Measurement of Radon Concentrations and Annual Dose Rate in some Regions of Baghdad City using LR-115 Nuclear Track Detector

Lutfi Majeed Mohammed Salih
Department of Physics, College of Science, Al-Nahrain University, Baghdad-Iraq.
E-mail: lutfi_mjd@yahoo.com.

Abstract

In this work, LR-115 solid state nuclear track detector used to measure the indoor and outdoor radon concentrations, the annual absorbed dose rate and annual effective dose rate to the lung, were measured in nine houses at different places of Baghdad city, the observed values of indoor and outdoor radon concentrations was in range of 14.7-46.17 Bq/m^3 and 9.69–35.69 Bq/m^3 respectively. The resulting concentration of Short-lived radon daughters expressed in term of an equilibrium-equivalent radon concentration (EEC), the minimum and maximum indoor results of (EEC) was 5.88-18.46 Bq/m^3 and the outdoor results was 6.78-24.98 Bq/m^3. The Potential Alpha Energy (PAE) concentration expressed in Working Level (WL) units was in the range of 1.58-4.99 mWL in indoor and 1.8-6.75 mWL in outdoor regions. The annual effective dose calculated according to the radiation weighting (W_R) factor for alpha particles and the tissue weighting (W_T) factor and the annual absorbed dose rate, the present results confirmed that the radon gas concentrations in all the nine places of Baghdad city are lower than the International Commission Radiation Protection (ICRP) agency, recommended value (200Bq/m^3).

Keywords**:** radon Concentration, LR-115, track detector, annual absorbed dose rate, alpha emitting.

Introduction

Radiations have always been a part of our natural environment. Exposure of ionizing radiation, which cannot be detected by any sense of our body, is injurious to Human beings health [1]. Radon is an α-emitting radioactive noble gas, colorless, odorless, inert gas and heavier than air, it is directly produced by a sequence formed of decay process that begins with the most prevalent form of natural uranium U-238, having half-life time 3.8 days and emitting alpha particles of energy 5.49 MeV [2]. Its emanation from building materials, as well as, its infiltration from the ground and further migration is restricted to a few centimeters only. The process of the migration of Radon is a function of radioactivity concentration, and the porosity and permeability of the medium [3]. Radon gas can be inhaled and trapped in the lungs; inhaled radon contributes about half of the total environmental ionizing radiation dose to the world population. The Radon concentration in air varies in accordance with location, high level of the houses, material of the houses built, and ventilation rate [4]. Indoor Radon variations occur hourly, diurnally, and seasonally, and are influenced by numerous factors, including Radon infiltration rates, pressure differentials, soil characteristic weather conditions (e.g. rainfall, wind speed) and occupant behavioral.

Exposure to high concentrations of radon for a long period lead to pathological effects like the respiratory functional changes and the occurrence of lung cancer and other cancers, such as leukemia; Genetic and human fertility damage will also occur, thus impacting adversely on future generations [5].

Many techniques are used for radon measurements, the solid state nuclear track detectors (SSNTD) are employed for the most reliable technique to determination of the Radon concentration, LR-115 cellulose nitrate type-II thin films ($C_6H_2O_9N_2$) are widely used as track dosimeters for radon concentration measurement, the color of this track detectors is bold red and insensitive for electrons and electromagnetic radiation [6]. In the present measurements sheets of LR-115 with thickness (90) μm type II detectors are supplied by Kodak Co. France, used for recording the alpha particles emitted by radon gas present inside the house and in our ambient air.

Experimental details

The measurement of radon was made in the selected houses in different nine places of Baghdad city, those houses are constructed of cement and bricks plastered with gypsum. Eighteen detectors of small size 1cmx1cm were hanged in outside and inside houses, nine of them hanged in the ceiling inside the room at a height of about 200cm from the ground for recording the indoor radon concentration and the other nine detectors hanged outside the houses at the same height to record the outdoor radon concentration.

