Determination of Indoor Radon Concentration in Some Buildings at Tikrit University by using CR-39 Detector

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Abstract: ***In this work, radon concentration for the seasons 2017-2018 was measured in various buildings of Tikrit University by using the technique of calculating the track of alpha particles emitted from the dissolution of radon on the solid state nuclear track detector (SSNTDs) type CR-39. The results of the first season samples collected in October 2017 showed that the concentration of Rn^{222} is from the lowest value of PHs3 (36.35 ± 18.04 Bq / m3) to the highest value of B3-1 (270.50 ± 32.86 Bq / m3) The average concentration is (147.18 ± 45.56 Bq / m3). The results for the second season of January 2018 were the lowest for P3 (71.57 ± 14.40 Bq / m3) and the highest value of B2-1 (278.95 ± 19.20 Bq / m3) while the The average is (150.41 ± 52.20Bq / m3) All These radon concentrations are within the recommended natural concentrations of the International Atomic Energy Agency (IAEA) [ICRP, 1993] Annual effective dose values, lung cancer risk per 1 million LCR, and alpha energy concentrations were calculated, the results were lower than those recommended by the International Atomic Energy Agency [ICRP, 1993] and the Scientific Committee on the Track of Radiation of the United Nations [UNSCEAR.1993].***

Keywords: Radon concentration, Solid state nuclear detectors CR-39, Annual effective dose

1. Introduction

Radiation is a natural part of the environment in which we live and every human being is exposed to radiation through air, soil, food and water [1]. Therefore, studies and radiological surveys of air, surface soil, rocks, food, water, etc. have been expanded to measure the level of radiation doses to which humans are exposed [2].Environmental pollution is defined by the presence of a radiating element with a concentration higher than the natural concentration allowed in global and local environmental measurements, which cause damage to the environment in general and to humans in particular [3]. Radon Rn^{222} is a source of natural radiation, which is mainly generated by the natural degradation of the ^{238}U series, ^{232}Th thorium and uranium ^{235}U, and is the only metal in the gaseous state [4]. Radon belongs to the chemically inert group of gases, which is seven and a half times heavier than the air, so it tends to stay close to the ground on the ground floors [5]. The subject of air pollution of buildings is important, especially in the absence of ventilation or in the case of poor ventilation in buildings. In addition, the main sources of radon inside buildings are the materials used in construction and gases emitted from soils, which are spread through the rooms through cracks in the walls and floors of the rooms. When inhaled radon, its non-invasive newborns such as polonium (^{214}po-^{218}po) will be deposited into lung cells and increase the risk of lung cancer [6]. In addition, irradiated radon is considered the second causative agent after smoking for lung cancer [7]. The United Nations Scientific Committee on the Track of Radiation (UNSCERAR) estimates that radon contributes with the nascent nuclei resulting from its degradation by about three quarters of the annual effective dose received by humans from natural sources [8].

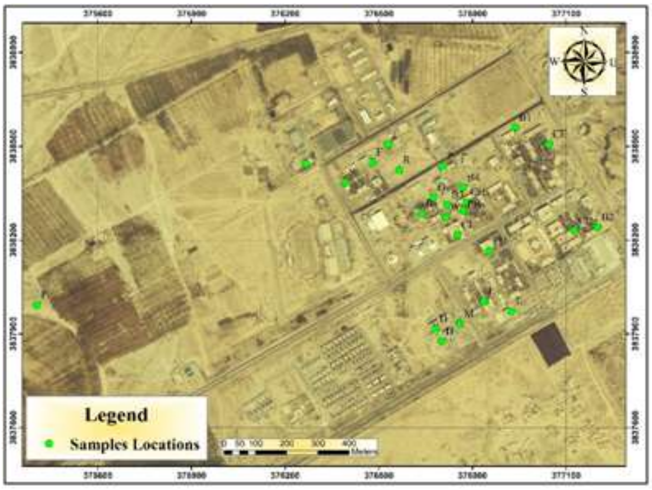
Radon is the ^{222}Rn, ^{220}Rn and ^{219}Rn. Environmental studies and geology are concentrated on ^{222}Rn, with a relatively long half life (3.8D). While the role of the ^{220}Rn counterpart neglects its half-life (5.66Sec). The Rn^{219} counterpart has a half life (3.92Sec) [9]. The results of studies conducted in recent years indicate the increase of radon concentrations in housing to the extent that makes radon the most dangerous sources on human life has been confirmed by the adoption of designs that resist the fluctuations of the climate and the characteristics of maintaining the internal atmosphere to control the process of ventilation and reduce exposure to Radon is within the acceptable minimum limits and according to the criteria. It should also note that the ventilation rate of accommodation ranges between (12-36) times per day [10].

