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Indoor radon concentrations and effective dose estimation in Al-Karkh side of Baghdad dwellings

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Abstract

Indoor radon concentrations, the annual effective dose rate and the annual equivalent dose rate to the lung and to the public were measured in the dwellings of 10 neighborhoods located on the west side of the river Tigris (Al-Karkh) in Baghdad city using passive dosimeters. CR-39 solid state nuclear track detector (SSNTD) technique was used for radon measurements. Ninety-one dosimeters were distributed in the dwellings of the study area, three dosimeters were planted in three rooms of each house depending on the usage of the room (bedroom, living or sitting room and kitchen). They were left for a period of 3 months during winter time from November 2013 to February 2014. Radon concentrations were found to range from 64.9 Bq.m^{-3} to 94.7 Bq.m^{-3} in Daoudi and Hayy Al-Jamiaa, respectively, with a mean value of 79.82±1.05 Bq.m^{-3}. The mean annual effective dose rate and the mean equivalent dose rate were found 2.00±0.04 mSv.y^{-1}and 4.81±0.06 mSv.y^{-1}. The dwellers of Hayy Al-Jamiaa were found to be exposed annually to the highest equivalent dose rate of 5.74 mSv.y^{-1}. All measured values were lower than the international recommended value given by ICRP.

Keywords*:* Indoor radon; CR-39; annual effective dose; annual equivalent dose; Baghdad

1. Introduction

Radon is a colorless, odorless and tasteless radioactive gas. It forms naturally from the decay of radioactive Uranium, which is found at different levels in soils and rocks throughout the world. Radon gas in the soils and rocks can move into the air and into ground water and surface water. Radon is present everywhere outdoors and indoors. It normally can be found at higher levels indoor houses and other buildings, as well as in water from underground sources, such as well water. The levels of radon in homes and other buildings depends on the characteristics of the rock and soil in the area. The radon gas can enter buildings through cracks in floors or walls; construction joints; or gaps in foundations around pipes, wires, or pumps (UNSCEAR, 2000).

Long-term exposure to radon can lead to lung cancer. Radon gas in the air breaks down to another radioactive element (radon progeny) that can be deposited in the lining of the lungs. Radon progeny continue to decay into other radioactive elements by emitting radiation. The radiation released in this "radioactive decay" process can damage lung cells and eventually lead to lung cancer (Binesh et al., 2012). Radon has been classified as a known human carcinogen and has been recognized as a significant health problem by the Centers for Disease Control, the American Lung Association, the American Medical Association, and the American Public Health Association groups.

The objectives of the present study were to assess the radon concentration levels in dwellings of different neighborhoods in the west bank of the river Tigris (Al-Karkh) in Baghdad city using SSNTD CR-39. Also, annual dose rate exposed to the inhabitants is also calculated.

2. Region of the study

The city of Baghdad is divided into 89 administrative neighborhoods, gathered into nine administrative districts, five districts located east of the river Tigris called Rusafa side (Rusafa, Adhamiyah, Thawra, 9 Nissan and Karadah) districts, whereas four other districts located west of the river Tigris are called Karkh side (Karkh, Kadhimiya, Mansour and Al Rasheed) districts.

Radon level measurements were carried out in dwellings of two districts on Karkh side of Baghdad city, Mansour and Al-Rasheed districts. Mansour district consists of 12 neighborhoods (Qadissiya, Mansour, Al-Washash, Iskan, Daoudi, Yarmouk, Safarat complex, Ameria, Al Khadhraa Hayy Al-Jami'a, Al-Adel and Ghazaliya). While, Al Rasheed

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district consists of 13 neighborhoods (Dora, Al-Saydiya, Hayy Al-A'amel, Hayy Al-Jihad, Al-Atiba'a, Hayy Al-Shurtta, Al-Furat, Makasib, Resala, Ewairij, Hor Rejab, Al-alam and Bo'aitha) (wikipedia).

