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Radiation Hazards due to radon in the air of Buildings Surrounding Imam Hussain Holy Shrine in Karbala, Iraq

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Radiation Hazards due to radon in the air of Buildings Surrounding Imam Hussain Holy Shrine in Karbala, Iraq

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Abstract
Introduction: In this work, radon measurements have been carried out in different Buildings Surrounding Imam Hussain Holy Shrine in Karbala, Iraq.
Materials and Methods: Radon concentrations were determined by using time-integrated passive radon dosimeters containing (CR-39) solid state nuclear track detectors.
Results: The radon concentration in the building has been found to vary from 23.958 to 88.233 Bqm^{-3} with an average 39.372 Bqm^{-3} this value is less than (200-300 Bqm^{-3}) recommended range (ICRP, 2009). The internal annual effective dose value ranged from (0.399) to (1.469 $mSvy^{-1}$) with an average value (0.655$mSvy^{-1}$) which is less than the lower limit of the recommended range (3-10 $mSvy^{-1}$) (ICRP, 1993).
Conclusion: The values of lung cancer cases per year per million person ranged between (7.181) to (26.445) with an average value (11.800) per million person which is lower than the recommended range (170- 230) per million person (ICRP, 1993). The positive relationship between the concentration of radon gas and lung cancer cases per year per million person (LCC) in indoor building samples in all locations studied.
It can be said that all the results of this study are less than the internationally permitted limits and therefore do not pose a risk to the health of workers and visitors to the Imam Hussain Holy shrine.

Keywords: Radon, CR-39 nuclear track detector, Health Risk Assessment, Indoor air, annual effective dose.

1. Introduction

Radon gas (222Rn) and its daughters (214Po and 218Po) no gas are considered an important radioactive source because they cause about half of the effective dose resulting from the natural radioactive background [1, 2]. This gas is produced by the decay of the element (226Ra) in the uranium chain, the uranium chain is found in soil and building materials. The concentration of radon gas (222Rn) in closed areas is much more than when compared to its concentration in open areas, and the concentration of it depends on the amount of air exchange to and from closed areas. Many of us spend most of our time

in closed areas, whether at work or home, so it is necessary to measure the concentrations of radon gas inside buildings [3]. The natural sources of radon gas inside buildings are building materials such as (sand, cement, rocks used in floors, etc.) as they contain elements of uranium chain (238U), and these elements enter the human body through swallowing or inhalation with and stay in the lungs and the result of its decay product alpha particles which causes chemical and biological damage and lead to cancer. The exposure to the population can be assessed by knowing the radon gas concentrations.
Radon gas may arise by the rocks and soil surrounding the buildings and once this gas enters them it is difficult to get rid of it because many buildings are closed. This reduces gas exchange, so the situation is very difficult. Radon gas concentrations are in the basement of buildings, mines, etc, and ground floor more. Due to its proximity to the sources of this gas (rocks, soil) [4].
Risk factor for lung cancer because inhalation of air polluted by radon gas and its daughters different from one person to another, according to the age of a person, so many scientists and researchers have made an effort to measure the concentrations of radon gas and its daughters [5, 6]. As a result of these efforts, several places have been monitored and indented as radon-contaminated areas [7].
In this study, it was used technique to nuclear track detection according to the radon measurement with CR-39 because the sensitivity to an alpha particle is very good, Long-term integrated readout, and handling ease. The CR-39 plastic detector considered sensitive up to 40 MeV of α- particles. Therefore used to detect the alpha particles from 222Rn and progeny nuclei. The alpha particle when infiltrating in the detector leaves traces along its path, by chemical etching the trace made visible. The trace produces a hole along the path of the particle in the detector. And can be easily observed the hole by optical microscope with sensible enlargement. CR-39 detects α-particles from both radon gas and its progeny throughout the Measurement period inside the Buildings [8].
There have been several studies in Karbala governorate of 222Rn in the air of school buildings and residential [9-14].
This study aims to determine the indoor radon level in the buildings surrounding the Imam Hussain Holy Shrine in Karbala of Iraq. The main purpose of this study to measure the concentrations of radon 222Rn For several reasons, one of which is no information about the concentration of radon gas for this region, Therefore, this study provides some data of the concentration of radon levels and data to exposures to employees and the general visitors. Moreover, by this work, we aim to create interest and raise the public awareness of the radon gas hazard in the community.

