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Indoor radon and thoron levels and the associated effective dose rate determination at the health centres in the Basrah Governorate-Iraq

Hussam Najem Abood and Isa Jasem Al-khalifa

Department of Physics, College of Education for Pure Sciences, University of Basrah, Basrah, Iraq

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ABSTRACT

Study of indoor radon and thoron has been carried out in the health centres in Basrah Governorate-Iraq, using LR-115 type II and CR-39 solid state nuclear track detectors (SSNTDs). In the present study the average value of indoor radon and thoron concentration of ranges from 59 Bq.m^{-3} in the first strip to 125 Bq.m^{-3} in Shatt Al-Arab strip for radon, and ranges from 9 Bq.m^{-3} in the first strip to 20 Bq.m^{-3} in Al Zubair and Al Hurtha strip for thoron. The average annual effective dose due to radon and thoron varies from 0.43 mSv.y^{-1} in the first strip to 0.90 mSv.y^{-1} in Shatt Al-Arab strip. This study is the first in this region.

Key words: Indoor radon , thoron, SSNTDs, effective dose.

INTRODUCTION

According to the UNSCEAR Report 2000, the world mean of annual effective dose due to the inhalation of radon, thoron and their decay products is estimated to be 1.2 mSv. This value corresponds to a half of the total of the worldwide average background radiation dose of 2.4 mSv/y. In general, indoor radon concentration and the occupancy factor are larger than those of outdoor environments, it has been widely from many surveys that the dose due to indoor radon is much larger than that due to outdoor [1].

The protection from radon has become important in dwellings and workplaces. Radon monitoring in the dwellings and workplaces has started all over the world and still continuing in some countries. Thoron, an isotope of radon produced in thorium disintegration series, was neglected earlier because of its shorter half life (55.6 s). But later thoron progeny was also found to be hazardous and thoron was included in the dose estimations. Knowledge on the distribution of radon and thoron in the dwellings and workplaces is useful in estimating the inhalation dose due to them. On the other hand, the indoor life is mainly divided into dwelling and office lives. Especially, in the advanced countries, the occupancy factor for working people in their offices can equal to or even exceed that in their homes. Therefore, for a more accurately estimation of radon exposure, it is very important to evaluate radon concentrations in both offices and dwellings [2].

Although radon and thoron are chemically inert and electrically uncharged, when the resulting atoms, called radon and thoron progeny, are formed, they are electrically charged and can attach themselves to tiny dust particles (aerosols) in indoor air and gets trapped in the tracia bronchial system during inhalation there by irradiating the bronchial tissues. Alpha particles from the decay of radon and thoron progeny irradiating the bronchial tissues. It is constitutes a significant radiation hazard to human lungs and occurrence of lungs cancer and that are deposited in the lungs cannot reach any other organs, so it is likely that lung cancer is the only potential important cancer hazard posed by radon in indoor air [3-4].

Recently, radon investigations have been concentrated specifically in workplaces all over the world. However, there have not been any significant radon studies for the workplaces in Iraq. The goals of this study are to determine the radon/thoron concentrations and annual effective radiation doses exposed by radon/thoron in health centres in Basrah Governorate, and to find the relationship of the radon/thoron concentrations between different types of workplaces.

AREA UNDER STUDY

Basrah governorate located in southern Iraq and northern Arabian Gulf see Fig.1. Health centres in Basrah governorate, divided into eight strips:1- The first strip. 2- The second strip. 3- Shatt Al Arab strip. 4- Abu Al Khaseeb strip (including Al Fao). 5- Al Zubair strip. 6- Al Hartha strip. 7- Al Qurna strip. 8- Al Mudaina strip. The first and the second strip were located in the centre of the governorate, while other strips distributed over the districts of the province. Each strip consists of a main building represents the center for the management of the strip, and a number of health centres distributed according to population density. Health centers built during different periods of time, including the old and the modern which built after 2003.

a- Map of Iraq. b- Map of Basrah Governorate.

