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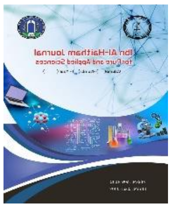

Measuring the Concentration of Radon Gas in Book Stores in Primary Schools in Diyala Governorate

Mothana Jassem Kadhim
Department of Physics, College of Education for Pure Science \ Ibn Al-Haitham, University of Baghdad, Baghdad, Iraq.
Mothana.Jassem1204a@ihcoedu.uobaghdad.edu.iq

Sameera Ahmed Ebrahiem
Department of Physics, College of Education for Pure Science \ Ibn Al-Haitham, University of Baghdad, Baghdad, Iraq.
sameera.a.i@ihcoedu.uobaghdad.edu.iq

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Abstract

In this research, the concentration of radon gas was calculated in the book store rooms of schools in Diyala Governorate, it was calculated by Solid State Nuclear Track Detectors (SSNTDS) when the detector (CR-39) was used, the detector was placed and suspended at a distance of 160 cm from the surface of the earth, and the detector was exposed for 30 days to record alpha tracks. The results of radon concentration showed that the highest concentration percentage was found in (Eishtar) school, which was equal to (84.896) Bq/m^3, while the lowest value was recorded in (Habhib) school, which was equal to (11.242) Bq/m^3, where the concentration rate was equal to (28.158) Bq/m^3. When we compared our results with the global results, we found that the calculated radon concentrations are much less than the internationally permissible limits recorded by (ICRP), which were in the range of (200-300) Bq/m^3.

Keywords: Radon, Lung cancer per million people, solid state nuclear track detectors (SSNTDS) (CR-39), Diyala.

1. Introduction

The fifth radioactive element, radon, was discovered in 1900 by German physicist Friedrich Ernst Dron, who gave it the name Niton. Since then, it's been known as Radon (1923). In the periodic table, it has an atomic number of (Z=86)and a mass number of (A=222)[1]. Radon is a radioactive gas produced by the disintegration of Uranium-235 and 238 or Thorium-232. Because Thorium and Uranium are both causes of Radon and are frequent naturally occurring elements found in low concentrations in rock and soil, The three primary series of gaseous Radon, headed by U-235, U-238, and Th-232, all release radioactive alpha particles[2] . The radioactive decay of Radium produces Radon (Rn-222), a chemical element with an atomic number of 86, and a heavy radioactive gas of the Noble Gas Group on the periodic chart (Ra-226). It's colorless, odorless, and tasteless, with a density of (9.73g/liter) at (1 atm/0°C), and it may permeate through soil and rocks, with detection levels of 10 to 20 atoms per million atoms. It is (7.5) times the weight of air and over 100 times the weight of hydrogen. At (-61.8°C), the gas liquefies and at (-71°C), it freezes. When solid Radon is cooled further, it emits a mellow yellow light that turns orange-red when it reaches the temperature of liquid air (-195°C)[3]. When radon (Rn-222) enters the lungs, it decays inside the lungs, except for a few small amounts carried by the blood. When radon decays, the resultant solid decays settle in the airways and interior surfaces of the lungs, and this is the main source of damaging radiation, i.e. if it stabilizes within the lung[4]. (Ra-226) decays to (Rn-222), which has a half-life of 3.8 days, when it undergoes alpha emission decay. Similarly, (Ra-224), a descendent of the (Th-232) chain, decays to 55.6-second (Rn-220), formerly known as thoron, via alpha emission (Rn-219), also known as action, is a member of the (U-235) chain that decays quickly, with a half-life of 3.92 seconds[5]. Radon-222 is a naturally occurring radioactive gas that accounts for around half of worldwide human yearly background radiation exposure. Chronic exposure to radon and its decay products is thought to be the second biggest cause of lung cancer after smoking, with possible ties to other cancers[6].

