seconds; and the gas Actinon, (Rn-219), has a half-life of 3.96 seconds. Owens and Rutherford, English scientists, discovered the gas Thoron, Radon-220, in 1899., who noticed that some of the radioactivity of Thorium compounds could be blow away. The gas Actinon, Radon-219 was found in (1904), independently by Friedrich Ander-Louis Debiernce, who will be linked to Actinium [4].

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Study Area

The research was carried out at a number of schools in Diyala Governorate, which is located in the center part of eastern Iraq between latitudes (33.3 - 35.6) in the north and longitudes (45.22 - 46.56) in the east, and covers an area of (17685) km^2, or about 4.4 percent of Iraq's total area[5].

FIGURE 1. Map of Diyala governorate city[6]

TABLE 1. School names, coordinates and symbols

NO.	Code Sample	Coordinates GPS	School Name
1.	A4	33°49'15.53"N 44°24'33.39"E	Alandalusia
2.	A5		
3.	B5	33°49'52.12"N 44°24'55.22"E	Bint Zuin
4.	B6		
5.	C3	33°51'07.02"N44°28'51.60"E	Alshahid Alsayid Jawad Aleadhari
6.	C4		
7.	D5	33°51'29.31"N44°31'02.54"E	Alshumue
8.	D6		
9.	E5	33°51'19.70"N44°31'07.43"E	Alsamwl
10.	E6		
11.	F4	33°50'58.08"N44°31'29.14"E	Albalagha
12.	F5		
13.	G5	33°50'56.56"N 44°30'58.73"E	Eishtar
14.	G6		

NO.	Code Sample	Coordinates GPS	School Name
15.	H3	33°50'51.47"N44°31'16.32"E	Mustafa Jawad
16.	H4		
17.	I5	33°47'05.55"N44°30'08.96"E	Habhib
18.	I6		
19.	J5	33°44'06.43"N44°28'45.46"E	Alshahid Muhamad Qasim Aleabaadii
20.	J6		
21.	K4	33°41'22.95"N 44°25'24.87"E	Ibn Hazm
22.	K5		
23.	L5	33°56'08.64"N44°27'42.94"E	Bashayir Alkhayr
24.	L6		
25.	M3	33°56'09.94"N44°27'43.29"E	Alfalah
26.	M4		

MATERIALS AND METHODS

Collect and Prepared Samples

In this research, the difference of radon gas concentration in each school for a number of schools in Diyala Governorate was studied using the nuclear track detector CR-39. This detector is available in the market and comes in plates of different sizes. In our study, the plates were cut into small chips with an area of (1 cm x 1 cm). This detector was placed inside a special cloth bag as shown in figure (3) this bag was used because the ability of alpha particles to penetrate materials is weak, and hung in the study sites for a period of 30 days. The height of the detector was 160 cm above ground level (which is the average height of the students) so that the detector is placed with the level of inhalation. After the exposure process, the reagents were etched using a special chemical solution, which is a solution of sodium hydroxide (NaOH).

Chemical Etching and Microscopic Scanning

The solution of sodium hydroxide (NaOH) which is considered one of the strong alkaline bases that has the ability to interact with plastic nuclear tracks detector, as the skimming solution spreads in the area of radiation damage and attacks the area affected by radiation more quickly than the intact area, meaning that the intact areas interact with the skimming solution at a lower speed than the damaged areas, so this method was used to enlarge the path of the hidden effect, so its diameter increases and its depth expands as the scraping time increases. This solution is prepared with a caliber of 6.25 N, we get it by dissolving 250 g of sodium hydroxide granules in one liter of distilled water. This process is called chemical etching[7].

The detectors are put in a water bath at 60°C for 4 hours, then the detector is carefully washed with purified water (to avoid the deposition of impurities on the reagent if normal water is used), so that the stage of counting the tracks alpha particles, which are shown in figure (2) by light microscopy comes for the purpose of calculating the density of traces through the following equation[8], [9]:

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

Where:

ρ_x : Track density in unit (Tracks/mm^2).

N_{av} : The average number of tracks.

A : is area of field view, using a special lens divided into several squares, through which the area of the square is calculated, (which is equal 0.0676 mm^2).

FIGURE 2. Tracks of alpha particles emitted by (Rn-222) seen in (CR-39) detector.