Fig. 1 Map of Iraq and Basrah Governorate

MATERIALS AND METHODS

In the present study to measure indoor radon and thoron concentration, we used a method based on using two track detectors having different sensitivities CR-39 and LR-115. Film track detector (LR-115 type II) is a cellulose nitrate ($C_6H_2O_9N_2$) film of 12 μm thickness manufactured by Kodak Path, France. The CR-39 SSNTD (500 μm thick) is the diglycol carbonate ($C_{12}H_{18}O_7$) supplied by Pershore Mouldings Ltd., UK. These plastics films of size ~ 1.5 cm×1.5 cm were fixed on glass slides and then these slides were mounted on the walls of different rooms at a height of about 2m from the ground level with their sensitive surfaces facing the air in bare mode, taking due care that there was nothing to obstruct the detectors. For the present study where the observation were taken from October to December, 2013. After an exposure time of 3 months, detector films were removed and etched in a NaOH solution (2.5N at $60^{\circ}\pm1$ C for 120 min for LR-115 type II films and 6.25N at $70^{\circ}\pm1$ C during 7 h for the CR-39 detectors) in a constant temperature bath. Then these SSNTDs were washed, dried and scanned under a binocular microscope for track density measurements.

An unexposed film of the LR-115, CR-39 was also etched and scanned for the determination of background track density of the film. This background track density was subtracted from the observed value of the readings.

For our experimental etching conditions, the residual thickness of the LR-115 type II film is 5 μm which corresponds to the lower (E_{min} =1.6 MeV) and upper (E_{max} = 4.7MeV) energy limits for registration of tracks of alpha particles in LR-115 type II films. All α-particles that reach the LR-115 SSNTD with a residual energy situated between 1.6 and 4.7MeV are registered as bright track-holes. The CR-39 SSNTD is sensitive to all α-particles reaching its surface under an angle smaller than its critical angle of etching [5].

The global track density rates, due to α-particles emitted by radon (three α-emitting nuclei: ^{222}Rn;^{218}Po and ^{214}Po) and thoron (four α-emitting nuclei: ^{220}Rn, ^{216}Po, ^{212}Bi and ^{212}Po) series, registered on the CR-39 and LR-115 type II detectors are, respectively, given by [6]:

$$\rho_G^{CR} = \frac{1}{4} A_c\,(^{222}Rn)\Big[\big(R_1B_1sin^2\theta_{c1} + M(^{218}Po)R_2B_2sin^2\theta_{c2} + M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po)R_3B_3sin^2\theta_{c3}\big) + \frac{A_c(^{220}Rn)}{A_c\,(^{222}Rn)}\big(R_1B_1sin^2\theta_{c1} + M(^{216}Po)R_2B_2sin^2\theta_{c2} + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)R_3B_3sin^2\theta_{c3} + M(^{212}Po)M(^{212}Bi)M(^{212}Pb)\,M(^{216}Po)R_4B_4sin^2\theta_{c4}\big)\Big] \quad (1)$$

$$\rho_G^{LR} = \frac{1}{4}\Delta R\,sin^2\theta'_c\,A_c\,(^{222}Rn)\Big[\big(B_1 + M(^{218}Po)B_2 + M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po)B_3\big) + \frac{A_c(^{220}Rn)}{A_c\,(^{222}Rn)}\big(R_1B_1 + M(^{216}Po)B_2 + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_3 + M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_4\big)\Big] \quad (2)$$

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

$$\frac{\rho_G^{CR}}{\rho_G^{LR}} = \left[\frac{\begin{pmatrix} R_1B_1sin^2\theta_{c1} + M(^{218}Po)R_2B_2sin^2\theta_{c2} \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po)\;\; R_3B_3sin^2\theta_{c3}) \end{pmatrix} + \frac{A_c(^{220}Rn)}{A_c\,(^{222}Rn)}\begin{pmatrix} (R_1B_1sin^2\theta_{c1} + M(^{216}Po)R_2B_2sin^2\theta_{c2} \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)R_3B_3sin^2\theta_{c3} \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po)\;\; R_4B_4sin^2\theta_{c4} \end{pmatrix}}{\Delta Rsin^2\theta'_c\begin{pmatrix} \begin{pmatrix} B_1 + M(^{218}Po)B_2 \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po)\;\; B_3 \end{pmatrix} \\ + \frac{A_c(^{220}Rn)}{A_c\,(^{222}Rn)}\begin{pmatrix} B_1 + M(^{216}Po)B_2 \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_3 \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po)\;\; B_4 \end{pmatrix}\end{pmatrix}}\right] \quad (3)$$

where R_i is the range of alpha particle in air, B_i is the branching ratio, θ_{ci} is crtical 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 one can evaluate the $A_c(^{220}Rn)/A_c(^{222}Rn)$ ratio [Eq. (4)] and consequently the $A_c(^{222}Rn)$ and $A_c(^{220}Rn)$ alpha-activities [Eq. (1)] as well as 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 of health centres, using method described in details in our previous work (Hussam and Isa, 2014).

