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

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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 diffuse 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).
Fig. 1. Show Kufa technical institute

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

| Sample location | Sample code | 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. 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 ensure that thoron cannot reach the detector. The SSNTD (LR-115 type II) is cut into (1×1) cm² piece which 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, ρ is the track density and t is the time exposure.

**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 ensure that thoron cannot reach the detector. The SSNTD (LR-115 type II) is cut into (1×1) cm² piece which 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, ρ is the track density and t is the time exposure.

**Calculations**

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

\[
Track\,density = \frac{Average\,number\,of\,total\,tracks}{view\,field\,of\,Area} \tag{1}
\]

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):

\[
C_{Rn} \left(\frac{Bq}{m^3}\right) = \frac{C_{f} \left(\frac{Bq\,day}{m^3}\right) \cdot \rho \left(\frac{track}{cm^2}\right) \cdot t}{\rho \left(\frac{track}{cm^2}\right) \cdot t} \tag{2}
\]

Where:

- \(C_{f}\): The radon concentration in Bq/m³ scale
- \(E_f\): The equilibrium factor (0.4)
- \(C_f\): The coefficient factor (9 nSv per Bq.h/m³)
- \(O_f\): 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; Mosaicdeh et al., 2011; Issa, 2007; Alberigi et al., 2011; Obed et al., 2012):

\[
H_{E} \left(\frac{mSv}{y}\right) = D_{Rn} \times W_{E} \times W_{T} \tag{4}
\]

Where:

- \(H_{E}\): The annual equivalent dose
- \(D_{Rn}\): The annual effective dose
- \(W_{E}\): 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):

\[
ELCR = H_{E} \times DL \times RF \tag{5}
\]

**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 ($D_n$), 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.

| No. | Sample code | Minimum (Bq/m$^3$) | Maximum (Bq/m$^3$) | 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 $D_{\text{Rn}}$, $H_{E}$ and ELCR per million in all samples of studied area

| No. | Sample Code | $D_{\text{Rn}}$ (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     |                        | 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 any ethical issues that may arise after the publication of this manuscript

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