1.1 The Aim of the Study

The current work is to measure concentrations of radon and radiation trackat the buildings of Tikrit University, which lies within the province of Salah al-Din-IRAQ as this province suffered from environmental neglect, same as in the provinces of central part of Iraq and have the increasing of population density and numbers of students

1.2 Study Location

The study area is in the city of Tikrit, which is located on the right bank of the Tigris River, 180km north of Baghdad and 330km south of Mosul. The Tikrit climate is described as a hot semi-desert climate in summer and cold in winter. The university itself is located on the bank of the eastern Tigris River within the Qadissiya colony, a flat land with no topography [11]. as shown in figure-1.



2. Practical Part

In this work, the [CR-39] detector was used of 250μm thickness two seasons it was cut to 1 x 1cm2. In the first season (October of 2017), pieces of sponge were used, where the reagent was placed inside the sponge to protect and to delay the Thoron-220 (^{220}Rn) with a half-life of 51.1Sec[12]. They were suspended at a height of 1.5m, which is the average length of the human being, with two detectors per room and three rooms were used for each building. As for the second season (January 2018), the detector was placed inside a cup and the sponge was covered with sponges and suspended at the same height in the same buildings. Figure 2 (a-b) shows the two methods in the suspension of the reagents.

Figure 2: A Method of spreading impact detectors inside cups

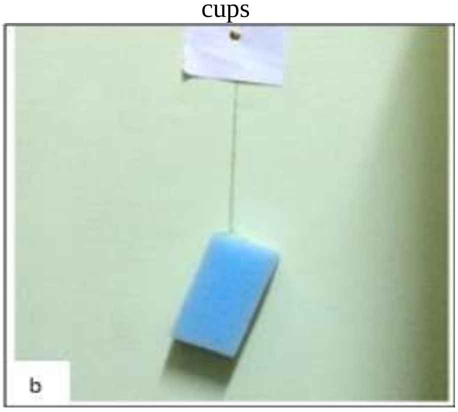


Figure 2: A Method of spreading impact detectors inside the sponge

The reagents were left for 30 days in different rooms of each building (laboratories, classrooms, stores and teaching rooms). After the exposure time, the regents were collected. The chemical scaling process was then carried out to show the hidden track of the passage of charged particles. It consists of narrow paths consisting of the breakdown of molecular chains, atomic defects, and spike gaps [13]. In the process of skimming, NaoH solution with a standard of 6.25 N.as shown in figure-3(a-b) .

The container containing sodium hydroxide solution mere placed in a water bath for heating at 60 ° C where the reagents are suspended in the straw solution container for 5 hours. This operation shall be followed by the sealing of the flask stop to prevent evaporation of the solution. The reason for the use of sodium hydroxide solution (abrasive solution) is that it is an alkaline metal hydroxide solution capable of scattering track in organic polymeric reagents such as CR-39 used [14]. After drying the reagents, the number of tracks generated by the optical microscope (type Novel) is detected by selecting the appropriate magnification power (the magnification capacity is 400X)

Using a special calibration lens divided into several squares, it calculates the area of square A and calculates the track of the area unit (10 attempts are taken for each detector). To calculate the intensity of the track the ratio of N_{avg} for each detector is divided by the square and in the equation (1).

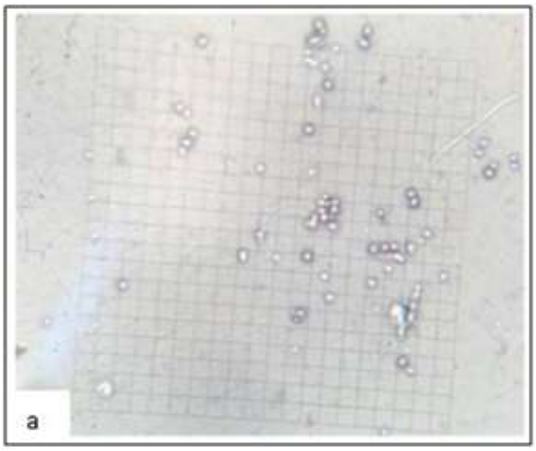


Figure 3 (a)

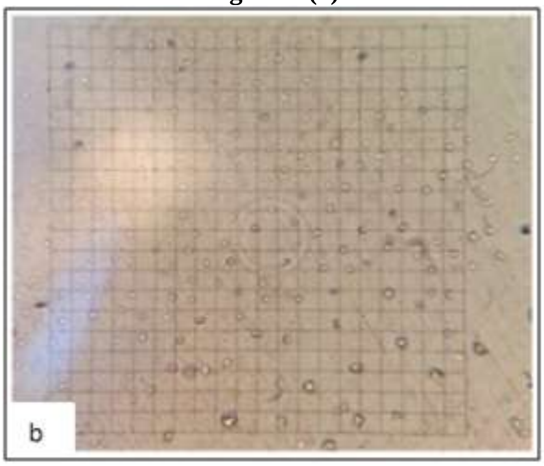


Figure 3 (b)

Figure 3 (a –b): The track of alpha particles in the detectorCR-39

Calibration of the detector

The ^{226}Ra radiometer and the 5µC emitter of radioactive radon ^{222}Rn have been used by calibrating directly to the CR-39 detector within the volume information room and for different periods. The process of skimming was then performed with the same solution NaoH and with the same standard 6.25 and at 60°C

Calculations

Equation (1) was used to calculate the intensity of the track of alpha particles on the detector

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

Where:

- Track intensity Track/mm^2 ρ 0.07 mm^2- The area of the large square is equal to A

- Rate track. N_{avg}

Equation (2) was also used to find the concentration of radon in buildings [15].

$$C_{Rn} = \frac{E_s}{\rho_s}\left(\frac{\rho}{t}\right) \qquad \text{... ... ... (2)}$$

Where:

C_{Rn} : the ^{222}R Concentration in (Bq/m^3) unites .