$$\frac{A_c\,(^{220}Rn)}{A_c\,(^{222}Rn)} = \frac{\left[\frac{\rho_G^{CR}}{\rho_G^{LR}}\,\Delta Rsin^2\theta'_c\begin{pmatrix} B_1 + M(^{218}Po)B_2 \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po)\;\; B_3 \end{pmatrix} - \begin{pmatrix} R_1B_1sin^2\theta_{c1} + M(^{218}Po)R_2B_2sin^2\theta_{c2} \\ +M(^{214}Po)M(^{214}Bi)M(^{214}Pb)M(^{218}Po)\;\; R_3B_3sin^2\theta_{c3}) \end{pmatrix}\right]}{\left[\begin{pmatrix} (R_1B_1sin^2\theta_{c1} + M(^{216}Po)R_2B_2sin^2\theta_{c2} \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)R_3B_3sin^2\theta_{c3} \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po)\;\; R_4B_4sin^2\theta_{c4} \end{pmatrix} - \frac{\rho_G^{CR}}{\rho_G^{LR}}\Delta Rsin^2\theta'_c\begin{pmatrix} B_1 + M(^{216}Po)B_2 \\ + M(^{212}Bi)M(^{212}Pb)M(^{216}Po)B_3 \\ M(^{212}Po)M(^{212}Bi)M(^{212}Pb)M(^{216}Po)\;\; B_4 \end{pmatrix}\right]} \quad (4)$$

The annual exposure to potential alpha energy E_p (effective dose equivalent) is then related to the average radon concentration $A_c\ (^{222}Rn)$ by following expression [7]:-

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

For thoron:

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

T : is the indoor occupancy time (24h×365 = 8760 $h.y^{-1}$)
n : is the occupancy factor, its equal to (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 an equilibrium factor (F) of 0.4 for radon and 0.1 for thoron [8].

The annual effective dose received by the bronchial and pulmonary regions of human lungs has been calculated using a conversion factor of 3.88mSv/WLM for radon daughters and 3.4 mSv/WLM for thoron daughters [9].

The lifetime fatality risk associated with indoor radon and thoron exposure was calculated by using 1 WLM = 10×10^{-6} cases/year. If the risk persists for 30 year, the lifetime fatality risk was made using the conversion factors of $3\times10^{-4}\ WLM^{-1}$ according to equation (7)[10]:

$$\text{Lifetime fatality risk} = \text{Annual exposure } \times 3\times10^{-4}\ WLM^{-1} \qquad (7)$$

RESULTS AND DISCUSSION

The measured values of indoor radon, thoron concentration, annual exposure, life time fatality risk, and annual effective dose in different health centres of study area are tabulated in table (1-8). These measurements were carried out in winter season (November 2013 to February 2014). The indoor radon and thoron levels in the first strip are found to vary from 30–131 $Bq.m^{-3}$ and 3–23 $Bq.m^{-3}$ with an average value of 59 $Bq.m^{-3}$ and 9 $Bq.m^{-3}$, respectively. The corresponding standard deviations are 26 and 6. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.04- 0.17 WLM and 0.01- 0.10 WLM respectively. The total annual exposure of ($^{222}Rn+^{220}Rn$), Life time fatality risk factor and annual effective dose are vary from 0.07-0.24 WLM, 0.2×10^{-4} - 0.71×10^{-4}, 0.24 - 0.89 mSv/y with an average value of 0.12 WLM, 0.35×10^{-4} and 0.43 mSv/y, respectively. The corresponding standard deviations are 0.05, 0.16×10^{-4} and 0.20 respectively.

The indoor radon and thoron levels in the second strip are found to vary from 45–178 $Bq.m^{-3}$ and 8–35 $Bq.m^{-3}$ with an average value of 95 $Bq.m^{-3}$ and 16 $Bq.m^{-3}$, respectively. The corresponding standard deviations are 38 and 8. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.06 - 0.23 WLM and 0.03- 0.15 WLM respectively. The total annual exposure of ($^{222}Rn+^{220}Rn$), Life time fatality risk factor and annual effective dose are vary from 0.09 - 0.38 WLM, 0.28×10^{-4} - 1.13×10^{-4}, 0.34 - 1.39 mSv/y with an average value of 0.19 WLM, 0.57×10^{-4} and 0.70 mSv/y, respectively. The corresponding standard deviations are 0.12, 0.36×10^{-4} and 0.44 respectively.