2. Study area

The governorate of Karbala is located geographically between the two latitudes (32^o 50 33-32^o 10 30) north and longitude (44^o 12 30 – 43^o 43 40) east. It is bordered to the north by the governorates of Babylon and Anbar, from the east by Babylon governorate, and from the south and west by the governorates of Anbar and Najaf. About 5034 km^2, or 1.2% of the total area of Iraq, which amounts to 434.934 km^2. The city of Karbala has an area of about 2397 km^2[10].
The city of Karbala is of great religious importance due to the presence of the shrine of Imam Al-Hussain and his brother Al-Abbas, peace be upon them. This importance comes through the arrival of thousands of visitors daily, in addition to millions of Iraqi and foreign Muslim visitors on religious occasions, especially in visiting the anniversary of

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the martyrdom of Imam Al-Hussain on the tenth of Muharram every year in addition to the visit of the forty. Figure 1 below shows the location of Karbala governorate on the map of Iraq , in addition to the map of the city of Karbala indicating the location of Imam Hussain Holy shrine, in addition to that the names of the buildings included in the study are specified on the map of Imam Hussain Holy shrine and as shown below the figure. This study included 12 buildings surrounding the Imam Hussain shrine, shown in Table 1. Table 2 shows the location of each sample according to the latitude and longitude of the study area.

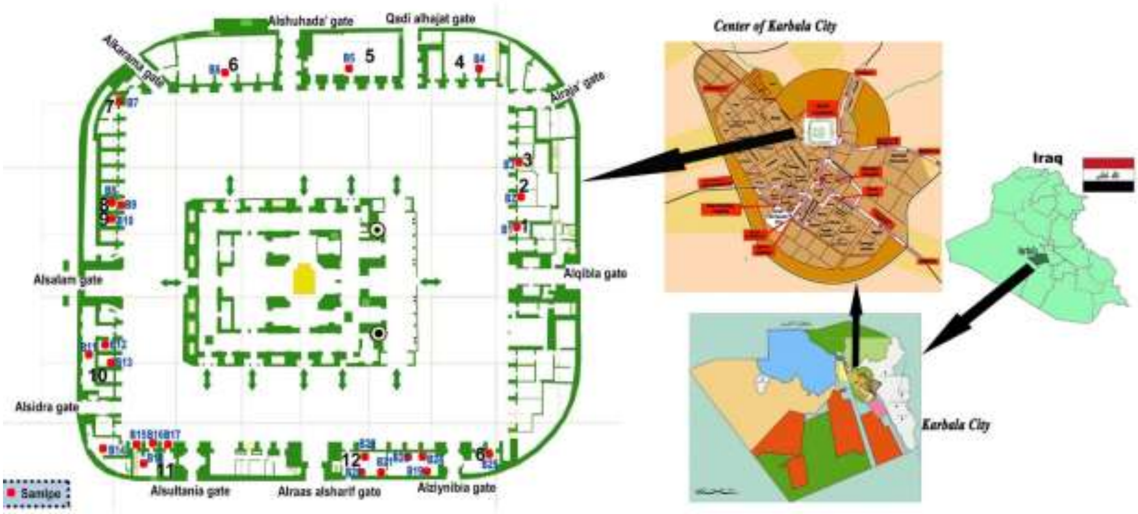

Figure 1. Shows locations of samples in the air of Buildings Surrounding Imam Hussain Holy shrine in Karbala of Iraq.

