Determination of Radon Concentration and Annual Effective Dose Inside Houses in Left Side of Mosul City During Winter

Sabah Y. Hasan
Department of Radiology/ Mosul Technical Institutes

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ABSTRACT

In this study, radon concentration, annual effective dose, potential alpha energy concentration (PAEC), and average of lung cancer per million persons from radon were measured using (closed can technique) containing CR-39 nuclear track detector.

Measurements were carried during winter season inside twenty four hoses in eight locations in the left side of Mosul City. The average radon concentration ranged between (52.97±5.315 to 74.98±5.433) $Bq.m^{-3}$ with an average value (62.36±7.518) $Bq.m^{-3}$ which is much lower than the recommended by ICRP action level (200-600) $Bq.m^{-3}$. The results showed that the potential alpha energy concentration ranged between ($5.71\times10^{-3}\pm0.566\times10^{-3}$ to $8.11\times10^{-3}\pm0.586\times10^{-3}$) WLM with an average value ($6.7\times10^{-3}\pm0.820\times10^{-3}$) WLM, while the annual effective dose ranged between (1.34±0.134 to 1.89±0.137) $mSvy^{-1}$ with an average value (1.57±0.189) $mSvy^{-1}$. It is observed that this value less than the recommended levels (3-10) $mSvy^{-1}$ reported by ICRP. The average lung cancer cases per year per million persons were found to be 28.3±3.404, there were no induction of existence of radon problems in this survey.

Keywords: CR-39, annual effective dose, indoor radon.

تحديد مستويات تركيز الرادون والجرعة المؤثرة السنوية في الدور السكنية لبعض أحياء الساحل الأيسر من مدينة الموصل شتاءً

الملخص

في هذه الدراسة تم تحديد معدل تركيز الرادون، الجرعة المؤثرة السنوية ومعدل خطر الاصابة بسرطان الرئة لكل مليون شخص، وقد اجريت الدراسة خلال فصل الشتاء على 24 منزلا في ثمانية احياء سكنية شرق مدينة الموصل باستخدام مجراعات رادونية تراكمية تمت معايرتها مسبقا وهي محتوية على كواشف الحالة الصلبة للمسارات النووية نوع CR-39 خلال فصل الشتاء. تراوحت تراكيز الرادون بين (52.97±5.315 - 74.98±5.433) $Bq.m^{-3}$ وبمعدل (62.36±7.518) $Bq.m^{-3}$. تعد هذه القيم اقل من القيم المسموح بها من قبل ICRP التي تتراوح بين (200-600) $Bq.m^{-3}$. تراوحت تراكيز طاقة الفا الكامنة بين ($5.71\times10^{-3}\pm0.566\times10^{-3}$ - $8.11\times10^{-3}\pm0.586\times10^{-3}$) WLM وبمعدل ($6.7\times10^{-3}\pm0.820\times10^{-3}$) WLM، في حين تراوحت الجرعة المؤثرة السنوية بين (1.34±0.134 - 1.89±0.137) $mSvy^{-1}$ وبمعدل (1.57±0.189) $mSvy^{-1}$ وهي اقل من المستوى الذي اوصت به ICPR والبالغ (3-10) $mSvy^{-1}$. أظهرت النتائج بأن خطر الإصابة بسرطان الرئة السنوي يساوي 28.3±3.404 لكل مليون شخص، كما تبين بأنه ليس هناك خطراً للرادون في المناطق قيد الدراسة.

INTRODUCTION

Radon ^{222}Rn is naturally occuring colourless, odourless, tasteless. It is a natural radioactive decay product of ^{226}Ra an element of uranium ^{238}U decay series. Radon gas ^{222}Rn breaks down in eight radioactive decay steps to become stable element, lead ^{206}Pb (Dorschel and Piesch, 1993). During this process both alpha and beta particles and gamma radiation are released. The radon and its decay products are reported as major causes of lung cancer (Abu-Haija *et al*., 2010).

