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Assessment of Internal Exposure to Radon in Schools in Karbala, Iraq

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Abstract: In this study, radon concentrations were measured in the air of nineteen schools, including six secondary schools and thirteen primary schools in Karbala city using the passive accumulative technique, which includes solid-state nuclear track detectors LR-115 type II and CN-85 By Kodak, pathe, France with thickness 12 micrometers. Radon concentrations ranged from 13.140±4.11 Bq/m^3 to 38.439±6.79 Bq/m^3 and ranged from 13.842±2.35 Bq/m^3 to 36.867±4.28 Bq/m^3 with an average value(25.408±4.54 and 25.317±3.15) Bq/m^3 in closed dosimeters for LR-115 and CN-85 detectors respectively, also in open dosimeters ranged from 15.719±7.30 Bq/m^3 to 51.825±28.26 Bq/m^3 and varied from 17.269±3.90 Bq/m^3 to 46.872±4.74 Bq/m^3 with an average of (36.253±5.23and 34.732±4.36) Bq/m^3 in LR-115 and CN-85 detectors, respectively. The mean of annual effective dose was 0.028 mSv/y and 0.020 mSv/y for closed dosimeters , whereas in open dosimeters the mean of annual effective dose was 0.048 mSv/y and 0.032 mSv/y in LR-115 and CN-85 detectors, the mean value of lung cancer cases per year per million person was found 0.859 and 0.580 in open dosimeters ,and the mean was 0.496 and, 0.366 in closed dosimeters of LR-115 and CN-85, respectively. The results of this study were lower than the normal limits of radiation (200-300) Bq/m^3according to ICPR

Keywords: Radon, LR-115, CN-85, Annual Effective Dose.

1 Introduction

Radon is a noble gas that is one of the natural radioactive decay products of radium resulting from the disintegration of uranium . Radium is present in the earth at rates that can be considered fixed because of its half-life of 1600 y, and radon is emitted from the soil into the atmosphere [1] .

A number of techniques have been used to measure the concentrations of Rn -222 and its decaying products in the environment. Three characteristics were used to describe radon measurement techniques: (i) whether the technique measured Rn -222 or its daughter's products; (ii) time accuracy; and (iii) radiation detection of the transmission type either with alpha or beta particles or gamma radiation due to radioactive decay [2].However, humans are exposed to sources of natural radiation activity, being radon and its progeny breathing air responsible for more than 50% of the annual dose received from natural radiation [3]. Radon has half-life $T_{1/2}$ = 3.82 days that is decay naturally reaching the final stable daughter of lead. When radon is inhaled, the intensity of alpha-ionized particles emitted from short-term sedimentation produces radon decay products (Po-218 and Po-214) with biological tissue in the lungs, leading to DNA damage[4]. Radon is a gas but its daughter Po-218 and Po-214 are solid particles that are associated with air molecules and may therefore be inhaled directly. Not everyone who breathes radon decay products will develop lung cancer. Individual risk of lung cancer from radon depends mostly on several factors: radon level, exposure period and

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smoking habits of people. The risk increases as an individual is exposed to higher levels of radon for a longer period of time [5]. In addition, soil, groundwater and drinking water from the main sources can contribute to the upgrading of radon in the air of school buildings, because some of the nuclei associated with natural radioactive sequential may degrade in water, especially underground water, where the precipitant researchers in many studies and research to find out [6-10].

The aim of this study is to measure the concentrations of radon in the air of nineteen schools in Karbala, calculate the annual effective dose of radon as well as the number of students who may be exposed to lung cancer due to inhalation of radon in the air from school buildings.

2 Study Areas

Karbala is the center of the province of Karbala, located in the center of Iraq, passing through its territory. The geography of the Hussainya River, a branch of the Euphrates River (29 km), is bordered by Baghdad (105 km) from the city center to the north. Najaf governorate (74 km) to the south and south west and Babylon governorate (45 km) to the south . Karbala occupies the northeastern part of Anbar province (112 km) to the north and north west from the province of Karbala. As shown in figure 1 .With latitude (32`, 34º-32`.37º N), longitude (58`, 43º-60`, 44º E). The area of Karbala is (2793 km^2) [8].