Solid state nuclear track detectors (SSNTDs) are the simplest, most straightforward, and least expensive technique of detecting a variety of ionizing particles, including alpha particles, protons, neutrons, and fission fragments. As a result, SSNTDs can be used in a variety of scientific and technological sectors. One of these detectors is the CR-39 detector. The CR-39 (Columbia Resin) plastic detector, also known as pollyallyldigycol carbonate (PADC), is a solid state nuclear track detector (SSNTD) that includes the element of component ($C_{12}H_{18}O_7$), has a density of around (1.32 $g.cm^{-3}$) and the quantity of ionization is about 1.32 $g.cm^{-3}$ (70.2 eV)[7].

2. Study area

The study was conducted at eleven schools in Diyala Governorate, which is located in eastern Iraq between latitudes (33.3 - 35.6) north and longitudes (45.22 - 46.56) east and encompasses an area of (17685) km^2, accounting for (4.4 percent) of Iraq's total area. It is bordered on the southwest by Baghdad Governorate, on the east by the Republic of Iran, on the north by Kirkuk and Sulaymaniyah, on the northwest by Salah al-Din Governorate, and on the south by Wasit Governorate[8].

Figure 1: Map of Diyala governorate city[9].

3. Materials and methods

The radon gas concentration was studied and calculated for eleven schools from Diyalagovernorate in the book store rooms, using the nuclear track detector (CR_39), which is classified as one of the solid-state nuclear track detectors (SSNTDs). This detector is in the form of sheets, it is cut into small pieces with a total area of (1cmx1cm), then it is suspended in the study sites, the detector was parturition at a distance of 160 cm from the surface of the earth, and the detector Left for 30 days to exposed to air (radon). After the exposure process, the chemical etching process is carried out, by placing the detector inside a chemical solution sodium hydroxide solution (NaOH), which is prepared by dissolving 250 g of sodium hydroxide granules in 1 liter of distilled water. The detector is placed in a pot and then placed in a water bath for four hours. After that, it is washed well with water to follow the stage of counting and reading the number of alpha tracks using a light microscope.

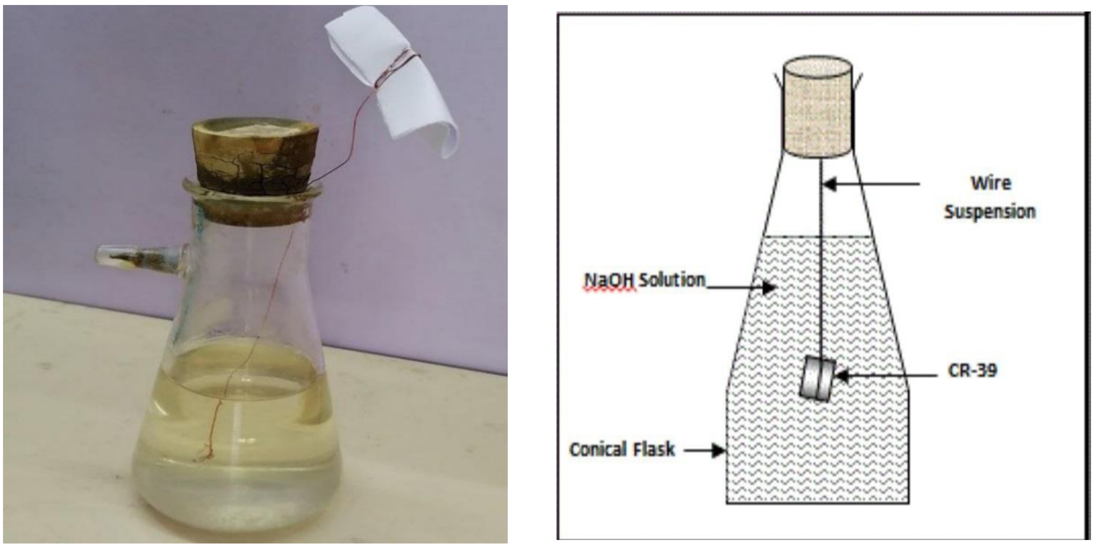

Figure 2. chemical etching process for (CR-39) track detector.