After the exposure period of 60 days, the detectors were etched for 90 minutes in 2.5N NaOH solution maintained at 60^{o}C. The etched detectors were washed with distilled water and finally dried in air and count the number of tracks by the track counting technique, which was performed using an optical microscope.

The tracks density is measured by using equation (1) [7]:

$$\text{Tracks density } (\rho_X) = \frac{\text{Average number of total tracks}}{\text{Area of field view}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Results and Discussion

The radon gas concentration obtained by the comparison between track densities registered on the detectors and that of the standard samples which are shown in Fig.(1), using equation (2) [8,9]:

$$C_X = (\rho_X / \text{slope}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where:
C_X: concentration of the radon gas (Bq/m^3)
ρ_X: tracks density ($tracks/mm^2$)
Slope = 11.775 ($tracks.m^3/mm^2.Bq$)

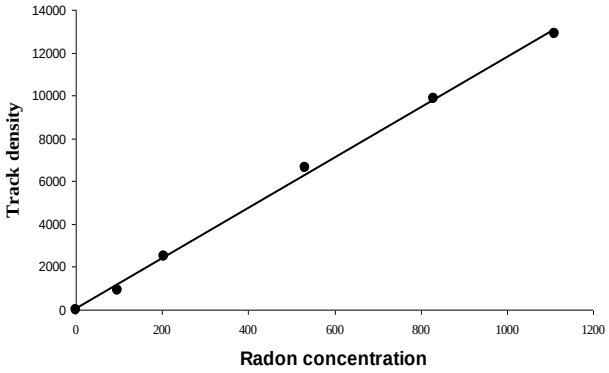

Fig. (1) Standard relation of radon gas concentration and track density [8,9].

The result of indoor radon concentration measurements in the selected houses in different nine places of Baghdad city are shown in Table (1).

Table (1)
Indoor radon concentration.

S. No.	*Location*	*C_X (Bq/m^3)*
1	Al- Dora	14.7
3	Hay Al-Jamiah	40.35
5	Al-Mansour	44.64
7	Al-Yarmouk	35.69
9	Al-Adamiyah	46.17
11	Hay-Ur	32.19
13	Al-Sha'ab	27.16
15	Falastin Street	22.5
17	Al-Ghadeer	29.12
Average value		32.5

The minimum and maximum observed values of indoor radon concentration are $14.7Bq/m^3$ in al-Dora and $46.17Bq/m^3$ in Al-Adamiyah respectively, the average indoor radon concentration is found to be approximately $32.5Bq/m^3$.

The track density on the detector is related to the potential alpha energy (PAE) concentration expressed in Working Level (WL) units. WL is the concentration of any combination of radon progeny corresponds to 1.3×10^5 MeV of PAE per liter of air [5].

The resulting concentration of short-lived radon daughters expressed in term of an equilibrium-equivalent radon concentration (EEC), is related to the activity concentration of radon (C_X) by the equation (3) [1,5]:

$$EEC = C_X \times F \quad \text{.....(3)}$$

where F is an equilibrium factor which is equal 0.4 in indoor air [1,5].

The Potential Alpha Energy (PAE) concentration calculated in mWL using equation (4) [5]:

$$PAE = \frac{CX \times F}{3700} \quad \text{.....(4)}$$

The calculated (EEC) and the (PAE) concentration of indoor location was shown in Table (2),

Table (2)
The indoor calculated (EEC) and (PAE).

S. No.	*EEC (Bq/m^3)*	*PAE (mWL)*
1	5.88	1.58
3	16.14	4.3
5	17.85	4.82
7	14.27	3.85
9	18.46	4.99
11	12.87	3.48
13	10.86	2.93
15	9	2.43
17	11.64	3.14
Average value: 12.99		3.5

From Table (2) we can see that the higher values of the equilibrium-equivalent radon concentration and the Potential Alpha Energy concentration was 18.46 Bq/m^3 and 4.99 mWL respectively in Al-Adamiyah which were the maximum value of indoor radon concentration was measured, and the lower values was 5.88 Bq/m^3 and 1.58 mWL respectively in Al- Dora which were the minimum value of indoor radon concentration was measured.