3 Materials and Methods

In this work, 19 schools were selected, including thirteen primary schools and six secondary schools for girls in Karbala, Iraq. The long-term passive cumulative technique method, which contains two types of nuclear track detectors CN-85 $(C_6H_{18}O_5N_2)_n$ and LR-115 $(C_{12}H_{17}O_{16}N_3)_n$ with a thickness of 12 micrometers, were used to measure radon concentrations in the air of school buildings. The cumulative passive dosimeters are a 6.8 cm diameter plastic cup with a height of 4.6 cm, one open to allow radon isotopes, while the other is closed with a 3 cm hole covered with 0.5 cm thick sponge in the top cover of the roller to ensure that only the radon entered, to detectors as shown in figure 2 . LR-115 type II and CN-85 were cut into square pieces (1 × 1) cm^2 and installed in the bottom of the plastic cup in a two-sided adhesive placed at a height of 2 meters

above the floor. A number was placed on all the reagents (LR-115 type II and CN-85) for the purpose of distinguishing them when making calculations and results. Then ,the dosimeters are kept in the school buildings from 27/11/2017 to 3/3/2018 in schools for three months in winter season . The samples are then collected and the reagents are removed from the dosimeters and cleaned from the dust. After that the electrochemical etching of LR-115typeII and CN-85 singly was started to show the nuclear tracks of the alpha particles on the detector surface using sodium hydroxide solution at 2.5M at 60 ° C for 90 minutes. After removing the reagents from the solution and washing them with well distilled water and drying them in the air, the number of alpha particle pathways is calculated on the detector surface using an optical microscope with 100X magnification.

4 Results and Discussion

The concentration of radon in the air of school buildings for both CN-85 and LR-115 type-II nuclear detectors is measured in the following equations [11, 12] :

$$C(Bq/m^3) = \frac{\rho}{KT} \quad (1)$$

where, ρ is the surface density of tracks on the LR-115 and CN-85 detectors which is measured(Track.cm^{-2}) , T is the exposure time (day) and K is the calibration factor to convert track density to the radon concentration[Track.cm^{-2} / Bq.m^{-3}

day]. The calibration factor (K) value was determined by the calibration process which used standard radon source(radium-226) and used the following equation [12] :

$$K = \frac{\rho_o}{C_o t_o} \quad (2)$$

Where C_o (1.126×10^7) Bq/m^3 is the activity density of the calibration chamber (standard radon concentration) $C_o = A/V$ .Where: A=3.989 KBq (activity) ,V (dosimeter volume) V=π r^2 L. Where: r =5 cm, L=5 cm , t_o is the calibration exposure time for the calibration process (35 min) , ρ_o is the number of tracks per cm^2 on the LR-115 and CN-85 detectors.

The calibration experiment performed for LR-115 and CN-85 track detectors that is calibrated at a nuclear lab in the physics department at the Faculty of Science at Kerbala University. Five LR-115type II detectors and five CN-85