1- Keep system department
2- Religions affairs department
3- Education coordination and rehabilitation department
4- The religion school of Imam Hussein (pbuh)
5- General relationship department
6- Gifts and vows department
7- Medical department
8- Checking and super visor interior department
9- Wire and wireless communication department
10- Engineering and technical affairs department
11- Finance affairs department
12- Media department

Table 1: Symbol, and location name of the different studied sites in the air of Buildings Surrounding Imam Hussain Holy shrine in Karbala of Iraq.

Location	Sample code	Department	Location	Sample code	Department
1	B1	Keep system department	14	B14	Engineering and technical affairs department
2	B2	Religions affairs department	15	B15	Finance affairs department

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3	B3	Education Coordination and rehabilitation department	16	B16	Finance affairs department
4	B4	The religion school of Imam Hussain (pbuh)	17	B17	Finance affairs department
5	B5	General relationship department	18	B18	Finance affairs department
6	B6	Gifts and vows department	19	B19	Finance affairs department
7	B7	Gifts and vows department	20	B20	Media department
8	B8	Medical department	21	B21	Media department
9	B9	Checking and super visor interior department	22	B22	Media department
10	B10	Checking and super visor interior department	23	B23	Media department
11	B11	Wire and wireless communication department	24	B24	Media department
12	B12	Engineering and technical affairs department	25	B25	Media department
13	B13	Engineering and technical affairs department			

Table 2: The location of the samples in the study area.

Sample code	Latitude	Longitudinal	Sample code	Latitude	Longitudinal
B1	32 ˚36 `56.71"N	44˚01`57.01"E	B14	32˚37 `00.35"N	44˚ 01`56.63"E
B2	32˚36 `56.56"N	44˚01`57.46"E	B15	32˚37 `00.15"N	44˚ 01`55.47"E
B3	32˚36 `56.67"N	44˚01`57.88"E	B16	32˚37 `00.39"N	44˚ 01`55.66"E
B4	32˚36 `57.43"N	44˚01`58.77"E	B17	32˚36 `59.84"N	44˚ 01`55.41"E
B5	32˚36 `58.08"N	44˚01`59.02"E	B18	32˚36 `59.45"N	44˚ 01`55.38"E
B6	32˚36 `58.69"N	44˚01`59.17"E	B19	32˚37 `00.03"N	44˚ 01`55.43"E
B7	32˚36 `57.91"N	44˚01`55.13"E	B20	32˚36 `58.15"N	44˚ 01`54.68"E
B8	32˚37 59.87"N	44˚01`58.6"E	B21	32˚36 `58.64"N	44˚ 01`54.99"E
B9	32˚37 `00.11"N	44˚01`57.79"E	B22	32˚36 `58.54"N	44˚ 01`55.04"E
B10	32˚37 `00.17"N	44˚01`57.83"E	B23	32˚36 `58.69"N	44˚ 01`54.88"E

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B11	32°37 `00.15"N	44°01`57.44"E	B24	32°36 `58.68"N	44° 01`54.75"E
B12	32°37 00.28"N	44°01`57.18"E	B25	32°36 `58.58"N	44° 01`56.86"E
B13	32°37 `00.5"N	44°01`56.87"E			

3. Methodology

Indoor radon concentrations were measured in the air of Buildings Surrounding Imam Hussain Holy shrine the high-quality CR-39 SSNTD from Pershore Moulding Ltd., UK, 500 μm thick in the form of large sheets which were cut into 1.5 cm × 1.5 cm which is fixed by double side solo tape on the bottom of the plastic cup. A total of 25 dosimeters were distributed inside various rooms in the region under investigation. In each room, the detectors were placed above the floor at a height of about 1.25 m. The time of exposure in all sites was approximately 3 months. The structure of these passive radon dosimeters had been described as shown in Figure 1. The design of the chamber ensures that the radon gas diffuses through it to the chamber and all aerosols and radon decay products are deposited on the soft sponge from the outside. After that, have been collected detectors and chemically etched by using 6.25 M solution of NaOH in the water bath with a controlled electric heater for 8 hours at a fixed temperature of 70°C in temperature-controlled etching bath (to ± 0.1 oC). After etching, the detector is dried off after washed in distilled water. After that the tracks were counted manually by chosen for 30 randomly fields of view, by the optical microscope and using a magnification of 400X, to obtain the best value of average and representative of the density of track for each dosimeter.

