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Indoor radon and Thoron levels and the associated effective dose rate determination at government hospitals in Basrah Governorate-Iraq

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ABSTRACT

Study of indoor radon and thoron has been carried out inside ten (10) Government hospitals 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 are ranges from 40±6 Bq.m^{-3} in General Al Fayhaa Hospital to 109±15 Bq.m^{-3} in General harbours hospital for radon, and ranges from 10±1 Bq.m^{-3} in General Al Fayhaa Hospital to 46±9 Bq.m^{-3} in General harbours hospital for thoron. The average annual effective dose received by the workers due to radon and thoron varies from 0.35±0.04mSv.y^{-1} in General Al Fayhaa Hospital to 1.20±0.17 mSv.y^{-1} in General harbours hospital. The average value of indoor radon and thoron concentration and there corresponding effective dose are 73±14 Bq.m^{-3}, 24±6 Bq.m^{-3} and 0.72±0.15 mSv.y^{-1} respectively. This performed study was the first in this region.

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

INTRODUCTION

The exposure of population to natural sources of radiation has become an important issue in terms of radiological protection. Mostly natural radiation comes from radon (^{222}Rn), thoron (^{220}Rn) and their solid short-lived daughter products [1]. Radon and its daughters are the most important radio-nuclides present in the ambient air as well as in the indoor environment. The radiation dose received by human beings due to the inhalation of radon, thoron and their progeny present in the indoor environment contribute about more half of the average radiation dose from all natural sources of radiation. When radon inhaled, α-particles emitted by its short lived decay products can damage the cellular DNA mainly. Cellular mutagenesis studies, experimental research in animals, and occupational epidemiologic studies have established radon as a human lung carcinogen [2].

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, is an isotope of radon produced in thorium disintegration series, was neglected earlier because of its shorter half life (55.6 s), so it is assumed that the effective dose from thoron and its progeny is about 10% of that of radon and its progeny to the general public [3]. There for, there are only limited studies related to the measurements of thoron in the environment in comparison with radon and its progeny. 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 [4].

The goals of this study are to determine the radon and thoron concentrations and annual effective radiation doses exposed by radon and thoron in Government hospitals in Basrah Governorate - Iraq. This study is complement of previous studies for establishing a map showing the radioactivity in Basrah Governorate [5][6].

AREA UNDER STUDY

Basrah governorate located in southern Iraq and northern Arabian Gulf see Fig.1. This Study of indoor radon and thoron has been carried out inside Government hospitals in Basrah Governorate-Iraq. Most of these Government hospitals in Basrah are located in centre of the Governorate, including: 1- Teaching Al Sadr Hospital. 2- General Al Basrah hospital. 3- Basrah Hospital for Women´s and Obstetrics. 4- General Al Fahaa hospital. 5- General Al Shafa hospital. 6- General harbours hospital. other hospitals, Al Fao hospital located in Al Fao district, General Abu Al Khaseeb hospital in Abu Al Khaseeb district, Al Qurna General hospital in Al Qurna district, General Al Mudaina hospital in Al Mudaina district.

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 type II. 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. After an exposure time of 3 months, detector films were removed and etched in a NaOH solution (2.5N at 60°±1 C for 120 min for LR-115 type II films and 6.25N at 70°±1 C during 7 h for the CR-39 detectors) in a constant temperature water bath. Then these SSNTDs were washed, dried and scanned under a binocular microscope with a magnification of 400X for track density measurements. The number of tracks counted per unit area is proportional to the indoor radon and thoron concentration (Bq.m^{-3}) and the exposure time. The correction was applied for the background alpha tracks in CR-39 and LR 115 type II by subtracting the number of tracks observed in the unexposed detector.

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 [7].

