Physics International

Original Research Paper

Radiation Hazards Due to Radon Concentrations in Dwellings of Kufa Technical Institute, 'Iraq'

Ali Abid Abojassim Al-Hamidawi and Afnan Ali Husain

Department of Physics, Faculty of Science, University of Kufa, Iraq

Article history
Received: 14-07-2015
Revised: 18-03-2016
Accepted: 06-04-2016

Corresponding Author:
Ali Abid Abojassim Al-Hamidawi
Department of Physics, Faculty of Science, University of Kufa, Iraq
Email: ali.alhameedawi@uokufa.edu.iq

Abstract: Radon concentrations were measured in Kufa dwellings of the technical institute, Al-Najaf- Iraq using LR-115 type II plastic track detectors. Additionally, annual effective dose and the excess lifetime cancer risk for the aforementioned dwellings were calculated. The results demonstrate that the radon concentration ranged from 37.4±6.4 Bq/m^3 to 55.7±12.0 Bq/m^3 with an average of 46.2±8.2 Bq/m^3. The latter is found to be closer to the acceptable radon levels (e.g., 200-300 Bq/m^3) that recommended by ICRP (2010). The average value of the excess lifetime cancer risk were ranged from 8.09 million persons to 15.12 million persons with an average of 10.77±1.32 million persons. The obtained results are in good agreement with the published literature.

Keyword: SSNTD, Radon Concentration, Excess Lifetime Cancer Risk, Radon in Dwellings and Annual Equivalent Dose

Introduction

Radon is a naturally existed element found as a noble gas in the environment in form of radioactive isotope. The radon and its radioisotopes are mobile and therefore being able to transfer over large distances (Banjanac *et al*., 2006). The radon decay series starts with uranium-238 and goes through four intermediate states to form radium-226. The half-life of radium is 1,600 years which then decays to form radon-222 gas. Radon has a half-life of 3.8 days, which provides sufficient time for it to diffuses through soil and homes. The radon is further disintegrates to produce a more radiologically active radon progeny (ALAKCS, 2009). The biological effects of radon have been investigated for several decades. Initially, investigations have focused on underground miners that exposed to high radon concentrations in their occupational environment. However, in the early nineteenth, several studies on radon levels in homes and other buildings were carried out and the results of these have provided indirect evidence on that radon may be a critical cause of lung cancer in the general population. Recently, efforts to directly investigate the association between indoor radon and lung cancer have been carried out. These, in fact, provided a convincing evidence of the increased lung cancer risk causally associated with radon, even at levels commonly found in buildings. Risk assessment for both radon in mines and in residential settings have provided clear insights into the health risk due to radon existence. Currently, the radon is well recognized as the second important reason of lung cancer after smoking in the general public (ALAKCS, 2009; CNSC, 2011). Because of the radon is continuously escaping from the ground, it is therefore present in the air, but under certain circumstances the concentration of radon in a building can be increased significantly over its normal outdoor level (NCRP, 1987). The majority of buildings have both limited air space and air movement; this also associated with reduced air ventilation. As a result the concentration of any particulate or gas that would be released into the buildings will tend to increase above the normal concentration in outdoor air. The concentration of its particulate progeny will increase as the radon decays. Therefore, high concentrations of radon gas in soils with high transport efficiency (i.e., loose, porous, dry soil) can results in increasing radon concentrations of buildings (Borgoni *et al*., 2011). Indoor radon percentage is rather important because its contribution to radiation dose to human is estimated to be more than 55% of the total dose, taken into account that from the natural sources (UNSCEAR, 1998). Several techniques have been approached to measure radon and is daughters concentration. LR-115 detector has widely been used to measure time integrated radon levels in dwellings under different conditions (Pundir *et al*., 2014; Al-Mosuwi and Subber, 2013; Al-Hamidawi *et al*., 2013; Gupta *et al*., 2012; Abd-Elzaher, 2012; Singha *et al*., 2015).

