Indoor Radon and Thoron Concentration and the Associated Effective Dose Rate Determination in Dwellings of Suq Alshouk, Thiqar (Iraq)

Hussam Najem Abood[1*], Ahmed Abbas Mohamed[2]

Abstract

Indoor radon/thoron concentration has been determined in some dwellings of Suq Alshouk district in Thiqar Governorate southern of Iraq, using LR-115 type II and CR-39 (SSNTDs). In this work the indoor radon/thoron concentration varies from (8-73) Bq m^{-3} for radon with an average 35±2Bq m^{-3}, and ranges (1- 47) Bq m^{-3} for thoron with an average16±2Bq m^{-3}. The average annual effective dose due to radon and thoron varies from 0.43-3.38m Sv y^{-1} with average value 1.43±0.11 mSv y^{-1}.

Key Words: Indoor Radon, Thoron, SSNTDs, Annual Effective Dose (AED).

DOI Number: 10.14704/nq.2021.19.12.NQ21189 **NeuroQuantology 2021; 19(12):06-10**

Introduction

All creatures are exposed to radiation all the time. This is broadly classified into two groups: Naturally-Occurring Radioactive Materials (NORM) exposure and man-made exposure. The average for AED from natural radiation sources is around 2.4mSv y^{-1} (UNSCEAR, 2010).

The types of natural exposures are (1) out space sources from cosmic rays, (2) radioactive elements in earth crust (3) exposure coming from water, food...etc, and (4)indoor exposures from radon (^{222}Rn), thoron (^{220}Rn) and their progeny (Ramachandran, 2011).

There are three isotopes for Radon due to uranium, actinium and thorium radioactive series.

The longest lived isotope, ^{222}Rn (alpha emitter of 3.825 days half-life), arises in the uranium series, the other isotopes are thoron ^{220}Rn' and actinon^{219}Rn.

The importance of radon isotopes increases because of their mean lives and abundance. ^{219}Rn (3.92s half-life) is the shortest isotope and always produced in very smaller amounts than ^{222}Rn and ^{220}Rn, so their contribution is negligible.

Thoron (55.6s half-life), released a small fraction of α-particle energy which absorbed within bronchial epithelium cells than in the case of ^{222}Rn.

Method of the Study

To measure^{222}Rn and ^{220}Rn levels, we used two track detectors with different sensitivities.

(LR-115 II) and CR-39 detectors of 12µm and 500µm thickness have been cut to size 1.5×1.5cm and then fixed to slide. After that the slide was fixed on the wall at 2m height for more than 45 different dwellings. The study was observed in 2020 from October to December.

Corresponding author: Hussam Najem Abood

Address: [1*]General Directorate of Education in Basrah, Basrah, Iraq; [2]Department of Mathematics, College of Computer Science & Mathematics, University of Thi-Qar, Iraq.

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 05 October 2021 **Accepted:** 12 November 2021

The two detectors had been removed after 3 months of exposure. (LR-115 II)detectors were etched by NaOH solution (2.5N) for 2h at 60°C, while CR-39 detectors were etched by NaOH solution (6.25N) for 7h at 70° C, in water bath with constant temperature (Hafez, 1992).
The plastic detectors had been washed under water and track density measured for them by using (400x) microscope, taking the care of subtracting the background reading.
A film of 5µm remains from SSNTD because of etching conditions, which corresponds to energy limits (1.6 to 4.7) MeV. Alpha particles reached LR-115 II within this limits will be registered a bright spot track.
All alpha particles reaching CR-39 detector within angle less than etching critical angle will registered (Misdaq, 2013).
The total track density, is given by:

$$\rho_G^{CR} = \frac{1}{4} A_c(^{222}Rn) \Big[(R_1 B_1 \sin^2\theta_{c1} + M(^{218}Po) R_2 B_2 \sin^2\theta_{c2} + M(^{214}Po) M(^{214}Bi) M(^{214}Pb) M(^{218}Po) R_3 B_3 \sin^2\theta_{c3}) + \frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} (R_1 B_1 \sin^2\theta_{c1} + M(^{216}Po) R_2 B_2 \sin^2\theta_{c2} + M(^{212}Bi) M(^{212}Pb) M(^{216}Po) R_3 B_3 \sin^2\theta_{c3} + M(^{212}Po) M(^{212}Bi) M(^{212}Pb) M(^{216}Po) R_4 B_4 \sin^2\theta_{c4}) \Big] \quad (1)$$

$$\rho_G^{LR} = \frac{1}{4} \Delta R \sin^2\theta'_c A_c(^{222}Rn) \Big[(B_1 + M(^{218}Po) B_2 + M(^{214}Po) M(^{214}Bi) M(^{214}Pb) M(^{218}Po) B_3) + \frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} (R_1 B_1 + M(^{216}Po) B_2 + M(^{212}Bi) M(^{212}Pb) M(^{216}Po) B_3 + M(^{212}Po) M(^{212}Bi) M(^{212}Pb) M(^{216}Po) B_4) \Big] \quad (2)$$