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 [8]:

$$\rho_G^{CR} = \frac{1}{4} A_c\left({}^{222}Rn\right)\Big[\big(R_1 B_1 sin^2\theta_{c1} + M({}^{218}Po)R_2B_2 sin^2\theta_{c2} + M({}^{214}Po)M({}^{214}Bi)M({}^{214}Pb)M({}^{218}Po)R_3B_3 sin^2\theta_{c3}\big) + \frac{A_c({}^{220}Rn)}{A_c({}^{222}Rn)}\big(R_1B_1 sin^2\theta_{c1} + M({}^{216}Po)R_2B_2 sin^2\theta_{c2} + M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)R_3B_3 sin^2\theta_{c3} + M({}^{212}Po)M({}^{212}Bi)M({}^{212}Pb)\, M({}^{216}Po)R_4B_4 sin^2\theta_{c4}\big)\Big] \quad (1)$$

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

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

$$\frac{\rho_G^{CR}}{\rho_G^{LR}} = \left[\frac{\begin{pmatrix} R_1B_1 sin^2\theta_{c1} + M({}^{218}Po)R_2B_2 sin^2\theta_{c2} \\ +M({}^{214}Po)M({}^{214}Bi)M({}^{214}Pb)M({}^{218}Po)\ R_3B_3 sin^2\theta_{c3}) \end{pmatrix} + \frac{A_c({}^{220}Rn)}{A_c({}^{222}Rn)}\begin{pmatrix} (R_1B_1 sin^2\theta_{c1} + M({}^{216}Po)R_2B_2 sin^2\theta_{c2} \\ + M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)R_3B_3 sin^2\theta_{c3} \\ M({}^{212}Po)M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)\ R_4B_4 sin^2\theta_{c4} \end{pmatrix}}{\Delta R sin^2\theta'_c \left(\begin{pmatrix} B_1 + M({}^{218}Po)B_2 \\ +M({}^{214}Po)M({}^{214}Bi)M({}^{214}Pb)M({}^{218}Po)\ B_3 \end{pmatrix} + \frac{A_c({}^{220}Rn)}{A_c({}^{222}Rn)}\begin{pmatrix} B_1 + M({}^{216}Po)B_2 \\ + M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)B_3 \\ M({}^{212}Po)M({}^{212}Bi)M({}^{212}Pb)M({}^{216}Po)\ B_4 \end{pmatrix}\right)}\right] \quad (3)$$

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 hospitals, using method described in details in our previous work [8].

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

There are several computer codes that can be used to calculate the range of alpha particle R_i in air or material as a function of the alpha-particle energy. In the present study, we will refer to the well-known and widely used program called SRIM (Stopping and Range of Ions in Matter). The program is freely downloadable from and the version to which we are referring in this study is the one published in 2013, which will be hereafter referred to as SRIM2013 [9]. As default, SRIM2013 uses an air density of 0.00163 g.cm^{-3} and this should be corrected for the room temperature to 0.001225 g.cm^{-3}.

$\Delta R = R_{max} - R_{min}$, depend on residual thickness for LR-115 type II SSNTDs. According to our etching condition 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. Where R_{min} and R_{max} are the range of alpha particle in air, represent the minimum and maximum distances respectively, below and above which alpha-particle do not induce an observable track. These distances are defined as:

$$R_{min} = R_i - R_{4.7\,MeV} \quad (5)$$

$$R_{max} = R_i - R_{1.6\,MeV} \quad (6)$$

where $R_{1.6\,MeV}$ and $R_{4.7\,MeV}$ represent the range in air of α-particle of 1.4 MeV (0.81 cm) and 4.7 MeV (3.22 cm), respectively. R_i represents the total range in air of one of α-particle group. The R_{min} and R_{max} values are given in table 1.

Table 1 alpha particle rage in air, minimum and maximum distances using SRIM 2013.