Radon gas and its solid decay products are carcinogens. The greatest health risks come from exposure to inhaled solid radon gas decay products that are produced during the radioactive decay of radon gas. Two of these decay products ^{218}Po and ^{214}Po, present a significant radiological hazard. Once the radioactive decay products are inhaled into the lung, they undergo further radioactive decay, releasing small bursts of energy in the form of alpha particles that can either causes DNA breaks or creat free radicals (Abed-Elzaher and Fahmi, 2008). The main natural sources of indoor radon are building materials (Sand, rock, cement, ….etc), tap water, natural energy sources like (gas, coal, etc.) which contain traces of ^{238}U. The topography, house construction type, soil, ventilation rate, wind direction and even the life style of people (Abed-Elzaher and Fahmi, 2008), (Al-Saleh, 2007). Most of our time is spent within buildings; therefore, the measurement and limitation of radon concentration of building are important.

In the present investigation, solid state nuclear track detectors, known as passive method, are widely used for radon measurement. Radon concentrations are determined by measuring the emitted alpha particles, which causes damage in the detector surface. Because of its good ionization sensitivity and stability against various environmental condition and high degree of optical clarity, CR-39 has become the state of the art track detector for environmental radon monitoring (Danis *et al*., 2001). Several researchers studied indoor radon concentration levels in Iraq and other countries (Abdulla and Hussien, 2010) used solid state nuclear track detector CR-39 to study ^{222}Rn concentration in the right area of Shirkatt district in summer season. (Al-Gaim *et al*., 2012) used the polymer track detector LR-115 type II to measure indoor radon concentration in the dwellings and multistory buildings of Basrah technical institute (Iraq) in winter season. (Hussien *et al*., 2013) used CR-39 detectors to measure indoor radon concentration levels and its risks inside hospitals in Iraqi Kurdistan region in autumn season. While (Al-Jundi and Haninger, 2003) have studied the ^{222}Rn concentration in the houses of Russaifa city, Jordan by using SSNTD's (CR-39). (Al-Bataina and Elzin, 2003) also used CR-39 detectors to study the seasonal variation of indoor ^{222}Rn concentration levels in Zarqa city of Jordan. (Rassas *et al*., 2005) used CR-39 detectors to measure ^{222}Rn and its daughter's concentration in dwellings of Gaza strip Palestine from August to December 2001.

The main aim of this study is measure the concentration and the annual effective dose from ^{222}Rn in left side of Mosul City areas in winter season in order to measure the lung cancer risk.

EXPERIMENTAL

Passive radon dosimeter containing solid state nuclear track detectors (SSNTD's), CR-39, was used in this work. The schematic diagram of the dosimeter is shown elsewhere (Abumurad *et al*., 1994) and composed of plastic cup 7.0 cm in diameter and 4.6cm in depth. A circular hole of radius 0.75cm was made at the center of the Lid. The hole is covered by a piece of sponge with an area of 2cm× 2cm and thickness 0.5cm, this configuration was used in order to maintain the same calibration conditions and to stop aerosol and thoron ^{220}Rn from entering the cup and only radon ^{222}Rn diffuses into the sensitive volume of dosimeter. Plastic contains one piece of CR-39 with area 1×1 cm^2 fixed to the bottom of the cup using a scotch tape, the calibration process for this dosimeters was done by (Al-Kofahi *et al*., 1992). After preparing the dosimeter, they were distributed into the houses of eight different areas of left side of Mosul city. These locations are, Al-Kafaat/2, Al-Hadba, Al-Baladyat, Al-Massaref, Al-Tahreer, Al-Zahraa, Al-Noor and Nenavah-al-Sharqiya. We chose three houses in each location randomly, one dosimeter were hung in the ceiling inside each selected house, in living room on the top about 2m above the floor. The rooms under study were built, in general, using cement, sand, iron structure, blocks and concrete as the construction materials. The walls of the dwellings are often covered with gypson, most of the rooms are of sizes approximately 4×4×3 m^3 with one window and one door. The measurement were performed for a period of two months (27/12/2010-25/2/2011).

