SHORT REPORT

Assessment of tracheobronchial and lung dose due to radon and thoron inhalation

Shatha Farhan Alhous[1], Ansam Fadil Showard[2], Shaymaa Awad Kadhim[3]

Abstract

The main sources of natural background radiation are radon, thoron and their progeny, which may cause health risks to humans. Keeping in mind the importance of the subject, three samples each from 10 selected residential areas, including the centre of Babylon Governorate, Iraq, and its districts, were collected. Concentration of radon and thoron was measured using solid-state track detectors (CR-39). The arithmetic means of the concentration of radon and thoron were 47.367±19.56 and 133.246±16.585 Bqm-3, respectively; these values are considered safe when compared with the upper reference level of 200-600 Bqm-3 recommended by the International Commission for Radiological Protection (ICRP). The value of the inhalation equivalent dose from radon gas discovered in these areas with rate 37.893 nSv is less than the value of the global average of 1.15 mSv. This indicates that the risks related to inhalation of radon are low as the lung dose rate (DLung), tracheobronchial region (DT-B), annual effective dose (AED) and excess lifetime cancer risk (ELCR) is (1.894 nGyh-1, 22.736 nSv, 0.236 mSvy-1 and 0.835 x10-3), respectively. While the value of the inhalation equivalent dose (IED) from thoron as effective dose to lung DLung, AED and ELCR are equal to (0.133 nSv, 0.167 mSvy-1 and 0.587 x 10-3), respectively. To conclude, the rates in the study area are less than the ICRP recommended level of 3 mSv; therefore, the studied areas are safe from the health risks of inhalation of radon and thoron.

Key Words: Radiation, Radon, Lung,

DOI: https://doi.org/10.47391/JPMA-BAGH-16-83

Introduction

The exhalation of radon gas present in the earth's crust is related to the presence of radium and its precursors. Although these elements are present in virtually all types of rocks and soils, their concentration varies depending on the soil's location and geological components.[1, 2] The health effects of radon and its products are a source of concern because they are heavier than air, and tend to stay close to the ground, where they emit alpha ionized particles. The risk to human health is very low when we inhale the air in open spaces due to its low concentration. Radon is generated because of the spontaneous decay of the radium isotopes 226Ra. A reference level of 3 mSv for lung dose due to inhalation of 222Rn and 220Rn has been set by the International Commission on Radiological Protection (ICRP) to ensure the safety of people living in dangerous areas.[2-5] The concentration of radon in closed places is greater than in open places and more in winter than in summer, as closed places and lack of ventilation make matters worse because they lead to the accumulation of gas in these closed places. The danger of inhaling radon lies in the emission of alpha particles. The human respiratory system, especially the lung, can be vulnerable to this internal exposure, because it is the respiratory organ of the human body. Exposure to high doses can lead to the possibility of lung cancer.[6-9] Many studies have been conducted around the world to determine the concentration of radon and thoron in the soil and its health consequences, such as the radon concentrations in farmland soil collected from Al-Qadisiyah, Iraq.[1] On the other hand, a study in Pirayiri, India, shows that the geometric mean of radon and thoron concentration is slightly higher than the nationwide average value. The Jalandhar and Kapurthala districts of Punjab, India, were chosen to estimate the quantity in the lung, tracheobronchial region, pulmonary and pulmonary lymph region due to radon concentration and thoron exposure[10]. This study aimed to determine the health risk from inhalation of radon and thoron in the soil of Babylon, Iraq, by nuclear track detector CR-39.

Methods and Result

Thirty samples were collected during November to December 2021, from the city of Babylon and its suburbs, in the centre of Iraq, as shown in Figure 1. CR-39 is a plastic polymer that is the abbreviation for Columbia Resin-39 and has optical properties similar to those of optical glass[2,3]. In the current study, CR-39 detectors have been used, with sizes (1.5 and 1.5) cm. A can with size 10cm in height and 5.5cm in inner diameter was used to

[1,3]Department of Physics, University of Kufa, Iraq.[2] Department of Radiological Techniques, Al-Mustaqbal University College, Hilla, Iraq
Correspondence: Shatha Farhan Alhous
Email: shathaf.alfatlawi@uokufa.edu.iq

measure the level of radon and thoron from the collected samples. Twenty grams of the samples were stored for two months in a can with two detectors, the first on top to measure Rn-222 and the second on top of the sample to measure Rn-220. After 60 days of exposure, the detectors from all the cans were retrieved. The optimum condition of etching of the CR-39 detectors was 6.25% N-NaOH at 70 °C with an accuracy of ± 0.1 °C and an etching time of six hours.1 After etching, the detectors were washed in distilled water and then dipped for a few seconds in a 3% acetic acid solution. After that, the detectors were washed again and allowed to dry in the air. The number of tracks in 40 fields were scanned for each detector using an optical microscope (400X objective lens) which was used to determine the track density.