E_s : the radon exposure of standard Source in (Bq.day.m^{-3}) units.

ρ_s: the track density (number of track. mm^{-2}) of the stander source.

ρ: the track density (number of track. mm^{-2}) of the detectors exposed.

t: the exposure time (days).

$$C_{Rn} = \frac{\rho}{k\,t} \qquad \text{... ... ... (3)}$$

The intensity of the track of the (ρ_s) samples was calculated and the relationship between the intensity of the track(ρs) and the Excess Radon(Ex) exposure was obtain to estimate the calibration factor (K). The linear relationship and the curved value were equal to K (0.169 Track. m^3 / Bq.Day.mm^2) [16]. As in figure (4)

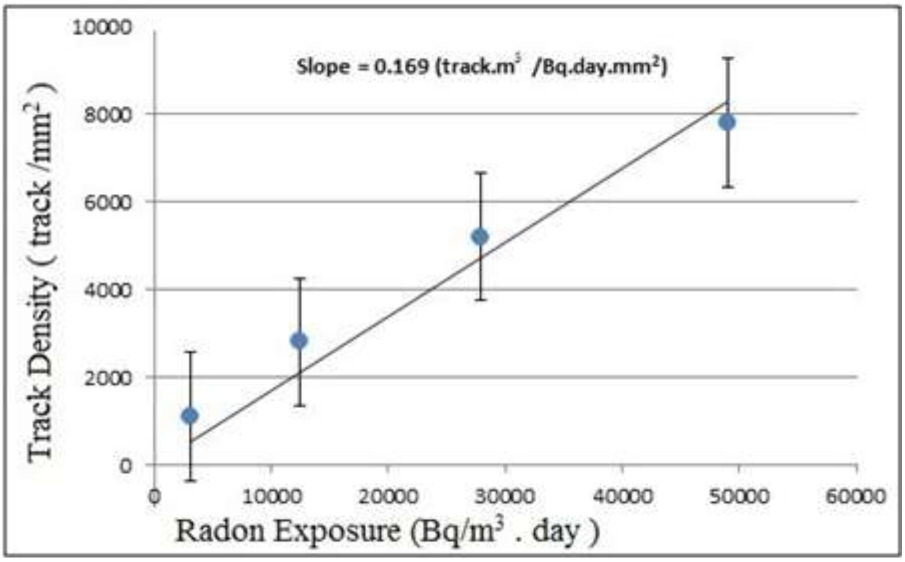


Figure 4: The relationship between intensity of tracks ρs and exposure to radon Ex

Some radon measurements inside buildings

1) Indoor Radon Concentration.

The results of the study showed that the concentration of radon in the elected buildings is below the ICRP recommended level of [200-300 Bq / m3] [17].

2) Annual effective doses (A.E.D)

In all buildings surveyed, the annual effective dose was less than the recommended limit by the International Atomic Energy Agency [ICRP, 1993], which is equal to (3-10 mSv / y)[18].

In order to estimate the effective annual dose of workers in buildings, especially for individuals who spend long periods of work, the following equation was used[19]:

$$AED = C_{Rn} * F * H * T * D \text{ ... ... (4)}$$

Where:

AED : Annual effective dosesin units (mSv/y)

C_{Rn} : Radon concentration in units(Bq/m^3)

F : Equilibrium factor is equal to (0.4)

H : Occupancy factor is equal to (0.8)

T : The number of hours per year (8760 h)

D : The dose conversion factor is equal (9.0×10^{-6} mSv /Bq.m^{-3}.h)

3) Lung Cancer Risk(LCR)

The International Radiological Protection Agency (ICRP, 1993) identified a potential exposure (170-230) per million people [20]. The probability of lung cancer was calculated from the following equation [21].

$$(LCR) = A.E.D \times (18 \times 10^{-6}\, mSv^{-1}.y) \text{..........(5)}$$

4) Potential Alpha Energy Concentration (PAEC)

With regard to the percentage of possible Alpha potential concentrations, it has been identified for the United Nations Scientific Committee on the Track of Atomic. Radiation UNSCEAR, 1993 (53.33 mWL) [22].It was calculated from the following relationship: [23]

$$PAEc = \frac{F \times C_{Rn}}{3700} \ldots\ldots\ldots\ldots(6)$$

Where:
(C_{Rn}) The Radon concentration.
(F) The equilibrium factor between radon and its progeny and it is equal to (0.4) as suggested by (UNSCEAR, 2000)[24].