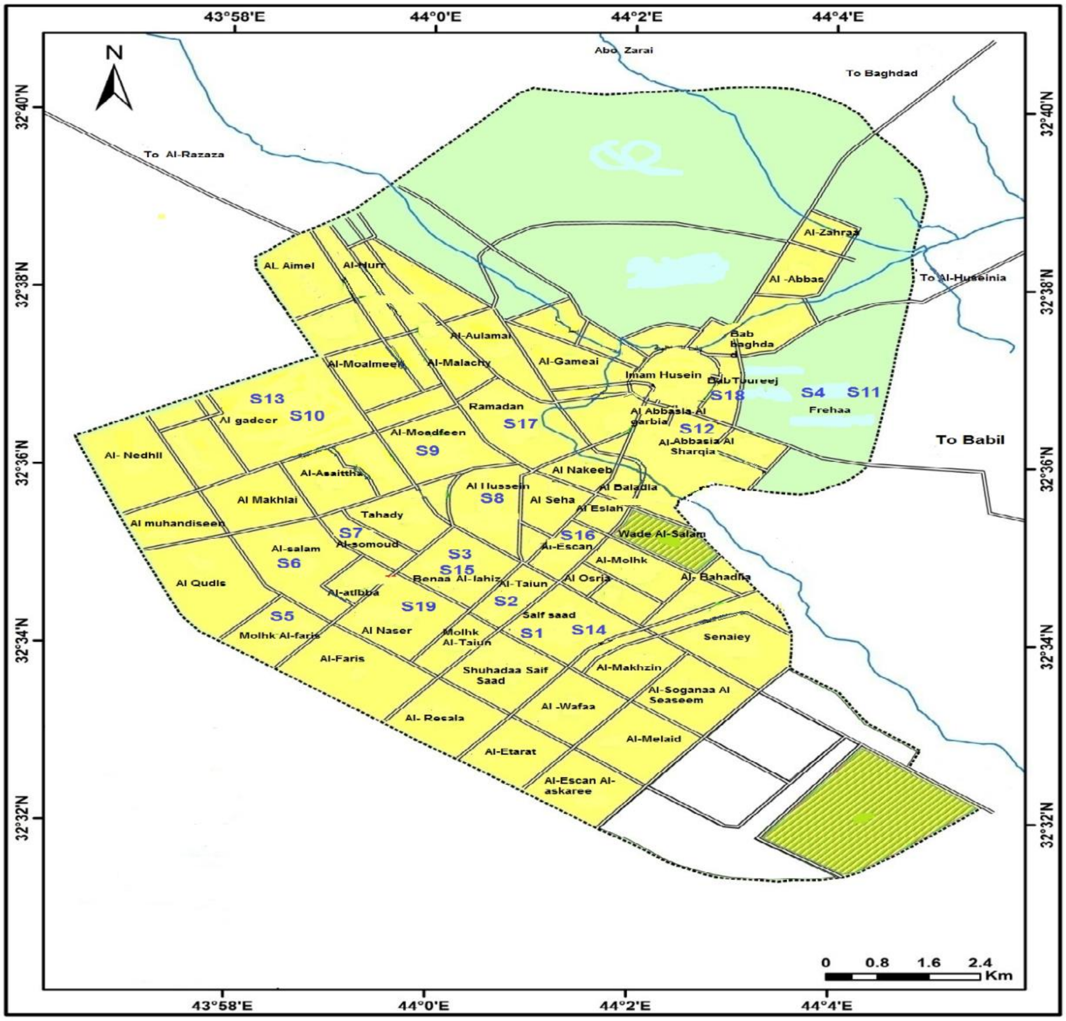

Fig. 1: Map of Karbala city and samples of schools.

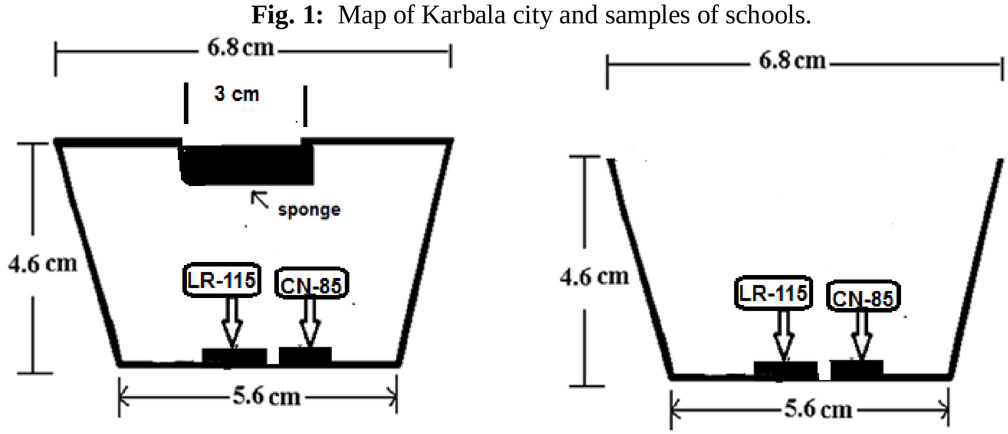

Fig. 2: Closed and open passive cumulative dosimeters.

detectors were used in the calibration process and subjected to radon source concentration by using Ra- 226 with an effective 4 KBq for 35 minutes. The detectors were placed them in a barrel length of 11 cm and diameter of 10 cm and exposed to the radioactive element Ra -226 on distance 5 cm from the detectors. The average value of the calibration factor for LR-115 and CN-85 detectors that were found equal to (0.285 and 0.256 Track.cm^{-2} / Bq.m^{-3} day) respectively.