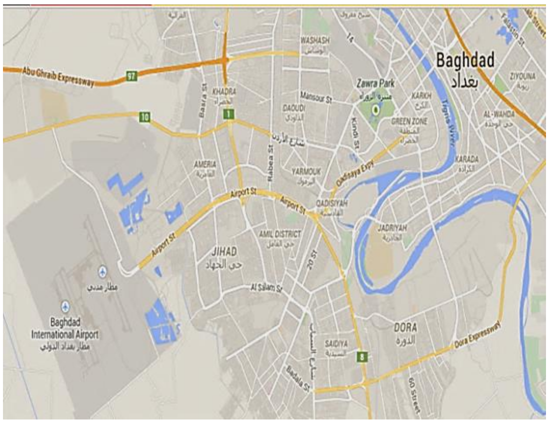

Fig. 1. Administrative map of Baghdad

Dwellings in six neighborhoods of Mansour districts (Mansour, Al-Yarmuk, Ameria, Hayy Al-Jami'a, Daoudi, Al-khadraa) and in four neighborhoods of Al-Rasheed districts (Hayy Al-Jihad, Dora, Saydiya and Al-alam) were investigated. Fig 1 shows the administrative map of Baghdad city

3. Measuring procedures

In the present work, the technique of passive radon dosimeter was applied, which is usually used for long-term measurements inside dwellings. Dosimeters containing CR-39 solid-state nuclear track detectors were used. Details of the dosimeters have previously been described (Amin et al., 2014). Total of 91 dosimeters were prepared and distributed in dwellings of the study districts in Al-Karkh side west of Tigris River. In each house, three dosimeters were planted in three rooms (sitting room, bed room and kitchen) at a height of about 2 m above the floor. The exposure time were taken through winter time from November 2013 to February 2014. After 3 months of exposure time, the dosimeters were collected. The collected CR-39 detectors were then chemically etched, using a 6.25N solution of NaOH at a temperature of $80^{o}C$ for four hours. After etching, they were scanned with an optical microscope with a magnification of 40×10 and the number of tracks per cm^2 recorded on each detector was counted. The track density of alpha particles in the detectors provides information about the relative concentration of radon in the houses surveyed.

The tracks of 20 fields of view (FOV) ($12.57x10^{-4}$ 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 detectors were converted into radon concentrations ($Bq.m^{-3}$) using the calibration factor of (0.00883 $Tracks.cm^{-2}.h^{-1}$ per $Bq.m^{-3}$) (Ismail and Jaafar, 2009) by adopting an exposure period of 90 days. The radon activity density C, in units of $Bq.m^{-3}$, is then calculated using the following relation (Najam, et al., 2013):

$$C = \frac{\rho}{TC_F} \quad (1)$$

where, ρ is the average track density per cm^2 recorded on the CR-39 detectors, T is the exposure time of the distributed dosimeters in hours and C_F is the calibration factor in $Tracks.cm^{-2}.h^{-1}Bq.m^{-3}$.

Hence, equation (2) was used in order to estimate annual effective dose rate in units $mSv.y^{-1}$ received by the inhabitants (Nsiah-Akoto, 2011).

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

where, C_{Rn} is the measured concentration (in $Bq.m^{-3}$), D is the dose conversion factor (9.0×10^{-6} $mSv.h^{-1}$ $/Bq.m^{-3}$) (UNSCEAR, 2000), 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) (Nsiah-Akoto, 2011).

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

where, D_{Rn}= Annual Absorbed dose, W_R=Radiation Weighting Factor for Alpha Particles which equal 20 as recommended by ICRP (1991), W_T=Tissue Weighting Factor for the Lung 0.12 according to ICRP (1991).

4. Results and discussion

Table 1 gives the results of the indoor radon concentrations ($Bq.m^{-3}$), the annual effective dose rate ($mSv.y^{-1}$) and the annual equivalent dose rate in 31 houses in two districts (Mansour and Al-Rasheed) in Al-Karkh side of Baghdad city. Fig.2 shows the frequencies of radon concentrations in the surveyed houses. The figure shows that the frequency distribution is a lognormal-like, as is the case in most other national radon surveys (Ya'qouba et al., 2009; Kullab et al., 2009; Al-Kofahi et al., 1993).