Calculations

The radon CR and thoron CT concentrations in the air were calculated according to the following equations:[10-12]

$$C_R = \frac{T_R - B_R}{T \times K_{RR}}$$

1

2

$$C_T = \frac{(T_{RT} - B_{RT}) - (T \times C_R \times K_{RRT})}{T \times K_{TRT}}$$

KRR, KRRT and KTRT are the calibration factors for radon and thoron, BR, BRT, TR and TRT are the background count stand tracks obtained after exposure, and T is the time (60 days). The equivalent dose (H) of radon was determined by equation 3 according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).[13]

$$H = 8 \times 10^{-10} \times C_R$$

3

The effective dose is related to the location of the organ exposed to radiation and its sensitivity to radiation. For the tracheobronchial region (DT-B), it was determined using tissue weight (WF) values of 0.6 as defined in equation4.[11]

$$D_{T-B} = H \times W_F$$

4

The radon and thoron concentration of the air present inside the lung must also be taken into account to calculate the annual equivalent dose to the lungs, where the air volume in the lungs is taken to be 3.2 x10-3m^3 for the reference in human beings.[13] It was assumed that the short-lived decay products of 222Rn will stay in the lungs. The dose rate due to alpha particles emitted by radon was determined by equation 5. Whilst the lung exposure was estimated from thoron using Postendorfer's dose conversion factor11, based on a lung dose model with a structure comparable to the ICRP respiratory model by equation 6: [11].

$$D_{Lung} = 0.04 \times C_R$$

5

$$D_{Lung} = 0.001 \times C_T$$

6

The annual Effective Inhalation Dose (EID) was calculated using formula 7:[10, 12]

$$EID = EEC \times DCF \times OF$$

7

where EEC is the equilibrium equivalent concentration of radon or thoron were calculated using equation [8].

$$EEC = F \times C$$

8

where F is the equilibrium factor is 0.4 for radon and 0.1 for thoron. While C is the concentration for radon and thoron.

The dose conversion factors DCF for radon (9 nSvh-1Bq-1m3) and (40 nSvh-1Bq-1m3) for thoron and OF (7000 h) is the occupancy.

The estimation of excess lifetime cancer risk (ELCR) is determined for radon and thoron exposure by equation 9:[10, 12]

$$ELCR = EID \times DL \times RF$$

9

DL is the mean adult lifespan of 70 years, Annual Effective Dose (AED) and RF is the risk factor value for random effects for the general population, which is 0.05 per Sievert as recommended by the ICRP.[14]

Discussion

Radon concentration measured in 30 samples collected

Table-1: ^{222}Rn concentration and their corresponding doses at different locations.