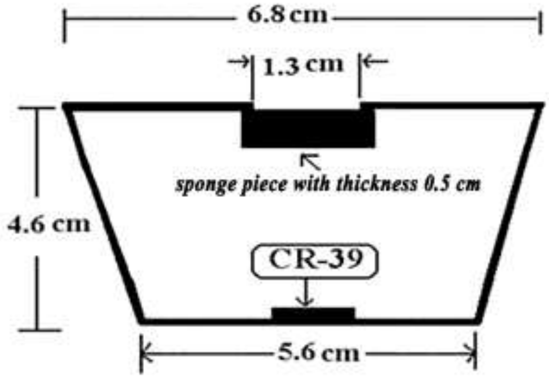

Figure.2: dosimeter radon passive cumulative

Radon concentration (C) was measured by passive methods, calculated as [14,15]:

$$C\ (Bq/m^3) = \frac{\rho}{k.t} \qquad (1)$$

Where

ρ: the surface density of tracks on the exposed detectors(Tr/cm^2), *t:* the exposure period (90 day)

k: the experimentally value of factor of calibration (0.223 $track.cm^{-2}/ Bq.d.m^{-3}$) [17].

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The annual effective dose for 222Rn and it daughters assessed by the measured concentrations of ^{222}Rn based on conversion factors given by UNSCEAR reports [4]. The annual effective dose at any location depends upon the occupancy factor and to annual absorbed dose. The occupancy factor for the workers and the stuffs in the Imam Al-Hussain Holy shrine were calculated using the following equations [18]: For Buildings Surrounding Imam Hussain Holy shrine: (48 h /wk)×(40 wk /yr)= 1920 h /yr. Thus, the Buildings Surrounding Imam Hussain Holy shrine occupancy factor (Q) = 1920h/8760h = 0.22. For homes: the occupancy factor (Q) = 0.8. The annual absorbed dose (D_{Rn}) is given by the following:

$$D_{Rn}\,(m\,Sv/y) = C \times D \times Q \times E \times T \qquad (2)$$

Where

C: the measured ^{222}Rn concentration (in Bqm^{-3}).

E: the equilibrium factor between radon and its progeny (0.4).

T: (24 h ×365 days in year = 8760 h y^{-1}).

D: the factor of dose conversion (9.0 x 10^{-6} mSvh^{-1} per Bqm^{-3}), represented the effective dose that adults were received it per unit activity of radon gas per unit of air volume [19,20].

To calculate the annual effective dose, Should apply a tissue and radiation weighting factors with in ICRP, 1991 [21]. The equivalent dose resulted from absorbed dose of radiation. The weighting of radiation (W_R) index for α-particles is 20 as recommended by ICRP, 1991 [21]. With the effective dose, a index of tissue weighting (W_T) is applied. According to ICRP, the index of tissue weighting for lung is 0.12. The annual effective dose can be calculated by the equation below:

$$H_E(mSv/y) = D_{Rn} \times W_T \times W_R \qquad (3)$$

^{222}Rn decays quickly, when inhaled radon gas which consist of tiny radioactive particles with Long-term exposure of it caused damage or distort the cells in the lung and can lead to lung cancer. the probability of lung cancer per year per million person (LCC) can be calculate by using the risk factor lung cancer induction 18×10^{-6} (mSv^{-1}) and by using the following equation [22].

$$LCC = H_E(mSv/y) \times 18 \times 10^{-6}(mSv^{-1}) \qquad (4)$$

In order to calculated the probability of increase in the lung cancer in the air of Buildings Surrounding Imam Hussain Holy shrine in Karbala of Iraq using the following equation:

$$C_P = C \times 9.7 \times 10^{-5} \qquad (5)$$

Where:

C_P : The probability (%) of cancer caused by ^{222}Rn

C: is the concentration of radon in Bq.m^{-3} and the conversion factor (cancer probability / Bq.m^{-3}) comes from Cross [23].

