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ESTIMATION OF THE EXCESS LIFETIME CANCER RISK FROM RADON EXPOSURE IN SOME BUILDINGS OF KUFA TECHNICAL INSTITUTE, IRAQ

A number of international health organizations consider the exposure to residential radon as the second main cause of lung cancer after cigarette smoking. For this, it was found that there is no data base on radon concentrations for the Kufa Technical Institute buildings in literature. This therefore triggers a special need for radon measurement in some Kufa Technical Institute buildings. This study aims to investigate the indoor radon levels inside the Kufa Technical Institute buildings for the first time using different radon measurement methods such as active (RAD-7) and passive methods (LR-115 Type II). Seventy eight of Solid-State Nuclear Track Detectors (SSNTDs) LR-115 Type II was distributed at four buildings within the study area. The LR-115 Type II detectors were exposed in the study area for three months period. In parallel to the latter, seventy two active measurements were conducted using RAD-7 in the same buildings for correlation investigation purposes between the two kinds of measurements (i.e. passive and active).The results demonstrate that the radon concentrations were generally low, which are ranging from 38.4 to 77.2 Bq/m^3, with a mean value of 50 Bq/m^3. The mean of the equilibrium equivalent radon concentration and annual effective dose were assessed to be 19.9 Bq/m^3 and 1.2 mS/y respectively; the excess lifetime lung cancer risk was approximately 11.6 per million personal. A high correlation was found between the methods of measurements (i.e. LR-115 Type II and RAD-7), $R^2 = 0.99$ which is significant at $P < 0.001$. The results of this work revealed that that Radon concentration was below the action level set by the United States Environmental Protection Agency of 148 Bq/m^3. This therefore indicates that no radiological health hazard exists. However, the relatively high concentrations in some classrooms can be addressed by the natural ventilation or the classrooms being supplied with suction fans.

Keywords: radon concentrations, excess of lung risk factor, Kufa Technical Institute buildings.

Introduction

Humans are exposed to radiation from different sources. An example of those sources is the naturally occurring radioactive materials (NORM) that exists in food, water and atmosphere. The biggest proportion of natural radiation comes from a radioactive gas which is known by radon whose its chemical symbol is ^{222}Rn. However, the annual average effective dose of natural radiation that the human is exposed is established to be 2.4 mSv/y. The radon contribution to this is estimated to be around 1.2 mSv/y [1]. The body exposure to ionizing radiation from the above sources may cause certain changes in the sensitive biological structures, either directly by transferring of the energy to the atoms of the tissue resulting in a chain of biological changes; this is known by direct action of radiation or by interacting with water molecules inside a cell to produce free radicals. The free radicals are able to diffuse over a distance to interact with the critical biological targets and then causing intercellular damages. The latter interaction is called indirect action of radiation [2].

Buildings are generally having low indoor air pressure compared with that of ground. This may, in turn, leads to some soil gas to leak from ground into the building. Radon gas can diffuse into a building by several ways, however the most common ways are through the diffusion and pressure that driven flow from the ground beneath and straight off adjacent to the building, providing an appropriate ingress routes. The route of ingress of radon can typically be described as holes and cracks in walls and floors, and gaps exist nearer to cables and pipes. In most dwellings with elevated indoor radon concentrations pressure-driven flow has been recognized as the dominant mechanism of entry [3]. The indoor radon is naturally originated from soil, building materials (rocks, sand, cement, etc.), and water born transport, natural energy sources such as gas and coal which include ^{238}U traces. The concentration of indoor radon depends mainly upon radon exhalation from surrounding materials [4]. In this context, radon gas is heavier than air, so it is not often a problem within the higher stories or high buildings [3]. Radon, Rn-222 ($T_{½}$ = 3.82 days), is a daughter product of ^{226}Ra, which is in turn derived from the longer-lived antecedent, ^{238}U. Thoron, Rn-220 ($T_{1/2}$ = 56 s) is a daughter of ^{232}Th, which presents in a big percentage in the earth's crust than radon. Because of thoron's short half-life, it is essentially gone before it leaves the ground, and it of no significant radiobiologic consequences.