The outdoor radon concentration measurement in the different nine places of Baghdad city, where the (EEC) and the (PAE) concentration, calculated by using equations (3) and (4) assuming to be F=0.7 in outdoor air [1,5] were shown in Table (3).

Table (3)
Outdoor radon concentration and the (EEC) and (PAE).

S. No.	*location*	*Cx (Bq/m^3)*	*EEC (Bq/m^3)*	*PAE (mWL)*
2	Al- Dora	9.69	6.78	1.8
4	Hay Al-Jamiah	20.17	14.11	3.8
6	Al-Mansour	15.88	11.11	3
8	Al-Yarmouk	28.70	20.09	5.4
10	Al-Adamiyah	35.69	24.98	6.75
12	Hay-Ur	24.04	16.82	4.54
14	Al-Sha'ab	20.54	14.37	3.88
16	Falastin St.	15.88	11.11	3
18	Al-Ghadeer	13.56	9.49	2.56
Average value		20.5	14.3	3.86

From Table (3) it is apparent that the minimum value of outdoor radon concentration was in al-Dora which is 9.69Bq/m^3 and the maximum value was in Al-Adamiyah which is 35.69Bq/m^3, the average outdoor radon concentration is found to be approximately (20.5Bq/m^3).

The present results indicate that the radon gas concentrations in all the nine places of Baghdad city are lower than the ICRP, recommended value 200Bq/m^3 [1].

Now the equation (5) is used to calculate the annual absorbed dose and effective dose rate received by the population, according to the UNSCEAR (2000) report, the committee proposed 9×10^{-6} ($mSv.m^3/h.Bq$) to be used as conversion factor [4,5]:

$$D_{Rn} = C_X \times D \times H \times F \times T \quad \text{.....(5)}$$

where:
D_{Rn} is the annual absorbed dose (mSv/y)
C_X is the indoor radon concentration
D is the dose conversion factor = (9×10^{-6} $mSv.m^3/h.Bq$)
H is the indoor occupancy factor = (0.4), and
T is the indoor occupancy
time = 24 h × 365 = 8760 h/y

The annual effective dose (H_E) was calculated according to the equation (6) [4]:

$$H_E = D_{Rn} \times W_R \times W_T \quad \text{.....(6)}$$

where W_R and W_T are the radiation weighting factor and tissue weighting factor respectively according to ICRP, (W_R = 20) and (W_T = 0.12), and the annual absorbed dose and

effective indoor dose rate received by the population is given in Table (4).

Table (4)
Annual absorbed dose and the annual effective dose.

S. No.	*D_R (mSv/y)*	*H_E (mSv/y)*
1	0.185	0.44
3	0.508	1.22
5	0.563	1.35
7	0.450	1.08
9	0.582	1.4
11	0.406	0.97
13	0.342	0.82
15	0.283	0.68
17	0.367	0.88
Average value	0.4	0.98

The annual effective dose (H_E) from the corresponding measured radon concentration in different houses varies from (0.44 to 1.4) mSv/y with average value of (0.98 mSv/y), and the mean value of the annual absorbed dose rate to the lung is (0.4 mSv/y) with range of (0.185 – 0.582) mSv/y, which is lowest than the recommended ICRP intervention level (10 mSv/y).

Conclusions

This work estimated the indoor and outdoor radon concentration, the annual effective dose rate and annual absorbed dose rate to the lung in nine houses at different places of Baghdad city. The radon activities were measured from December 2012 to February 2013 in each location. The results of the present research led to the following conclusions: the mean radon concentration for the two months period was for indoor (32.5 Bq/m^3), and for outdoor (20.5 Bq/m^3). The mean annual effective dose rate and the mean annual absorbed dose rate to the lung in the indoor area were (0.98mSv/y) and (0.4mSv/y) respectively. All recorded concentrations are below the recommended action level from International Commission Radiation Protection (ICRP) Agency 200Bq/m^3. It is concluded that the poor ventilation, the distance from the generators and the lifestyle of the people raise the accumulation of radon gas to a risky level for the people, measurement obtained stresses the need for more extended survey on the risk of radon concentration all over the country.