The detectors were collected after 60 days and chemically etched using 6.25N solution NaOH at 70±1°C for 4 hrs.

After etching process taking, the detectors were washed for 30 min., by running water, then by distilling water and then drying out.

Track densities were counted by using an optical microscope with magnification of 400X. the correction was applied for the background alpha tracks in CR-39 plastic by subtracting the number of tracks observed in the unexposed detector. The average concentration of radon gas was determined by using the relation (Al-Bataina and Elzain, 2003).

$$\mathbf{C} = \frac{C_0 t_0 \rho}{t \rho_0} \qquad \text{………… (1)}$$

Where C_0 is radon concentration of calibrated champer (90 kBq.m^{-3}), t_0 is the calibration exposure time (48 hours), ρ is the measured track number density per cm^2 on the CR-39 detectors inside the dosimeters used in the study, ρ_0 is the measured track number density per cm^2 on the detectors of the calibrated dosimeters which is equal 96768 Tr.cm^{-2} and t is the indoor exposure time for the survey.

To find the potential alpha energy concentration (PAEC) of ^{222}Rn in term of working level WL first of all we found the concentration of radon in PCiL^{-1} units, so the equivalent equilibrium concentration EEC of radon deduce as in equ. (Abdulla and Hussein, 2010).

$$EEC = F x C_{Rn}\ (PCiL^{-1}) \qquad \text{………… (2)}$$

Were F is the equilibrium factor, which equal to 0.4 indoor. Then EEC times 0.01 to find PAEC (WLM), while $WLMY^{-1}$ is equivalent to WL times factor 40 (Abdulla and Hussein, 2010).

The effective dose from ^{222}Rn progeny H (mSvy^{-1}) was calculated from the following formula according to (UNSCAR, 2000), (Al-Saleh, 2007).

$$H_E = C \times F \times O \times T \times D \text{……….(3)}$$

Where C is the radon concentration in Bq.m^{-3}, F equilibrium factor 0.4 indoor, O occupancy factor 0.8, T time 8760 hy^{-1} and D dose conversion factor 9×10^{-6} m Svh^{-1}/Bq.m^{-3}. While the Lung cancer cases per year per million persons based on the risk factor lung cancer induction of 18×10^{-6} mSvy^{-1} (Mansur *et al*., 2005).

RESULTS AND DISCUSSION

Table (1) shows that the indoor radon concentration measured in living rooms of twenty four different houses in left side of Mosul city. The data showed that the minimum radon concentration was in Al-Kafaat/2 house No. 21 (49.006) Bq.m^{-3} which is very near to radon concentration in house No. 14 (49.7) Bq.m^{-3} in Al-Tahreer location, while the maximum radon concentration found in house No. 7 (81.23) Bq.m^{-3} in Al-Masaref location. Houses (4, 8, 9, 11) approximately having the same radon concentrations. The average radon concentration ranged between (52.97 ± 5.315 to 74.98 ± 5.433) Bq.m^{-3} in Al-Tahreer and Al-Masaref locations respectively. The average radon concentration in all locations was (62.3 6±7.518) Bq.m^{-3}, which is much lower than the recommended by ICRP action level of (200-600) Bq.m^{-3} (ICRP, 1993).

