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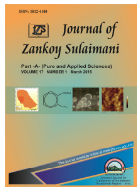

Indoor Radon measurements in dwellings in four districts of Al-Rusafa side - Baghdad

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Abstract

Indoor radon level measurements were carried out in 36 dwellings in Al-Rusafa side of Baghdad, using CR-39 solid state nuclear track detectors. The measurements were performed during spring 2013 (March, April and May) for a period of 90 days using a total of 120 dosimeters. The dosimeters were distributed in 4 districts in Al-Rusafa side (Rusafa, Adhamia, 9 Nissan and Karrada) and installed in living rooms, bedrooms and kitchens of each house, selected randomly in the investigated area. The average indoor radon concentration in Al-Rusafa dwellings was found with mean values of 13.9 Bqm-3. Annual effective dose and annual equivalent dose that Al-Rusafa inhabitants exposed to were 346.5μSvy-1 and 8.31mSvy-1, respectively. The mean values of radon concentration levels in bedrooms, kitchens and living rooms are 14.3, 15.0 and 14.5 Bqm-3 respectively. The results show that radon concentration levels in the investigated dwellings are far below 100 Bqm-3 as recommended by ICRP and WHO.

Introduction

The presence of radon and its decay products in the human environment are considered as a potential health hazard and is one of the most significant natural sources of radiation exposures. Radon represents 52% of the entire radiation exposure [1], and its measurement is important to assess the threat they might pose. It is a naturally occurring radioactive gas and it is one of the products of the natural decay chains of uranium and thorium, which are present in soil and rocks. In particular, ^{222}Rn, product of the decay series of ^{238}U, is generated from ^{226}Ra; with a half-life of 3.82 days is enough to allow its release into the environment. After inhalation, its decay products will deposit in the lung, hence it will receive a considerable dose of alpha radiation, emitted during subsequent decay of these products. They also emit gamma rays that increase the external human exposure.

The radiation from radon and its progeny, in fact, is considered the second leading cause of lung cancer after smoking, according to the National Academy of Sciences report [2]. Over the past four decades, natural radiation exposure due to radon ^{222}Rn and its progeny inside houses has been recognized as a worldwide problem and a cause of significant lung cancer risk to the population. It is also of great importance to assess the exposure to ^{222}Rn and its progeny in houses and areas of high ^{222}Rn levels for the purposes of quality control, radioactivity monitoring of building materials and for correction measures recommendations. Indoor radon concentration depends on many parameters, viz. type of building material, soil beneath the house, household water and domestic gas supplies [3].

In the present study, measurements of indoor radon concentrations in dwellings of Al-Rusafa region, the eastern shore of river Tigris in Baghdad, were carried out using solid state nuclear track detector (SSNTD) technique, in order to assess whether the general public is at any risk due to this exposure to excessive levels of radon. The results of the present study shall help in establishing a baseline map of natural radiation background in this part of the world. The results were compared with the recommended level of annual average radon gas concentration limits of 100 Bq/m^3 given by ICRP and WHO [4 and 5].

Area of study

Governorate of Baghdad is the capital of the Republic of Iraq. It is the smallest governorate in Iraq in terms of land area, with a total area of 4,071 km^2, situated on the Tigris River. Tigris River passes through the city, dividingit into two parts: Al-Karkh (Western part) and Al-Rusafa (Eastern part). Administrative map of Baghdad is shown in Fig. 1.