After the determination of the radon concentrations for all closed (C_c) and open (C_o) dosimeters, the equilibrium factor(F) between radon and its isotopes can be calculated from the following formula [11, 13] :

$$F = a \exp\left(-b\frac{C_c}{C_o}\right) \quad (3)$$

Where a and b are constants magnitude 15 and 7.5

Respectively. The annual effective dose (AED) can be obtained in terms of $m\,Sv/y$ for both closed and open dosimeters for all detectors using the relationship [14, 15]

$$\text{AED}\,(m\,Sv/y) = \text{C} \times \text{F} \times \text{H} \times \text{T} \times \text{D} \quad (4)$$

Where; C: represent radon concentrations for both closed and open dosimeters. H is the occupancy factor in schools which is equal to (0.13) and (T) is the time in hours in a year, T=7860 h/y, D is the dose conversion factor which is equal to [9×10^{-6} $(m\,Sv)$ / (Bq.h.m^{-3})].

The lung cancer cases per year per million person (CPPP), was obtained using the relation [16-18]

$$(\text{CPPP}) = \text{AED} \times (18\times10^{-6}\ /mSv/y) \quad (5)$$

Table 1 shows the names and locations of the schools in the neighborhoods of Karbala and the special code in each school for the purpose of distinguishing between them.

Table 1: School name , locations and code numbers in Karbala city.

School name	Locations	codes	School name	Locations	Codes
Ramallah primary	Saif Saad	S1	Al Qimah primary	Frehaa	S11
Fatima Al- zahra primary	Taiun	S2	Al Sharqia primary	Al abassia Al Sharqia	S12
Nahj Al - Balaghah primary	Benaa ALjahiz	S3	Al Sahaba primary	Al gadeer	S13
Al Kawakeb	Frehaa	S4	shuhada' Mu'tah secondary	Saif Saad	S14
Al - Wadq primary	Molhk Al fairs	S5	Nahj Al-alaghah secondary	Benaa ALjahiz	S15
Al- Fatat primary	Salam	S6	Al- Nagah secondary	Al Eskan	S16
Al - Maysam primary	Sumod	S7	Nazik Al - Malayikih secondary	Ramadan	S17
Al- Wydad primary	Al-Hussein	S8	AL Rawdatain Secondary girls	Bab Toureej	S18
Ashab AL-kesaa primary	Moadafeen	S9	Al Thurai secondary	Al Naser	S19
Ouhran primary	Al gadeer	S10			

The final results reached are summarized in Table 2 , from this table, we observe that the radon concentrations in CN-85 detectors for closed dosimeters varied from 13.842±2.35 Bq/m^3 to 36.867±4.28 $q/m^3$with an average value 25.317±3.15 Bq/m^3, whereas in open dosimeters ranged from 17.269±3.90 Bq/m^3 to 46.872±4.74 Bq/m^3 with an average value 34.732±4.36 Bq/m^3. As for the LR-115 type II detectors, the radon concentrations in closed dosimeters varied from 13.140±4.11 Bq/m^3 to 38.439±6.79 Bq/m^3 with mean value 25.408±4.54 Bq/m^3 , also in open dosimeters ranged from 15.719±7.30 Bq/m^3 to 51.825±7.74 Bq/m^3 with mean 36.253±5.23 Bq/m^3 as shown figure 3 ,all results are lower than the radon levels (200-300) Bq/m^3 which are recommended by ICRP.