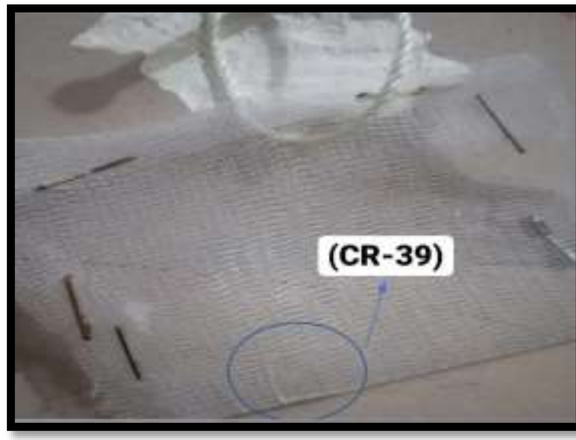

FIGURE 3. How to hang the detector

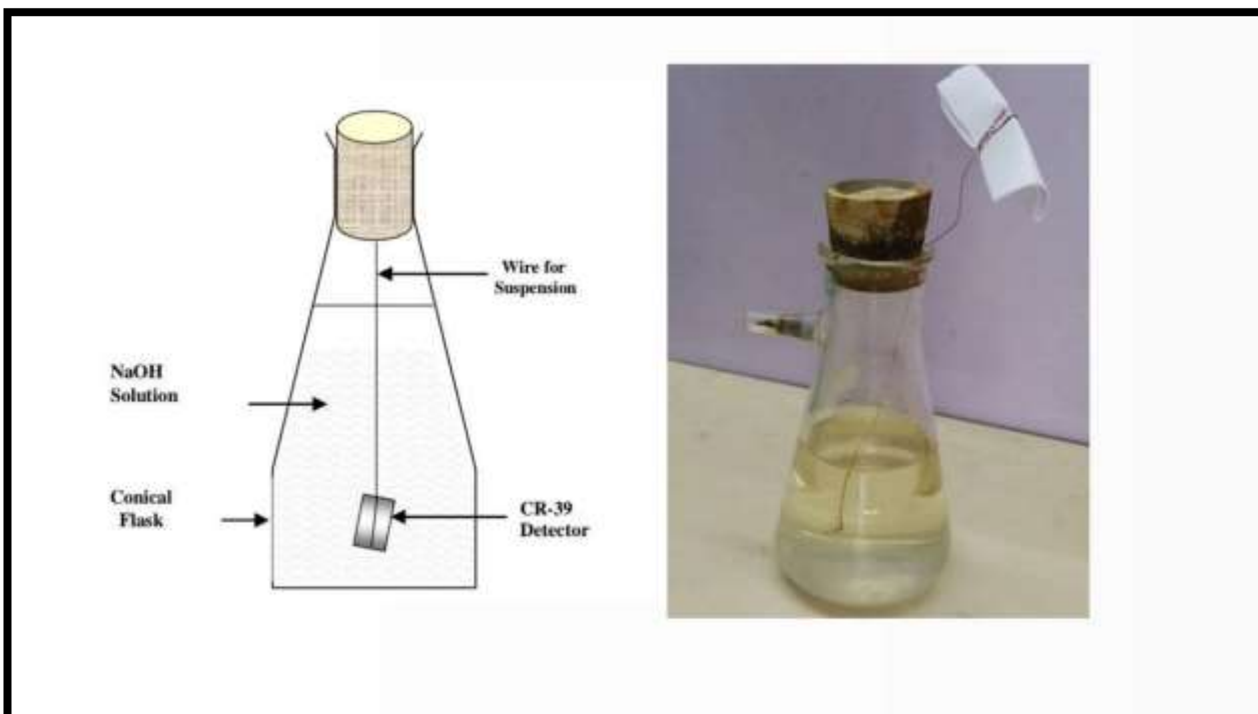

FIGURE 4. Chemical etching of CR-39 detector.

FIGURE 5. Water Path.

Measurement of Radon Concentrations

The radon concentrations in the air of some Diyala schools are measured in units of (Bq / m^3), which is compared to the highest regulatory reference limits. The following formulae are used to compute radon concentration[10][11].:

$C_{Rn} = \frac{\rho_x}{k*t}$ ………… (2)

Where:

C_{Rn} : The radon concentrations in unit of (Bq/m^3), {where Bq is unit of activity and the Activity is the number of disintegration per second, its (SI) unit for measurement is Becquerel (Bq) ,where

1 Curie (Ci) = 3.7×10^{10} Bq (dis/s)}[12].

ρ_x : The density of traces for the unknown samples.

t: time Exposure which equal to(30day).

k : the calibration factor which is equal to (0.2544).

Determination of Some Radon Parameters in Dwellings

1- The annual effective dose (AED) that gains by the residents due to their exposure to radiate radon. It was calculated in the unit of (mSv/y) as given in the UNSCEAR report by the following relation[13] :
AED (m Sv/y) = $T \times H \times C_{Rn} \times F \times D$ ………..(3)
Where :
F : It is equivalent to the equilibrium factor (0.4).