The latter radionuclide series are existing in small proportion within the environment (geologic time scale). This owned to radioactive decay of their parents, which has been recognized and understood since the end of the last century [5]. There are many methods that can be used for radon measurements. These include solid-state nuclear track detectors (SSNTD) which are considered to be the most reliable technique for the determination of the radon concentration; LR-115 cellulose nitrate Type II thin films ($C_6H_2O_9N_2$) which is widely used as a radon concentration measurement device. In this detector, the color of track is seen as red and it is characterized by being insensitive to electrons and electromagnetic radiations [6]. Many previous studies have focused on measuring the concentrations of radon in buildings were identified [6 - 10]. The aim of this work is to measure the radon using SSNTD technique and estimation of excess in cancer due to increment in radon gas.

The Area of Study

The Technical Institute of Kufa was established in 1980 at a location of (32°3'34"N) latitude and (44°24'18"E) longitude with a total area of 268035m^2 [11] as seen in Fig. 1.

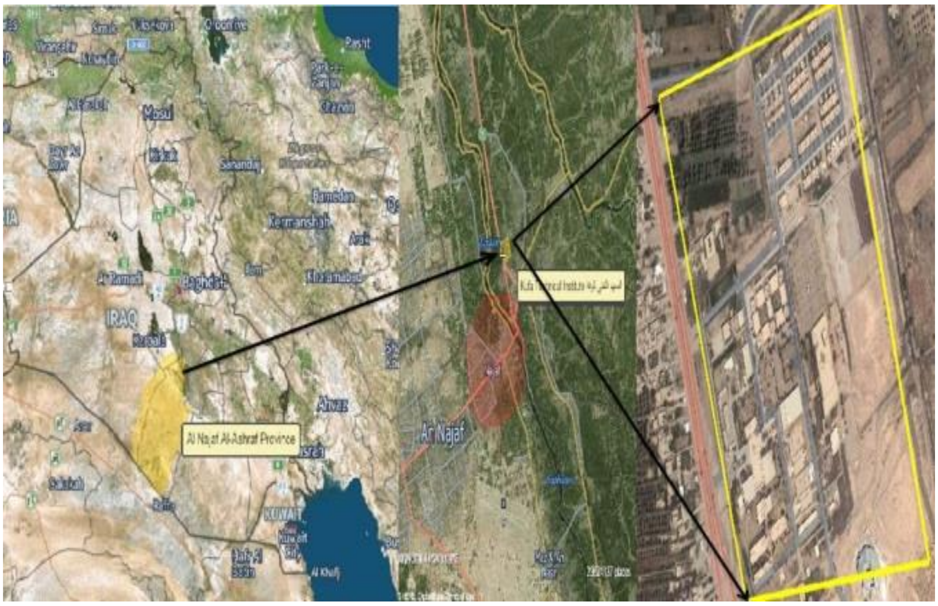

Fig. 1. Location of Kufa Technical Institute.

The Institute includes four health departments namely: pharmacology, pathological analyses and community health and nursing. It also includes three engineering departments; these are electricity, mechanics and automotive division (cars). In addition to these departments, it contains the administrative department and two departments of agriculture that are specialized in plant and animal production. The study area was chosen for a number of reasons. First, these buildings are easy to access and it is easy to deal with educated people that will reduce the losses in distributed detectors; second, it is easy to distribute and collect detectors in governmental buildings compared with other public places; finally, institutional buildings are highly populated with people who exposed to radon as they are spending long working time in the buildings. The dwelling of this Technical Institute was built using different materials. This includes cement, sand stones, bricks, iron structure, marble, and concrete. In this regards, building materials are another source of radiation exposure (external and internal) in both dwelling and public buildings [3]. The external is resulted from the emission of gamma rays from ^{238}U and ^{232}Th series as well as from ^{40}K radionuclides. By contrast, the internal exposure is caused by the inhalation of radon gas together with their short lived decay products. In Iraq, many studies have been conducted to assess the radioactivity in building materials that have been used in construction of buildings of Kufa Technical Institute, Iraq. The results of specific activity of ^{238}U, ^{232}Th and ^{40}K of certain local building materials in the middle Euphrates of Iraq ranged between 32.9 (Najaf gypsum) to 179.32 Bq/kg (Karbala cement), 1.98 (Najaf sand) to 17.43 Bq/kg (Qadisiya brick) and 108.73 (Karbala sand) to 977.79 Bq/kg (Najaf bricks) respectively [12]. Some of them contribute greatly to indoor radon emission. All buildings were occupied throughout this measurement. It should be noted that the studied buildings include a number of storey (i.e. 2 or 3) which equipped with a central air conditioning. Further to this, a considerable attention has been given to the ventilation system taken into account the governmental rules for constructing buildings aimed for residency. Nevertheless, it is worth mention that radon, as a noble gas, being heavier seven times than the air; therefore it is practically suitable to place the detector at the lower floor for good a measurement and for all buildings.