Annual effective dose was varied from 0.003 mSv/y to 0.090 mSv/y and varied from 0.003 mSv/y to 0.086 mSv/y the mean value of annual effective dose was 0.028 mSv/y and 0.020 mSv/y for closed dosimeters in LR-115 and CN-85 respectively also varied from 0.003 mSv/y to 0.188 mSv/y and varied from 0.003 mSv/y y to 0.176 mSv/y with an average value 0.048 mSv/y and 0.032 mSv/y for open dosimeters ,as shown figure 4 ,the mean of lung cancer cases per year per million person was found 0.496 and 0.366 in open dosimeters for LR -115 and CN-85 respectively, whereas 0.859 ,0.580 in open dosimeters for LR -115 and CN-85 respectively. In figure 5 shows an excellent correlation (R^2=1) between lung cancer cases per million per person and annual effective dose for LR -115 and CN -85 in open dosimeters and closed dosimeters as shown in figure 5 and figure 6.

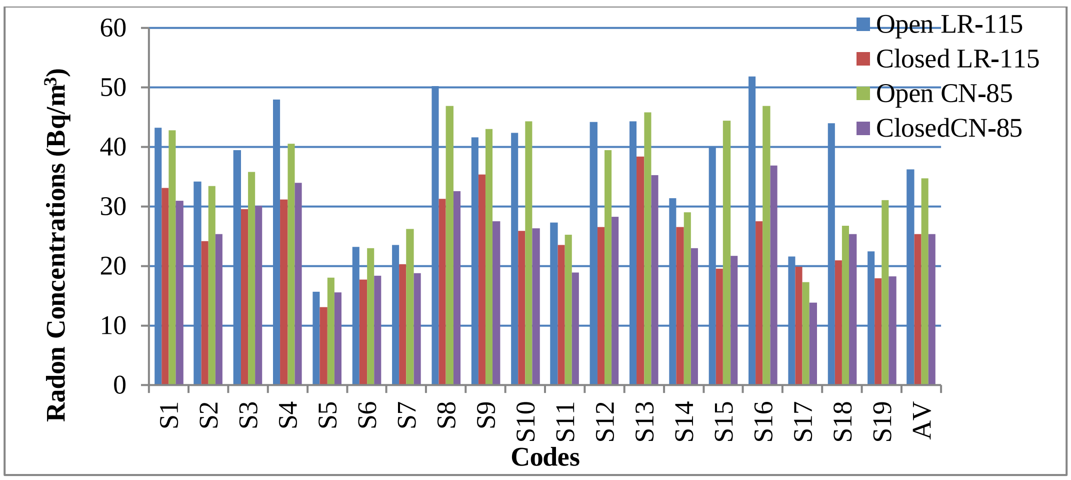

Fig. 3: Radon concentrations for open and closed and dosimeters by LR-115 and CN-85 detectors in the air of selected schools in Karbala city.

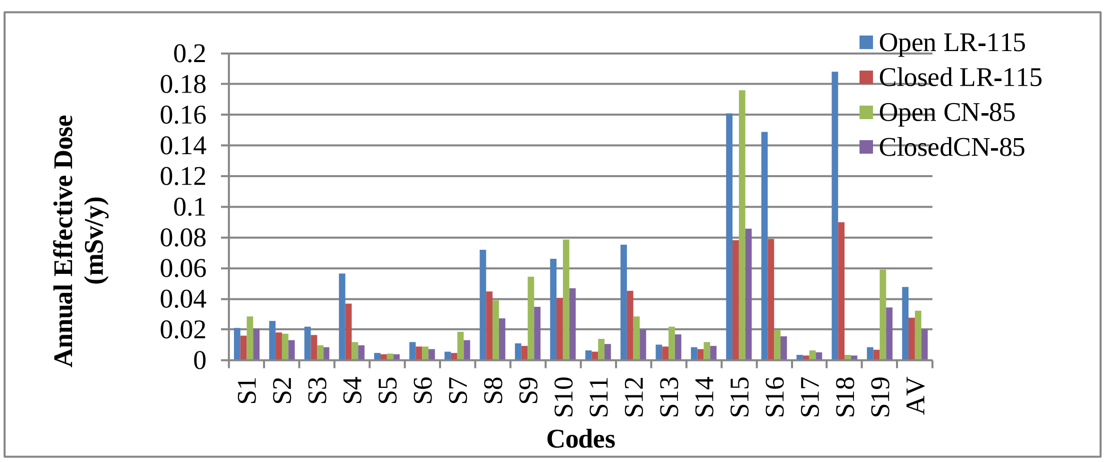

Fig. 4: Annual effective dose (AED) in the air of selected schools by LR-115 and CN-85 detectors.