3. Results and discussion

In this study, concentrations of radon and radiation track were determined in different buildings of the University of Tikrit and for the seasons 2017-2018. Table (1) and (2) shows the resulting concentrations of gas and Radiation effects.

The results showed that the highest concentration in the first season of October 2017 for B3-1 was (270.50 ± 32.86 Bq / m3) in the pharmacy store building of the Faculty of Pharmacy. The lowest concentration was in the building of the Faculty of Science Physics Department of PHS3 (36.35 ± 18.04 Bq / m3). As shown in Fig. 6, the concentration rate in the first season was calculated (147.18 ± 45.56Bq / m3) As for the second season (January 2018 to February), the results showed that the highest concentration was in (B2-1) (278.95 ± 19.20 Bq / m3) for the building of chemicals and solvents of the Faculty of Education and the lowest concentration of model P3) (71.57 ± 14.40Bq / m3). As shown in Figure (8), the concentration rate was calculated in the second season (150.41 ± 52.20Bq / m3)

The annual effective dose was calculated as the results showed that the highest percentage of the first season of the model (B3-1) is (6.82) in the building of the chemical store of the Faculty of Pharmacy, the lowest percentage in the building of the Faculty of Science Physics Department of model (PHs3) (3.71 ± 1.15mSv / y). The linear relationship between the concentration of radon in the first season and the annual effective dose, as shown in Figure 5As for the second season, the results showed that the highest percentage of the sample (B2-1) was (7.04) in the building of the store of chemicals of the Faculty of Education, either the lowest proportion in the College of Pharmacy for the model (P3), which is (1.8) (3.77 ± 1.33mSv / y) and Figure (7) represents the linear relationship between the concentration of radon in the second season and the annual effective dose.

The risk of lung cancer per million people was the lowest for PHs3 (16.51) and the highest value of the model (B3-1) (122.84) and the rate of (66.07 ± 21.94) for the first season, while the second season was the lowest value of the model (P3), which is (32.50) and the highest value of the model (B2-1) which is (126.68) and the rate of (67.78 ± 23.92).The maximum value of the model (PH3) was (3.93 mWL) and the highest value of the model (B3-1) was (29.24 mWL) at (15.91 ± 4.93 mWL) for the first season. For the second season, (7.74 mWL) and the highest value of the model (B2-1) which is (30.16 mWL) and the rate of (16.14 ± 5.70 mWL)

The results showed that there is a difference in concentrations of radon and radiation track in different buildings, where the results of the first season were less than the results of the second season. This is due to differences in air changes between the seasons, nature and age of buildings and height of sea level and building materials used as it is known that the main source of radon in The buildings are the earth because they contain uranium ore. In addition, some buildings are small in size and lack proper ventilation. The doors and windows of the buildings are closed, leading to the accumulation of radon released from the walls and floors, leading to a high concentration.

Table 1: Radon gas concentration, Annual effective doses (A.E.D), Lung Cancer Risk case per year per million person (LCR), Potential Alpha Energy Concentration (PAEC)

N	Location	Sample	Floor	C_{Rn} (Bq/m^3)	AED (mSv/y)	LCR Cases per year per 10^6persons	PAEC (mWL)
1	Physics department	PH_s1	Ground	134.97±22.90	3.41	61.29	14.59
		PH_s2	Ground	117.78±21.15	2.97	53.49	12.73
		PH_s3	First floor	36.35±18.04	0.92	16.51	3.93
2	Chemistry department	CH_s1	Ground	147.37±51.75	3.72	66.92	15.93
		CH_s2	Ground	155.26±29.50	3.92	70.50	16.78
		CH_s3	Ground	139.19±23.15	3.51	63.21	15.05
3	Geology department	G_s1	Ground	92.14±20.17	2.32	41.84	9.96
		G_s2	Ground	122.85±23.54	3.10	55.79	13.28
		G_s3	Ground	112.71±18.86	2.84	51.18	12.18
4	Biology department	B_s1	Ground	129.33±22.94	3.26	58.73	13.98
		B_s2	Ground	153.56±21.79	3.87	69.74	16.60
		B_s3	Ground	148.21±28.15	3.74	67.31	16.02
5	Presidency University	PU1	Ground	122.29±15.06	3.09	55.53	13.22
		PU2	Ground	106.79±18.08	2.69	48.50	11.54
		PU3	Ground	116.93±29.10	2.95	53.10	12.64
6	Deanship of Faculty of Pharmacy	P1	Ground	123.42±23.25	3.11	56.05	13.34
		P2	Ground	132.43±20.97	3.34	60.14	14.32
		P3	Ground	131.02±29.48	3.31	59.50	14.16
7	Dean of the Faculty of Law	L1	Ground	147.93±31.26	3.73	67.18	15.99
		L2	Ground	120.88±25.54	3.05	54.89	13.07
		L3	Ground	111.86±23.77	2.82	50.80	12.09
8	Chemistry Science Store B4	B4- 1	Basement	216.40±34.36	5.46	98.27	23.39
		B4- 2	Basement	193.86±40.20	4.89	88.03	20.96