By combining Eqs. (1) and (2) we obtain:-

$$\frac{\rho_G^{CR}}{\rho_G^{LR}} = \left[\frac{\begin{pmatrix} R_1 B_1 \sin^2\theta_{c1} + M(^{218}Po) R_2 B_2 \sin^2\theta_{c2} \\ + M(^{214}Po) M(^{214}Bi) M(^{214}Pb) M(^{218}Po) R_3 B_3 \sin^2\theta_{c3}) \end{pmatrix} + \frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} \begin{pmatrix} (R_1 B_1 \sin^2\theta_{c1} + M(^{216}Po) R_2 B_2 \sin^2\theta_{c2} \\ + M(^{212}Bi) M(^{212}Pb) M(^{216}Po) R_3 B_3 \sin^2\theta_{c3} \\ + M(^{212}Po) M(^{212}Bi) M(^{212}Pb) M(^{216}Po) R_4 B_4 \sin^2\theta_{c4} \end{pmatrix}}{\Delta R \sin^2\theta'_c \begin{pmatrix} \begin{pmatrix} B_1 + M(^{218}Po) B_2 \\ + M(^{214}Po) M(^{214}Bi) M(^{214}Pb) M(^{218}Po) B_3 \end{pmatrix} \\ + \frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} \begin{pmatrix} B_1 + M(^{216}Po) B_2 \\ + M(^{212}Bi) M(^{212}Pb) M(^{216}Po) B_3 \\ + M(^{212}Po) M(^{212}Bi) M(^{212}Pb) M(^{216}Po) B_4 \end{pmatrix} \end{pmatrix}} \right] \quad (3)$$

Where R_i is the range of alpha particle in air, B_i is the branching ratio, θ_{ci} is critical angle of etching and M_i is ratio of the *i*-th daughter to its parent. Measuring ρ_G^{CR} and ρ_G^{LR} track density lead to find the $A_c(^{220}Rn)/A_c(^{222}Rn)$ ratio [Eq. (4)], consequently $A_c(^{222}Rn)$ and $A_c(^{220}Rn)$ alpha-activities[Eq. (1)], and the activities of the radon decay products [$A_c(^{218}Po)$, $A_c(^{214}Pb)$ - β emitter, $A_c(^{214}Bi)$- β emitter, $A_c(^{214}Po)$] and thoron [($A_c(^{216}Po)$, $A_c(^{212}Pb)$ - β emitter, $Ac(^{212}Bi)$, $A_c(^{212}Po)$] decay products in a given room, using method described in details (Hussam, 2015).

$$\frac{A_c(^{220}Rn)}{A_c(^{222}Rn)} = \frac{\begin{bmatrix} \frac{\rho_G^{CR}}{\rho_G^{LR}}\Delta R \sin^2\theta'_c \begin{pmatrix} B_1 + M(^{218}Po)B_2 \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po).B_3 \end{pmatrix} \\ -\begin{pmatrix} R_1B_1\sin^2\theta_{c1} + M(^{218}Po)R_2B_2\sin^2\theta_{c2} \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po).R_3B_3\sin^2\theta_{c3}) \end{pmatrix} \end{bmatrix}}{\begin{bmatrix} \begin{pmatrix} (R_1B_1\sin^2\theta_{c1} + M(^{216}Po)R_2B_2\sin^2\theta_{c2} \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)R_3B_3\sin^2\theta_{c3} \\ +M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po).R_4B_4\sin^2\theta_{c4} \end{pmatrix} - \\ \frac{\rho_G^{CR}}{\rho_G^{LR}}\Delta R \sin^2\theta'_c \begin{pmatrix} B_1 + M(^{216}Po)B_2 \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_3 \\ + M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po).B_4 \end{pmatrix} \end{bmatrix}} \quad (4)$$

The annual exposure for potential alpha energy C_p (effective dose equivalent) is given by (Sharma, 2012):

$$C_{p(^{222}Rn)}[\mathrm{WLM.y^{-1}}] = \frac{T \times n \times F \times A_c(^{222}Rn)}{170 \times 3700} \quad (5)$$

For thoron:

$$C_{p(^{220}Rn)}[\mathrm{WLM.y^{-1}}] = \frac{T \times n \times F \times A_c(^{220}Rn)}{170 \times 275} \quad (6)$$

T: time of occupancy =8760 h.y^{-1}
n: Occupancy factor = (0.8 and 0.2) indoor and outdoor respectively.