DOI: 10.3844/pisp.2016.28.34

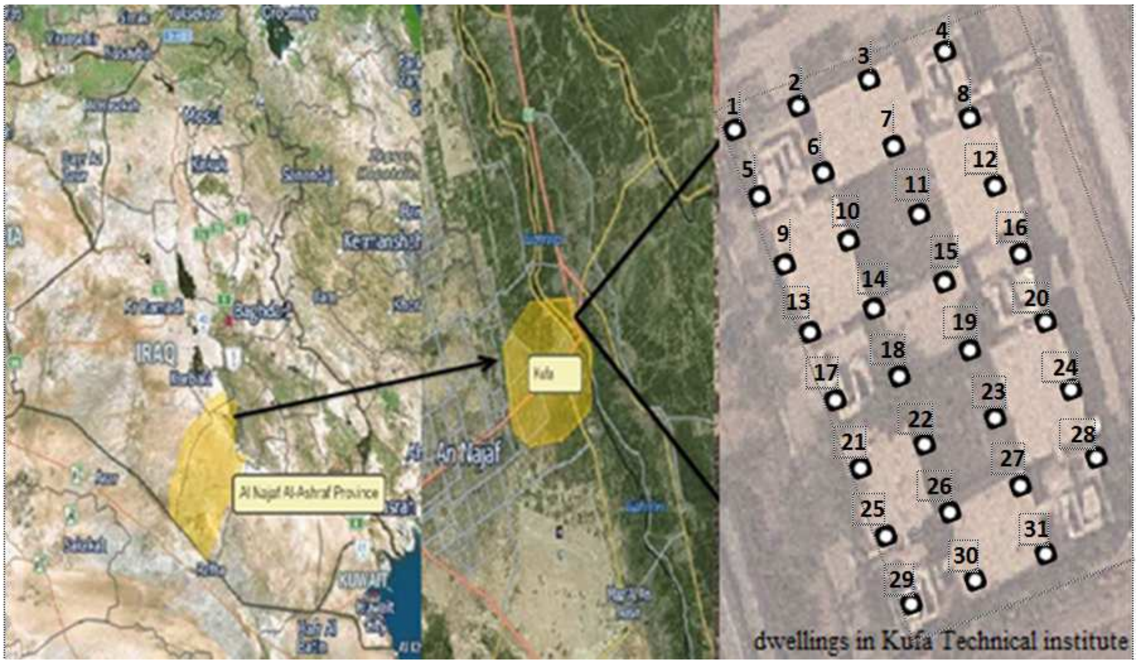

Fig. 1. Show Kufa technical institute

Table 1. Sites of measurements in studied area for taking samples

Sample location	Sample code	Coordinates	
		Lat.(deg)	Long.(deg)
1	T1	44.404522	32.061271
2	T2	44.405205	32.061521
3	T3	44.405899	32.061754
4	T4	44.406566	32.061993
5	T5	44.404706	32.060883
6	T6	44.405394	32.061088
7	T7	44.406121	32.061310
8	T8	44.406763	32.061543
9	T9	44.404940	32.060353
10	T10	44.405618	32.060628
11	T11	44.406337	32.060882
12	T12	44.406987	32.061104
13	T13	44.405066	32.060100
14	T14	44.405749	32.060346
15	T15	44.406481	32.060593
16	T16	44.407142	32.060805
17	T17	44.402581	32.059872
18	T18	44.402941	32.060054
19	T19	44.403396	32.060298
20	T20	44.402689	32.059634
21	T21	44.403094	32.059784
22	T22	44.403578	32.060005
23	T23	44.402814	32.059374
24	T24	44.403207	32.059562
25	T25	44.403749	32.059855
26	T26	44.403215	32.059193
27	T27	44.403542	32.059325
28	T28	44.403940	32.059474
29	T29	44.403261	32.058906
30	T30	44.403647	32.059100
31	T31	44.404057	32.059298

The present work was aimed to measure the indoor radon concentration in the Kufa technical Institute building of Kufa city by using SSNTDs technique because there is no studying of radon concentration in this Institute.