		B4- 3	Basement	211.89±40.69	5.35	96.22	22.91
9	Petrol Engineering	PE1	Ground	176.39±30.53	4.45	80.10	19.07
		PE2	Ground	63.68±42.61	1.61	28.92	6.88
		PE3	Ground	182.02±22.33	4.59	82.66	19.68
10	Dental Hospital	H1	Ground	143.98±31.12	3.63	65.39	15.57
		H2	Ground	129.05±26.65	3.26	58.60	13.95
		H3	Ground	158.92±26.81	4.01	72.17	17.18
11	Department of Gardening	g1	Ground	186.81±18.83	4.71	84.84	20.20
		g2	Ground	193.01±23.24	4.87	87.65	20.87
		g3	Ground	191.89±39.16	4.84	87.14	20.74
12	The central Library	CL 1	Ground	111.02±15.30	2.80	50.41	12.00
		CL2	Ground	110.17±20.15	2.78	50.03	11.91
		CL 3	Ground	101.44±23.99	2.56	46.06	10.97
13	Faculty of education Department of chemistry	CHe1	Ground	153.00±24.29	3.86	69.48	16.54
		CHe2	Ground	144.55±27.60	3.65	65.64	15.63
		CHe3	Ground	136.94±27.93	3.45	62.19	14.80
14	Chemical Engineering	CE1	Ground	129.33±30.17	3.26	5.73	13.98
		CE2	Ground	140.32±17.87	3.54	63.72	15.17
		CE3	Ground	121.44±16.80	3.06	55.5	13.13
15	Dean of the Faculty of Administration and Economics	E1	Ground	106.51±20.75	2.69	48.37	11.51
		E2	Ground	119.47±21.57	3.01	54.25	12.92
		E3	Ground	149.90±25.18	3.78	68.07	16.21
16	Department of science and Soils	S1	Ground	162.58±44.81	4.10	73.38	17.58
		S2	Ground	142.86±20.08	3.60	64.87	15.44
		S3	Ground	96.93±27.65	2.45	44.02	10.48
17	Building classroom and laboratory	R1	Ground	137.50±23.01	3.47	62.44	14.87
		R2	Ground	127.64±22.62	3.22	57.96	13.80
		R3	Ground	156.95±22.03	3.96	71.27	16.97
18	Department of Science and Food	F1	Ground	128.49±34.67	3.24	58.35	13.89
		F2	Ground	162.30±13.88	4.09	73.70	17.55
		F3	Ground	120.32±14.61	3.04	54.64	13.01
19	Store Chemical Engineering B1	B1-1	Basement	267.40±30.96	6.75	121.43	28.91
		B1-2	Basement	264.86±32.04	6.68	120.28	28.63
20	Dental Laboratory Building	M1	Ground	125.39±23.19	3.16	56.94	13.56
		M2	Ground	104.54±13.58	2.64	47.47	11.30
		M3	Ground	152.72±26.58	3.85	69.35	16.51
21	Plant food industry	I1	Ground	158.64±45.35	4.00	72.04	17.15
		I2	Ground	167.09±17.57	4.22	75.88	18.06
22	Store Chemical education B2	B2-1	Basement	259.23±31.09	6.54	117.72	28.02
		B2-2	Basement	248.24±33.99	6.26	112.73	26.84
23	Dean of dentistry	D1	Ground	119.75±48.12	3.02	54.38	12.95
		D2	Ground	133.56±28.85	3.37	60.65	14.44
		D3	Ground	110.45±16.87	2.79	50.16	11.94
24	The workshop engineering	W	Ground	140.32±33.80	3.54	63.72	15.17
25	Chemical Store for College of Pharmacy B3	B3-1	Basement	270.50±32.86	6.82	122.84	29.24
		B3-2	Basement	222.03±35.51	5.60	100.83	24.00
Average				147.18±45.56	3.71±1.15	66.07±21.94	15.91±4.93
Global limit				200 - 300 (Bq/m^3) [17]	3 - 10 (mSv/y) [18]	170-230 [20]	53.33 (mWL) [22]

Table 2: Radon gas concentration, Annual effective doses (A.E.D), Lung Cancer Risk case per year per million person (LCR), Potential Alpha Energy Concentration (PAEC)

N	Location	Sample	Floor	C_{Rn} (Bq/m^3)	AED (mSv/y)	LCR Cases per year per 10^6persons	PAEC (mWL)
1	Physics department	PH_s1	Ground	192.45±14.87	4.86	87.39	20.81
		PH_s2	Ground	136.09±25.40	3.43	61.80	14.71
		PH_s3	First floor	88.48±11.78	2.23	40.18	9.56
2	Chemistry department	CH_s1	Ground	119.75±19.29	3.02	54.38	12.95
		CH_s2	Ground	211.05±39.85	5.32	95.84	22.82
		CH_s3	Ground	168.78±28.61	4.26	76.65	18.25
3	Geology department	G_s1	Ground	154.97±24.68	3.91	70.38	16.75
		G_s2	Ground	208.79±17.44	5.27	94.82	22.57
		G_s3	Ground	173.01±19.80	4.36	78.57	18.70