4. Results and Discussion

In this study, indoor radon concentrations were meas-ured in different compartments for 25 different locations of Buildings Surrounding Imam Hussain Holy Shrine in Karbala of Iraq. Table 3 and figure 3 summarize the results ob-tained in the current study for concentrations of radon gas in indoor Buildings Surrounding Imam Hussain Holy Shrine in Karbala of Iraq, it can be noticed that the highest radon concen-tration in indoor

buildings was found in B1 (Keep system department) region which was (88.233 Bq/m3), while the smallest aver-age concentration of radon was found in B11 (Wire and wireless communication department) region which was (23.958Bq/m3)
with an aver-age value of (39.958 Bq/m3), which is less than even the lower limit of the recommended range (200- 300 Bq/m3) (ICRP, 2009) [24].
From eq. (3) and Table (3); the annual effective dose in the studied buildings varies between are0.399 to 1.469 mSvy-1 with an average 0.655mSvy–1. In its recent reports of UNSCEAR, the world average is 1.15mSvy-1 [19].
Based on this recommendation, it has been observed that most of the values are higher than the global average value reported by UNSCEAR, but there are within the limit of the recommended action level of 3-10 mSvy-1 [20]. Therefore, the health risk due to radon is possibilities, and for a few of those rooms, the health risk is very high. According to this study, the radon induces lung cancer risks. In the study area, the total average values of LCC in the building are 11.800 per million person per year. This means that the dose due to radon may cause 11.800 lung cancer cases among each 1 million inhabitants of building per year. As shown in table 2, it is found that LCC ranged between 7.181 and 26.445 per million person per year. These values in this study within the limit of the range (170-230) per million person per year, which recommended by the ICRP 1993 [25], which means that there is a high risk of cancer due to high concentrations of radon. The results of this study showed that it is less than the results of previous studies of researchers conducted on the air of different buildings in Karbala Governorate [9-14].
The risk of lung cancer Increase when the radon concentration increases if we took the coefficient of lung cancer caused by natural radiation [23]. Therefore, the increase in the probability of lung cancer caused by radon gas for the study area. (See Table 4).
Figures 4 and 5 show the Positive correlation between radon concentration with lung cancer cases per year per million person(LCC) and Increase the probability of lung cancer due to radon (%) in indoor building samples in all locations studied.
Our work showed that a secondary source of indoor radon gas is associated with the natural radioactivity of cement, concrete, bricks, and gravel used in the construction of studied buildings. We can decrease Radon gas concentration levels in several ways, including:
1- Improving the Air exchange of the building.
2- Sealing walls and floors.
3- Increasing under-floor Air exchange.
4- Installing system of radon sump.
5- Installing a positive supply ventilation system or whole dwelling positive pressurization.

Table 3. Track density (ρ), radon gas concentration(C), absorbed dose (D_{Rn}) , annual effective dose(H_E) and lung cancer cases per year per million person (LCC).

Location	sample code	ρ Track/cm^2	C Bq/m^3	D_{Rn} $mSvy^{-1}$	H_E $mSvy^{-1}$	$LCC \times 10^{-6}$
1	B1	1770.833	88.233	.612	1.469	26.445
2	B2	563.334	28.068	.195	.467	8.413
3	B3	645.834	32.179	.223	.536	9.645