Area of Study

Kufa is a city in Iraq located at a latitude of (32°1'46"N) and a longitude of (44°23'53"E) (Ring, 1996a; 1996b). In this study we measured the radon concentration for dwellings in Kufa Technical institute as shown in Fig. 1. Table 1 showed the sites of measurement in studied area for taking samples.

Martials and Methods

Experimental Part

A 31 sites, were measured in dwellings of Kufa Technical institute. These sites were chosen to be representative of the whole region. Experimental methods of radon measurements were based on alpha-counting of radon and its daughters. The SSNTD detector (LR-115 type II) is a cellulose nitrate film of 12 μm thickness manufactured by Kodak Path, France (Eappen and Mayya, 2004). The radon dosimeter employed for this work measurements is made of a plastic cup of 10 cm in diameter with a depth of 13 cm. These dosimeters were covered by a piece of sponge to ensures that thoron cannot reach the detector. The SSNTD (LR-115 type II) is cut into (1×1) cm^2 piece which it is hung in the ceiling at distance range (1.5-2) m above the earth of room. The exposure time of the detector in dwelling under study was three month. The detectors were etched of sodium hydroxide (NaOH) solution at 60°C temperature for 90 min in solution of 2.5 normality. After etching of the detectors have been removed from the solution and extensively washed by a distilled water and dried by soft tissue papers. At last, using an optical microscope for counting the number of tracks. The calibration factor for dosimeters exposed for range from (5-30) day to Radium ^{226}Ra (Radon source) of activity 3.3 kBq was calculated to be (0.0217±0.0033) (track/cm^2)/(Bq.day/m^3), which agree well within the reported in many works (Eappen and Mayya, 2004; Pundir *et al*., 2014; Duggal *et al*., 2014).

Calculations

The tracks density was calculated using the following equation (Lymburner, 2003):

$$Track\ density\left(\frac{track}{cm^2}\right)=\frac{Average\ number\ of\ total\ tracks}{\text{view field of Area}} \quad (1)$$

Radon concentrations (C_{Rn}) in present work are determined by the Equation 2 (Al-Kofahi *et al*., 1992; Khader, 1990; Corporation *et al*., 1981; Gupta *et al*., 2012; Khan *et al*., 2012):

$$C_{Rn}\left(\frac{Bq}{m^3}\right)=\frac{C_0\left(Bq.day/m^3\right)}{\rho_{o\left(\frac{track}{cm^2}\right)}}\frac{\rho_{\left(\frac{track}{cm^2}\right)}}{t(day)} \quad (2)$$

$\dfrac{\rho_o\left(\frac{track}{cm^2}\right)}{C_o\left(Bq.day/m^3\right)}$ is the calibration factor for dosimeters exposed, ρ is the track density and t is the time exposure.

Can be calculated the annual effective dose (D_{Rn}) due to radon concentration by (Marley *et al*., 1998; Chen, 2005; WHO, 2009; IARC, 1988; UNSCEAR, 2000):

$$D_{Rn}\left(\frac{mSv}{y}\right)=E_f\times C_f\times O_f\times C_{Rn}\times T \quad (3)$$

Where:
C_{Rn} = The radon concentration in Bq/m^3 scale
E_f = The equilibrium factor (0.4)
C_f = The coefficient factor (9 nSv per Bq.h/m^3)
O_f = the occupancy factor (0.8)
T = The time that people spend indoors (7008 hour)

In addition to, the annual equivalent dose was calculated using the following Equation (ICRP, 2011; Mossadegh *et al*., 2011; Issa, 2007; Alberigi *et al*., 2011; Obed *et al*., 2012):

$$H_E\left(\frac{mSv}{y}\right)=D_{Rn}\times W_R\times W_T \quad (4)$$

Where:
H_E = The annual equivalent dose
D_{Rn} = The annual effective dose
W_R = Radiation weighting factor (20)
W_T = Tissue weighting factor (0.12)