4	Biology department	B_s1	Ground	191.89±45.27	4.84	87.14	20.74
		B_s2	Ground	206.54±20.03	5.21	93.79	22.33
		B_s3	Ground	139.48±21.70	3.52	63.34	15.08
5	Presidency University	PU1	Ground	105.38±15.70	2.66	47.86	11.39
		PU2	Ground	145.67±27.38	3.68	66.15	15.75
		PU3	Ground	118.34±24.27	2.99	53.74	12.79
6	Deanship of Faculty of Pharmacy	P1	Ground	148.21±19.03	3.74	67.31	16.02
		P2	Ground	77.77±13.84	1.96	35.32	8.41
		P3	Ground	71.57±14.40	1.81	32.50	7.74
7	Dean of the Faculty of Law	L1	Ground	81.43±19.12	2.05	36.98	8.80
		L2	Ground	77.49±17.55	1.95	35.19	8.38
		L3	Ground	117.22±21.22	2.96	53.23	12.67
8	Chemistry Science Store B4	B4- 1	Basement	232.18±15.03	5.86	105.44	25.10
		B4- 2	Basement	233.59±14.93	5.89	106.08	25.25
		B4- 3	Basement	211.05±22.80	5.32	95.84	22.82
9	Petrol Engineering	PE1	Ground	235.00±21.11	5.93	106.72	25.40
		PE2	Ground	205.13±14.83	5.18	93.15	22.18
		PE3	Ground	157.51±25.63	3.97	71.53	17.03
10	Dental Hospital	H1	Ground	123.42±18.58	3.11	56.05	13.34
		H2	Ground	103.69±21.47	2.62	47.09	11.21
		H3	Ground	136.66±11.80	3.45	62.06	14.77
11	Department of Gardening	g1	Ground	177.51±28.84	4.48	80.61	19.19
		g2	Ground	134.69±13.41	3.40	61.16	14.56
		g3	Ground	168.22±18.86	4.24	76.39	18.19
12	The central Library	CL 1	Ground	127.36±17.82	3.21	57.84	13.77
		CL2	Ground	109.89±15.36	2.77	49.90	11.88
		CL 3	Ground	116.93±16.26	2.95	53.10	12.64
13	Faculty of education Department of chemistry	CHe1	Ground	211.61±11.00	5.34	96.10	22.88
		CHe2	Ground	161.45±15.03	4.07	73.32	17.45
		CHe3	Ground	107.64±11.91	2.72	48.88	11.64
14	Chemical Engineering	CE1	Ground	142.29±16.27	3.59	64.62	15.38
		CE2	Ground	123.70±18.92	3.12	56.17	13.37
		CE3	Ground	105.10±14.20	2.65	47.73	11.36
15	Dean of the Faculty of Administration and Economics	E1	Ground	102.00±17.40	2.57	46.32	11.03
		E2	Ground	76.92±13.35	1.94	34.93	8.32
		E3	Ground	73.82±17.54	1.86	33.52	7.98
16	Department of science and Soils	S1	Ground	147.37±11.49	3.72	66.92	15.93
		S2	Ground	113.27±21.57	2.86	51.44	12.25
		S3	Ground	131.87±24.00	3.33	59.88	14.26
17	Building classroom and laboratory	R1	Ground	169.06±24.17	4.27	76.77	18.28
		R2	Ground	174.13±25.25	4.39	79.08	18.83
		R3	Ground	108.76±19.21	2.74	49.39	11.76
18	Department of Science and Food	F1	Ground	103.41±21.83	2.61	46.96	11.18
		F2	Ground	86.50±17.84	2.18	39.28	9.35
		F3	Ground	72.13±17.51	1.82	32.76	7.80
19	Store Chemical EngineeringB1	B1-1	Basement	232.46±7.85	5.86	105.56	25.13
		B1-2	Basement	231.61±12.46	5.84	105.18	25.04
20	Dental Laboratory Building	M1	Ground	146.52±20.83	3.70	66.54	15.84
		M2	Ground	144.55±20.62	3.65	65.64	15.63
		M3	Ground	147.65±17.59	3.72	67.05	15.96
21	Plant food industry	I1	Ground	91.29±19.73	2.30	41.46	9.87
		I2	Ground	133.00±13.61	3.36	60.40	14.38
22	Store Chemical education B2	B2-1	Basement	278.95±19.20	7.04	126.68	30.16
		B2-2	Basement	236.40±9.11	5.96	107.36	25.56
23	Dean of dentistry	D1	Ground	127.64±27.66	3.22	57.96	13.80
		D2	Ground	125.95±12.46	3.18	57.20	13.62
		D3	Ground	79.74±14.33	2.01	36.21	8.62
24	The workshop engineering	W	Ground	217.53±9.02	5.49	98.78	23.52
25	Chemical Store for College of Pharmacy B3	B3-1	Basement	238.10±9.94	6.01	108.12	25.74
		B3-2	Basement	249.65±15.06	6.30	113.37	26.99
Average				**150.41±52.20**	**3.77±1.33**	**67.78±23.92**	**16.14±5.70**
Global limit				**200 - 300 (Bq/m^3) [17]**	**3 - 10 (mSv/y) [18]**	**170-230 [20]**	**53.33 (mWL)[22]**