H : is the factor of occupancy (0.8).
C_{Rn}: Radon Concentrations in unit of (Bq/m^3).
T : the number of hours in a year in hours , T=8760 h/y
D : the conversion factor for doses, which is equal to [9×10^{-6} (m Sv) / ($Bq.h.m^{-3}$].

2- The lung cancer cases per year per 10^6 person:
Lung cancer risk is the increasing rate of cancer exposure per million people per year due to exposure to radioactive radon gas or its products. The risk factor is known as the cases of lung cancer incidence as a consequence of exposure to indoor radon for a work level per month (WLM)[14]. the lung cancer cases per year per 10^6 person (CPPP) is calculate by the following relation [15].

$$(CPPP) = AED \times (18\times10^{-6}\ mSv^{-1}.\ y) \qquad \ldots\ldots\ldots\ldots..(4)$$

3- The Potential Alpha Energy Concentration :
Potential alpha energy concentration (PAEC) is explained as the total alpha energy sent during the decay of radon to ^{210}Pb per unit volume of air[16]. It is necessary to assess the lung dose from the inhalation of radon or thoron products. The (PAEC) differ with time, it relies on lifestyle and other reasons related to increasing radon concentration in homes (ICRP1987) [17]. The Potential Alpha Energy Concentration (PAEC) is calculated by the following relation [18] :

$$PAEC\ (WL) = F \times C_{Rn} / 3700 \qquad \ldots\ldots\ldots\ldots..(5)$$

4- Exposure to radon progeny (E_P):
The parallel equilibrium equivalent concentration of radon that the person is exposed over a given period time (one year), so it is sometimes called the annual effective dose equivalent. often expressed in the working level month (WLM), where 1 WL is knower as a concentration of potential alpha energy of 13 x 10^{10} MeV/ m^3[17]. Exposure to radon progeny is intended using the equation [13][15] :

$$E_P\ (WLMY^{-1}) = 8760 \times n\times F \times C_{Rn}/3700 \times 170 \quad \ldots\ldots\ldots\ldots\ldots(6)$$

(8760): is the number of hours per year.
(170): is the amount of working hours in a month.
n : the percentage of time spent indoors that is equivalent to (0.8).
F : It is equivalent to the equilibrium factor. (0.4).

RESULTS AND DISCUSSION

In this research, the radon gas concentration was calculated in thirteen schools in Diyala Governorate, and the gas concentration was calculated in two classrooms from each school using the nuclear trace detector (CR-39), the concentration of radon gas was calculated using equation (2) and through the results that appear in Table No. (2)where the highest concentration of gas was found for sample (A4), which was In (Alandalusia) school, which is equal to (50.395 Bq/m^3), and the lowest value recorded for the sample (D5), which was in (Alshumue) school, which is equal to (8.528 Bq/m^3) as shown in figure (6).The mean concentration was(25.257 Bq/m^3). From the same table No. (2) we notice a discrepancy in the values of radon gas concentration, and this is due to many reasons, but the main reason is the ventilation factor, in addition to the behavior of students inside the classroom, as well as the building materials used in each school and the school site and its height above the level of the surrounding buildings. We note from Table (2) that the effective annual dose values ranged from (0.215 mSv/y) for sample (D5) which was in (Alshumue) school to (1.271 mSv/y) for sample (A4) which was in (Alandalusia) school, With a dose rate equal to (0.637 mSv /y) .In addition, the lung cancer cases per year per million-person (CPPP) were calculated using equation No. (4) and as shown in Table (2), where the values ranged from the lowest value, which equals (3.873) for the sample (D5) in (Alshumue) school to the largest value, which is equal to (22.885) for sample (A4) in (Alandalusia) school as shown in figure (7), where the average values equal to (11.470). The Potential Alpha Energy Concentration (PAEC) was also calculated, and the results ranged from the lowest value (0.922 mWL) to the largest value (5.448 mWL) with a rate equal to (2.731 mWL). Exposure to radon progeny (E_P) was also calculated, and the results showed that the lowest value was in the sample (D5), which was equal to (38.008 $mWLMY^{-1}$) in (Alshumue) school, and the largest recorded value was (224.591 $mWLMY^{-1}$) for the sample (A4) in (Andalusia) school, where the mean values were (112.561 $mWLMY^{-1}$). After studying the results of the radon gas concentration, it was found that All of the values are lower than the permissible limits recommended by the International Commission on Radiological Protection (ICRP) which was (200-300 Bq/m^3)[19]. Figure (8) depicts the linear association between radon gas levels and lung cancer cases, as we note that the increase in the concentration of radon gas leads to an increase in the number of cases of lung cancer. From this point of view, the risks of radon gas begin and interest in studying it in order to preserve the health and public safety of society and people.