The indoor radon and thoron levels in the Shatt Al Arab strip are found to vary from 90 -155 $Bq.m^{-3}$ and 15–23 $Bq.m^{-3}$ with an average value of 125 $Bq.m^{-3}$ and 19 $Bq.m^{-3}$, respectively. The corresponding standard deviations are 22 and 3 respectively. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.11- 0.20 WLM and 0.06- 0.10 WLM respectively. The total annual exposure of ($^{222}Rn+^{220}Rn$), Life time fatality risk factor and annual effective dose are vary from 0.19-0.29 WLM, 0.56×10^{-4} - 0.87×10^{-4}, 0.69-1.08 mSv/y with an average value of 0.24 WLM, 0.72×10^{-4} and 0.9 mSv/y, respectively. The corresponding standard deviations are 0.04, 0.11×10^{-4} and 0.14 respectively.

The indoor radon and thoron levels in the Abu Al Kuseeb strip are found to vary from 34–124 $Bq.m^{-3}$ and 2-21 $Bq.m^{-3}$ with an average value of 84 $Bq.m^{-3}$ and 11 $Bq.m^{-3}$, respectively. The corresponding standard deviations are 28 and 6 respectively. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.04- 0.16 WLM and 0.01- 0.09 WLM respectively. The total annual exposure of ($^{222}Rn+^{220}Rn$), Life time fatality risk factor and annual effective dose are vary from 0.05-0.24 WLM, 0.15×10^{-4} - 0.72×10^{-4}, 0.18-0.89 mSv/y with an average value of 0.15 WLM, 0.46×10^{-4} and 0.57 mSv/y, respectively. The corresponding standard deviations are 0.05 WLM, 0.16×10^{-4} and 0.20 mSv/y, respectively.

Table 1. Indoor radon and thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of the first strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual Exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	131	17	0.17	0.07	0.24	0.71	0.89
2	Al-bradhaah	47	9	0.06	0.04	0.10	0.29	0.36
3	Almtaiha	30	6	0.04	0.03	0.07	0.20	0.24
4	Al Razi	87	23	0.11	0.10	0.21	0.63	0.76
5	Al kplh	49	6	0.06	0.03	0.09	0.27	0.33
6	Hai Almhendsain	56	15	0.07	0.07	0.14	0.41	0.50
7	Hai Alkaum	65	4	0.08	0.02	0.10	0.30	0.38
8	Hai AlZahra	43	3	0.06	0.01	0.07	0.21	0.26
9	Al Mishraq	62	5	0.08	0.02	0.10	0.30	0.38
10	Hai Al Jihad	47	8	0.06	0.04	0.10	0.29	0.36
11	Sharaa 60	33	5	0.04	0.02	0.07	0.20	0.24
12	Intifada Al-Aqsa	46	4	0.06	0.02	0.08	0.23	0.28
13	Al Rasshala Alnmodji	74	17	0.09	0.07	0.17	0.50	0.62
14	Alsseev	76	15	0.10	0.06	0.16	0.48	0.59
15	Al Ashar	36	4	0.05	0.02	0.07	0.20	0.25
	Average	59	9	0.08	0.04	0.12	0.35	0.43
	Max	131	23	0.17	0.10	0.24	0.71	0.89
	Min	30	3	0.04	0.01	0.07	0.20	0.24
	S.D.	26	6	0.03	0.03	0.05	0.16	0.20

Table 2. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of the second strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual Exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	45	8	0.06	0.03	0.09	0.28	0.34
2	Almakl	81	9	0.10	0.04	0.14	0.42	0.53
3	Al Rabat	83	18	0.10	0.08	0.18	0.55	0.67
4	Al Jubaila Alnmodji	125	16	0.16	0.07	0.23	0.68	0.85
5	Al Geneina	65	12	0.08	0.05	0.14	0.41	0.50
6	Mohammed al-Dura	57	12	0.07	0.05	0.12	0.37	0.45
7	Al Muwafaqiya	73	12	0.09	0.05	0.15	0.44	0.54
8	15 tamoz	178	35	0.23	0.15	0.38	1.13	1.39
9	Al Gmhoria	86	9	0.11	0.04	0.15	0.44	0.55
10	Al Kawthar	87	13	0.11	0.06	0.17	0.50	0.62
11	Al Qadisiyah	126	23	0.16	0.10	0.26	0.77	0.95
12	Alnehedha	133	23	0.17	0.10	0.27	0.80	0.99
	Average	95	16	0.12	0.07	0.19	0.57	0.70
	Max.	178	35	0.23	0.15	0.38	1.13	1.39
	Min.	45	8	0.06	0.03	0.09	0.28	0.34
	S.D.	38	8	0.05	0.03	0.08	0.24	0.30