Materials and Methods

There are two different methods used to measure the radon concentration. First, a passive technique called solid state nuclear track detector (LR-115 Type II), and a continuous active radon sampling such as RAD-7 detector. Further details on these two techniques can be seen in the next sections.

Measurement of Radon Using Passive Method (LR-115 Type II Detector)

The radon dosimeter used in this work is made up of plastic cup 10.0 cm in diameter and 13 cm in depth, its cover includes a 0.5 cm hole sealed with a piece of sponge with an area of 1×1 cm^2 and 0.5 cm thickness, this configuration was necessary to ensures that the thoron cannot reach the detector. The plastic cup contains one LR-115 Type II, 12 μm thick, cellulose nitrate based SSNTDs manufactured by Kodak Pathe, France with an area of 1×1 cm^2 fixed at the bottom by double-sided cello-tape. The region indicated in the right side of figure (1) was divided into 10 parts, in each part and according to the size of building, six to fourteen dosimeters were allocated. Specifically, the dosimeters were placed in a sitting room at a height about (1 - 2) m above the floor. The period of dosimeters' exposure was 90 days extended from 1/11/2014 to 1/2/2015; throughout this period, α-particles emitted by the radon and their progeny which in turn bombard the SSNTD films. After the irradiation, the exposed films were etched in a NaOH solution with optimum conditions (2.5N at 60°C for 2 hr, for LR-115 II films). After that, the track densities on the LR-115 Type II SSNTD were determined by an optical microscope. Each LR-115 Type II detector was scanned with five fields of views. The area of the field of view was calculated using laptop and RZ Camera application software. The software has three functions: video process function, image process function and image measure function. For each detector the number of tracks was averaged over all five fields of views. During this process care was taken to distinguish between the tracks and dust particles.

For dosimetry purposes, it is important to measure the average radon concentration over time which should be long enough relative to the typical time scale of radon fluctuations caused by environmental conditions. The measured signal of the etched track detectors is the integrated track density as follows:

$$\text{Track density } (\rho(\text{track}/\text{ cm}^2) = \frac{\text{Average number of total pits (tracks)}}{\text{Area of field view}}, \qquad (1)$$

where ρ is recorded on the detector, track/cm^2; C_{Rn} is the ^{222}Rn concentration, Bq/m^3, which was determined using the following Eqs. (i.e. 2, 3 and 4) [13]:

$$C(\text{Bq}\cdot\text{m}^{-3}) = K\left\{\frac{\rho(\text{track}\cdot\text{cm}^{-2})}{t(\text{day})}\right\}_{\det}, \qquad (2)$$

$$\sigma_n(S.D.) = \sqrt{\frac{\sum_i^n (X_i - \bar{X})^2}{n-1}}, \qquad (3)$$

where C is ^{222}Rn concentration within the seals-cup air above the detector, Bq/m^3; C_o is the activity of standard sample, Bq · day · m^{-3}; ρ_o is track density, number of track · cm^{-2}, on the detector, exposed to standard source; ρ is track density, number of track · cm^{-2}, of the detectors exposed to the samples under study; t is exposure time, days, and σ_n ($S.D.$) is the standard deviation; K is the average value of the calibration factor of ^{222}Rn. Bq/(m^3 · day) per tracks · cm^2, and t exposure time, day. K can be obtained using Eq. (4)

$$k = \frac{C_o(\text{Bq}\cdot\text{day}\cdot\text{m}^{-3})}{\rho(\text{track}\cdot\text{cm}^{-2})}. \qquad (4)$$