At last, we can calculated the excess lifetime cancer risk ELCR per million persons per year depending on the Duration of Life DL (70 y), the annual equivalent dose H_E and the Risk Factor RF (0.055 Sv^{-1}) recommended by the ICRP as following (ICRP, 2011; Obed *et al*., 2012):

$$ELCR=H_E\times DL\times RF \quad (5)$$

Results and Discussion

The results of radon gas concentrations for each monitored dwelling is reported in Table 2. The value of the average radon concentration in dwellings was

(46.2±8.2) Bq/m^3, where the minimum and maximum values for indoor radon concentration were found in sample (T10) and sample (T19) which equal to (32.6±1.8) Bq/m^3 and (64.8±17.7) Bq/m^{3}respectively. The variable from one region to another due to different concentration of uranium in different regions, these results are within the radon levels (200-300) Bq/m^3 which are recommended by ICRP (2010). Table (3) shows the values of annual effective dose (D_{Rn}), annual equivalent dose (H_E) and the Excess Lifetime Cancer Risk per million persons per year (ELCR). The results of the annual effective dose and the annual equivalent dose varied from **(**0.82) mSv/y to (1.63**)** mSv/y with an average of (1.16±0.14) mSv/y and from (0.001) mSv/y to (0.003) mSv/y with an average of (0.002±0.0003)mSv/y respectively.

The maximum value of the annual effective dose in this study were (1.63) mSv/y which it is lower than the permissible limits recommended by ICRP (2010). According to ours estimations, the excess lifetime cancer risk that shown in Table 3 were ranged from (7.60) to (15.12) with an average value of (10.77±1.32) per million persons. In general, these estimates indicated that the dwelling under study are characterized by low radon exposure dose, so the people who live in those dwelling are subject to relatively low risk factor for radon induced lung cancer. In general the low levels of radon concentration in these buildings can be attributed to the following reasons such as the good ventilation systems in most places and the good geometric designs, all walls are painted and most locations have covered floors and there are no cracks in the building basement. The correlation between radon concentrations and the annual effective dose are shown in Fig. 2 which it is a very good correlation between them.

Table 4 summarizes the comparison between our results with those conducted in other countries. It seems that our results are near or around the other results

Table 2. Observed radon concentrations at different places in study area

		Radon concentrations (Bq/m^3)		
No.	Sample code	Minimum	Maximum	Average ± S.D
1	T1	43.1	60.6	50.4±8.2
2	T2	40.0	50.1	43.5±4.7
3	T3	33.8	51.3	42.1±7.6
4	T4	43.9	57.8	48.6±6.5
5	T5	36.4	51.6	42.0±6.7
6	T6	35.4	43.5	40.9±3.7
7	T7	30.5	55.7	43.1±10.9
8	T8	36.2	46.5	40.6±5.1
9	T9	50.2	66.8	59.2±7.6
10	T10	30.5	35.0	32.6±1.8
11	T11	30.8	44.1	36.3±6.2
12	T12	31.1	42.1	38.4±4.9
13	T13	29.4	43.1	34.9±5.9
14	T14	36.7	54.9	44.9±8.0
15	T15	29.9	39.2	34.7±5.0
16	T16	27.6	46.7	38.1±7.8
17	T17	32.4	53.7	45.1±9.4
18	T18	30.3	47.4	37.4±7.2
19	T19	46.5	83.4	64.8±17.7
20	T20	40.1	76.6	52.4±16.5
21	T21	45.3	67.7	57.5±10.1
22	T22	47.1	83.8	63.9±16.5
23	T23	45.4	68.1	55.4±9.9
24	T24	45.0	49.6	47.4±1.9
25	T25	44.3	51.2	46.7±3.1
26	T26	37.3	53.3	46.1±6.7
27	T27	37.9	57.3	43.8±9.0
28	T28	33.1	67.4	53.5±14.7
29	T29	43.5	57.2	49.7±5.6
30	T30	30.7	63.4	50.4±13.9
31	T31	35.5	57.1	46.9±10.2
Average		37.4±6.4	55.7±12.0	46.2±8.2