No.	*Radioisotope*	*Alpha-energy MeV*	*Range in air cm*	*R_{min} cm*	*R_{max} cm*
1	^{222}Rn	5.49	4.07	0.85	3.26
2	^{218}Po	6.00	4.66	1.44	3.85
3	^{214}Po	7.69	6.91	3.69	6.10
4	^{220}Rn	6.29	5.02	1.80	4.21
5	^{216}Po	6.78	5.65	2.43	4.84
6	^{212}Bi	6.05	4.73	1.51	3.92
7	^{212}Po	8.78	8.56	5.34	7.75

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 [10]:-

$$\mathrm{E}_{\mathrm{p},(^{222}Rn)}[\mathrm{WLM.y^{-1}}] = \frac{\mathrm{T \times n \times F} \times A_c\,(^{222}Rn)}{170 \times 3700} \quad (7)$$

For thoron:

$$\mathrm{E}_{\mathrm{p},(^{220}Rn)}[\mathrm{WLM.y^{-1}}] = \frac{\mathrm{T \times n \times F} \times A_c\,(^{220}Rn)}{170 \times 275} \quad (8)$$

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 [11].

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 [12].
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)[13]:

$$\text{Lifetime fatality risk} = \text{Annual exposure } \times 3 \times 10^{-4}\, WLM^{-1} \quad (9)$$

RESULTS AND DISCUSSION

The measured values of indoor radon, thoron concentration, annual exposure, life time fatality risk, and annual effective dose in different Government hospitals Government hospitals of study area were tabulated in tables (2-11). These measurements were carried out in winter season (November 2013 to February 2014).

The indoor radon and thoron levels in Teaching Al Sadr Hospital are found to vary from 15–251 $Bq.m^{-3}$ and 4–238 $Bq.m^{-3}$ with an average value of 63±13$Bq.m^{-3}$ and 26±13$Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.13×10^{-4} - 4.01×10^{-4}, 0.16 - 4.70 mSv/y with an average value of (0.57±0.22) $\times10^{-4}$ and 0.69±0.25 mSv/y, respectively.

We notice anomalous value for indoor radon and thoron concentration in services room in ground floor, this may be due to several reason, firstly poor ventilation rate because this room contain one door and no window, secondly this room is very narrow, its dimension (6×2×3), which have smaller volume relative to other rooms in this hospital.

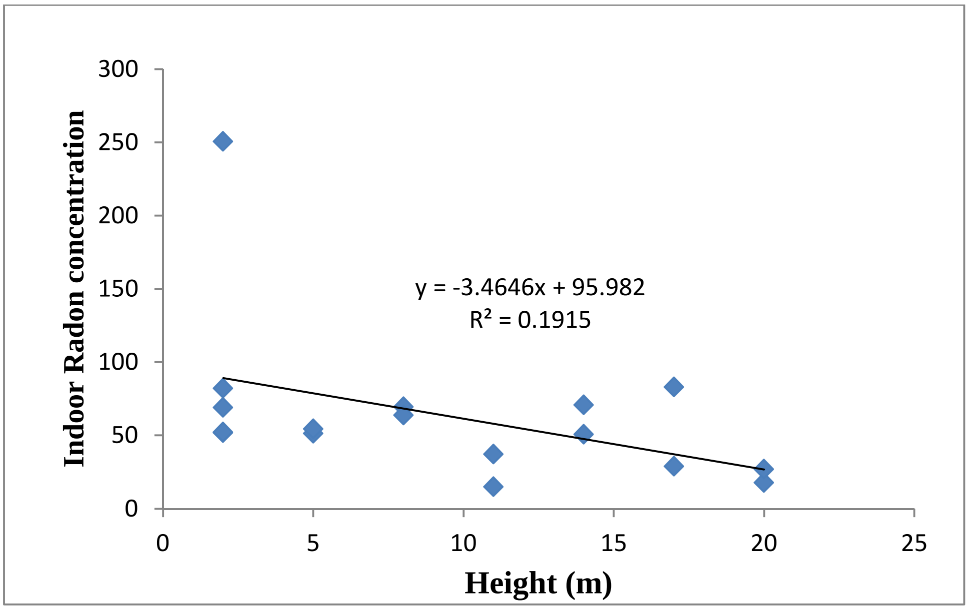

Fig. 2 the correlation between indoor radon concentration and height of building in teaching Al Sadar hospitals

From figure (2) we can see the relation between indoor radon concentrations and the height of the building (SSNTDs) from the ground level. From this figure we notice the slope of the straight line is negative (slope= -3.465) and the correlation between indoor radon concentration and the height is also negative (R= -0.438). Therefore one can conclude the indoor radon concentration decreases as the height of the building increases.