The calibration factor was obtained by exposing reference dosimeters for a period of time ranged from 5 - 30 days to ^{226}Ra (Radon source) which activity is 3.3 kBq which was found to be 0.0217 ± 0.0013 track · cm^{-2} per Bq · day · m^{-3}. The latter value is approximately similar to that reported in many previous works [14 - 17]. The resulting concentration of short-lived radon daughters expressed in term of an equilibrium-equivalent radon concentration (EEC), that is related to the activity concentration of radon (C) by the Eq. (5) [18]:

$$EEC = C \cdot F, \qquad (5)$$

where F is an equilibrium factor which is equal 0.4 in indoor air. Now the Eq. (6) was used to calculate the annual absorbed dose and effective dose rate received by the population, according to the UNSCEAR (2000) report [19], in this regard the committee proposed $9 \cdot 10^{-6}$ mSv · m^3/h · Bq to be used as conversion factor [20]:

$$D_{Rn} = C \cdot D \cdot H \cdot F \cdot T , \qquad (6)$$

where D_{Rn} is the annual absorbed dose, mSv/y; C is the indoor radon concentration; D is the dose conversion factor which is equal $9 \cdot 10^{-6}$ mSv/m^3/h × × Bq; H is the indoor occupancy factor which is equal 0.4; and T is the indoor occupancy time which is equal 24 hr · 365 = 8760 hr/yr.

The annual effective dose H_E was calculated according to the Eq. (7) [20]:

$$H_E = D_{Rn} \cdot W_R \cdot W_T , \qquad (7)$$

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).

Excess Lifetime Cancer Risk (ELCR) calculation is also considered in this study. This can be defined as potential carcinogenic effects that estimate the probability of incidence of cancer in a population of individuals for a specific lifetime from exposures and dose-response data (i.e., slope factors). This is achieved by multiplying the intake by the slope factor. Then, the ELCR result is a matter of a probability. The extra risk of developing cancer owing to exposure to a toxic substance incurred across the lifetime of an individual. Overall, the ELCR deals with the probability of developing cancer over a lifetime at a given exposure.

The ELCR per million persons per year (MPY) was calculated using formula in Ref. [21]:

$$ELCR = H_E \cdot DL \cdot RF , \qquad (8)$$

where DL is the duration of life (70 yr) and RF is the risk factor (0.055 Sv^{-1}) recommended by the ICRP [21].

Measurement of Radon Using an Active Method (RAD-7) Detector

In this study, six buildings were tested for measuring radon concentration using RAD-7 technique taken from some locations of certain buildings which were already tested by LR-115 Type II detector. Sniff phase and circulation time were set to be for one day in accordance with running time of each path of the valve. For the purpose of investigating the amount of radon released from the sample to air, the sample was placed in a closed cylinder which allows airborne radon to be measured with a continuous monitor of electrostatic type (RAD-7, Durridge company, USA) [22].

Results and Discussions

The resulted data from LR-115 Type II measurements of the 14 buildings in Kufa Technical Institute are presented in 14 Tables (from Table 1 to Table 14). Each Table includes the minimum, maximum and average of concentration of radon. Also it includes information about the dosimeters sample No and sample code.

Table 1. **Observed indoor radon concentrations in school**

No.	Sample Code	Radon concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	S1	48.7	63.7	58.0 ± 6.4
2	S2	46.2	59.6	55.1 ± 6.2
3	S3	50.0	83.3	62.6 ± 15.5
4	S4	53.1	87.1	64.5 ± 15.4
5	S5	47.3	85.7	62.6 ± 16.8
Average		**49.1 ± 2.6**	**75.9 ± 13.1**	**60.6 ± 3.8**

Table 2. **Observed indoor radon concentrations in Student Housing**

No.	Sample Code	Radon concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	SHM1	52.6	62.0	56.1 ± 4.1
2	SHM2	48.0	62.8	54.8 ± 7.8
3	SHM3	43.5	62.2	52.0 ± 7.7
4	SHM4	49.4	63.4	55.8 ± 6.0
5	SHM5	39.3	61.3	51.0 ± 9.0
Average		**46.6 ± 5.2**	**62.3 ± 0.8**	**53.9 ± 2.3**