Table 3. Results of D_{Rn}, H_E and ELCR per million in all samples of studied area

No.	Sample Code	D_{Rn} (mSv/y)	H_E (mSv/y)	ELCR
1	T1	1.27	0.0035	11.76
2	T2	1.09	0.0026	10.14
3	T3	1.06	0.0025	9.82
4	T4	1.22	0.0029	11.34
5	T5	1.06	0.0025	9.79
6	T6	1.03	0.0024	9.54
7	T7	1.08	0.0026	10.06
8	T8	1.02	0.0024	9.47
9	T9	1.49	0.0035	13.81
10	T10	0.82	0.0019	7.60
11	T11	0.91	0.0021	8.46
12	T12	0.96	0.0023	8.95
13	T13	0.88	0.0021	8.14
14	T14	1.13	0.0027	10.48
15	T15	0.87	0.0021	8.09
16	T16	0.96	0.0023	8.87
17	T17	1.14	0.0027	10.53
18	T18	0.94	0.0022	8.71
19	T19	1.63	0.0039	15.12
20	T20	1.32	0.0031	12.23
21	T21	1.45	0.0034	13.42
22	T22	1.61	0.0038	14.91
23	T23	1.39	0.0033	12.92
24	T24	1.19	0.0028	11.06
25	T25	1.17	0.0028	10.89
26	T26	1.16	0.0027	10.76
27	T27	1.10	0.0026	10.21
28	T28	1.35	0.0032	12.48
29	T29	1.25	0.0030	11.59
30	T30	1.27	0.0030	11.75
31	T31	1.18	0.0028	10.93
Average		1.16±0.14	0.0027±0.0003	10.77±1.32

Table 4. Comparison between our result with international studies

Country	Indoor radon concentration (Bq/m^3)	Reference
Saudi Arabia	34.0	Abu-Jarad and Islam (1993)
Iraq	61.2	Tawfiq (1996)
Iran	82.0	Sohrabi and Solaymanian (1993)
Yemen	42.0	Khayrata *et al*. (2003)
Kiewit	40.0	Bem *et al*. (1996)
Syria	45.0	Othman *et al*. (1996)
Study area	46.2	---------

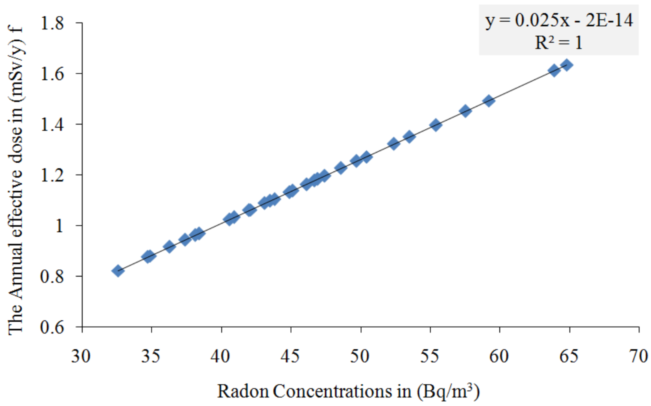

Fig. 2. Correlation between radon concentrations and the annual effective dose

Conclusion

The radon concentrations levels and the annual effective dose in present study were lower than the permissible limits recommended by ICRP (2010). Therefore, it may be concluded there are no radiation hazard due to radon concentrations in dwellings of Kufa technical institute.

Acknowledgment

The authors would like to acknowledge all those who have contributed in this issue. Special thanks to the staff of the Department of Physics at Kufa University.

Funding Information

The authors declare that they have no funding information.

Author's Contributions

Ali Abid Abojassim Al-Hamidawi: Carried out the Nuclear radiation studies, participated in the sequence alignment and drafted the manuscript.