The variation in radon concentration values inside locations under study is mainly due to geological characteristics of the soil, building materials, climate, also poor ventilation rate plays an important role of radon concentration, because people often close their doors and windows for warmth during winter, this will increase of radon concentration. When comparing the present results with others obtained by (Stojanovask *et al*., 2011) studied indoor radon concentration in FYR of Macedonia results showed that the average radon concentration was 115 $Bq.m^{-3}$ in winter season. (Al-Jundi and Haninger, 2003) measured indoor radon concentration levels in Zarqa city of Jordan, results indicated that radon concentration ranged from (81 to 294) $Bq.m^{-3}$ in winter season. (Abdulla and Husain, 2010) found an average radon concentration (103.98) $Bq.m^{-3}$ on his study for radon concentration in Shirkatt district in summer season. Also (Najeba and Mohamad, 2012) found an average radon concentration 187.215 $Bq.m^{-3}$ on their study for radon concentration in 30 spatial dwellings in three governorates in Iraqi Kurdistan. These researches revealed that our result for radon concentration is lower. However the present results were similar to those obtained by (Guo *et al*., 2001) on his survey for indoor radon and thoron and it's progeny in four areas in China which is equal to 61.2 $Bq.m^{-3}$ in winter season, while our results are higher than that obtained by (Buzkurt and Kam, 2007) which it was 49.2 $Bq.m^{-3}$ in the city of Edirne, Turky, also (Al-Gaim *et al*., 2012) found that radon concentration ranged from (13.52 to 51.17) $Bq.m^{-3}$ in the dwellings and multistory buildings of Basrah Technical institute (Iraq) in winter season.

Table 1: Indoor radon concentration in the left side of Mosul city

Location	Houses No.	$C_{Rn}(Bq.m^{-3})$	Average ± S.D. $C_{Rn}(Bq.m^{-3})$	C(pci/L)	Average ± S.D. C(pci/L)
Nenavah Al-Sharqiya	1	65.3	60.94 ± 4.43	1.745	1.64 ±0.11
	2	61.1		1.651	
	3	56.44		1.525	
Al-Noor	4	70.5	65.99 ±4.613	1.905	1.78 ±0.124
	5	66.2		1.789	
	6	61.28		1.656	
Al-Masaref	7	81.23	74.98 ±5.433	2.195	2.02 ±0.146
	8	72.4		1.957	
	9	71.33		1.928	
Al-Baladyat	10	74	68.98 ±5.923	2	1.86 ±0.159
	11	70.51		1.91	
	12	62.45		1.69	
Al-Tahreer	13	50.12	52.97 ±5.315	1.35	1.43 ±0.141
	14	49.7		1.34	
	15	59.11		1.59	
Al-Zahraa	16	63.003	58.001 ±4.584	1.7	1.56 ±0.122
	17	57		1.54	
	18	54		1.46	
Al-Kafaat/2	19	60	54.002 ±5.565	1.62	1.45 ±0.151
	20	53		1.43	
	21	49.006		1.32	
Al-Hadba	22	65.1	62.99 ±2.993	1.759	1.70 ±0.079
	23	64.23		1.736	
	24	59.64		1.612	
Average ±S.D.		62.36±8.250	62.36±7.518	1.68±0.224	1.68±0.203

Table (2) shows that the potential alpha energy ranged between 5.28×10^{-3} WLM in house No. 21 in Al-Kafaat/2 location and 8.78×10^{-3} WLM in house No. 7 in Al-Masaref location, while the average PAEC ranged between ($5.71\times10^{-3}\pm0.566\times10^{-3}$ to $8.11\times10^{-3}\pm0.586\times10^{-3}$) WLM in Al-Tahreer and Al-Masaref location respectively. The average for all locations was ($6.7\times10^{-3}\pm0.820\times10^{-3}$) WLM.