Table 3. **Observed indoor radon concentrations in Agricultural Department**

No.	Sample Code	Radon concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	AG1	49.5	86.6	64.6 ± 18.0
2	AG2	35.3	56.5	43.1 ± 9.5
3	AG3	53.3	77.0	63.4 ± 11.0
4	AG4	35.5	50.0	42.7 ± 6.8
Average		**43.4 ± 9.3**	**67.5 ± 17.1**	**53.5 ± 12.1**

Table 4. **Observed indoor radon concentrations in Nursing Department**

No.	Sample Code	Radon concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	N1	24.3	32.3	27.5 ± 3.5
2	N2	35.6	58.9	42.8 ± 10.9
3	N3	52.9	65.7	62.3 ± 6.2
4	N4	20.2	34.2	28.6 ± 6.5
5	N5	34.9	49.8	42.6 ± 6.8
Average		**33.6 ± 12.7**	**48.2 ± 14.7**	**40.8 ± 14.1**

Table 5. **Observed indoor radon concentrations in Computer Center**

No.	Sample Code	Radon concentrations. Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	C1	48.8	62.3	54.3 ± 6.5
2	C2	52.0	57.8	55.4 ± 2.6
3	C3	50.5	58.3	55.8 ± 3.6
4	C4	44.3	62.3	54.9 ± 7.9
5	C5	48.5	60.8	56.7 ± 5.6
6	C6	57.3	85.5	64.4 ± 14.0
Average		**50.2 ± 4.3**	**64.5 ± 10.4**	**56.9 ± 3.7**

Table 6. **Observed indoor radon concentrations in Administrative Department**

No.	Sample Code	Radon concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	AD1	33.1	65.2	48.7 ± 15.7
2	AD2	21.5	32.8	29.3 ± 5.3
3	AD3	29.9	43.9	35.7 ± 5.8
4	AD4	23.7	68.0	39.8 ± 19.5
Average		**27.0 ± 5.3**	**52.5 ± 16.9**	**38.4 ± 8.1**

Table 7. **Observed indoor radon concentrations in Institute Deanship**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	ID1	29.1	55.7	43.4 ± 11.7
2	ID2	33.1	60.0	46.1 ± 11.1
3	ID3	31.2	50.2	40.9 ± 7.7
4	ID4	42.5	73.3	56.2 ± 12.7
5	ID5	37.9	49.5	41.7 ± 5.3
6	ID6	14.8	69.0	34.5 ± 24.5
7	ID7	18.4	47.1	34.4 ± 14.3
8	ID8	35.5	51.0	43.5 ± 6.8
9	ID9	51.8	66.9	56.9 ± 6.9
10	ID10	27.2	79.1	60.4 ± 23.5
11	ID11	34.5	40.5	37.5 ± 3.3
12	ID12	30.1	39.8	33.7 ± 4.4
13	ID13	22.0	83.0	49.4 ± 25.7
14	ID14	49.3	60.9	53.9 ± 5.2
Average		**32.7 ± 10.6**	**59.0 ± 13.7**	**45.2 ± 8.9**

Table 8. **Observed indoor radon concentrations in Pharmacy Department**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	P1	36.4	41.6	38.7 ± 2.1
2	P2	44.9	62.1	54.0 ± 7.1
3	P3	38.5	41.8	40.3 ± 1.6
4	P4	47.7	59.8	56.0 ± 5.5
5	P5	31.2	42.2	36.2 ± 4.6
6	P6	39.0	55.3	47.0 ± 7.2
Average		**39.6 ± 5.9**	**50.5 ± 9.6**	**45.4 ± 8.2**

Table 9. **Observed indoor radon concentrations in Health and Analyses Departments**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	HA1	47.0	96.7	68.6 ± 21.6
2	HA2	34.9	55.7	44.6 ± 9.5
3	HA3	36.1	58.8	46.1 ± 11.2
4	HA4	36.5	56.4	45.8 ± 10.5
5	HA5	30.1	69.4	43.9 ± 17.8
6	HA6	39.6	60.2	45.6 ± 9.7
7	HA7	37.1	56.6	46.4 ± 8.0
8	HA8	38.8	46.5	43.0 ± 3.2
9	HA9	41.5	54.6	46.4 ± 5.7
10	HA10	41.8	53.4	45.6 ± 5.3
11	HA11	39.1	58.8	45.2 ± 9.1
12	HA12	41.1	50.0	44.7 ± 3.8
Average		**38.6 ± 4.2**	**59.8 ± 12.9**	**47.2 ± 6.8**