Figure 3. Water Path.

Figure 4.Typical alpha tracks on(CR-39) detector.

4.calculations

The density of the tracks is calculated through the following equation[10] [11]:

$$\rho = \frac{N_{av}}{A} \qquad (1)$$

Where:

N_{av}: an average track of sample.

A: the calculated area which is equal to (0.0676 mm^2).

ρ: density of the tracks in the unit (track/mm^2)

Calculation of radon gas concentration and some other related quantities :

1- Radon gas concentration can be calculated through the following equation[4][12]:

$$C_{Rn} = \frac{\rho_x}{K\,.t} \qquad (2)$$

Where:

ρ_x : is the Density of tracks in the unit (track/mm^2)

t: Exposure time which was in our study 30 days.

K = slope, which can be found by calibrating the detector and finding the density of tracks for standard samples and the exposure rate of standard samples

Slope = $\frac{\rho_s}{E_s}$ = 0.2544 Track .m^3/Bq.day.mm^2

2- The annual effective dose (AED) in unit of (mSv /y)[13]:

$$AED\ (mSv/y) = C_{Rn} \times F \times H \times T \times D \qquad (3)$$

Where:

C_{Rn}: Radon gas concentration.

F: is the equilibrium factor which is equal to (0.4).

H: is the occupancy factor which is equal to (0.8).

T: is the time in hours per year, (T=8760 h/y).

D: is the dose conversion factor which equals to $[9*10^{-6} \frac{\text{m Sv}}{\text{Bq . h .} m^{-3}}]$

3- Potential Alpha Energy Concentration (PAEC)[14][15] :

$$PAEC\ (WL) = F \times C_{Rn} / 3700 \qquad (4)$$

4- Exposure to radon progeny which calculated by the following equation[14]:
E_P (WLM Y^{-1}) = T× H × F × C_{Rn} / 170 × 3700 (5)

5- The lung cancer cases per year per million people (CPPP) which calculated by the following equation [13]:
(CPPP) = AED × (18×10^{-6} mSv^{-1}. y) (6)

5. Results and Discussion

In this research, the concentration of radon gas was measured in eleven book stores in eleven schools in Diyala Governorate, and **Table (1)** shows the names of the schools and their coordinates. Where the results in **Table (2)** showed that the greatest concentration of gas was equal to (84.896) Bq/m^3 for the sample (G2) which was in (Eishtar) school, and the lowest concentration was equal to (11.242) Bq/m^3 for the sample (I2) which was in (Habhib) school as shown in **Figure (5)**.Where the concentration rate was equal to (28.158) Bq/m^3.And after checking in the room in which the gas concentration was higher than the rest of the rooms, which were in (Eishtar) School, it was found that the room did not open during the ban days and schools were disrupted due to the Corona pandemic, in addition, the room windows were closed well and this caused an increase to the gas from the rest of the studied rooms. But after comparing the Our results of radon concentration with the global results, it was found that all values were less than the internationally permissible limit recorded by ICRP. Therefore, must be noted that our study coincided with the beginning of the school year in mid-October as the storerooms were open for the distribution of books and stationery for students, this leads to an increase in the ventilation of the room, so we find that the concentration of radon gas is low. In addition, the effective annual dose (AED) was calculated, and the results showed that the greatest value was equal to (2.142) (mSv/y) for the sample (G2), which was in (Eishtar) School and the lowest value was (0.284) (mSv/y) for the sample (I2) which was in (Habhib) school as shown in **Figure (7)**, and the mean dose value was (0.710) (mSv/y). lung cancer cases per year per million-person (CPPP) were also calculated and the greatest value was (38.553) for sample (G2), which was in (Eishtar) school, and the lowest value was (5.105) for (I2) in (Habhib) school as shown in **Figure (6),** with an average of (12.787).