The indoor radon and thoron levels in Al-Basra General Hospital are found to vary from 23–257 $Bq.m^{-3}$ and 2–57 $Bq.m^{-3}$ with an average value of 82±16 $Bq.m^{-3}$ and 27±5 $Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.13×10^{-4} - 1.72×10^{-4}, 0.16 - 2.10 mSv/y with an average value of $(0.65\pm0.11)\times10^{-4}$ and 0.79±0.14 mSv/y, respectively.

The indoor radon and thoron levels in Basrah Hospital for Women´s and Obstetrics Basrah Hospital for Women´s and Obstetrics are found to vary from 32–243 $Bq.m^{-3}$ and 18–131 $Bq.m^{-3}$ with an average value of 99±21 $Bq.m^{-3}$ and 42±12 $Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.37×10^{-4} - 2.61×10^{-4}, 0.44 - 3.11 mSv/y with an average value of $(0.91\pm0.22)\times10^{-4}$ and 1.09±0.26 mSv/y, respectively.

The indoor radon and thoron levels in General Harbours Hospital are found to vary from 23–212 $Bq.m^{-3}$ and 2–111 $Bq.m^{-3}$ with an average value of 109±15 $Bq.m^{-3}$ and 46±9 $Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.13×10^{-4} - 2.19×10^{-4}, 0.16 - 2.61 mSv/y with an average value of $(1.00\pm0.15)\times10^{-4}$ and 1.20±0.17 mSv/y, respectively.

The indoor radon and thoron levels in General Al Fayhaa Hospital are found to vary from 4–104 $Bq.m^{-3}$ and 2–21 $Bq.m^{-3}$ with an average value of 40±6 $Bq.m^{-3}$ and 10±1 $Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.10×10^{-4} - 0.54×10^{-4}, 0.12 - 0.68 mSv/y with an average value of $(0.29\pm0.03)\times10^{-4}$ and 0.35±0.04 mSv/y, respectively.

The indoor radon and thoron levels in General Al Shafa Hospital are found to vary from 14–111 $Bq.m^{-3}$ and 4–37 $Bq.m^{-3}$ with an average value of 57±11 $Bq.m^{-3}$ and 15±3 $Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.16×10^{-4} - 0.84×10^{-4}, 0.19 - 0.10 mSv/y with an average value of $(0.45\pm0.07)\times10^{-4}$ and 0.55±0.09 mSv/y, respectively.

The indoor radon and thoron levels in Abu Al Khaseeb hospital are found to vary from 20–130 $Bq.m^{-3}$ and 11–31 $Bq.m^{-3}$ with an average value of 83±16 $Bq.m^{-3}$ and 18±3 $Bq.m^{-3}$, respectively. The Life time fatality risk and annual effective dose received by the workers are vary from 0.23×10^{-4} - 0.83×10^{-4}, 0.28 - 1.01 mSv/y with an average value of $(0.54\pm0.09)\times10^{-4}$ and 0.67 ± 0.11 mSv/y, respectively.

Table 2 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in Teaching Al Sadr Hospital