Table 10. **Observed indoor radon concentrations in Electric Department**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	E1	21.1	53.4	41.4 ± 15.1
2	E2	24.9	38.5	29.5 ± 6.0
3	E3	26.0	46.3	31.6 ± 9.8
4	E4	29.2	63.3	46.6 ± 14.1
5	E5	27.3	41.1	33.4 ± 6.2
6	E6	31.9	50.1	43.5 ± 9.3
7	E7	40.4	61.1	50.1 ± 10.7
8	E8	28.0	40.1	33.4 ± 5.0
Average		**28.6 ± 5.7**	**49.2 ± 9.8**	**38.7 ± 7.6**

Table 11. **Observed indoor radon concentrations in Workshops**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	W1	76.3	89.1	82.7 ± 6.7
2	W2	60.8	87.3	71.6 ± 11.3
3	W3	67.6	91.3	74.5 ± 11.2
4	W4	68.3	92.6	79.9 ± 12.8
Average		**68.3 ± 6.3**	**90.1 ± 2.3**	**77.2 ± 5.0**

Table 12. **Observed indoor radon concentrations in Mechanics Department**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	M1	50.6	60.5	55.6 ± 4.8
2	M2	29.2	48.1	37.0 ± 8.6
3	M3	47.1	54.8	51.8 ± 3.2
4	M4	43.3	56.4	48.1 ± 5.9
5	M5	37.4	69.6	49.7 ± 13.9
6	M6	28.7	51.2	41.8 ± 9.7
Average		**39.4 ± 9.2**	**56.8 ± 7.5**	**47.3 ± 6.7**

Table 13. **Observed indoor radon concentrations in Cars Department**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	CD1	51.6	62.4	57.1 ± 4.8
2	CD2	34.9	56.8	45.5 ± 8.9
3	CD3	53.6	63.6	58.9 ± 5.0
4	CD4	39.2	57.5	50.5 ± 8.4
5	CD5	36.5	57.8	47.0 ± 10.4
6	CD6	47.8	59.1	53.3 ± 6.1
Average		**43.9 ± 8.0**	**59.5 ± 2.7**	**52.0 ± 5.3**

Table 14. **Observed indoor radon concentrations in Healthy Technical Deanship**

No.	Sample Code	Radon Concentrations, Bq/m^3		
		Minimum	Maximum	Average ± S.D
1	HD1	27.1	36.5	31.7 ± 3.8
2	HD2	37.9	53.6	46.4 ± 8.6
3	HD3	34.4	48.9	41.8 ± 7.4
4	HD4	29.2	34.8	31.7 ± 2.5
5	HD5	33.9	53.0	38.9 ± 9.3
6	HD6	30.0	42.8	38.4 ± 5.8
7	HD7	21.0	43.9	30.8 ± 9.5
8	HD8	45.3	63.7	55.4 ± 7.5
9	HD9	21.7	70.8	50.6 ± 23.6
10	HD10	37.4	62.4	52.4 ± 10.8
Average		**31.8 ± 7.5**	**51.0 ± 11.9**	**41.8 ± 9.0**

The results obtained from the 94 LR-115 Type II detectors demonstrated that the radon concentration in a fourteen buildings of Kufa Technical Institute, Iraq varied from (38.4) to (77.2) with an average of (50) Bq/m^3, this finding can still be considered within normal limits and below the action level of buildings set by the international environment organizations which is 148 Bq/m^3 [23]. The average radon concentration obtained in this study was compared with other similar studies in literature that can be seen in references [24 - 28]. The difference between our study and those mentioned in literature are attributed to the variations in the factors that determine indoor radon concentrations such as the building material, ventilation rate and most importantly is the geology factor. In fact, this study can be considered as the first attempt to evaluate the risk that is related to radon existence in buildings of Kufa Technical Institute, Iraq. The total number of locations measured should be extended in the future.

