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Estimation of Indoor Radon Concentration in Some Houses in Al-Shatra District, Dhi-Qar Governorate, Iraq

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ABSTRACT

Radon is present in houses and everywhere and causes lung cancer, heart problems, and respiratory infections in those who breathe it. Indoor Radon levels were tested for two months in 65 houses in the Al-Shatra, Dhi-Qar Governorate, Iraq, using solid-state nuclear track detectors CR-39. The results obtained indicate that the concentration rates varied clearly, as the lowest concentration was 20.805 Bq/m^3 in Al-Moalmen, while the highest concentration was 114.431Bq/m^3 in AL-Shaala, with an average of 63.391±22.73Bq/m^3. The annual effective inhalation has varied between 0.524 mSv/y and 2.886 mSv/y with a mean of 1.598 mSv/y. On the other hand, the average lung dose was 2.529 nGy/ h. All the results indicate the radon gas levels are within the permissible limits compared to the recommended by American Environmental Protection Agency EPA, which are set at 148Bq/m^3, and the inhalation dosage is less than ICRP recommended action limit of 3 mSv/y.

INTRODUCTION

Natural sources of radioactivity in the environment are known as naturally occurring radioactive materials (NORM) and are classified as cosmic and terrestrial in origin. NORM is naturally found in the environment. NORM is present in varying amounts in rocks, soil, water, vegetables, air, building materials, and the human body itself. The specific levels of radioactivity in various soils are related to the nature of the parent rock (Ramsiya et al. 2017).

The radionuclides emit alpha particles, beta particles and gamma rays. It can be ingested or inhaled into the body, enters the lungs, and has an impact on the cells of the lungs, the cases of lung cancer, or it enters the human bloodstream and damages blood cells, causing leukemia (Showard & Aswood 2019). Radon is a noble radioactive gas that is produced when the natural uranium chain decomposes. It is colorless, odorless, and tasteless, and it is imperceptible to the human senses. It consists of three isotopes: Radon (^{222}Rn), Thoron (^{220}Rn), and Actinon (^{219}Rn) (Tawfiq et al. 2015, Bineng et al. 2020). The main contribution to inhalation exposure comes from the short half-life decay products of radon. It may infiltrate houses through cracks and pores in floor tiles, as well as through soil through building materials such as sand, cement, and other components (Kadhim et al. 2022, Fahiminia et al. 2016). The internal focus of Radon may depend on the parent elements connecting the dwellings as well as the interior designs (Mehra et al. 2017, Aswood et al. 2019). Radon has been identified as a risk factor for lung cancer because it breaks down into radioactive particles that can get stuck in the lungs (Rashid 2014). There are many studies have shown that (5 to 20%) of lung cancer deaths can be attributed to breathing air containing radon and its daughters, and Indoor Radon concentration measurements in nations to create baseline data on natural radiation levels (Farid 2016, Tawfiq et al. 2015, Fahiminia et al. 2016). Studies have confirmed that exposure to radon gas and its daughters the risk of developing bronchial epithelial cells, the cause of lung cancer (Tawfiq et al. 2015, Kaur et al. 2018). Exposure to Radon and its components contributes to more than 50% of the total radiation dose received by humans from natural sources (Aswood et al. 2018, Salih et al. 2019). The goal of the present study is to measure the Indoor Radon in 65 homes in the Al-Shatra, Dhi-Qar Governorate, Iraq using CR-39 detectors as well as their related lung doses.

MATERIALS AND METHODS

Study Area

Indoor Radon was carried out in 65 dwellings in the city of Al-Shatra and located approximately 40 km the North of Nasiriyah. It is located from 46°11'34'' to 46°8'42'' N latitude and 31°23' 5'' to 31°26'16'' E longitude. The governorate is divided into five administrative divisions: Nasiriyah, the center of the governorate, Al Shatra, Suq Al-Shuyoukh, Al-Rifai, and Al-Jabayish. The area of Al Shatra is estimated at 384 km^2, and its population according to the 2014 census is 254 thousand people (Rashid 2014). The city is located on one of the two branches of the Gharraf river, which descends from the Tigris river, in the middle Euphrates region in southern Iraq.