Through **Table (2)**, and observing the concentration of radon and other quantities in the same Table, we note that there is a linear relationship between the radon gas concentration and each of (AED) and (CPPP), as well as other quantities, as an increase in the concentration of radon gas leads to an increase in the dose (AED) and leads to an increase in lung cancer cases (CPPP), As shown in **Figure (8)**, the rest of the quantities are closely related to the gas concentration.

Table 1. Sample codes and school coordinates and names.

NO.	CODE SAMPLE	CoordinatesGPS	School name
1.	A2	33°49'15.53"N 44°24'33.39"	Alandalusia
2.	B2	33°49'52.12"N 44°24'55.22"	BintZuin
3.	C2	33°51'07.02"N44°28'51.60"E	AlshahidAlsayid Jawad Aleadhari
4.	D2	33°51'29.31"N44°31'02.54"E	Alshumue
5.	E2	33°51'19.70"N44°31'07.43"E	Alsamwl
6.	F2	33°50'58.08"N44°31'29.14"E	Albalagha
7.	G2	33°50'56.56"N 44°30'58.73"	Eishtar
8.	I2	33°47'05.55"N44°30'08.96"E	Habhib
9.	J2	33°44'06.43"N44°28'45.46"E	Alshahid Muhamad QasimAleabaadii
10.	L2	33°56'08.64"N44°27'42.94"E	BashayirAlkhayr
11.	M2	33°56'09.94"N44°27'43.29"E	Alfalah

Table 2. The effects rate (N_{AV}), the density of the tracks(ρ), the radon concentration (C_{Rn}), the annual effective dose (AED), the lung cancer cases per year per million persons (CPPP), exposure to radon progeny (E_P) and potential alpha energy concentration (PAEC) in the schools.

CODE	Effects rate (N_{av})	ρ (No. of tracks/mm^2)	C_{Rn} (Bq/m^3)	AED (mSv/y)	CPPP*10^{-6}	E_P (WLM/Y)	PAEC (WL)
A2	23.800	352.071	46.131	1.164	20.949	0.206	0.005
B2	19.000	281.065	36.827	0.929	16.724	0.164	0.004
C2	8.600	127.219	16.669	0.421	7.570	0.074	0.002
D2	9.000	133.136	17.444	0.440	7.922	0.078	0.002
E2	6.400	94.675	12.405	0.313	5.633	0.055	0.001
F2	7.600	112.426	14.731	0.372	6.690	0.066	0.002
G2	43.800	647.929	84.896	2.142	38.553	0.378	0.009
I2	5.800	85.799	11.242	0.284	5.105	0.050	0.001
J2	8.200	121.302	15.894	0.401	7.218	0.071	0.002
L2	15.400	227.811	29.849	0.753	13.555	0.133	0.003
M2	12.200	180.473	23.647	0.597	10.739	0.105	0.003
AV	14.527	214.900	28.158	0.710	12.787	0.125	0.003
MAX	43.800	647.929	84.896	2.142	38.553	0.378	0.009
MIN	5.800	85.799	11.242	0.284	5.105	0.050	0.001