No.	Department	Room	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM/y)	Life time fatality risk factor ($\times10^{-4}$)	Annual effective dose (mSv/y)
1	Ground floor	Morning pharmacy	82	15	0.17	0.51	0.63
2		Room service	251	238	1.34	4.01	4.70
3		Emergency laboratory	52	17	0.14	0.41	0.50
4		Cancer tumors center - Women's 5	69	15	0.15	0.46	0.56
5		Cancer tumors center -men's 1	52	17	0.14	0.42	0.51
6	First floor	Laboratory 1	51	17	0.14	0.41	0.50
7		Laboratory 2	55	12	0.12	0.37	0.45
8	Second floor	Hearty lobby 3	70	22	0.18	0.55	0.66
9		Hearty lobby 4	64	13	0.14	0.41	0.50
10	Third floor	Fractures 4	37	7	0.08	0.23	0.28
11		Fractures 5	15	8	0.05	0.16	0.19
12	Fourth floor	Thoracic surgery 2	51	15	0.13	0.39	0.47
13		Thoracic surgery 3	71	18	0.17	0.50	0.61
14	Fifth floor	Special wing 1	83	7	0.14	0.41	0.51
15		Special wing 2	29	4	0.05	0.16	0.20
16	Sixth floor	Women's lobby 2	18	5	0.04	0.13	0.16
17		Women's lobby 3	27	6	0.06	0.18	0.22
	Av. ±SE		63±13	26±13	0.19±0.07	0.57±0.22	0.69±0.25
	Max.		251	238	1.34	4.01	4.70
	Min.		15	4	0.04	0.13	0.16
	S. D.		53	55	0.30	0.90	1.05

Table 3 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in General Al-Basrah Hospital

No	Department	Room	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor ($\times10^{-4}$)	Annual effective dose (mSv/y)
1	Surgical	Women´s	78	31	0.23	0.70	0.84
2		The urinary-mens	124	36	0.31	0.93	1.13
3		Official of the hallway	31	4	0.06	0.17	0.21
4	Face and hands surgery	Official of the hallway	257	57	0.57	1.72	2.10
5		Men´s	230	53	0.52	1.56	1.90
6	The esoteric-men´s	Men´s -1	82	52	0.33	0.98	1.16
7		Men´s - 2	98	55	0.36	1.08	1.28
8	Special Wing -second floor.	The office	44	11	0.10	0.31	0.38
9		Official of the hallway-mens	39	4	0.07	0.20	0.25
10	Laboratories	Parasites	200	52	0.48	1.43	1.75
11		Clinical immunology	41	17	0.12	0.37	0.45
12	Nervous system- men´s	Nursing unit	62	51	0.30	0.89	1.05
13		Official of the hallway.	82	44	0.29	0.87	1.04
14		Men's -1	85	13	0.17	0.50	0.62
15	Nervous system- women´s.	Womens 1	25	4	0.05	0.15	0.19
16		Womens 2	27	2	0.04	0.13	0.16
17	Department Surgical - Special wing	Official of the hallway.	25	9	0.07	0.21	0.25
18		Men's	23	18	0.11	0.32	0.37
19	Pediatric Department	Critical cases	43	8	0.09	0.27	0.33
20		Diarrheal	35	10	0.09	0.26	0.31
	Av.		82±16	27±4	0.22±0.04	0.65±0.11	0.79±0.14
	Max.		257	57	0.57	1.72	2.10
	Min.		23	2	0.04	0.13	0.16
	S. D.		70	21	0.17	0.50	0.61

The indoor radon and thoron levels in Al Fao hospital are found to vary from 25-115 Bq.m^{-3} and 5-24 Bq.m^{-3} with an average value of 57±14 Bq.m^{-3} and 12±2 Bq.m^{-3}, respectively. The Life time fatality risk factor and annual effective dose received by the workers are vary from 0.19×10^{-4} - 0.75×10^{-4}, 0.23 - 0.92 mSv/y with an average value of $(0.37\pm0.08)\times10^{-4}$ and 0.45 ± 0.10 mSv/y, respectively.

The indoor radon and thoron levels in Al Qurna General Hospital are found to vary from 27–149 Bq.m^{-3} and 1–77 Bq.m^{-3} with an average value of 73±14 Bq.m^{-3} and 28±10 Bq.m^{-3}, respectively. The Life time fatality risk factor and annual effective dose received by the workers are vary from 0.11×10^{-4} - 1.35×10^{-4}, 0.15 - 1.59 mSv/y with an average value of $(0.64\pm0.15)\times10^{-4}$ and 0.77 ± 0.18 mSv/y, respectively.