LOCATION	ID	C_R (Bq.m^{-3})	H (nSv)	D_{Lung} (nGy.h^{-1})	D_{T+B} (nSv)	EID (mSv.y^{-1})	ELCR *10
Al-Mudhatia	S_{01}	52.59	42.072	2.103	25.243	0.265	0.9276
	S_{02}	41.15	32.92	1.646	19.752	0.207	0.725
	S_{03}	40.27	32.216	1.610	19.329	0.202	0.710
Al-Qasim	S_{04}	47.31	37.848	1.892	22.708	0.238	0.834
	S_{05}	52.59	42.072	2.103	25.243	0.265	0.927
	S_{06}	37.62	30.096	1.504	18.057	0.189	0.663
Al-Shomali	S_{07}	41.39	33.112	1.655	19.867	0.208	0.730
	S_{08}	47.31	37.848	1.892	22.708	0.238	0.834
	S_{09}	39.51	31.608	1.580	18.964	0.199	0.696
Al-Kifl	S_{o10}	36.74	29.392	1.469	17.635	0.185	0.648
	S_{o11}	64.04	51.232	2.561	30.739	0.322	1.129
	S_{o12}	63.10	50.48	2.524	30.288	0.318	1.113
Al-Mhawyl	S_{o13}	41.15	32.92	1.646	19.752	0.207	0.725
	S_{o14}	60.4	48.32	2.416	28.992	0.304	1.065
	S_{o15}	37.62	30.096	1.504	18.057	0.189	0.663
Al-Hashimiyah	S_{o16}	38.51	30.808	1.540	18.484	0.194	0.679
	S_{o17}	30.58	24.464	1.223	14.678	0.154	0.539
	S_{o18}	34.10	27.28	1.364	16.368	0.171	0.601
Centre City	S_{o19}	73.73	58.984	2.949	35.390	0.371	1.300
	S_{o20}	49.95	39.96	1.998	23.976	0.251	0.881
	S_{o21}	150.21	120.168	6.008	72.100	0.757	2.649
Al-Musayib	S_{o22}	29.82	23.856	1.192	14.313	0.150	0.526
	S_{o23}	32.34	25.872	1.293	15.523	0.265	0.927
	S_{o24}	43.79	35.032	1.751	21.019	0.207	0.725
Abu-Griq	S_{o25}	43.79	35.032	1.751	21.019	0.202	0.710
	S_{o26}	34.86	27.888	1.394	16.732	0.238	0.834
	S_{o27}	39.39	31.512	1.575	18.907	0.261	0.927
Al-Iskandaria	S_{o28}	28.82	23.056	1.152	13.833	0.189	0.663
	S_{o29}	43.79	35.032	1.751	21.019	0.208	0.730
	S_{o30}	44.55	35.64	1.782	21.384	0.238	0.834
Mean		47.367±19.56	37.893	1.894	22.738	0.236	0.835

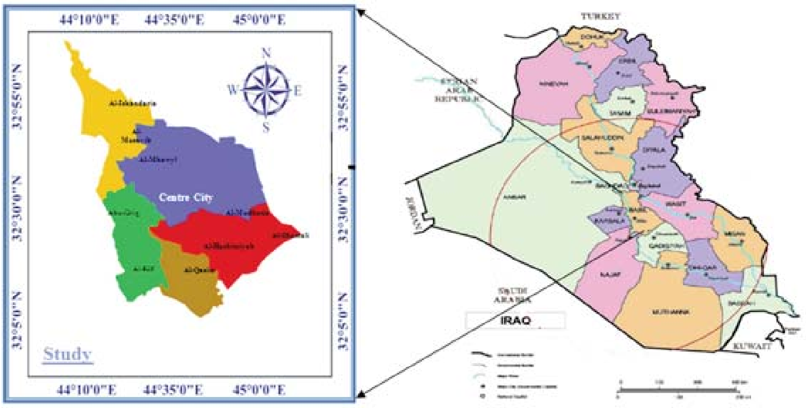

Figure: Map of Babylon Governorate, Iraq present the study area (3).

from different regions of Babylon Governorate, Iraq are summarised in Table 1. The concentrations of radon ranged from 28.82 to 150.21Bqm^{-3}with an average of 47.367±19.56 Bqm^{-3}. Moreover, the inhalation equivalent dose from radon gas has been calculated to be 23.056 to 120.168 at a rate of 37.893 nSvy^{-1}, while the risks of inhaled radon for average dose of lung (DLung) and tracheobronchial region (DT-B) have been determined to be 1.894 nGyh^{-1} and 22.736 nSvy^{-1}, respectively. On the other hand, the average of annual effective dose and the excess lifetime cancer risk has been noted to be 0.238 mSvy^{-1} and 0.835 x 10^{-3}, respectively. According to UNSCEAR 2000[13] and ICRP 1993,[14] the concentration of radon in the soil sample has been below the value (200 - 600 Bq m-3). While, the average of annual inhalation dose has been less than the world average of 1.15 mSv recommended by the UNSCEAR2000[13]. On the other hand, dose of lung and tracheobronchial, as well as the annual effective dose and excess lifetime cancer risk was below the permissible dose equivalent limit of 1 mSv and 2.5 x 10^{-3}, respectively, as mentioned by ICRP.[14] The geological nature is the main reason to contrast the concentrations of radon from one region to another. Depending on the results, the soil samples from the study areas are safe and do not pose any hazard to human health. The thoron concentration is presented in Table 2. The range of

Table-2: ^{220}Rn concentration and their corresponding doses at different locations.