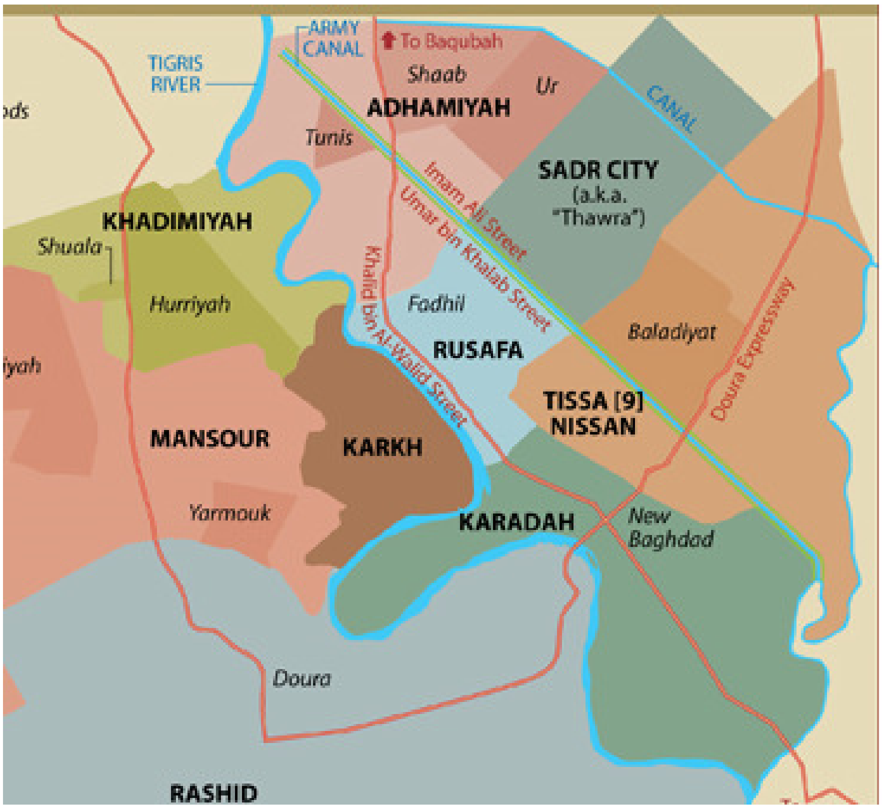

Fig. 1 Administrative map of Baghdad

Al-Rusafa side is divided into five administrative districts, they are Adhamia, Karadah, Sadr City, Rusafa and 9 Nissan. The measurements were carried out and covered the neighborhoods given in Table-1. Al-Rusafa side has more than 4 million inhabitants and constitutes about 50 % of Baghdad total population.

Materials and Methods

In the present work, passive radon dosimeter technique (solid-state nuclear track detectors CR-39), is usually used for long-term measurements inside dwellings. It is based on a closed can containing CR-39 sheet, they have been cut to (1x1.5) cm^2 size rectangles, and were fixed at the bottom of a plastic cup using double-sided tape (Figure 2). On the cover of the cup there is a hole sealed by a 5-mm thickness sponge [6]. This set-up allows radon to diffuse inside the cup. The track density of alpha particles in the detectors provides information about the relative concentration of radon in the houses surveyed.

Table 1: Investigated neighborhoods in Al-Rusafa side

District	Rusafa	Adhamia	Karadah	9Nissa
Neighborhood	Sa'adoon	Adhamiya	Sina'a	Ghadeer
	Mustansirya	Wazirea	Inner Karada	Baghdad Jadida
	Rusafa	Qahira	Outer Karada	Mashtal
	Palastine st.	Sha'ab		Baladiyat
	Hayy Jamila			