Assuming (T × n) 7000 h per year indoors or (T × n) 2000 hours per year at work and equilibrium factor (F) 0.4 for radon and 0.1 for thoron (ICRP, 2010).

The calculated AED received by human lungs has been determined by using a conversion factor of (3.88 and 3.4) mSv/WLM for radon and thoron respectively (ICRP, 1993).

Results & Discussion

The measured values for indoor radon & thoron in dwelling of study area are listed in table (1). The indoor radon, thoron concentrations are varies from 8 - 73Bq.m^{-3} and 1-47 Bq m^{-3} with average 35±2Bq m^{-3} and 16±2 Bq.m^{-3} with standard deviations (s.d) 16 and 11, respectively. The total annual exposure of (^{222}Rn+^{220}Rn) vary from 0.11-0.96WLM with average 0.40±0.03 WLM and s.d 0.21.The annual effective dose due to (^{222}Rn+^{220}Rn) are found to vary from 0.43-3.38 mSv/y with average 1.43±0.11 mSv/y and (s.d) 0.74.

The concentration of radon, thoron in some dwelling have been reported to be higher than 40Bq m^{-3}, for dwellings (UNSEAR, 2000). The main reasons for (^{222}Rn,^{220}Rn) concentrations came from the radioactive nuclides uranium, thorium and radium in soil, water, building, ventilation rate, lifestyle, and air-conditioning. Also, most of these studies places have radon level lower than the concern level, i.e 150Bq m^{-3} and none of them higher than the action levels (200–300)Bqm^{-3} (ICRP, 2010). So it does not require taking any behaviour to reduce the radon concentration in these dwelling.

Table 1. Indoor radon/thoron concentrations, annual exposure and Annual effective dose in the dwellings of Suq Alshouk

No.	Room	ρ_G^{LR} T.cm^{-2}.d^{-1}	ρ_G^{CR} T.cm^{-2}.d^{-1}	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	C_p Total (^{222}Rn+^{220}Rn) (WLM/y)	AED (mSv/y)
1	Bedroom	3.61	12.94	36	28	0.58	2.04
	Waiting room	1.75	6.09	24	7	0.20	0.75
	kitchen	2.21	7.90	23	16	0.34	1.21
2	Bedroom	2.21	7.80	27	12	0.30	1.07
	Waiting room	1.28	4.39	21	1	0.11	0.43
	kitchen	5.47	19.60	54	42	0.87	3.08
3	Bedroom	1.28	4.51	16	7	0.17	0.61
	Waiting room	2.21	7.91	22	17	0.35	1.23
	kitchen	5.94	20.93	73	31	0.79	2.85
4	Bedroom	5.94	21.30	58	47	0.96	3.38
	Waiting room	2.21	7.95	21	18	0.36	1.28
	kitchen	1.75	6.11	23	7	0.21	0.76
5	Bedroom	5.47	19.37	64	32	0.77	2.75
	Waiting room	3.14	10.75	52	3	0.27	1.03

	kitchen	2.68	9.33	37	10	0.31	1.13
6	Bedroom	2.68	9.58	27	20	0.42	1.49
	Waiting room	3.61	12.57	50	13	0.41	1.51
	kitchen	3.14	10.86	48	7	0.32	1.19
7	Bedroom	4.54	16.40	40	40	0.78	2.75
	Waiting room	2.68	9.59	27	20	0.42	1.50
	kitchen	3.14	11.27	31	25	0.51	1.79
8	Bedroom	4.08	14.51	44	28	0.61	2.17
	Waiting room	5.01	17.91	51	37	0.79	2.78
	kitchen	3.61	12.68	46	17	0.46	1.67
9	Bedroom	2.21	7.94	21	18	0.36	1.26
	Waiting room	0.82	2.92	8	6	0.13	0.45
	kitchen	2.68	9.22	42	5	0.26	0.97
10	Bedroom	2.21	7.68	32	7	0.24	0.89
	Waiting room	1.75	6.24	18	13	0.27	0.96
	kitchen	2.68	9.14	45	1	0.22	0.85
11	Bedroom	1.75	6.08	25	6	0.20	0.72
	Waiting room	3.61	12.66	47	16	0.45	1.64
	kitchen	5.01	17.51	67	21	0.61	2.21
12	Bedroom	3.14	11.25	32	24	0.50	1.75
	Waiting room	1.28	4.58	13	10	0.20	0.71
	kitchen	3.61	12.43	56	7	0.35	1.31
13	Bedroom	1.75	6.18	20	10	0.24	0.87
	Waiting room	2.68	9.45	32	15	0.36	1.31
	kitchen	1.75	6.31	15	16	0.30	1.06
14	Bedroom	2.68	9.70	22	25	0.47	1.66
	Waiting room	1.75	6.11	23	7	0.21	0.77
	kitchen	2.21	7.68	32	7	0.24	0.89
15	Bedroom	2.21	7.61	35	4	0.21	0.80
	Waiting room	1.75	6.26	17	13	0.28	0.98
	kitchen	3.61	12.80	41	22	0.52	1.85
	Av.±SE			35±2	16±2	0.40±0.03	1.43±0.11
	Max.			73	47	0.96	3.38
	Min.			8	1	0.11	0.43
	S.D.			16	11	0.21	0.74