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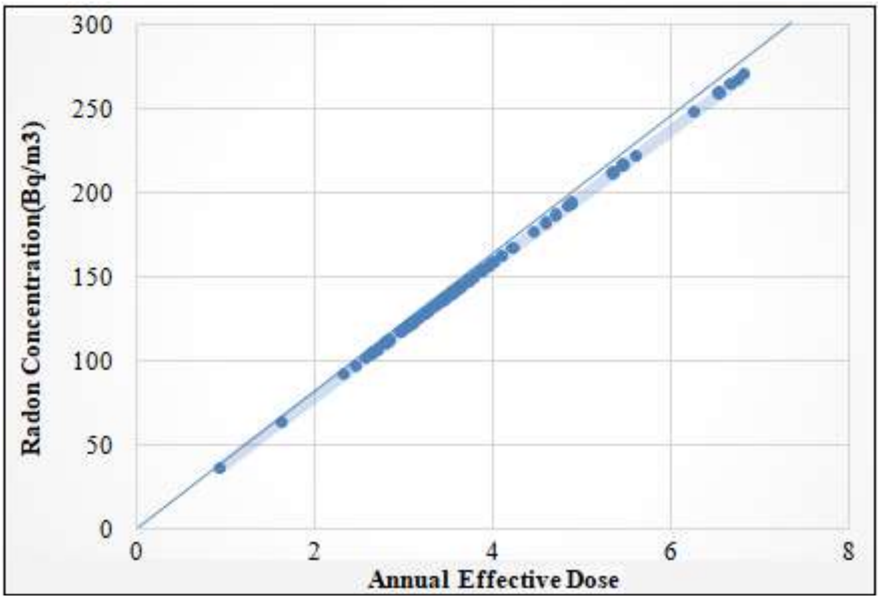

Figure 5: The linear relationship between radon concentration and the annual effective dose (season 1)