Table 2. Radon concentration (C) for open(O) and closed (C) dosimeter(D) ,annual effective dose (AED) and lung cancer cases per year per million person (CPPP) for the selected schools in Karbala city using(LR-115 and CN-85) detectors.

Code	D	LR-115			CN-85		
		C Bq/m^3	AED mSv/y	CPPP/10^6	C Bq/m^3	AED mSv/y	CPPP/10^6
S1	O	43.228±6.37	0.021	0.380	42.760±4.43	0.029	0.517
	C	33.158±5.95	0.016	0.291	30.973±4.84	0.021	0.375
S2	O	34.140±4.23	0.026	0.465	33.441±5.24	0.017	0.314
	C	24.193±4.29	0.018	0.329	25.355±4.56	0.013	0.238
S3	O	39.421±5.93	0.022	0.391	35.771±3.34	0.010	0.178
	C	29.596±5.28	0.016	0.294	30.152±4.20	0.008	0.150
S4	O	48.018±6.01	0.057	1.017	40.568±4.45	0.012	0.210
	C	31.193±5.75	0.037	0.661	33.989±4.73	0.010	0.176
S5	O	15.719±7.30	0.005	0.082	18.091±4.86	0.004	0.078
	C	13.140±4.11	0.004	0.069	15.596±5.11	0.004	0.067
S6	O	23.211±6.11	0.012	0.212	23.025±6.03	0.009	0.161
	C	17.684±9.51	0.009	0.161	18.365±4.23	0.007	0.128
S7	O	23.579±3.69	0.006	0.104	26.177±4.69	0.019	0.334
	C	20.263±3.11	0.005	0.089	18.776±3.12	0.013	0.240
S8	O	50.228±5.80	0.072	1.295	46.872±4.45	0.039	0.702
	C	31.315±6.62	0.045	0.807	27.548±3.93	0.027	0.488
S9	O	41.632±7.69	0.011	0.197	43.035±5.53	0.054	0.979
	C	35.358±7.12	0.009	0.167	27.548±4.34	0.035	0.627
S10	O	22.474±7.03	0.066	1.194	44.268±6.10	0.079	1.419
	C	42.358±3.57	0.041	0.730	26.314±3.02	0.047	0.843
S11	O	25.912±3.82	0.006	0.115	25.218±4.88	0.014	0.252
	C	44.211±3.33	0.006	0.099	18.913±2.47	0.010	0.189
S12	O	26.526±5.72	0.076	1.359	39.471±4.34	0.028	0.511
	C	25.053±4.34	0.045	0.815	28.232±3.72	0.020	0.366
S13	O	44.333±7.24	0.010	0.184	45.776±4.85	0.022	0.395
	C	38.439±6.79	0.009	0.159	35.223±3.88	0.017	0.304
S14	O	31.439±3.69	0.009	0.155	29.055±5.93	0.012	0.211
	C	26.526±2.87	0.007	0.131	23.025±2.56	0.009	0.167
S15	O	40.158±5.82	0.161	2.898	44.405±5.66	0.176	3.170
	C	19.526±4.17	0.078	1.409	21.654±2.86	0.086	1.546
S16	O	51.825±7.74	0.149	2.677	46.872±4.74	0.020	0.356
	C	27.50±5.06	0.079	1.421	36.867±4.28	0.016	0.280
S17	O	21.614±2.44	0.003	0.060	17.269±3.90	0.007	0.117
	C	19.895±2.17	0.003	0.055	13.842±2.35	0.005	0.094
S18	O	43.925±5.61	0.011	0.205	26.725±4.64	0.003	0.060
	C	21.000±3.84	0.009	0.160	25.355±3.15	0.003	0.057
S19	O	22.474±6.13	0.009	0.157	31.111±4.12	0.059	1.063
	C	17.930±3.52	0.007	0.125	18.228±2.99	0.035	0.623
AV	O	36.253±5.23	0.048	0.859	34.732±4.36	0.032	0.580
	C	25.408±4.54	0.028	0.496	25.317±3.15	0.020	0.366
Min	O	15.719±7.30	0.003	0.060	17.269±3.90	0.003	0.060
	C	13.140±4.11	0.003	0.055	13.842±2.35	0.003	0.057
Max	O	51.825±7.74	0.188	3.383	46.872±4.74	0.176	3.170
	C	38.439±6.79	0.090	1.616	36.867±4.28	0.086	1.546