TABLE 2. (N_{av}) ,(ρ) ,(C_{Rn}), (AED) , (CPPP) , (PAEC) and (E_p) to Radon Progeny in Different schools

Code	N_{av}	ρ (No. of tracks/mm^2)	C_{Rn} (Bq/m^3)	AED (mSv/y)	CPPP× 10^{-6}	PAEC (mWL)	E_P ($mWLMY^{-1}$)
A4	26.000	384.615	50.395	1.271	22.885	5.448	224.591
A5	8.800	130.178	17.057	0.430	7.746	1.844	76.015
B5	12.000	177.515	23.259	0.587	10.562	2.515	103.657
B6	8.600	127.219	16.669	0.421	7.570	1.802	74.288
C3	14.600	215.976	28.299	0.714	12.851	3.059	126.116
C4	16.600	245.562	32.175	0.812	14.611	3.478	143.393
D5	4.400	65.089	8.528	0.215	3.873	0.922	38.008
D6	15.000	221.893	29.074	0.734	13.203	3.143	129.572
E5	12.600	186.391	24.422	0.616	11.091	2.640	108.840
E6	18.200	269.231	35.277	0.890	16.020	3.814	157.213
F4	18.400	272.189	35.664	0.900	16.196	3.856	158.941
F5	16.400	242.604	31.788	0.802	14.435	3.437	141.665
G5	8.200	121.302	15.894	0.401	7.218	1.718	70.832
G6	17.200	254.438	33.338	0.841	15.140	3.604	148.575
H3	6.800	100.592	13.180	0.333	5.985	1.425	58.739
H4	12.400	183.432	24.035	0.606	10.915	2.598	107.112
I5	13.000	192.308	25.198	0.636	11.443	2.724	112.295
I6	16.400	242.604	31.788	0.802	14.435	3.437	141.665
J5	23.000	340.237	44.580	1.125	20.245	4.819	198.676
J6	13.800	204.142	26.748	0.675	12.147	2.892	119.206
K4	13.600	201.183	26.361	0.665	11.971	2.850	117.478
K5	6.800	100.592	13.180	0.333	5.985	1.425	58.739
L5	7.600	112.426	14.731	0.372	6.690	1.593	65.650
L6	9.400	139.053	18.220	0.460	8.274	1.970	81.198
M3	5.600	82.840	10.854	0.274	4.929	1.173	48.373
M4	13.400	198.225	25.973	0.655	11.795	2.808	115.751
AV	13.031	192.763	25.257	0.637	11.470	2.731	112.561
MAX	26.000	384.615	50.395	1.271	22.885	5.448	224.591
MIN	4.400	65.089	8.528	0.215	3.873	0.922	38.008

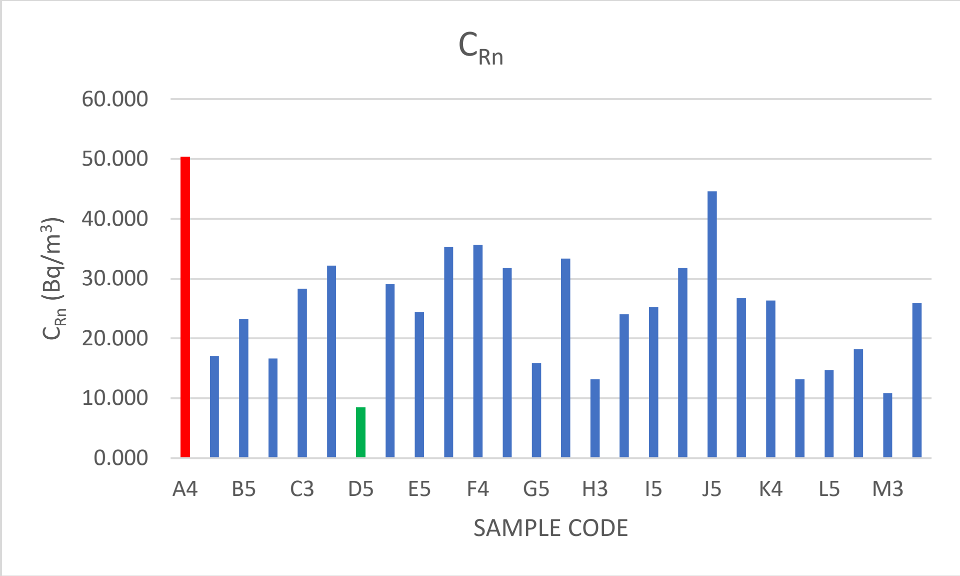

FIGURE 6. Levels concentration of radon in the school classroom using CR-39 detector.