The indoor radon and thoron levels in the Abu Al Zubair strip are found to vary from 68-204 Bq.m^{-3} and 8-35 Bq.m^{-3} with an average value of 117 Bq.m^{-3} and 20 Bq.m^{-3}, respectively. The corresponding standard deviations are 37 and 9 respectively. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.09- 0.26 WLM and 0.03- 0.15 WLM respectively. The total annual exposure of (^{222}Rn+^{220}Rn), Life time fatality risk factor and annual effective dose are vary from 0.12-0.41 WLM, 0.37×10^{-4} - 1.22×10^{-4}, 0.47-1.51 mSv/y with an average value of 0.24 WLM, 0.71×10^{-4} and 0.87 mSv/y, respectively. The corresponding standard deviations are 0.08 WLM, 0.25×10^{-4} and 0.30 mSv/y, respectively

The indoor radon and thoron levels in Abu Al Hartha strip are found to vary from 51-232 Bq.m^{-3} and 5-51 Bq.m^{-3} with an average value of 116 Bq.m^{-3} and 20 Bq.m^{-3}, respectively. The corresponding standard deviations are 66 and 14 respectively. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.07- 0.30 WLM and 0.02- 0.22 WLM respectively. The total annual exposure of (^{222}Rn+^{220}Rn), Life time fatality risk factor and annual effective dose are vary from 0.09-0.49 WLM, 0.27×10^{-4} - 1.47×10^{-4}, 0.33-1.79 mSv/y with an average value of 0.23

WLM, 0.70×10^{-4} and 0.86 mSv/y, respectively. The corresponding standard deviations are 0.13 WLM, 0.4×10^{-4} and 0.49 mSv/y, respectively

Table 3. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres in Shatt Al Arab strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	155	22	0.20	0.09	0.29	0.87	1.08
2	Shatt Al Arab	127	16	0.16	0.07	0.23	0.69	0.86
3	Nahar Hassan	142	21	0.18	0.09	0.27	0.81	1.00
4	Al Fayhaa	129	17	0.16	0.07	0.24	0.71	0.88
5	Al Kabasai	140	23	0.18	0.10	0.28	0.84	1.03
6	Al Hota	90	19	0.11	0.08	0.20	0.59	0.72
7	Al Zrigai	96	15	0.12	0.06	0.19	0.56	0.69
8	Al Jazeera	120	22	0.15	0.09	0.24	0.73	0.90
	Average	125	19	0.16	0.08	0.24	0.72	0.90
	Max.	155	23	0.20	0.10	0.29	0.87	1.08
	Min.	90	15	0.11	0.06	0.19	0.56	0.69
	S.D.	22	3	0.03	0.01	0.04	0.11	0.14

Table 4. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of Abu Al Kuseeb strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	64	10	0.08	0.04	0.12	0.36	0.45
2	Abu Macairh	110	14	0.14	0.06	0.20	0.60	0.75
3	Mhajeran	34	2	0.04	0.01	0.05	0.15	0.18
4	Hamdan	83	14	0.11	0.06	0.17	0.51	0.63
5	Fao	96	18	0.12	0.08	0.20	0.59	0.73
6	Al Seeba	115	21	0.15	0.09	0.24	0.72	0.89
7	Kairat Iraq	64	10	0.08	0.04	0.12	0.37	0.46
8	Abu Al Khaseeb	66	11	0.08	0.05	0.13	0.38	0.47
9	Al Hamzah	124	4	0.16	0.02	0.18	0.53	0.68
10	Alsnker	80	8	0.10	0.03	0.13	0.40	0.50
	average	84	11	0.11	0.05	0.15	0.46	0.57
	max	124	21	0.16	0.09	0.24	0.72	0.89
	min	34	2	0.04	0.01	0.05	0.15	0.18
	S.D.	28	6	0.04	0.03	0.05	0.16	0.20