Table 2: Summarized the measurement of EEC, PAEC, $WLMY^{-1}$

Location	House No.	EEC	PAEC (WLM) $\times 10^{-3}$	Average PAEC ± S.D. (WLM) $\times 10^{-3}$	$WLMY^{-1}$
Nenavah Al-Sharqiya	1	0.698	6.98	6.56 ±0.441	0.279
	2	0.660	6.6		0.264
	3	0.61	6.1		0.244
Al-Noor	4	0.762	7.62	7.13 ±0.5	0.305
	5	0.716	7.16		0.286
	6	0.662	6.62		0.265
Al-Masaref	7	0.878	8.78	8.11 ±0.586	0.351
	8	0.783	7.83		0.313
	9	0.771	7.71		0.308
Al-Baladyat	10	0.8	8	7.47 ±0.637	0.32
	11	0.764	7.64		0.305
	12	0.676	6.76		0.27
Al-Tahreer	13	0.54	5.4	5.71 ±0.566	0.216
	14	0.536	5.36		0.214
	15	0.636	6.36		0.254
Al-Zahraa	16	0.68	6.8	6.27 ±0.488	0.272
	17	0.616	6.16		0.246
	18	0.584	5.84		0.234
Al-Kafaat/2	19	0.648	6.48	5.83 ±0.625	0.259
	20	0.572	5.72		0.228
	21	0.528	5.28		0.211
Al-Hadba	22	0.703	7.03	6.81 ±0.312	0.281
	23	0.694	6.94		0.277
	24	0.645	6.45		0.258
Average			6.7±0.898	6.7±0.820	0.269±0.0359

Table (3) shows the annual effective dose ranged between 1.236 $mSvy^{-1}$ in house No.21 in Al-Kafaat/2 and 2.049 $mSvy^{-1}$ in house No. 7 in Al-Masaref location with an average value for all locations (1.57± 0.189) $mSvy^{-1}$. In the present survey the annual effective dose received by the resident less than the range of action level (3-10) $mSvy^{-1}$ recommended by (ICRP, 1993).

Table (3) also shows that radon induced lung cancer risk for all houses in left side of Mosul city was found and ranges from (24.1±2.415) per million persons to (34.02±2.483) per million persons with an average value of 28.3± 3.404 per million persons.

In general, these results indicate that the houses in left side of Mosul city are characterized by low radon exposure dose, so the people who live in those houses are subject to relatively low risk factor for radon induced lung cancer.

Table 3 : Annual effective dose ($mSvy^{-1}$) and risk assessment per million persons

Location	House No.	$mSvy^{-1}$	Average ± S.D. $mSvy^{-1}$	Risk Assessment per 10^6 person	Average Risk Assessment ± S.D. per 10^6 person
Nenavah Al-Sharqiya	1	1.647	1.54 ±0.111	29.65	27.7 ±2.01
	2	1.541		27.74	
	3	1.424		25.63	
Al-Noor	4	1.778	1.67 ±0.116	32.004	29.96 ±2.088
	5	1.67		30.06	
	6	1.546		27.83	
Al-Masaref	7	2.049	1.89 ±0.137	36.88	34.02 ±2.483
	8	1.823		32.81	
	9	1.799		32.38	
Al-Baladyat	10	1.867	1.74 ±0.147	33.6	31.32 ±2.687
	11	1.779		32.02	
	12	1.576		28.36	
Al-Tahreer	13	1.264	1.34 ±0.134	22.75	24.1 ±2.415
	14	1.254		22.57	
	15	1.491		26.84	
Al-Zahraa	16	1.589	1.46 ±0.155	28.6	26.3 ±2.077
	17	1.438		25.88	
	18	1.362		24.52	
Al-Kafaat/2	19	1.514	1.36 ±0.14	27.25	24.5 ±2.536
	20	1.337		24.06	
	21	1.236		22.24	
Al-Hadba	22	1.642	1.59 ±0.073	29.55	28.6 ±1.322
	23	1.62		29.16	
	24	1.505		27.09	
Average		1.57±0.208	1.57±0.189	28.3±3.755	28.3±3.404

CONCLUSION

It has been found that the average radon concentration level in left side of Mosul city was (62.36±7.518) $Bq.m^{-3}$ in winter season which is below radon reference levels ranged from (200 to 600) $Bq.m^{-3}$as recommended by ICRP, furthermore the average annual effective dose equivalent due to indoor radon was (1.57±0.189) m Svy^{-1} which is less than the range of action level (3-10) m Svy^{-1} recommended by ICRP.

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