Conclusions

This work shows the annual exposure results for indoor radon/thoron in Suq Alshouk district southern Iraq (see fig(1)). Calculation for Effective dose has been cured out for citizen there.

The total average for radon in this work is (8-73Bq m^{-3}) which is higher than the world average level for indoor radon (40 Bq m^{-3}). Nevertheless, it's lower than the ICRP action level (200–600Bq m^{-3}). The AED for citizen in dwellings has been found less than the world wide radiation dose 2.4mSv/y, and less than the ICRP action level (3-10) mSv/y.

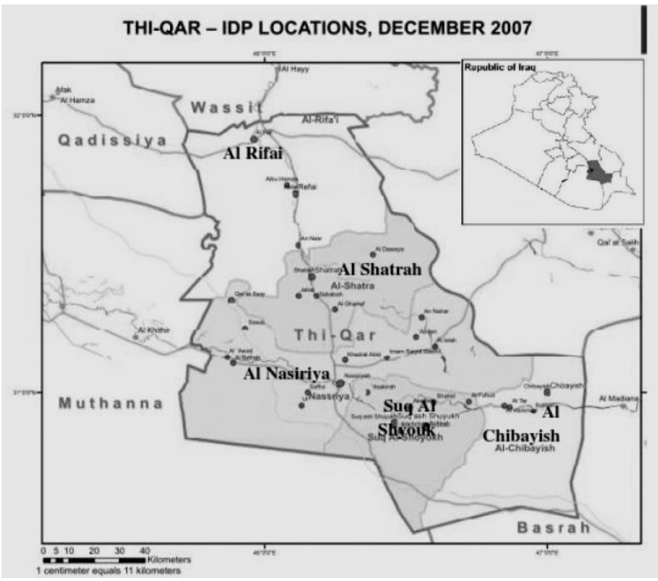

Figure 1. Thiqar Governorate Map [11]

References

UNSCEAR Report. Summary of low-dose radiation effects on health. United Nations. *United Nations Publication,* New York 2010.

Ramachandran TV. Background radiation, people and the environment. *Iranian journal of radiation research* 2011; 9(2): 63-76.

Hafez AF, Naim MA. Plastic nuclear track detection methods for estimation of thorium to uranium ratio in thick natural materials. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 1992; 69(2-3): 373-381.

Misdaq MA, Chaouqi A. ^{222}Rn and ^{220}Rn concentrations measured in bottled sweet drinks and their residual gases and resulting radiation doses to the consumers. *American Journal of Environmental Protection* 2013; 2(3): 95-102.

Hussam NA. *Indoor Radon and Thoron measurement in dwellings, health centers and hospitals in Basrah Governorate (Iraq).* Ph.D. Thesis, University of Basrah 2015.

Jyoti S, Mahur AK, Rupesh K, Rati V, Sonkawade RG, Swarup, R, Rajendra P. Comparative study of indoor radon, thoron with radon exhalation rate in soil samples in some historical places at Jaipur, Rajasthan, India. *Advances in Applied Science Research* 2012; 3(2): 1085-1091.

ICRP, Recommendations of the International Commission on Radiological Protection. ICRP Publication, Lung cancer risk from radon and progeny. *Annals of ICRP by Elsevier logo* 2010.

ICRP, International Commission on Radiological Protection, protection against radon-222 at home and at work, ICRP publication 65. *Ann. ICRP* 1993; 23(2).

UNSCEAR, United Nation Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation, *United Nations*, New York 2000.

Al-Mamoori MHK, Alshrefi SM, Jader MJ, Kodeary AK. Structural characteristics, synthesis of novel TiO2/VO (II) composites thin films decorated with chlorophyllvia solvothermal-laser dual technique. *NeuroQuantology* 2020; 18(3): 6-15.