Afnan Ali Husain: Distributed and arranged samples, also contributed to the collection of references of scientific.

Ethics

Authors declare address a ny ethical issues that may arise after the publication of this manuscrip

References

Abd-Elzaher, M., 2012. An overview on studying ^{222}Rn exhalation rates using passive technique solid-state nuclear track detectors. Am. J. Applied Sci., 9: 1653-1659. DOI: 10.3844/ajassp.2012.1653.1659

Abu-Jarad, F. and M.A. Islam, 1993. A passive radon detector survey in a three-story laboratory building. Nuclear Tracks Radiat. Measurements, 22: 257-258. DOI: 10.1016/0969-8078(93)90061-8

ALAKCS, 2009. Radon: What the public and policy makers need to know. American Lung Association in Kentucky Contributing Staff.

Alberigi, S.B., R.S. Pecequilo, H.A.S. Lobo and M.P. Campos, 2011. Assessment of effective doses from radon levels for tour guides at several galleries of Santana Cave, Southern Brazil, with CR-39 detectors: Preliminary results. Radiat. Protect. Dosimetry, 145: 252-255. DOI: 10.1093/rpd/ncr054

Al-Hamidawi, A.A., H.M. Nasir, A.H. Al Mashhadani and A.A. Al Bayati, 2013. Measurement of radon concentrations for some houses in Al-Najaf city Iraq. Iraqi J. Phys., 11: 51-55.

Al-Kofahi, M., B. Khader, A. Lehlooh, M. Kullab and K. Abumurad *et al*., 1992. Measurement of radon 222 in Jordanian dwellings. Nucl., Tracks Radiat. Measurement, 20: 377-382. DOI: 10.1016/1359-0189(92)90068-7

Al-Mosuwi, W.H. and A.R.H. Subber, 2013. Indoor radon concentration in the Basra Sport City, Basra, Iraq. J. Basra Res., 39: 150-157.

Banjanac, R., A. Dragić, B. Grabež, D. Joković and D. Markushev *et al*., 2006. Indoor radon measurements by nuclear track detectors: Applications in secondary schools. Phys. Chem. Technol., 4: 93-100.

Bem, H., T. Dománski and Y.Y. Bakir, 1996. Radon survey in Kuwait houses. Proceedings of the International Congress on Radiation Protection, (CRP' 96), pp: 101-103.

Borgoni, R., V. Tritto, C. Bigliottoand, D. de Bartolo and A. Geostatistical, 2011. A geostatistical approach to assess the spatial association between indoor radon concentration, geological features and building characteristics: The case of Lombardy, Northern Italy. Int. J. Environ. Res. Public Health, 8: 1420-1440. DOI: 10.3390/ijerph8051420

Chen, J., 2005. A review of radon doses. Radiat. Protect. Management, 22: 27-31.

CNSC, 2011. Radon and health. Canadian Nuclear Safety Commission.

Corporation, T., W. Lane, W. Creek and R. Fleischer, 1981. Passive integrating radon monitor for environmental monitoring. Health Phys., 40: 693-702. DOI: 10.1097/00004032-198105000-00008

Duggal, V., A. Rani and R. Mehra, 2014. A study of seasonal variations of radon levels in different types of dwellings in Sri Ganganagar district, Rajasthan. J. Radiat. Res. Applied Sci., 7: 201-206. DOI: 10.1016/j.jrras.2014.02.007

Eappen, K.P. and Y.S. Mayya, 2004. Calibration factors for LR-115 (type-II) based radon thoron discriminating dosimeter. Radiat. Measurements, 38: 5-17. DOI: 10.1016/j.radmeas.2003.09.003

Gupta, M., A.K. Mahur and K.D. Verma, 2012. Indoor radon levels in some dwellings surrounding the National Thermal Power Corporations (NTPCs), India. Adv. Applied Sci. Res., 3: 1262-1265.

IARC, 1988. Summaries and evaluations. International Agency for Research on Cancer.