CR-39

A passive method using CR-39 track detectors based on the SSNTD technique was employed for the assessment of radon concentration in some regions in Al Shatra city. Detectors (CR-39) of the thickness (500 µm) and size 1.5×1.5 cm^2 were exposed to the indoor environment of a dwelling for a known period of two months.

Collected Samples

Sixty five dwellings in Al Shatra city, Dhi-Qar governorate were selected for the Radon study. The choice of houses was random. The majority of the houses were built of concrete with plastered walls with a proper ventilation system. The detectors were placed at a height of about 1.5 m from the ground is the level of breathing. Detectors were placed in different rooms on the ground floor of the dwelling. After that, the reagents from houses were collected and prepared for etching using a sodium hydroxide solution NaOH with a density of 6.25 mol/L at a temperature of 70° C for 6 hours, and then washed with distilled water (Aswood et al. 2019). The number of tracks was calculated using an optical microscope with a magnification capacity of 400X.

Calculation

Measurement of Radon-222 concentrations (C_{Rn}) in the air was calculated according to equation 1 as suggested by (Karim et al. 2017).

$$\rho(\frac{tr}{cm^2}) = \frac{N_t}{A} \quad \ldots (1)$$

ρ: the track density (track /mm^2), N_t: the average number of tracks on the CR -39 detector, A: area of view field visible under the microscope**.**

Radon concentration has been calculated in samples using the following equation 2 (Showard & Aswood 2019).

$$C_{Rn}(\frac{Bq}{m^3}) = \frac{\rho}{K \times t} \quad \ldots (2)$$

Where, C_{Rn}: Radon concentration, t: The storage time 60 days, K: The calibration factor of CR-39, the calibration factor K is 0.02607 Track.cm^{-2} /Bq.m^{-3} day. This factor is determined using the equation below which is a function of tube parameters:

$$K=0.25r\ (2\cos\Theta_c - \frac{r}{r_\propto}) \quad \ldots(3)$$

Where, r: is tube radius and equals 1.75cm, Θ_c is the critical angle of CR-39 detectors and $\Theta_c = 35°$, and r_α is alpha particle range in air (r_α = 4.15 cm) (Ramsiya et al. 2017).

The annual effective dose was calculated by equation 4 (Obaed & Aswood 2020b).

$$AED\ (m\ Sv/y) = C_{Rn} \leftarrow F \leftarrow H \leftarrow T \leftarrow D \quad \ldots(4)$$

where (F) is the equilibrium factor and it is equal to (0.4), (H) is the occupancy factor which is equal to (0.8), (T) is the time in hours in one year, (T=8760 h.y^{-1}), and (D) is the dose conversion factor which is equal to [9 $\leftarrow 10^{-6}$ (m.Sv^{-}) / (Bqh.m^{-3}) (Obaed & Aswood 2020b).

When calculating the dosage rate to the lungs, the air volume in the lungs by equation 5 (Abbady et al. 2004).

$$\text{Dose rate to lung, D lung} = 0.04 \leftarrow C_{Rn} \quad \ldots(5)$$

RESULTS AND DISCUSSION

Indoor radon has been measured in 65 houses by CR-39, Shatra, Dhi-Qar Governorate-Iraq. The results showed the highest concentration of 114.431 ± 37.46 Bq.m^{-3} in AL-Shaala, while the lowest concentration of Radon 20,805 ± 5.67 Bq.m^{-3} was in the AL-Moalmen, with an average was 63.246 ± 22.8 Bq.m^{-3}, as presented in Table 1. The high concentration is attributed to the war in 1991 and 2003. In addition, the dwellings are quite old and cramped, with no good ventilation. On the other hand, the results have been compared with the worldwide concentration limit of 148 Bq.m^{-3} set by the International Commission on Radiological Protection (ICRP 1993). The annual effective inhalation has varied between 0.524 mSv.y^{-1} and 2.886 mSv.y^{-1} with a mean of 1.598 mSv.y^{-1}. On the other hand, the average lung dose was 2.529. The inhalation dosage levels indicate within the permissible limits compared to the recommended ICRP of 3 mSv/y.