Table 15 shows the relation between the average value of the ^{222}Rn EEC, the annual effective dose equivalent (AEDE) and ELCR per million persons per year for buildings under study with building code.

From Table 15, the range of the average equilibrium equivalent ^{222}Rn were found to be (15.3 - 30.8) Bq/m^3, while the range of the average of the annual effective dose were found to be (0.9 - 1.9) mSv/y. Additionally, and according to our estimations, the Excess Lung Cancer in all buildings of Kufa Technical Institute, Iraq was found to range from (8.9 to 18.0) with an average value of 11.6 per million persons. The maximum value of annual effective dose was 1.9 mSv/y, this value is indeed low when compared to the global limit

Table 15. **Observed Average of EEC, AEDE and ELCR duo to indoor radon concentrations in Buildings under Study**

No.	Building of Code	EEC, Bq/m^3	AEDE, mSv/y	ELCR
1	S	24.2	1.5	14.1
2	SH	21.5	1.3	12.5
3	AG	21.4	1.3	12.4
4	N	16.3	1.0	9.5
5	C	22.7	1.4	13.2
6	AD	15.3	0.9	8.9
7	ID	18.0	1.1	10.5
8	P	18.1	1.1	10.5
9	HA	18.8	1.1	11.0
10	E	15.4	0.9	9.0
11	W	30.8	1.9	18.0
12	M	18.9	1.1	11.0
13	CD	20.8	1.3	12.1
14	HD	16.7	1.0	9.7
Average		**19.9 ± 3.8**	**1.2 ± 0.2**	**11.6 ± 2.1**

(i.e. range 1 - 3) mSv/y [19]. We believe that this low value of the effective dose is related to low value of radon concentrations occupancy rate, while the average percentage value of the Excess Lung Cancer in all buildings of Kufa Technical Institute, Iraq was about 11.6 per million persons, associated to a chronic exposure to indoor radon. As the risk of lung cancer increases with increasing radon exposure, the preferred measure of this risk is the long-term average radon level. By way of comparison, the average values of ELCR results of the current study found to be lower than those in Kerbala which is 12.3 [29] (i.e. other Iraqi city – 80 km north-west to the studied area) and of Kurdistan at 19.4 [31] (500 km north to the studied area). However, the current ELCR findings were higher than those reported in Baghdad at 1.7 (150 km north-east to the studied area) [31]. Fig. 2 compares between the average radon concentrations in six buildings of studied area using LR-115 Type II and RAD-7 detector. As can be seen from the data plotted in Fig. 3, a high linear correlation (R^2 = 0.99) between long term passive detectors using LR-115 Type II and short term active detector using RAD-7 for indoor radon concentration measurements. The slope of the linear trend between long and short measurements is 1.02. For LR-115 Type II the measurements were conducted in around 3 months, and for RAD-7 the measurement was conducted for around 24 hr. This may indicate that the radon concentrations in case of buildings can be estimated using either long-term measurements of the LR-115 Type II or using short term measurements of the RAD-7 technique.