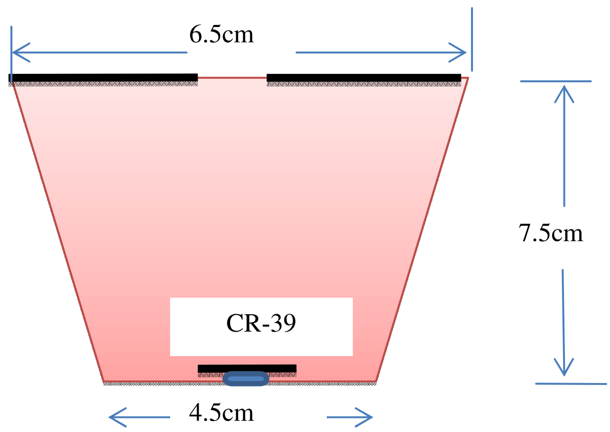

Fig.2 Schematic diagram of the dosimeter

Total of 120 dosimeters were prepared and distributed in dwellings in four districts in Al-Rusafa area east of Tigris river, which are (Rusafa; Adhamia; 9Nissan and Karadah). In each house, three dosimeters were placed in three rooms (sitting room, bed room and kitchen) at a height of about 2 m above the floor, and all the dosimeters were collected after 3 months of exposure. The exposure time was during spring 2013 (March, April and May).The collected dosimeters were then chemically etched, using a 6.25 N solution of NaOH at a temperature of 80^{o} C for five hours [7]. An optical microscope with a magnification of 10 × 40 was used to count the number of tracks per cm^{2} recorded on each detector. The tracks for 20 fields of view (FOV) (area 12.57 × 10^{-4} cm^{2}) were counted randomly all over the detector surface to obtain an average and representative value of track density for each dosimeter. The measured track densities formed on the analyzed nuclear track detectors (NTDs) were converted into radon concentrations (Bqm^{-3}) using the calibration factor of (0.00936 tracks.cm^{-}2.h^{-1} per Bqm^{-3}) by adopting an exposure period of 90 days. In order to calculate the calibration factor, we use the following procedure [8]

K=1 [(track/cm^{2}.day)/(Bqm^{3})]=[{track/cm^{2} (86400)sec}×{10^{6}sec.cm^{3}/track}]

= 11.574074cm

since 1 Bq = 1disintegration/second = track/sec, 1day=86400sec, 1m^{3}=10^{6}cm^{3}, so K=1cm = 0.0864[(track/cm^{2}.day)/(Bqm^{3})].

The radon activity density *C*, in units of Bqm^{-3}, is then calculated using the following relation [9]:

$$C = \frac{\rho}{T C_F} \qquad (1)$$

Where ρ is the average track density per cm^{2} on the CR-39 detectors that were inside our dosimeters used in this work, T is the exposure time of the distributed dosimeters in hours and C_F is the calibration factor in tracks.cm^{-2}.h^{-1} per Bqm^{-3}.

Hence, equation (2) was used in order to estimate annual effective dose rate in units $mSv.y^{-1}$ received by the inhabitants [10].

$$D_{Rn} = C_{Rn}.D.H.F.T \qquad (2)$$

Where, C_{Rn} is the measured concentration (in Bqm^{-3}), D is the dose conversion factor (9.0×10^{-6} $mSv.h^{-1}$ /Bqm^{-3}), H is the indoor occupancy factor (0.8), F is the ^{222}Rn equilibrium factor indoors (0.4) and T is the indoor occupancy time 24 h ×365 = 8760 h/y.
The annual equivalent dose in units of $mSv.y^{-1}$ was calculated using equation (3) [10].

$$H_E = D_{Rn}.W_R.W_T \qquad (3)$$

Where, D_{Rn}= Annual Absorbed dose, W_R = Radiation Weighting Factor for Alpha Particles which equal 20 as recommended by ICRP [4], W_T = Tissue Weighting Factor for the Lung 0.12 according to ICRP [4].

Results and Discussion

Fig.3 shows the frequencies of radon concentration in the surveyed dwellings. The Figure shows that the frequency distribution is a lognormal-like, as is the case in most other national radon surveys [11, 12, and 6]. The higher data frequency found for values between 6 - 8 Bqm^{-3}. Furthermore, a list of the results of radon levels in the houses of the four investigated districts is given in Table 2

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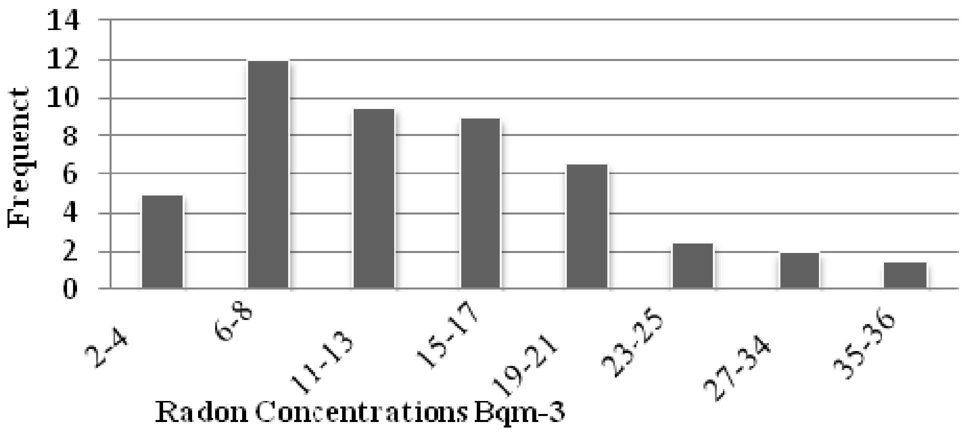

Fig.3 Frequency distribution of radon concentrations.