From Fig.1, the average concentration of Radon for the ten states has been indicated as the highest average in Besan (91.26 Bq.m^{-3}) and the lowest concentration was in AL-Fattahia (43.78 Bq.m^{-3}). The variance of the average concentration for ten states depends on different areas of the houses and different construction of the building of the house as well as the effect of the war, especially for the state of Besan. The annual effective doses of Besan are higher than the ICRP standard (Khalid et al. 2014). The increase in the effective annual dose depends on the building materials used,

Table 1: Indoor Radon concentration, annual effective dose (AED), and dose lung (D_{lung}) for Al-Shatra city in Thi-Qar Governorate, Iraq.

Sample code	Location	Concentration ($Bq.m^{-3}$)	Annual effective dose (AED) $msv.y^{-1}$	D_{lung} ($nGy.h^{-1}$)
S 1	AL-Moalmen	106.86 ± 13.4	2.69	4.27
S 2		74.71 ± 12.29	1.88	2.98
S 3		59.587 ± 10.4	1.508	2.38
S 4		79.44 ± 17.54	2.004	3.17
S 5		28.37 ± 9.45	0.715	1.13
S 6		20.805 ± 5.67	0.524	0.83
S 7		74.71 ± 36.49	1.884	2.98
S 8		34.045 ± 7.565	0.859	1.36
S 9		60.525 ± 22.053	1.526	2.423
average		59.89 ± 14.98	1.509	2.39
S 10	AL-Fattahia	43.503 ± 20.371	1.097	1.74
S 11		47.285 ± 18.914	1.193	1.89
S 12		45.394 ± 21.482	1.145	1.81
S 13		79.44 ± 35.435	2.004	3.17
S 14		33.10 ± 24.751	0.835	1.32
S 15		39.72 ± 15.131	1.002	1.58
S 16		29.317 ± 13.001	0.739	1.17
S 17		46.34 ± 20.48	1.169	1.85
S 18		25.534 ± 8.511	0.644	1.02
S 19		48.231 ± 17.667	1.216	1.92
average		43.78 ± 19.57	1.10	1.75
S 20	AL-Shomali	22.697 ± 4.633	0.572	0.90
S 21		27.425 ± 11.543	0.691	1.09
S 22		41.611 ± 19.927	1.049	1.66
S 23		65.254 ± 26.898	1.646	2.61
S 24		93.625 ± 29.741	2.362	3.74
S 25		83.223 ± 24.588	2.099	3.32
S 26		75.657 ± 18.914	1.908	3.02
S 27		77.548 ± 31.021	1.956	3.10
S 28		73.765 ± 29.545	1.861	2.95
average		62.31 ± 21.86	1.57	2.49
S 29	AL-Shortah	81.331 ± 38.808	2.051	3.25
S 30		46.34 ± 25.534	1.169	1.85
S 31		66.20± 24.295	1.67	2.64
S 32		86.06 ± 24.823	2.171	3.44
S 33		69.037 ± 29.921	1.741	2.76
S 34		66.20 ± 27.733	1.67	2.64
S 35		65.254 ± 18.652	1.646	2.61
S 36		43.502 ± 12.828	1.097	1.74
S 37		69.983 ± 22.057	1.765	2.79

Table cont....