The indoor radon and thoron levels in Al Quruna strip are found to vary from 31-106 Bq.m^{-3} and 6-16 Bq.m^{-3} with an average value of 71 Bq.m^{-3} and 11 Bq.m^{-3}, respectively. The corresponding standard deviations are 24 and 3 respectively. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.04- 0.13 WLM and 0.03- 0.07 WLM respectively. The total annual exposure of (^{222}Rn+^{220}Rn), Life time fatality risk factor and annual effective dose are vary from 0.07-0.21 WLM, 0.20×10^{-4} - 0.62×10^{-4}, 0.24-0.76 mSv/y with an average value of 0.14 WLM, 0.42×10^{-4} and 0.52 mSv/y, respectively. The corresponding standard deviations are 0.04 WLM, 0.12×10^{-4} and 0.16 mSv/y, respectively.

The indoor radon and thoron levels in Al Mudaina strip are found to vary from 60-120 Bq.m^{-3} and 5-19 Bq.m^{-3} with an average value of 83 Bq.m^{-3} and 13 Bq.m^{-3}, respectively. The corresponding standard deviations are 20 and 4 respectively. The corresponding annual exposure of ^{222}Rn and ^{220}Rn are vary from 0.08- 0.15 WLM and 0.02- 0.08 WLM respectively. The total annual exposure of (^{222}Rn+^{220}Rn), Life time fatality risk factor and annual effective dose are vary from 0.12-0.22 WLM, 0.35×10^{-4} - 0.65×10^{-4}, 0.43-0.81 mSv/y with an average value of 0.16 WLM, 0.48×10^{-4} and 0.59 mSv/y, respectively. The corresponding standard deviations are 0.03 WLM, 0.10×10^{-4} and 0.13 mSv/y, respectively.

We notice that indoor radon concentrations is higher than indoor thoron concentrations in the health centres studied. This is due to the fact that radon has a higher half-life (3.825 d) than thoron (55.6 s). Evidence indicates that the Evidence indicates that the equivalent radiation dose from thoron (^{220}Rn) and its progeny is about 5%-30% of that due to ^{222}Rn and its progeny [11].

Table 5. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of the Al Zubair strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual Exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	141	33	0.18	0.14	0.32	0.96	1.17
2	Sha'aban Intifada	107	23	0.14	0.10	0.23	0.70	0.86
3	Safwan	68	9	0.09	0.04	0.12	0.37	0.47
4	Ibn Aqeel	158	35	0.20	0.15	0.35	1.06	1.29
5	Alebattn	85	19	0.11	0.08	0.19	0.57	0.70
6	Hasan al-Basri	204	35	0.26	0.15	0.41	1.22	1.51
7	Haj Khudair	137	24	0.17	0.10	0.28	0.83	1.03
8	Al Marbad	75	13	0.09	0.06	0.15	0.45	0.56
9	Al-Shaiba	96	14	0.12	0.06	0.18	0.55	0.68
10	Al shifa	113	16	0.14	0.07	0.21	0.63	0.78
11	Alarhamh	109	16	0.14	0.07	0.20	0.61	0.76
12	Al Najemi	113	8	0.14	0.03	0.18	0.53	0.67
13	Khoor Al-zubear	116	21	0.15	0.09	0.24	0.71	0.88
	average	117	20	0.15	0.09	0.24	0.71	0.87
	max	204	35	0.26	0.15	0.41	1.22	1.51
	min	68	8	0.09	0.03	0.12	0.37	0.47
	S.D.	37	9	0.05	0.04	0.08	0.25	0.30

Table 6. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of the Al Hartha strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	52	9	0.07	0.04	0.10	0.31	0.38
2	Abu Saikhir	51	5	0.07	0.02	0.09	0.27	0.33
3	Al Batool	232	22	0.30	0.09	0.39	1.16	1.46
4	Hmrnyian	214	51	0.27	0.22	0.49	1.47	1.79
5	Al Rasheed	123	29	0.16	0.12	0.28	0.84	1.03
6	Al zwain	79	10	0.10	0.04	0.14	0.43	0.53
7	Hai al amil	80	15	0.10	0.06	0.16	0.49	0.60
8	Almcehab	111	20	0.14	0.08	0.22	0.67	0.83
9	Hurair	100	18	0.13	0.08	0.21	0.62	0.76
	Average	116	20	0.15	0.08	0.23	0.70	0.86
	Max.	232	51	0.30	0.22	0.49	1.47	1.79
	Min.	51	5	0.07	0.02	0.09	0.27	0.33
	S.D.	66	14	0.08	0.06	0.13	0.40	0.49

The average value of radon concentration in the health centres is higher than the average value of 40 Bq.m^{-3},reported for the dwellings worldwide [1]. This may be due to the difference in the concentration of radioactive elements, viz. uranium and radium in the soil and building materials of the study area. However, most of the health centres have the radon concentration below the level of concern i.e. 150 Bq.m^{-3} while none of them have a value higher than the action level 200–600 Bq.m^{-3}, recommended by ICRP [9].