The results reveal an average indoor radon concentration of 14.2, 15.05, 13.8 and 12.6 Bqm^{-3} for Rusafa, Adhamia, 9 Nissan and
Karadah districts respectively (see Fig. 4). The maximum value of 26.4 Bqm^{-3} is found in Adhamia district. It is noticeable that there is no large variation in mean concentrations presented between the four investigated districts which range from 12.6 Bqm^{-3} in Karadah district and 15.05 Bqm^{-3} in Adhamia district and with an average of 13.9 Bqm^{-3}. The measured concentrations all are below the recommended action limit (< 100 Bqm^{-3}) as reported by ICRP[4].

A comparison of indoor radon concentrations in dwellings in different countries is shown in Table 3. Average radon concentrations were found to depend on the usage of the room in the four districts (bedroom, living room and kitchen), and are listed in Table 4 and shown in Fig. 5.
The radon concentration levels in Karadah district have a little bit higher values in bedrooms than those in the living rooms and kitchen. This may be due to low ventilation rates in bedrooms. While the mean radon concentration in kitchens is higher than that in the other two rooms in Rusafa, Adhamia and 9Nissan districts at the opposite to the normal estimations.

Table 2: Average minimum and maximum radon concentrations in the four studied districts.

House No.	Radon concentration Bqm^{-3}			
	Rusafa	**Adhamia**	**9Nissan**	**Karadah**
1	16.0	9.1	11.8	11.8
2	22.3	6.3	7.0	12.6
3	10.5	20.8	5.3	17.4
4	16.7	16.0	23.5	13.9
5	8.3	12.5	18.8	7.3
6	16	16.7	16.0	
7	9.7	26.4	13.9	
8		9.0	18.8	
9		14.6	9.7	
10		20.2	13.2	
11		13.9	11.5	
12			9.0	
13			13.2	
Ave	14.2	15.1	13.8	12.6
Min	8.3	6.3	5.3	7.3
Max	22.3	26.4	23.5	118.9

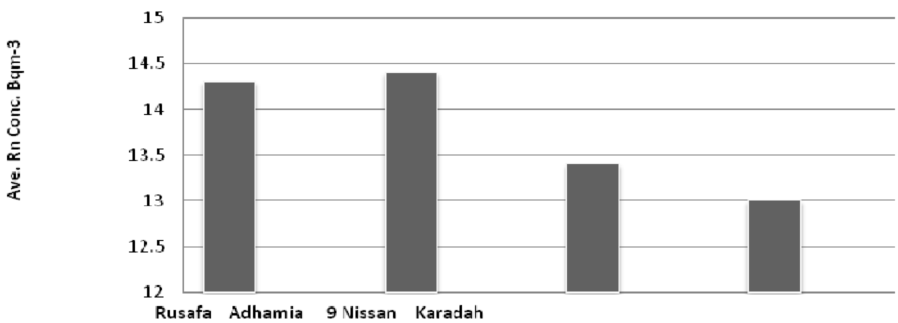

Fig. 4 Mean radon concentrations in four investigated districts.

Table 3: Comparison of indoor radon concentrations in dwellings in different countries

Country	Ave. Rn conc. Bqm^{-3}	Rn conc. Bqm^{-3} (Min – Max)	Ref.
Amritsar – India	8.76	1.56 -22.77	[13]
Podlasie - Poland	45	9 – 1182	[14]
Iran – yazd	137.36	5.55 – 747.4	[15]
Saudi Arabian	30	7 – 137	[16]
Eastern Sicily	107	24 – 468	[17]
Valencia	25	--- -105	[18]
Slovenia	54	7 – 1890	[19]
Jordan	111 ± 4	31 – 501	[6]
Romania-Bacău county	58	18 – 180	[20]
Transylvania –Romania	82.5	------	[21]
Bethlehem- Palestine	117	26 - 611	[22]
Dhamar, Taiz & Hodeidah - Yemer	42	3 - 270	[23]
Al-Rusafa side Baghdad – Iraq	13.9	2.1 – 35.5	Present paper

Table 4: Average radon concentration depending on the room use in the 4 districts.