Sample code	Location	Concentration (Bq.m^{-3})	Annual effective dose (AED) msv.y^{-1}	D_{lung} (nGy.h^{-1})
average		65.98 ± 24.69	1.66	2.63
S 38	AL-Zhour	69.983 ± 24.369	1.765	2.79
S 39		43.502 ± 29.362	1.097	1.74
S 40		23.642 ± 6.344	0.596	0.94
S 41		43.502 ± 7.565	1.097	1.74
S 42		61.471 ± 18.556	1.55	2.45
S 43		63.363 ± 26.765	1.598	2.53
S 44		59.58 ± 22.399	1.503	2.38
average		52.14 ± 19.33	1.31	2.08
S 45	AL-Shaala	45.394 ± 22.697	1.145	1.81
S 46		94.571 ± 39.221	2.385	3.78
S 47		114.431 ± 37.46	2.886	4.57
S 48		44.448 ± 41.016	1.121	1.77
S 49		49.177 ± 16.811	1.24	1.96
S 50		52.014 ± 12.147	1.3122	2.08
S 51		71.874 ± 25.092	1.813	2.87
average		67.410 ± 27.77	1.70	2.69
S 52	Besan	51.068 ± 20.371	1.288	2.04
S 53		99.30 ± 43.595	2.505	3.97
S 54		105.92 ± 32.978	2.672	4.23
S 55		108.757 ± 35.195	2.743	4.35
average		91.26 ± 33.03	2.30	3.65
S 56	AL-Hawi	61.471 ± 24.751	1.55	2.45
S 57	AL-Badaa	88.897 ± 30.848	2.242	3.55
S 58		82.277 ± 30.513	2.0757	3.29
S 59		65.254 ± 32.883	1.646	2.61
S 60		104.974 ± 33.953	2.648	4.19
average		85.35 ± 32.04	2.15	3.41
S 61	AL-Khalsah	102.137 ± 24.222	2.576	4.08
S 62		70.928 ± 19.496	1.789	2.83
S 63		34.991 ± 10.402	0.882	1.39
S 64		97.408 ± 33.582	2.457	3.89
S 65		69.037 ± 27.749	1.741	2.76
average		74.90 ± 23.09	1.89	2.99
Total Average		63.246 ± 22.806	1.59	2.52

the nature of the soil, and improper aeration. On the other hand, the lung dose value (D_{lung}) varies from 3.65 (nGy.h^{-1}) to 1.75 (nGy/ h^{-1}) as shown in Fig. 2. These results depend on the concentrations of radon.

The results have been compared with different studies in the world as presented in Table 2. The comparisons have been showing the results from Iraq (Hilla), India, Germany, Iran, and Saudi Arabia were lower than those in the present study. Whilst, the previous studies of Iraq (Baghdad, Kurdistan) have been highest than the present study, as shown in Table 3, and the difference in concentration is due to the nature of the land, as well as ventilation and temperature,

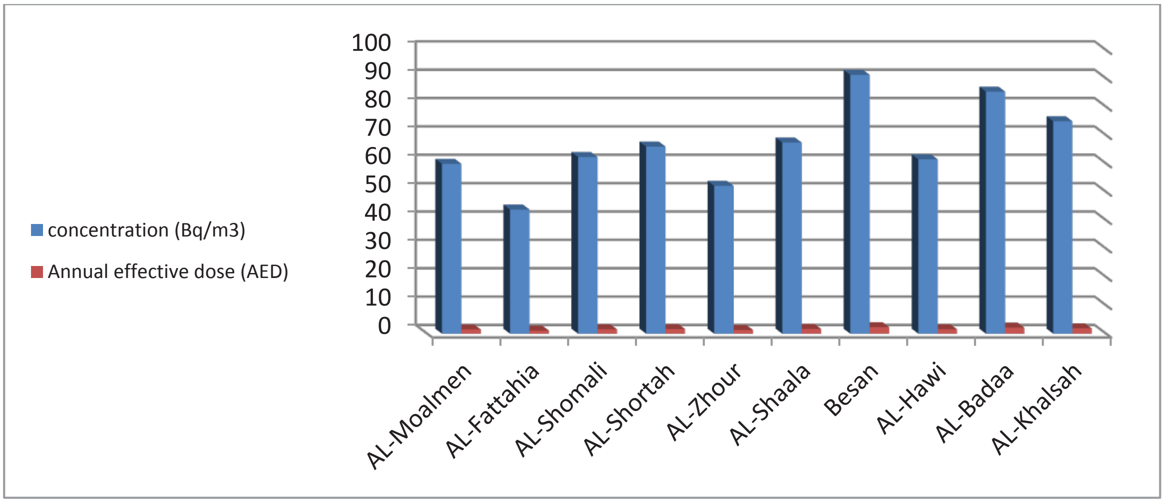

Fig. 1: Average Indoor Radon concentration and annual effective dose (AED) with different states.