The indoor radon and thoron levels in Al Mudaina General hosptial are found to vary from 11–213 Bq.m^{-3} and 4–60 Bq.m^{-3} with an average value of 71±15 Bq.m^{-3} and 20±4 Bq.m^{-3}, respectively. The Life time fatality risk factor and annual effective dose received by the workers are vary from 0.10×10^{-4} - 1.59×10^{-4}, 0.12 - 1.93 mSv/y with an average value of $(0.53\pm0.11)\times10^{-4}$ and 0.64±0.14 mSv/y, respectively.

Table 4 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in Basrah Hospital for Women´s and Obstetrics

No.	Room	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor ($\times10^{-4}$)	Annual effective dose (mSv/y)
1	Blood Bank - laboratory	32	20	0.12	0.37	0.44
2	Rays - physicians room	80	52	0.33	0.98	1.16
3	Early detection of blood diseases	93	28	0.24	0.72	0.87
4	Breast tumors - Statistics	64	32	0.22	0.66	0.79
5	Laboratory of breast tumors	243	131	0.87	2.61	3.11
6	Advisory of women	57	22	0.17	0.50	0.60
7	Pharmacy Advisory	144	18	0.26	0.78	0.97
8	Advisory physician	89	51	0.33	0.99	1.18
9	Advisory of children	86	21	0.20	0.60	0.73
	Av. ±SE	99±21	42±12	0.30±0.07	0.91±0.22	1.09±0.26
	Max.	243	131	0.87	2.61	3.11
	Min.	32	18	0.12	0.37	0.44
	S. D.	62	36	0.22	0.67	0.79

Table 5 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in General harbors Hospital

No.	Department	Room	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor ($\times10^{-4}$)	Annual effective dose (mSv/y)
1	X-ray department	X-ray room	91	32	0.25	0.76	0.92
2		Interior X-ray	75	11	0.14	0.43	0.54
3	Blood Bank	work room	106	90	0.52	1.56	1.83
4		Drawing blood	129	63	0.43	1.30	1.55
5	The esoteric - Men	Nursing station	180	95	0.64	1.91	2.28
6		First lobby	202	111	0.73	2.19	2.61
7	Intensive Care	Physicians Room	82	35	0.25	0.76	0.91
8	Surgery - Men	Nursing station	23	3	0.04	0.13	0.16
9		Room 2	189	6	0.27	0.80	1.03
10		Room 6	158	51	0.42	1.25	1.52
11	Special wing - Men	Room 2	46	2	0.06	0.19	0.25
12		Room 17	70	21	0.18	0.53	0.65
13		room 3	44	104	0.50	1.50	1.73
14		Nursing station	212	65	0.55	1.64	1.99
15	Advisory	The esoteric	92	26	0.23	0.68	0.83
16		Dermatology	124	41	0.33	1.00	1.21
17		Ear-Nose-throated	36	18	0.12	0.37	0.44
	Av. ±SE		109±15	46±9	0.33±0.05	1.00±0.15	1.20±0.17
	Max.		212	111	0.73	2.19	2.61
	Min.		23	2	0.04	0.13	0.16
	S. D.		61	37	0.20	0.61	0.72

Table 6 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in General Al Fayhaa Hospital

No.	Department	Room	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor ($\times10^{-4}$)	Annual effective dose (mSv/y)
1	Department of X-rays.	Director of rays	4	12	0.06	0.17	0.19
2		Mufras	49	14	0.12	0.37	0.45
3	Laboratories	Chemistry Lab	20	8	0.06	0.18	0.22
4		tissular examination	20	11	0.07	0.21	0.25
5	Special Wing	Director Suite	13	5	0.04	0.12	0.14
6	First floor.	Physician	50	7	0.10	0.29	0.35
7	The esoteric	The Office	13	4	0.03	0.10	0.12
8	Second floor.	Official of lobby	37	5	0.07	0.21	0.26
9	Womens	Statistics	48	18	0.14	0.41	0.50
10	Second floor.	Physicians	41	21	0.14	0.43	0.52
11	The Ophthalmology Department	Fractures	45	11	0.10	0.31	0.37
12		Surgery	74	11	0.14	0.43	0.53
13		Official of lobby	104	11	0.18	0.54	0.68
14		lobby of men´s	41	18	0.13	0.39	0.47
15	Children lobby	Official of lobby	60	15	0.14	0.42	0.51
16		Nursing station	50	2	0.07	0.21	0.27
17		Physician	17	3	0.03	0.10	0.13
	Av. ±SE		40±6	10±1	0.10±0.01	0.29±0.03	0.35±0.04
	Max.		104	21	0.18	0.54	0.68
	Min.		4	2	0.03	0.10	0.12
	S. D.		25	6	0.05	0.14	0.17