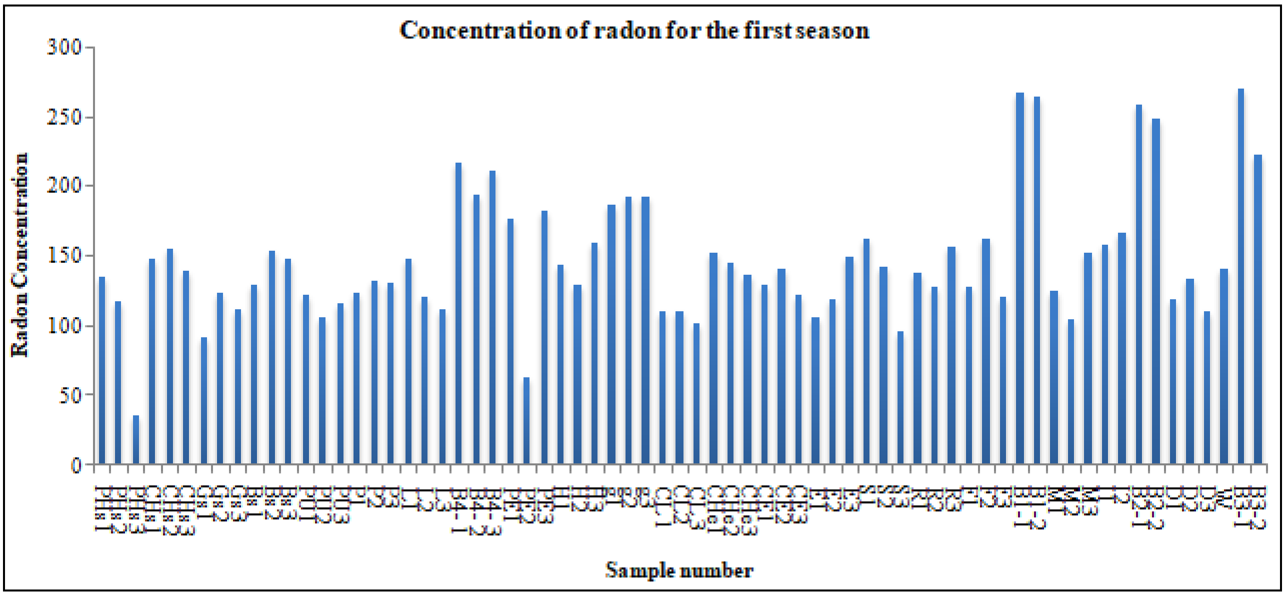

Figure 6: Concentration of radon for the first season

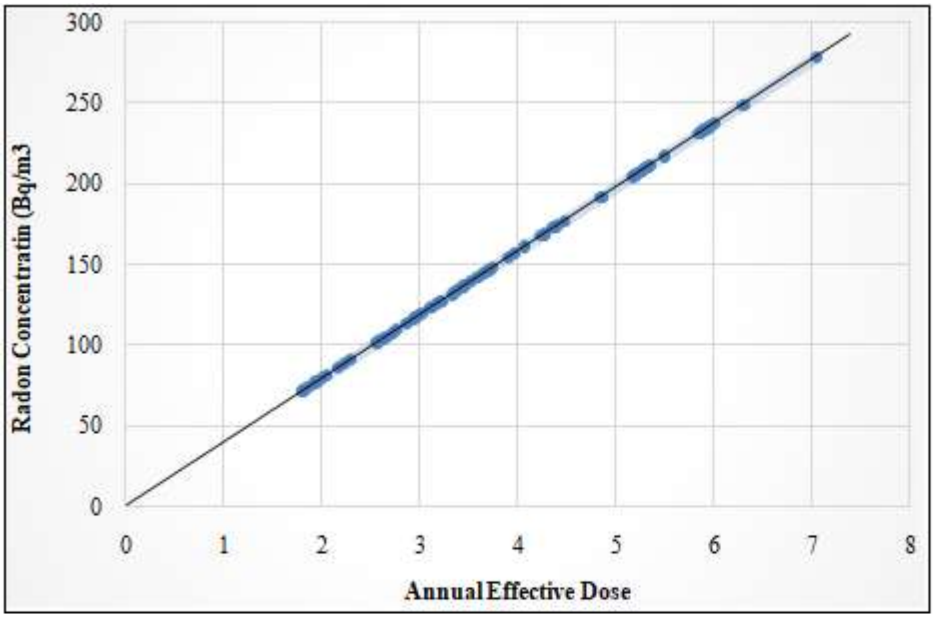

Figure 7: The linear relationship between radon concentration and the annual effective dose (season 2)

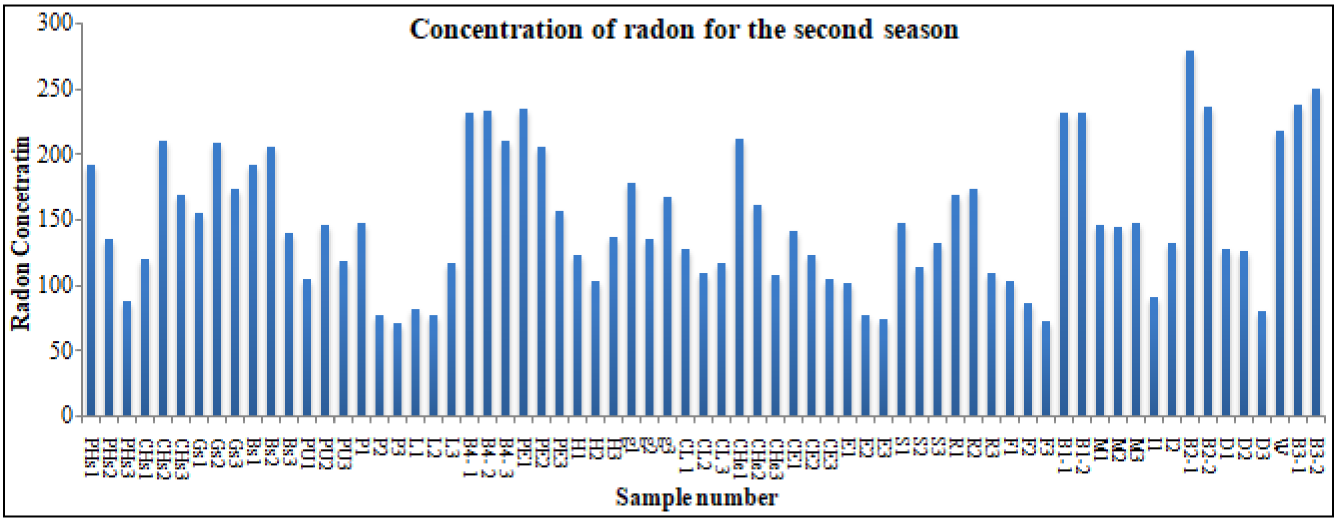

Figure 8: Concentration of radon for the second season

4. Conclusion

The results of this research provide additional data on the study of radon levels and radiative track in buildings in terms of the use of appropriate methods that give more accurate results and lower cost. The measurements made using two different methods, which showed variation in radon concentration from one season to another, conclude that radon measurements should be performed periodically, for different seasons and in more precise ways, and for all weather variables and geology, because of their effect on the rate of radiation activity. In the experiment, the results showed that the method of suspension of reagents using the mug used in the second season was more than the results of the first season using sponge. The reason is that the thickness of the sponge covering the nozzle is less than the sponge used in the first season. Which works to delay the thoron and the detector. Despite the differences in temperature and humidity in the two seasons, which certainly have a significant role and influence on readings, it is preferable to compare the two methods under the same temporal and spatial conditions.

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