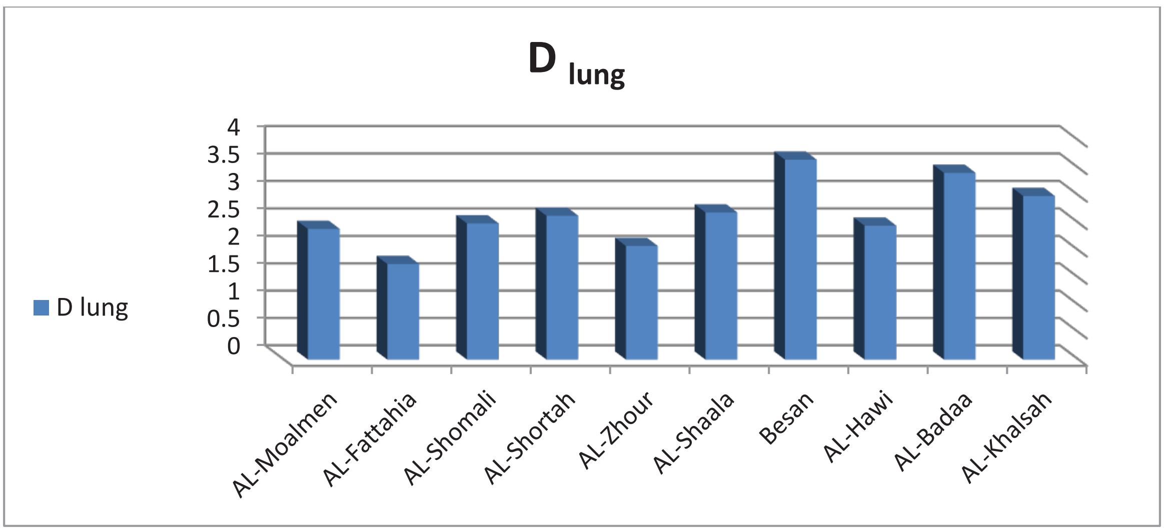

Fig. 2: Dose lung (D_{lung}) with different states.

and that Indoor Radon concentrations range within the safe levels.

CONCLUSION

Indoor Radon concentrations have been measured in some houses in the city of Al- Shatra, Dhi-Qar Governorate, Iraq for 65 houses by the CR-39 nuclear track detector. The variance results have been found in different houses in the city of Al- Shatra. The concentration of radon was higher in some houses than recommended by American Environmental Protection Agency. The highest concentration of radon attributes to wars in 1991 and 2003. On the other hand, the different building materials, ventilation, pressure, and temperature are the main reason for the variance in radon concentration. The average annual effective dose was within the ICRP standard. The results indicate that Indoor Radon levels are within the permissible limits compared to the recommended by the American Environmental Protection Agency.

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Table 2: Comparison of Indoor Radon concentrations of the present study with other studies in the world.

Region	Concentration (Bq.m^{-3})	Annual effective dose	References
Baghdad, Iraq	123.8652	2.958	Salim and Ebrahiem (2019)
Baghdad, Iraq	116.78	2.95	Tawfiq et al. (2015)
Hilla, Iraq	4.18 ± 1.1	0.11±0.01	Obaed and Aswood (2020a)
Kurdistan, Iraq	143.7±46.1	3.62±1.16	Ismail and Jaafar (2010)
Saudi Arabia	36.2 ± 1.21	0.61 ± 0.18	Farid (2016)
Iran	55.1 ± 59.3	1.39 ±1.49	Hassanand et al. (02019)
German	55.9	2.2	Abbady et al. (2004)
India	25.52	0.64	Kadhim et al. (2022)
Dhi-Qar, Iraq	63.246 ± 22.806	1.59	Present study

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