Table 7 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in General Al Shafa Hospital

No.	Department	Room	^{222}Rn $Bq.m^{-3}$	^{220}Rn $Bq.m^{-3}$	Total Annual exposure of ($^{222}Rn+^{220}Rn$) (WLM)	Life time fatality risk factor ($\times 10^{-4}$)	Annual effective dose (mSv/y)
1	Intensive Care	Physician	111	19	0.22	0.66	0.82
2		Intensive care	96	37	0.28	0.84	1.00
3		Sonar	41	12	0.10	0.30	0.37
4	Pediatrics Department	Lobby 1	52	18	0.14	0.43	0.52
5		Maintenance store	107	23	0.23	0.70	0.86
6		Refrigeration unit	28	5	0.06	0.18	0.22
7	Special Wing	Medical staff	53	11	0.11	0.34	0.42
8		Room 17	51	10	0.11	0.32	0.40
9	Esoteric - Men	Staff room	17	8	0.05	0.16	0.19
10		Lobby 1	14	4	0.20	0.59	0.72
	Av. ±SE		57±11	15±3	0.15±0.03	0.45±0.07	0.55±0.09
	Max.		111	37	0.28	0.84	1.00
	Min.		14	4	0.05	0.16	0.19
	S. D.		36	10	0.08	0.23	0.28

Table 8 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in Al Fao Hospital

No.	Room	^{222}Rn $Bq.m^{-3}$	^{220}Rn $Bq.m^{-3}$	Total Annual exposure of ($^{222}Rn+^{220}Rn$) (WLM)	Life time fatality risk factor ($\times 10^{-4}$)	Annual effective dose (mSv/y)
1	Follow-up room	39	5	0.07	0.21	0.26
2	The esoteric - Men	115	24	0.25	0.75	0.92
3	Emergency	69	11	0.14	0.41	0.50
4	X-ray room	25	8	0.06	0.19	0.23
5	Pharmacy Advisory	29	10	0.08	0.24	0.29
6	Advisory laboratory	27	12	0.09	0.26	0.31
7	Medicines store	94	14	0.18	0.54	0.66
	Av. ±SE	57±14	12±2	0.12±0.03	0.37±0.08	0.45±0.10
	Max.	115	24	0.25	0.75	0.92
	Min.	25	5	0.06	0.19	0.23
	S. D.	36	6	0.07	0.21	0.26

Table 9 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in Abu Al Khaseeb Hospital

No.	Department	Room	^{222}Rn $Bq.m^{-3}$	^{220}Rn $Bq.m^{-3}$	Total Annual exposure of ($^{222}Rn+^{220}Rn$) (WLM)	Life time fatality risk factor ($\times 10^{-4}$)
1	bacteriological shield Laboratory	113	31	0.28	0.83	1.01
2	Pharmacy Advisory	20	12	0.08	0.23	0.28
3	Women's Lobby	95	25	0.23	0.68	0.83
4	X-ray room	29	11	0.08	0.25	0.30
5	Radiology room- accessory	130	20	0.25	0.75	0.93
6	Medicines store	95	13	0.18	0.53	0.66
7	Childbirth hall	99	12	0.18	0.53	0.66
	Av. ±SE	83±16	18±3	0.18±0.03	0.54±0.09	0.67±0.11
	Max.	130	31	0.28	0.83	1.01
	Min.	20	11	0.08	0.23	0.28
	S. D.	42	8	0.08	0.23	0.29

Table 10 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in General Al Qurna Hospital