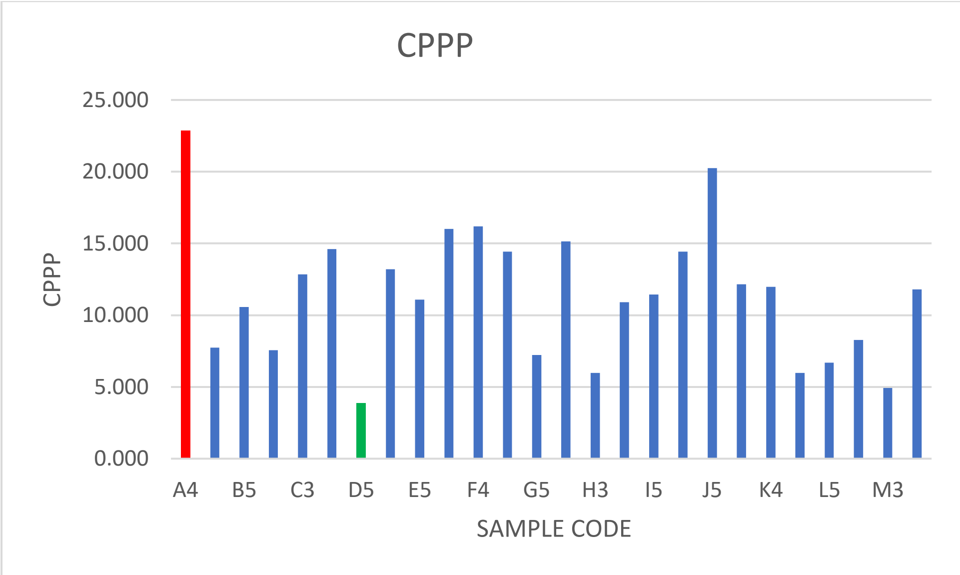

FIGURE 7. The lung cancer per10^6 people (CPPP) in the school classroom

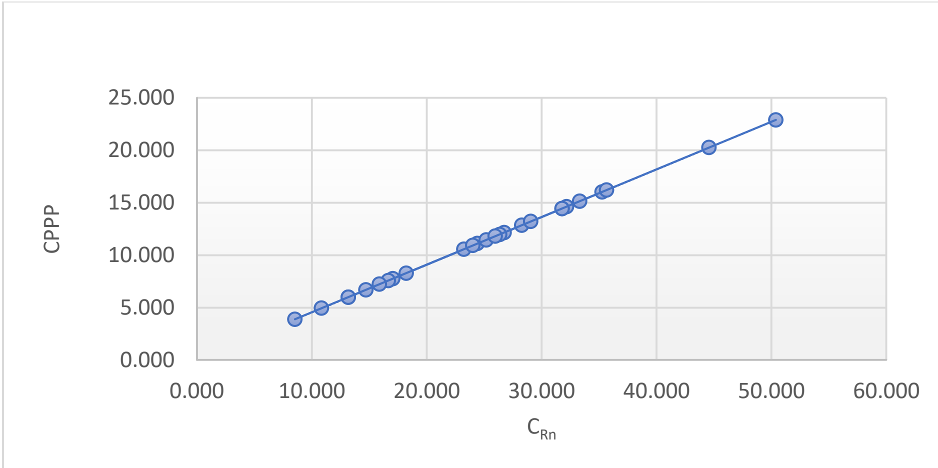

FIGURE 8. For the school, the relationship between radon concentrations and lung cancer per 10^6 persons

CONCLUSION

Through the results of the current work, which included calculating the concentration of radon gas in schools in Diyala Governorate, we conclude that the results were less than the upper limits recommended by the International Commission of Radiation Protection (ICRP) agency, which was (200-300 Bq/m^3). As the schools that were studied were working in the morning and evening shifts (due to the lack of school buildings), so these schools were open throughout the day and this helped to increase ventilation and reduce the concentration of indoor radon gas in these buildings.

RECOMMENDATIONS

Studies have proven that the concentration of radon gas decreases as the ventilation process increases in the building, so we recommend that architects and those in charge when building government buildings, including schools, take into consideration the risks of radon and work to increase ventilation in the building, and since soil and building materials are sources of radon, so we recommend Schools restoration from time to time, especially painting the walls, because this prevents radon gas from leaking through the cracks in the walls, as well as the floor covering that contains cracks , to work on reducing internal radon gas and reducing its future risks to make our environment safe and clean from radon pollution.

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