However, there were some differences some health centres have floor made of granite or inlaid with granite (for example Hmrnyain health centres in in Al Hurtha strip). Some laboratories have floor and some furniture made of granite. As we know granite is a rich source of radium (^{226}Ra) which further decay to radon (^{222}Rn) by alpha emission, so it may be a reason for higher concentration of radon in these health centres.

Table 7. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of the Al Qurna strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual exposure of ^{222}Rn (WLM)	Annual Exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1	Center of strip	56	12	0.07	0.05	0.12	0.37	0.45
2	Abu curb	43	9	0.05	0.04	0.09	0.28	0.34
4	Aldrijha Wal shehbin	100	12	0.13	0.05	0.18	0.54	0.67
5	Alnshoa	57	9	0.07	0.04	0.11	0.33	0.41
6	Al Busayri	85	12	0.11	0.05	0.16	0.48	0.60
7	Ali Noor	50	10	0.06	0.04	0.10	0.31	0.38
8	Al Swaileh	106	16	0.13	0.07	0.21	0.62	0.76
9	Al Qurna	75	11	0.10	0.05	0.14	0.43	0.53
10	Al Qurna Alnmodji	68	13	0.09	0.06	0.14	0.43	0.53
11	Al theqre	93	15	0.12	0.06	0.18	0.54	0.67
12	Alalloa	89	12	0.11	0.05	0.17	0.50	0.62
13	Al Basha	31	6	0.04	0.03	0.07	0.20	0.24
	Average	71	11	0.09	0.05	0.14	0.42	0.52
	Max.	106	16	0.13	0.07	0.21	0.62	0.76
	Min.	31	6	0.04	0.03	0.07	0.20	0.24
	S.D.	24	3	0.03	0.01	0.04	0.12	0.16

Table 8. Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in the health centres of the Al Mudaina strip

No	Health center	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Annual Exposure of ^{222}Rn (WLM)	Annual exposure of ^{220}Rn (WLM)	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual Effective dose (mSv/y)
1	Center of strip	60	9	0.08	0.04	0.12	0.35	0.43
2	Alahoare	79	19	0.10	0.08	0.18	0.54	0.66
3	Shellhut Alahjaj				0.05	0.15	0.44	0.54
4	Al hoair	73	12	0.09	0.05	0.14	0.43	0.54
5	Al Khas	74	12	0.09	0.05	0.14	0.42	0.52
6	Ultraba	76	16	0.10	0.07	0.17	0.51	0.62
7	Um Shuich	120	15	0.15	0.06	0.22	0.65	0.81
8	Al Mudaina Alnmodji	65	10	0.08	0.04	0.13	0.38	0.47
9	Mir Osman	93	5	0.12	0.02	0.14	0.41	0.52
10	Al Jalal	111	17	0.14	0.07	0.21	0.64	0.79
	Average	83	13	0.11	0.05	0.16	0.48	0.59
	Max.	120	19	0.15	0.08	0.22	0.65	0.81
	Min.	60	5	0.08	0.02	0.12	0.35	0.43
	S.D.	20	4	0.03	0.02	0.03	0.10	0.13

CONCLUSION

In the above study we have calculated the values of indoor radon, thoron and annual effective dose due to their progenies in the indoor environment of the health centres of Basrah governorate in southern Iraq. Life time fatality risk and effective dose have also been calculated for the occupants of these health centres. The conclusions of the present study are as follows:

The overall average value of radon in the present study (59-125 Bq.m^{-3}) is found higher than the world average value of indoor radon level (40 Bq.m^{-3}). Nevertheless, the present values are lower than the action level (200–600 Bq.m^{-3}) recommended by ICRP.

The values of annual effective dose in the health centres of study area, for Occupants (0.43-0.90 mSv/y) found less than the worldwide average radiation dose of 2.4 mSv/y, and less than the lower limit of action level (3-10) mSv/y recommended by ICRP.

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