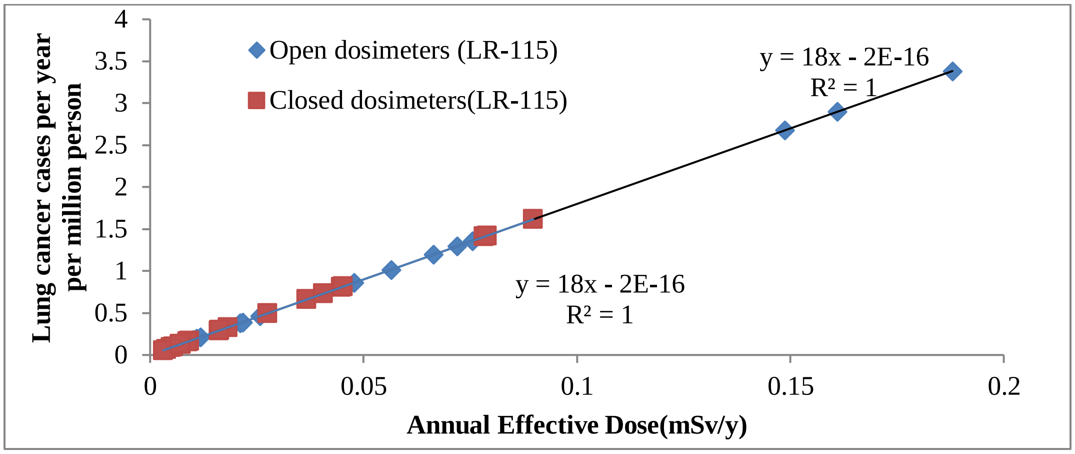

Fig. 5: Correlation between Lung cancer cases per million per person with Annual Effective dose in open and closed dosimeters for LR-115typeII detectors.

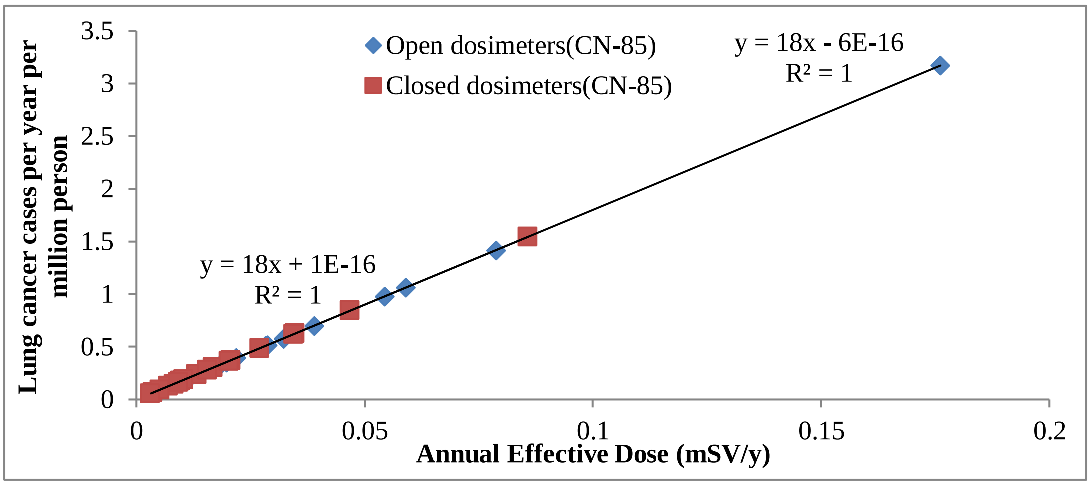

Fig. 6: Correlation between Lung cancer cases per million per person with Annual Effective dose in open and closed dosimeters for CN-85 detectors.