4	B4	815.418	40.629	.282	.677	12.177
5	B5	962.084	47.936	.333	.798	14.367
6	B6	604.584	30.124	.209	.502	9.029
7	B7	939.167	46.795	.325	.779	14.025
8	B8	870.418	43.369	.301	.722	12.999
9	B9	920.834	45.881	.318	.764	13.751
10	B10	732.918	36.518	.253	.608	10.945
11	B11	480.834	23.958	.166	.399	7.181
12	B12	545.000	27.155	.188	.452	8.139
13	B13	1021.667	50.905	.353	.848	15.257
14	B14	710.001	35.376	.245	.589	10.603
15	B15	1040.000	51.819	.360	.863	15.531
16	B16	875.001	43.597	.302	.726	13.067
17	B17	774.168	38.573	.268	.642	11.561
18	B18	856.668	42.684	.296	.711	12.793
19	B19	687.084	34.234	.238	.570	10.261
20	B20	627.501	31.266	.217	.521	9.371
21	B21	664.168	33.093	.230	.551	9.918
22	B22	650.417	32.407	.225	.540	9.713
23	B23	522.084	26.013	.180	.433	7.797
24	B24	783.335	39.030	.271	.650	11.698
25	B25	691.668	34.463	.239	.574	10.329
Average		790.200	39.372	0.273	0.655	11.800
Minimum		480.834	23.958	0.166	0.399	7.181
Maximum		1770.833	88.233	0.612	1.469	26.445

Table 4. Increase in the probability of lung cancer caused by radon gas for study area.

Location	sample code	Increase the probability of lung cancer due to radon (%)	Location	sample code	Increase the probability of lung cancer due to radon (%)
1	B1	0.85	15	B15	0.50
2	B2	0.27	16	B16	0.42
3	B3	0.31	17	B17	0.37
4	B4	0.38	18	B18	0.41
5	B5	0.46	19	B19	0.33
6	B6	0.29	20	B20	0.30
7	B7	0.45	21	B21	0.32
8	B8	0.42	22	B22	0.31
9	B9	0.44	23	B23	0.25
10	B10	0.35	24	B24	0.37
11	B11	0.23	25	B25	0.33

12	B12	0.26	mean	0.38
13	B13	0.49	minimum	0.23
14	B14	0.34	maximum	0.85

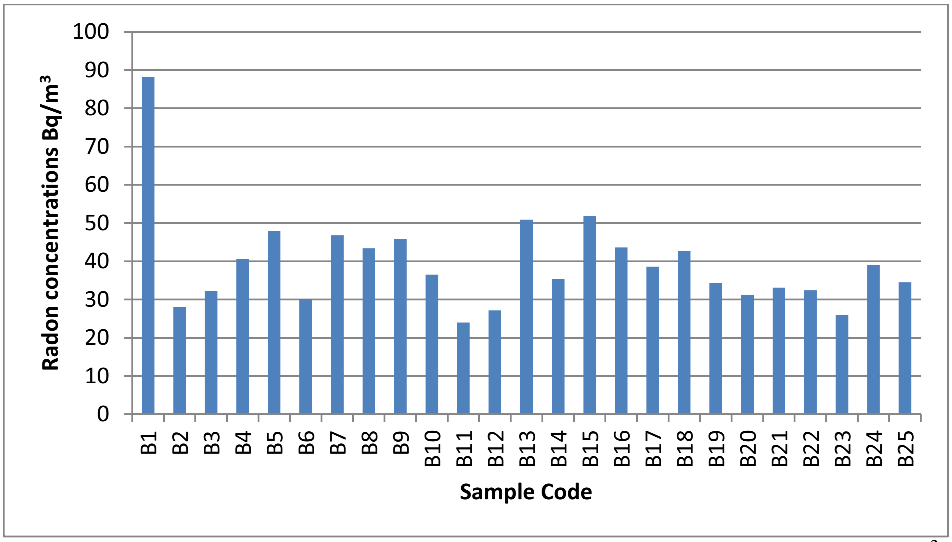

Figure 3: A histogram show the change in concentration of radon gas (Bq/m^3) in indoor building samples in all locations studied.