LOCATION	ID	C_T (Bq.m^{-3})	D_{Lung} (nSv)	EID (mSv.y^{-1})	ELCR *10
Al-Mudhatia	So1	66.575	0.066	0.083	0.293
	So2	88.287	0.088	0.111	0.389
	So3	211.564	0.211	0.266	0.933
Al-Qasim	So4	207.456	0.207	0.261	0.914
	So5	212.449	0.212	0.267	0.936
	So6	137.597	0.137	0.173	0.606
Al-Shomali	So7	89.175	0.089	0.112	0.393
	So8	105.374	0.105	0.132	0.464
	So9	85.993	0.085	0.108	0.379
Al-Kifl	So10	102.255	0.102	0.128	0.450
	So11	121.461	0.121	0.153	0.535
	So12	122.925	0.122	0.154	0.542
Al-Mhawyl	So13	162.256	0.162	0.204	0.715
	So14	120.575	0.120	0.151	0.531
	So15	73.738	0.073	0.092	0.325
Al-Hashimiyah	So16	180.164	0.180	0.227	0.794
	So17	107.364	0.107	0.135	0.473
	So18	150.222	0.150	0.189	0.662
Centre City	So19	7.387	0.007	0.009	0.032
	So20	154.327	0.154	0.194	0.683
	So21	32.232	0.032	0.040	0.168
Al-Musayib	So22	147.291	0.147	0.185	0.680
	So23	190.018	0.190	0.083	0.293
	So24	162.844	0.162	0.111	0.389
Abu-Griq	So25	143.002	0.143	0.266	0.933
	So26	95.920	0.095	0.261	0.914
	So27	135.601	0.135	0.267	0.936
Al-Iskandaria	So28	157.848	0.157	0.173	0.606
	So29	204.223	0.204	0.112	0.393
	So30	221.249	0.221	0.132	0.464
Mean		133.246±16.585	0.133	0.167	0.587

concentration is 7.387 to 221.249 with an average of 133.246±16.585 Bqm-3. On the other side, the lung dose, annual effective inhalation dose, and excess lifetime cancer risk have been measured to be 0.133 nSv, 0.167 mSvy^{-1}, and 0.587 x 10-3, respectively. The concentration of thoron in the soil sample has been below the acceptable limit as per recommendation of UNSCEAR 2000 and ICRP 2007, while the worldwide average of the annual inhalation dose and excess lifetime cancer risk have been lower than permission level of 3 mSvy^{-1} recommended by the UNSCEAR[13] and ICRP.[14] The results of radon and thoron concentrations show that the concentration of thoron is higher than the concentration of radon, attributed to the high content of ^{232}Th in soil compared to ^{226}Ra as mentioned in previous study in the study area.[15-18] According to the half-life of radon and thoron, the hazard risk of radon is higher than thoron.

Conclusion

Radon and thoron concentrations have been measured in soil samples collected from Babylon, Iraq. The concentration of radon and thoron has been below the acceptable limit, suggested by UNSCEAR 2000 and ICRP 2007, while the annual effective dose of lung and tracheobronchial and the annual inhalation dose has been lower than that recommended by UNSEAR and ICRP. On the other hand, the excess lifetime cancer risk is significantly lower than the 2.5 x 10^{-3} recommended by ICRP. The results of radon and thoron concentrations indicate that the concentration of thoron is higher than the concentration of radon which attributed to high content of ^{232}Th in soil compared to the ^{226}Ra as mentioned in a previous study in that area. Depending on the results, the soil samples from the study area are safe and do not pose any hazard for human beings.

Acknowledgement: The authors would like to extend their thanks and gratitude to Al-Mustaqbal University College, Iraq for the support it provided to complete this work.

Disclaimer: None.

Conflict of Interest: None.

Funding Disclosure: None.