ICRP, 2010. Lung cancer risk from radon and progeny and statement on radon. International Commission on Radiological Protection.

ICRP, 2011. Evolution of ICRP recommendations 1977, 1990 and 2007. NET Radiation. Protection Dosimetry.

Issa, E., 2007. Determination of the conversion factor for the estimation of effective dose in lungs, autography and cardiac procedures.

Khader, B., 1990. Radon-222 concentration in the air of the dwellings in Irbid Region-Jordan. M.Sc. Thesis, Yarmouk Univ., Irbid.

Khan, M.S.A., M. Tariq and R.B.S. Rawat, 2012. Preliminary measurements of radon radiations in "bare mode" in Rampur district of western U.P. (India). IOSR J. Applied Phys., 1: 4-7. DOI: 10.9790/4861-0140407

Khayrata, A.H., M.I. Al-Jarallahb, X. Fazal-ur-Rehmanb and F. Abu-Jaradc, 2003. Indoor radon survey in dwellings of some regions in Yemen. Radiat. Measurements, 36: 449-451. DOI: 10.1016/S1350-4487(03)00169-0

Lymburner, 2003. Another Human Experiment. DU Education Project, Metal of Dishonor, International Action Center, New York.

Marley, F., A.R. Denman and P.S. Philips, 1998. Studies of radon and radon progeny in air conditioned rooms in hospitals. Radiat. Protect. Dosimetry, 5: 273-276. DOI: 10.1093/oxfordjournals.rpd.a032274

Mossadegh, N., A. Karimian, E. Shahhossein, A. Mohammadzadeh and S. Sheibani, 2011. Experimental simulation of personal dosimetry in production of medical radioisotopes by research reactor. Radiat. Protect. Dosimetry, 147: 267-271. DOI: 10.1093/rpd/ncr356

NCRP, 1987. Exposures of the population in the United States and Canada from natural background radiation. National Council on Radiation Protection and Measurements.

Obed, R.I., A.K. Ademola and F.O. Ogundare, 2012. Radon measurements by nuclear track detectors in dwellings in Oke-Ogun area, South-Western, Nigeria. Radiat. Protect. Dosimetry, 148: 475-481. DOI: 10.1093/rpd/ncr196

Othman, I., M. Hushari, G. Raja and A. Alsawaf, 1996. Radon in Syrian houses. J. Radiol. Prot., 16: 45-50. DOI: 10.1088/0952-4746/16/1/006

Pundir, A., S. Kamboj and R. Singh, 2014. Estimation of indoor Radon, Thoron and their progeny levels in some dwellings of District Yamuna Nagar of India using SSNTD. Nature Sci., 12: 94-97.

Ring, T., 1996a. International Dictionary of Historic Places. 1st Edn., Taylor and Francis, Middle East and Africa.

Ring, T., 1996b. Najaf. Global Security.

Singha, P., P. Singha, S. Singha, B.K. Sahoob and B.K. Saprab *et al*., 2015. A study of indoor radon, thoron and their progeny measurement in Tosham region Haryana, India. J. Radiat. Res. Applied Sci., 8: 226-233. DOI: 10.1016/j.jrras.2015.01.008

Sohrabi, M. and A.R. Solaymanian, 1993. Indoor radon level measurements in Iran using AEOI passive dosimeters: Radiation protection practice. Proceedings of the 7th International Congress of the International Radiation Protection, Apr. 10-17, Association Pergamum Press, Sydney, pp: 242-245.

Tawfiq, N.F., 1996. Study compassion in some of organic and inorganic track detectors and applications in environment. PhD Thesis, University of Al-Mustansiriyah.

UNSCEAR, 1998. United Nations scientific committee on the effect of atomic radiation. United Nations New York.

UNSCEAR, 2000. United Nations scientific committee on the effect of atomic radiation sources, effects and risks of ionizing radiation. United Nations, New York.

WHO, 2009. Sets radon action level of 2.7- less lung cancer risk than EPA 4.0. World Health Organization, Global Press Release Distribution.