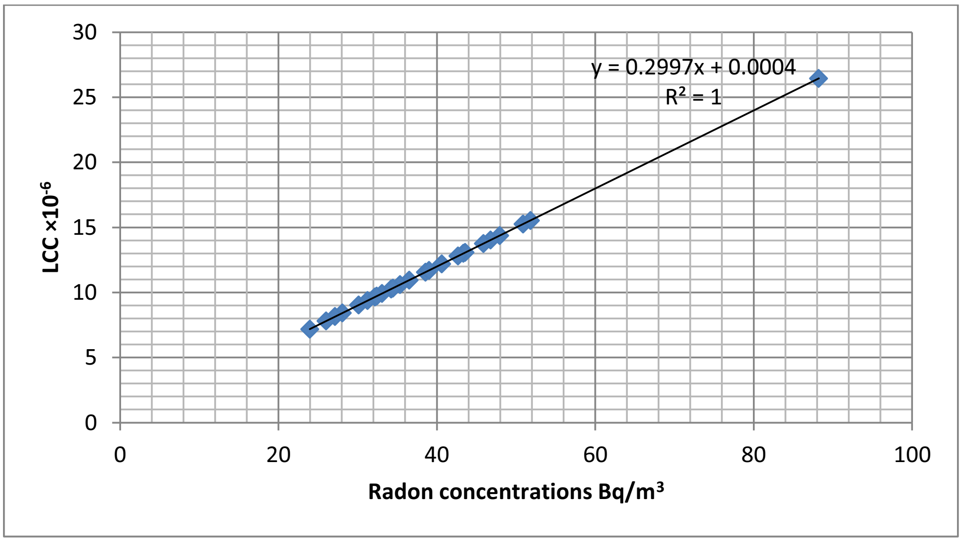

Figure 4. Correlation between concentration of radon and lung cancer cases per year per million person (LCC) in indoor building samples in all locations studied.

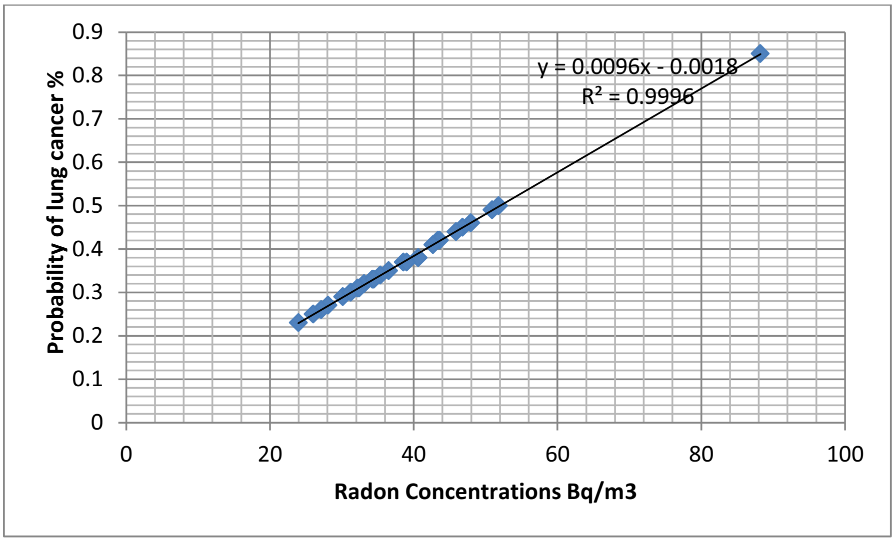

Figure 5. Correlation between radon concentration and Increase the probability of lung cancer result from radon (%) in indoor building samples in all locations studied.

5. Conclusions

The results of the present work provide an additional database on the indoor radon level in the Karbala governorate. The indoor radon concentration values measured in the air of buildings surrounding Imam Hussain holy shrine in Karbala of Iraq vary from 23.958 to 88.233 Bqm-3 with an average 39.372 Bqm-3 which is lower than the range (200-300 Bqm-3) recommended by (ICRP, 2009). The present values of indoor annual effective doses vary from 0.399 to 1.469 mSvy-1 with an average 0.655mSvy–1 which is on the lower side of the recommended range (3-10 mSvy-1) (ICRP, 1993). The positive correlation between radon concentration with lung cancer cases per year per million person (LCC) and Increase the probability of lung cancer due to radon (%) in indoor building samples in all locations studied. And hence will pose relatively none serious health risk.

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