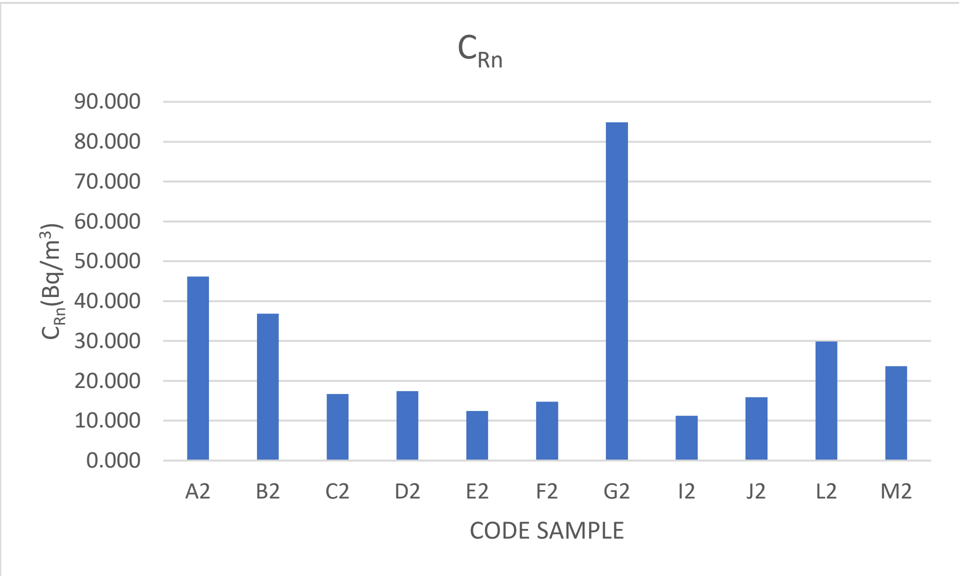

Figure 5.Levels concentration of radon in schools using CR-39 detector.