Room	**Average radon concentrations Bqm^{-3}**					
	Rusafa	**Adhamia**	**9Nissan**	**Karadah**	**Average**	**Min-Max**
Bed Room	14.0	13.7	11.5	17.9	14.3	2.1–35.5
Living Room	12.8	14.2	14.4	16.7	14.5	4.2– 35.0
Kitchen	16.7	17.3	14.0	12.0	15.0	4.2– 35.5

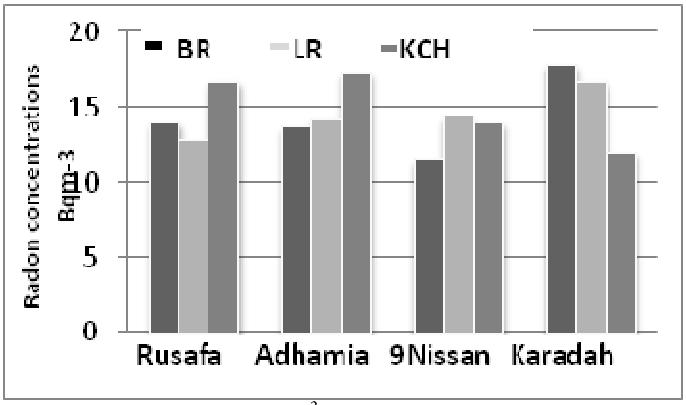

Fig.5 Mean radon concentrations in Bqm^{-3} depending on room type in 4 studied districts.

At the present time, there is no apparent reason for this difference which related with many parameters such as type of building material, soil beneath the house, household water and domestic gas supplies**.**
Estimation of the annual effective dose rate due to radon in units of µSvy^{-1} and the annual equivalent dose in units of mSvy^{-1} were determined and listed in Table 5. Cancer risk estimation, on the other hand, can be done by adopting a mean absolute risk factor of 5.38×10^{-4} per WLM Exposing to1 pCi/L (=37 Bqm^{-3}) of radon gas, the radon daughter exposure rate is 0.144 WLM per year. The average risk of a fatal lung cancer due to lifetime exposure at 1pCi/L is then [24]:
(0.144 WLM/y) (75.4 y/lifetime) (5.38×10^{-4} /WLM) = 0.58%
Accordingly, the inhabitants of the entire investigated area are exposed to an average effective dose rate of 346.5 µSvy^{-1}. This exposure produces an average annual equivalent dose rate of 8.31 mSvy^{-1}. Thus, the average cancer risk due to lifetime exposure (an average of 75 years) to the study area inhabitants is 0.22%.

Table 5: Effective dose rate in µSvy^{-1}, Annual equivalent dose in mSvy^{-1} and Cancer risk for the investigated area

District	**Rn conc. Bqm^{-3}**	**Effective Dose (µSvy^{-1})**	**equivalent dose rate (mSvy^{-}**	**Cancer risk**
Rusafa	14.20	358.2	8.60	0.22
Adhmia	15.05	379.7	9.11	0.23
9Nissan	13.80	330.0	7.92	0.21
Karadah	12.60	317.9	7.63	0.20
Average	13.90	346.5	8.31	0. 22

Conclusions

From this study it can be concluded that there is no significant variation in the radon concentrations in the four investigated districts. A reason for that is related to the use of building materials from similar origin and following similar construction techniques. Radon gas concentration levels inside houses of the investigated area were found to have an average value of 13.9Bqm^{-3}, which is far below the global recommended limits of 100 Bqm^{-3}. Therefore, there is no need for additional protection precautions, or supplementary ventilation in any of the selected houses. Room usage also affected radon concentration in connection with ventilation. In this context, rooms having continuous ventilation exhibited lower concentration. The differences in radon concentration between houses in the same districts are might be due to location of the dosimeter near or far away from the windows as well as the ventilation rate of the room. Finally, although the investigation showed no significant hazard, the obtained data was so useful to be used as a database.

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