Table 1. Radon concentrations, Annual effective dose rate and Annual equivalent dose rate in the study neighborhoods

Country	Radon Concentration Min	Max	Ave.	Ref.
RajasthanIndia	18.4	62.1	-----	Sharma et al., (2012)
Slovenia	7	1890	54	Vaupotic, (2003)
Valencia Spain	-----		24	Tondeur, et al., (2011)
Sicily-Italy	32	232	69	Catalano, et al., (2012)
Saudi Arabia	20	40	-----	A-Jarallah, et al., (2003)
Bucharest	-----	-----	574	Ghita & Vasilescu, (2011)
Yazd-Iran	5.55	747.4	137.4	Bouzarjo-mehr & Ehrampoo-sh, (2008)
Poland	9	2200	37	Karpińska et al., (2009)
Baghdad	64.9	94.7	79.8	(Present work)

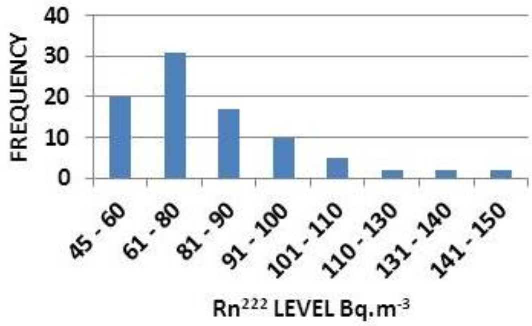

Fig. 2. Frequency of Radon levels in Al-Karkh districts

The higher data frequency was found for values between 61-80 Bq.m^{-3}. Average radon levels in the houses of the ten investigated neighborhoods are shown in Fig. 3. The results indicate that radon levels range from the lowest value of 54.9 Bq.m^{-3} to the highest value of 112.6 Bq.m^{-3} in Daoudi and Hayy Al-Jami'a, respectively. A comparison of indoor radon levels measured in different countries are given in Table 2.

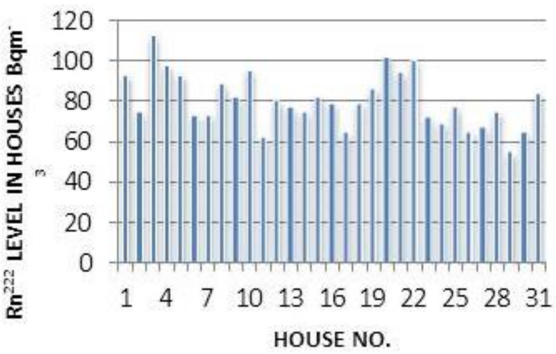

Fig. 3. Indoor radon levels in the houses of the ten investigated neighborhoods

Table 2. Comparison of indoor radon concentrations in different countries

Neighbor hoods	^{222}Rn Conc. Bq.m^{-3}	A.eff.dose mSv.y^{-1}	A.equ. dose mSv.y^{-1}
Hay Al-jamiaa	94.7	2.39	5.74
Ameria	82.3	2.08	4.98
Dora	78.3	1.98	4.74
Al-khadraa	75.5	1.19	4.57
Al-Yarmouk	89.5	2.26	5.42
Al-mansour	89.2	2.25	5.40
Hay Al-Jihad	73.3	1.85	4.44
Al-alam	66.4	1.68	4.02
Daoudi	64.9	1.64	3.93
Saidiya	84.1	2.12	5.09
Mean	79.8± 1.05	2.00± 0.04	4.81± 0.06

Whereas Fig. 4 illustrates the average radon concentrations measured for the surveyed neighborhoods. The results reveal an average indoor radon concentration with the lowest value of 64.9 Bq.m^{-3} and highest value of 94.7Bq.m^{-3} for Daoudi and Hayy Al-Jamiaa, respectively with mean value of 79.82±1.05 Bq.m^{-3}. It is noticeable that there is no large variation in mean concentrations presented between the investigated neighborhoods. All measured concentrations are found below the recommended global limit (< 200 Bqm^{-3}) as reported by ICRP (1993) and the new reference level (100 Bq.m^{-3}) set by WHO (2009) and ICRP (2007).

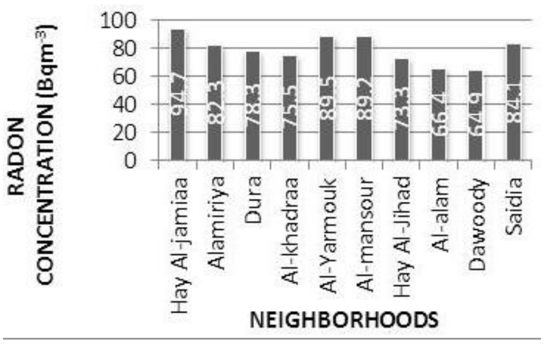

Fig. 4. Average radon concentrations in the investigated neighborhoods

The average radon concentrations depending on the usage of the room (bedroom, living room and kitchen) in the investigated neighborhoods are shown in Fig. 5. The figure indicates that the average radon concentration in bedrooms has higher value than those in sitting room and kitchen. Law ventilation rates in bedrooms cause higher radon level.