In table 3. The results in this study were compared with previous local , Arab and international studies, when using CN-85 , radon concentration that was observed to be close to the result in Pakistan [19] and less than those of other researchers in Pakistan (Muzaffarabad) [20] , Pakistan (Skardu) [21] , Pakistan [22] and Pakistan (Bahimber) [23] . In the case of LR-115 type II detector, it was observed to be close to the results of some countries , including Iraq (Kufa) [24] , Italian (Parma) [25], Greece (Patras) [26] and Tunis [27] , while the radon concentration were lower than from Osijek [28],

Turkey (Istanbul) [29], Egypt (Cario) [30], Greece (Patras) [31] , Turkey (Izmir) [32] .When comparing the results of the current study with other studies using the nuclear track detectors CR-39, our results were close to the results of previous studies in Palestine (Hebron) [33] , Kuwait [34] . While our results were lower than from other studies Iraq (Baghdad) [35], Iraq (Karbala) [8],Saudi Arabia 36][, Jordon (Amman) [37], Turkey(Batman) 38][, Pakistan (Punjab) [39]. The results of annual effective dose in all present study was lower than the results of the other studies, as shown in the table below.

Table 3: Comparison of the present study in schools with others studied of many different countries.

Country	Detectors type	Place of study	C(Bq/m^3)	AED(mSy^{-1})	Ref.
Pakistan	CN-85	Sitting rooms	28	-	[19]
Pakistan (Muzaffarabad	CN-85	Houses drawing room	85	-	[20]
Pakistan , (Skardu)	CN-85	Dwelling	111.34	-	[21]
Pakistan	CN-85	Dwelling	95.1	2.38	[22]
Pakistan (Bahimber)	CN-85	Dwelling	48	1.05	[23]
Iraq ,Kufa	LR-115	Technical Institute buildings	21.567	0.544	[24]
Italian (Parma)	LR-115	Kindergarten and schools	30	0.5	[25]
Greece (Patras)	LR-115	Schools	35	0.2	[26]
Tunisia (Tunis)	LR-115	Schools	26.9	0.084	[27]
Osijek	LR-115	Schools	70.6	2. 8	[28]
Turkey (Istanbul)	LR-115	Schools	125	-	[29]
Egypt (Cairo)	LR-115	Schools	57.6	0.85	[30]
Greece (Patras)	LR-115	Dwelling	38	0.9	[31]
Turkey (Izmir)	LR-115	University	161	0.79 - 4.27	32][
Palestine (Hebron)	CR-39	School	34.1	1.76	[33]
Kuwait	CR-39	School	16	0.97	[34]
Iraq (Baghdad)	CR-39	Dwelling	51.688	-	[35]
Iraq (Karbala)	CR-39	Dwelling	62.071.	0.683	[8]
Saudi Arabia	CR-39	Kindergarten and school	74.67	-	[36]
Jordon (Amman)	CR-39	Kindergarten	76.8	-	[37]
Turkey (Batman)	CR-39	Schools	49	0.25	[38]
Pakistan (Punjab)	CR-39	Schools	52	0.49	[39]
Iraq (Karbala)	LR-115	O – Schools	36.253	0.048	Present study
		C	25.408	0.028	
	CN-85	O – Schools	34.732	0.032	
		C	25.317	0.020	

5 Conclusions

Radon concentrations were measured in the air of Karbala school buildings. Results obtained for radon concentrations were different from school to school due to several factors, including school design, ventilation methods, materials used in construction, and student behavior. These factors caused the difference in radon concentrations. However, measurements in Karbala were much lower than in many countries of the world. It is within permitted limits and does not pose a risk to human health according to ICPR (200-300) Bq / m^3 [40].

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