References

1. Kadhim AY, Al-Ataya KH, Aswood MS. Distribution of Radon Concentration in Farmland Soil Samples in Al-Shamiyah City, Al-Qadisiyah, Iraq. J Phys Conf Ser 2020;1591:012089. doi:10.1088/1742-6596/1591/1/012089
2. Aswood MS, Alhous SF, Abdulridha SA. Life time cancer risk evaluation due to inhalation of radon gas in dwellings of Al-Diwaniyah Governorate, Iraq. Nat Env Poll Tech 2022;21:331-7. doi:10.46488/NEPT.2022.v21i01.040
3. Al-Hamzawi AA, Tawfiq NF, Aswood MS, Najim FA. Determination of radon concentrations near mobile towers in selected cities of Babylon governorate, Iraq. J Phys Conf Ser 2019;1234:012026. doi:10.1088/1742-6596/1234/1/012026
4. Alhous SF, Kadhim SA, Alkufi AA, Muhmood AA, Zgair IA. Calculation of radioactivity levels for various soil samples of Karbala-Najaf road (Ya-Hussein)/Iraq. IOP Conf Ser Mater Sci Eng 2020;928:072076. doi:10.1088/1757-899X/928/7/072076.
5. Kadhim SA, Harjan AH, Alhous SF, AL-Khafaji QS. Study of the difference between uranium concentrations in blood samples of healthy, newly infected and women who took chemotherapy in Iraq, Najaf. AIP Conf Proc 2022:2386:080004. doi: 10.1063/5.0067446
6. Salih NF, Aswood MS, Hamzawi AA. Effect of porosity on evaluation of radon concentration in soil samples collected from Sulaymania governorate, Iraq. J Phys Conf Ser 2019;1234:012024. doi:10.1088/1742-6596/1234/1/012024.
7. Bineng GS, Saïdou, Tokonami S, Hosoda M, Tchuente Siaka YF, Issa H, et al. The Importance of Direct Progeny Measurements for Correct Estimation of Effective Dose Due to Radon and Thoron. Front Public Health 2020;8:17. doi: 10.3389/fpubh.2020.00017.
8. Baptista E, Pereira AJSC, Domingos FP, Sêco SLR. Radon and thoron concentrations in the southwest region of Angola: dose assessment and implications for risk mapping. Environ Geochem Health 2023;45:665-86. doi: 10.1007/s10653-022-01226-8.

9. Rahman S. Studying 222Rn exhalation rate from soil and sand samples using CR-39 detector. Radiat Meas 2006;41:708-13. doi: 10.1016/j.radmeas.2006.03.005.
10. Ramsiya M, Joseph A, Jojo PJ. Estimation of indoor radon and thoron in dwellings of Palakkad, Kerala, India using solid state nuclear track detectors. j radiat res appl sci 2017;10:269-72. doi: 10.1016/j.jrras.2017.05.004
11. Mehra R, Jakhu R, Mittal HM. Assessment of lung dose from indoor 222Rn and 220Rn exposure in the Jalandhar and Kapurthala districts of Punjab, India. Indoor Built Environ 2017;26:1305-10. doi: 10.1177/1420326X15613559.
12. Obed RI, Oyelade EA, Lateef HT. Indoor radon levels in some selected nursery and primary schools in Ibadan, Oyo State, Nigeria. J Radiat Res Appl Sci 2018;11:379-82. doi: 10.1016/j.jrras.2018.07.003.
13. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report, Volume I: Report to the General Assembly, with Scientific Annexes. New York, USA: United Nations; 2000. doi: 10.18356/49c437f9-en.
14. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP 2007;37:1-332. doi: 10.1016/j.icrp.2007.10.003.
15. McCollough CH, Schueler BA. Calculation of effective dose. Med Phys 2000;27:828-37. doi: 10.1118/1.598948.
16. Harrison JD, Marsh JW. ICRP recommendations on radon. Ann ICRP 2020;49(Suppl 1):68-76. doi: 10.1177/0146645320931974.
17. Aswood MS, Salih AA, Al Musawi MS. Long-lived gamma-ray measurement in soil samples collected from city central of Al-Diwaniyah, Iraq. J Phys: Conf Ser 2019;1234:012003. doi:10.1088/1742-6596/1234/1/012003.
18. Ahmed RS. A review on soil radionuclide distribution in Iraq analysed using gamma ray spectroscopy. Environ Forensics 2021;22:91-8. doi: 10.1080/15275922.2020.1805827