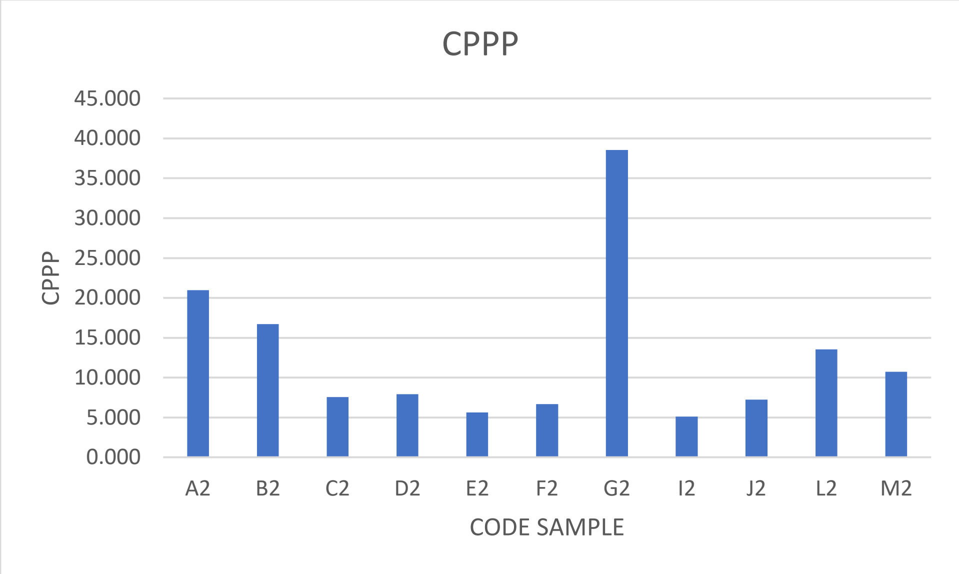

Figure 6: Lung cancer per million people (CPPP) in the school classroom

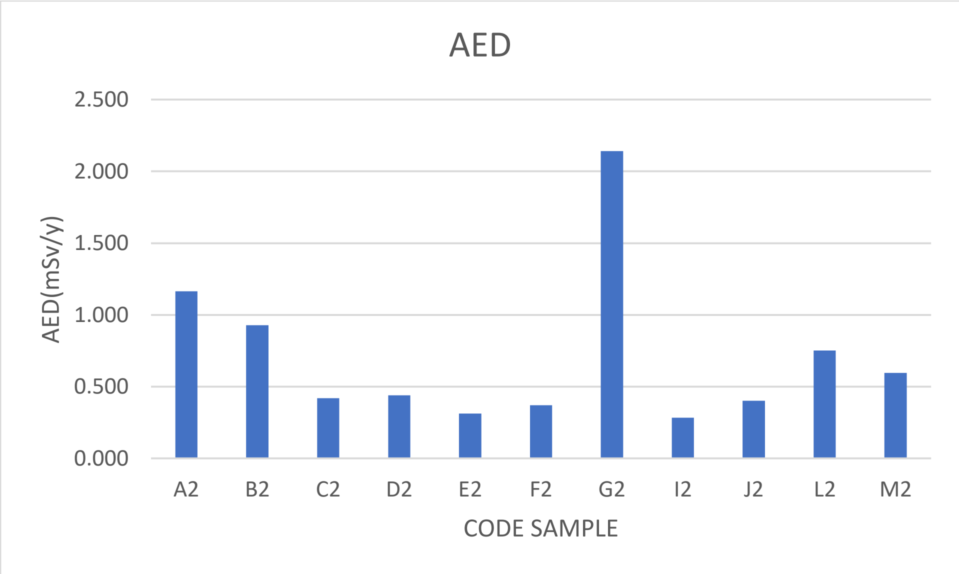

Figure 7. Annual effective dose (AED) in the air of selected schools by CR-39 detector

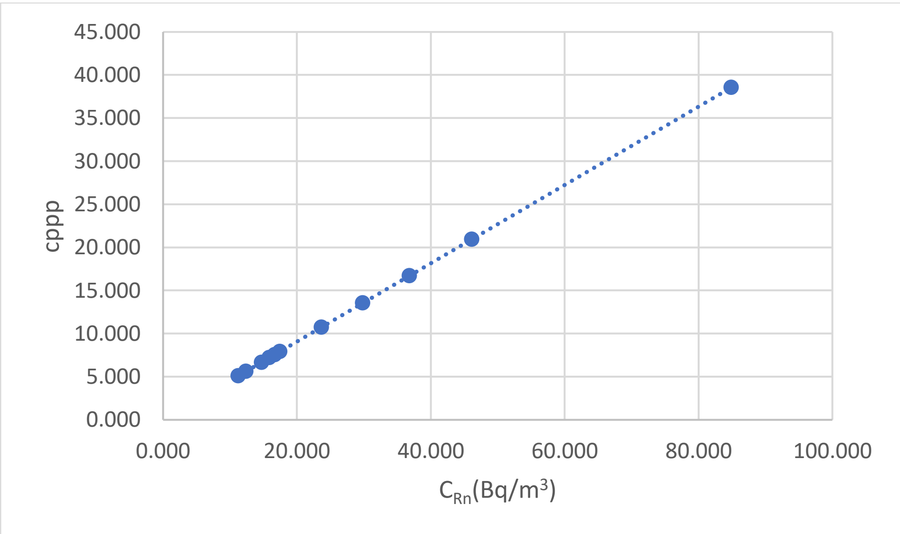

Figure 8. The correlation between radon concentrations and the lung cancer cases per year per million person in the school

Figure (8) shows the linear relationship of radon gas concentration with lung cancer cases, as the higher the radon gas concentration, the more lung cancer cases.As both the dose and the incidence of lung cancer are directly proportional to the concentration of radon gas, and this is what is shown in Equations (3)and (6) .

7. Conclusion

In this research, the concentration of radon gas was studied and measured in the storage rooms of schools in Diyala Governorate, where the results showed that the values recorded were less than the internationally permissible limits recorded by (ICRP), and found low concentrations of radon gas because our study coincided with the beginning of the official working hours. For schools, where storerooms were open for distributing books, in addition to that, most of the school rooms had upper ventilation windows open, and some of them did not contain glass, so these factors reduced the concentration of radon gas. Finally, after comparing the results obtained with the global results, it was less than the permissible limits for the concentration of radon gas recorded by (ICRP) from (200-300) Bq/m^3.

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