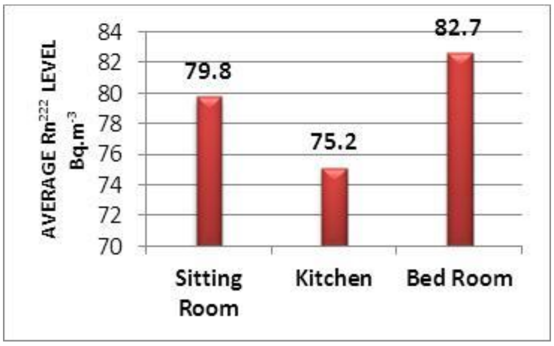

Fig. 5. Average radon concentrations according to room usage

The annual effective dose rate has been calculated from the corresponding measured radon concentration in the different houses and neighborhoods using equation (2) and represented in Fig. 6. The figure indicates that the value of the annual effective dose varies from the lowest value of 1.19 mSv.y^{-1} to the highest value of 2.39 mSv.y^{-1} in Al-Khadraa and Hayy Al-Jamiaa, respectively, with mean value of 2.00±0.04 mSv.y^{-1}. All values are below the recommended ICRP intervention level of (3-10) mSv.y^{-1} (ICRP, 1993).

Figure 7 shows the annual equivalent dose rate calculated using equation (3). The values of the equivalent dose from radon to the lung ranged from (3.93 to 5.74) mSv.y^{-1} in Daoudi and Hayy Al-Jamiaa, respectively, with mean value of 4.81±0.06mSv.y^{-1}. All values are within the recommended value by ICRP (1993).

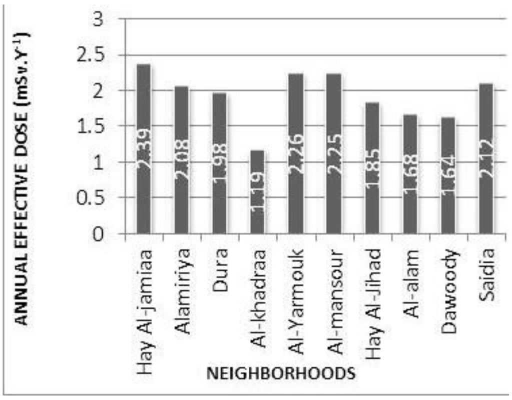

Fig. 6. Neighborhoods and their corresponding annual effective dose rate (mSv.y^{-1})

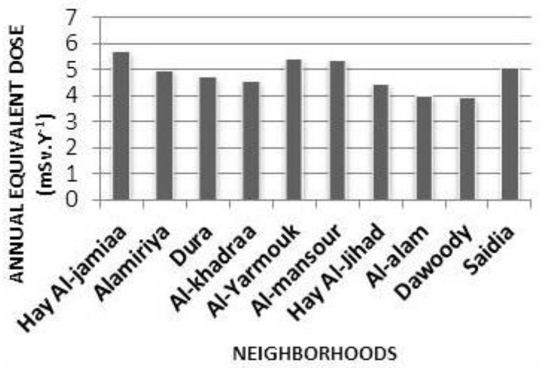

Fig. 7. Neighborhoods and their corresponding annual equivalent dose rate (mSv.y^{-1})

5. Conclusion

The objective of the present work is to assess the indoor radon concentrations in 10 neighborhoods in Al-Karkh side of Baghdad city. The results show that:

1. There is no significant variation in the radon levels in the investigated neighborhoods. The reason might be due to using slandered building materials and typical standards of construction techniques in the investigated area.
2. Radon gas concentration levels inside houses of the investigated area were found to have an average value of 79.82±1.05 Bq.m^{-3}, which is below the global recommended value. Therefore, precaution methods or any use of accessory ventilation in any of the investigated houses are not needed.
3. Low ventilation rate in the room exhibited higher radon concentration in comparison with well-ventilated room.
4. Mean annual effective dose rate and mean annual equivalent dose rate to the lung in the investigated neighborhoods were found to have the value of 2.00±0.04 mSv.y^{-1} and 4.81±0.06 mSv.y^{-1}, respectively, which are within the recommended international value given by ICRP (1993).

Finally, although the investigation showed no significant hazard, the obtained data was useful enough to be used as a database.

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