References

[1] Khan M.S.A., Tariq M., and Rawat R.B.S., "Preliminary Measurements of Radon Radiations in (Bare Mode) In Rampur District of Western U.P. (India)", IOSR Journal of Applied Physics, 1, Issue 4, 2012.

[2] Yu K.N. and Nikezic D., "Long-term measurements of radon progeny concentrations with solid state nuclear track detectors", Department of Physics and Materials Science, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, Science Publishers, Inc, 2009.

[3] Ab-Murad K.M., and Al-Tamimi, M.H., "Natural radioactivity due to radon in Some region, Jordan", Radiation Measurement, 39, 77-80, 2005.

[4] Nsiah-Akoto, J.J. Fletcher, O.C. Oppon and A.B. Andam, "Indoor Radon Levels and the Associated Effective Dose Rate Determination at dome in the Greater Accra Region of Ghana", Research Journal of Environmental and Earth Sciences Maxwell Scientific Organization, 2011.

[5] Mamta Gupta, Mahur A. K. and Verma K. D., "Indoor radon levels in some dwellings surrounding the National Thermal Power Corporations (NTPCs), India", Advances in Applied Science Research, 3(3), 1262-1265, 2012.

[6] Papaefthymiou H., Mauroudis A., and Kritidis P., "Indoor radon measurements in Patras, Greece, with solid state nuclear track detectors", Radon in the Living Environment, Athens, Greece,19-23, 1999.

[7] Lymburner, D. "Another Human Experiment", DU Education Project, Metal of Dishonor, International Action Center, NewYork, p 45-98, 2003.

[8] Shweikani R., "Variation of Radon Exposure in Damascus Dwellings", Applied Radiation and Isotopes 70, 785–789, 2012.

[9] David Pollard, "Radon Gas in Ireland", Radiological Protection Institute of Ireland, 2010.

الخلاصة

في هذه الدراسة تم استخدام كاشف الاثر النووي LR-115 لقياس تراكيز غاز الرادون في داخل الابنية وخارجها في تسعة منازل في مناطق مختلفة من مدينة بغداد. وتم حساب معدل الجرع السنوية الممتصة ومعدل الجرع الفعالة في الرئة، وقد أظهرت النتائج التي تم الحصول عليها أن قيم تراكيز الرادون في داخل وخارج الابنية تتراوح بين (14.7 - 46.17) Bq/m^3 و (9.69 – 35.69) Bq/m^3 على التوالي. ان تركيز النواتج الوليدة لغاز الرادون والتي يعبر عنها بمكافئ التوازن لتركيز غاز الرادون (EEC)، وكان الحد الاعلى والادنى لنتائج (EEC) داخل الابنية (5.88-18.46) Bq/m^3 وخارجها كانت (6.78-24.98) Bq/m^3. وتركيز الطاقة الكامنة لجسيمات الفا (PAE) تم حسابه بوحدات (WL) وكانت نتائجه داخل الابنية (mWL) (1.58-4.99) وخارجها (mWL) (1.8-6.75). وتم حساب الجرعة السنوية الفعالة نسبة الى عامل الترجيح للاشعاع لجسيمات الفا (W_R) وعامل الترجيح (W_T) ومعدل الجرع السنوية الممتصة، النتائج الحالية أكدت أن تراكيز غاز الرادون في تسعة مناطق من مدينة بغداد هي اقل من الحد المسموح به من قبل لجنة الوكالة الدولية للوقاية من الاشعاع (200 Bq/m^3).