No.	Department	Room	^{222}Rn $Bq.m^{-3}$	^{220}Rn $Bq.m^{-3}$	Total Annual exposure of ($^{222}Rn+^{220}Rn$) (WLM)	Life time fatality risk factor ($\times 10^{-4}$)	Annual effective dose (mSv/y)
1	Blood Bank	Laboratory	41	15	0.11	0.34	0.41
2		X-ray room 1	27	1	0.04	0.11	0.15
3	Surgical men	Nurses station	87	3	0.12	0.36	0.47
4		Maintenance room	54	14	0.13	0.38	0.47
5	Department of Pharmacy	Control	149	26	0.30	0.90	1.12
6	Advisory	Laboratory of	32	3	0.05	0.16	0.20
7		Ear and Throat	110	56	0.38	1.14	1.36
8		Administrative Associate	62	59	0.33	1.00	1.17
9		Hospital director	95	77	0.45	1.35	1.59
	Av. ±SE		73±14	28±10	0.21±0.05	0.64±0.15	0.77±0.18
	Max.		149	77	0.45	1.35	1.59
	Min.		27	1	0.04	0.11	0.15
	S. D.		41	29	0.15	0.46	0.54

Table 11 Indoor radon/thoron concentrations, annual exposure, life time fatality risk factor and Annual effective dose in General Al Mudaina Hospital

No.	Department	Room	^{222}Rn Bq.m^{-3}	^{220}Rn Bq.m^{-3}	Total Annual exposure of (^{222}Rn+^{220}Rn) (WLM)	Life time fatality risk factor (×10^{-4})	Annual effective dose (mSv/y)
1		Physical Therapy	14	7	0.05	0.14	0.17
2		Interior pharmacy	213	60	0.53	1.59	1.93
3	Esoteric	Men 2	68	16	0.15	0.46	0.56
4	Special Wing	Men 5	11	4	0.03	0.10	0.12
5		Children lobby 3	28	12	0.09	0.27	0.32
6		Children lobby 2	54	32	0.21	0.62	0.74
7	Esoteric	Nursing station	24	6	0.05	0.16	0.20
8	Surgery	women	34	5	0.06	0.19	0.24
9	Surgeries	Official of the anesthesia	131	41	0.34	1.02	1.24
10		Pharmacy Division	66	19	0.17	0.50	0.61
11	Internal laboratory	Viruses	42	11	0.10	0.31	0.37
12		X - Photographers	167	50	0.43	1.28	1.55
13	Emergency	Pharmacy	38	15	0.11	0.33	0.40
14	Advisory	Public Health	84	20	0.19	0.58	0.70
15	Childbirth	the nurses room	16	6	0.04	0.13	0.16
16	Blood Bank	matching examination	141	20	0.27	0.80	0.99
	Av. ±SE		71±15	20±4	0.18±0.04	0.53±0.11	0.64±0.14
	Max.		213	60	0.53	1.59	1.93
	Min.		11	4	0.03	0.10	0.12
	S. D.		61	17	0.15	0.44	0.54

We notice that the average indoor radon concentrations is higher than average indoor thoron concentrations in the hospital 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 [14].

The average value of radon concentration in the hospitals is higher than the average value of 40 Bq.m^{-3},reported for the dwellings worldwide [3]. 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 hospitals 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 200–300 Bq.m^{-3}, recommended by ICRP [12].

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 in Government hospitals of Basrah governorate in southern Iraq. Life time fatality risk and effective dose have also been calculated for the occupants of these hospitals. The conclusions of the present study are as follows:

The overall average value of indoor radon in the present study (40±6 -109±15 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 (200–300 Bq.m^{-3}) recommended by ICRP.

The average values of annual effective dose in the hospitals of study area, for Occupants (0.35±0.04 -1.2±0.17 mSv/y) found within typical range (0.2-10 mSv/y) of average radiation dose from Inhalation (mainly radon) [15], and less than the lower limit of action level (3-10) mSv/y recommended by ICRP. So the annual effective dose, radon and thoron concentrations are within the permissible limits.

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