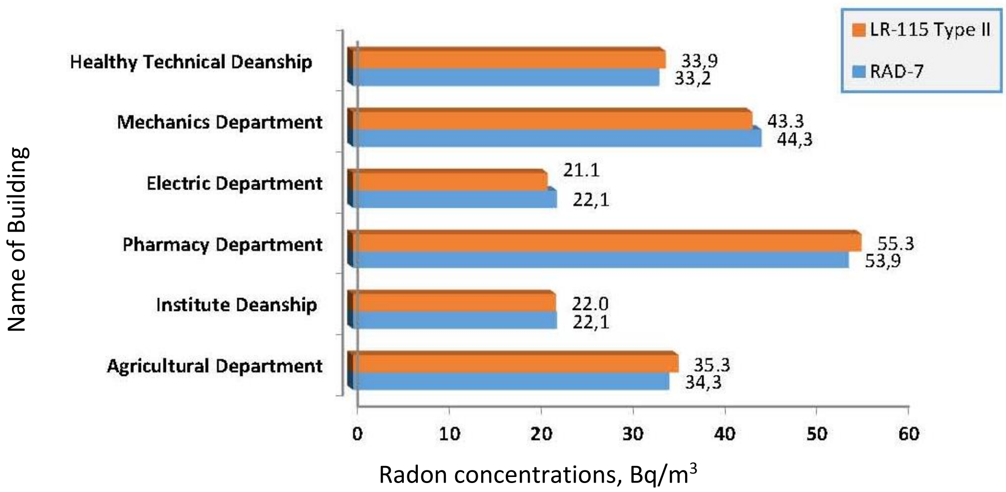

Fig. 2. Comparison of RAD-7 and LR-115 Type II results. (See color Figure on the journal website.)

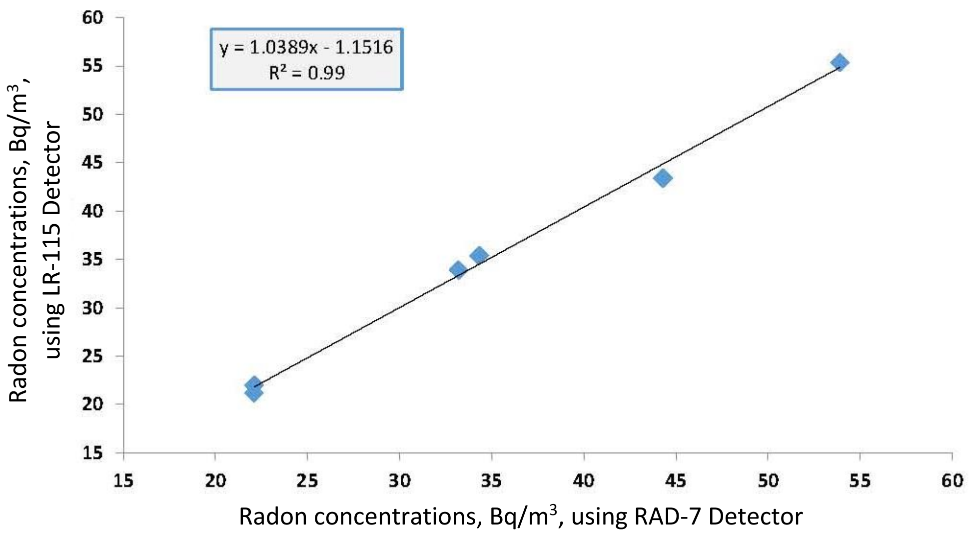

Fig. 3. Correlation between LR-115 Type II and RAD-7 measurements of indoor radon concentration.

Conclusions

Indoor radon concentration and excess relative risk of cancer were estimated for the residents of district Buildings of Kufa Technical Institute, Iraq. The measured indoor radon concentrations and calculated annual effective dose are found to be within acceptable ranges, according to the US EPA (148 Bq/m^3) and UNSCEAR (1 - 3 mSv/y). Also, it is found that the buildings in district are characterized by low radon, so the people who live in those buildings are subject to relatively low risk factor of radon induced cancer. Finally, all the buildings investigated are within the safe limits of radon exposure.

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ОЦІНКА ОНКОЛОГІЧНОГО РИЗИКУ ВІД РАДОННОГО ОПРОМІНЕННЯ У ДЕЯКИХ БУДІВЛЯХ ТЕХНІЧНОГО ІНСТИТУТУ КУФИ, ІРАК

Ряд міжнародних організацій з охорони здоров'я розглядає вплив житлового радону як другу основну причину раку легенів після куріння сигарет. Було встановлено, що бази даних щодо концентрацій радону для будівель Технічного інституту Куфи в літературі немає. Отже, існує потреба у таких вимірюваннях. Метою даного дослідження є вивчення внутрішніх рівнів радону в будівлях Технічного інституту Куфи вперше за допомогою різних методів вимірювання радону, таких як активні (RAD-7) та пасивні методи (LR-115 тип II). 78 твердотільних ядерно-трекових детекторів (SSNTD) LR-115 типу II було встановлено на чотирьох будівлях у досліджуваній області. Ці детектори накопичували опромінення протягом трьох місяців. Паралельно з цим було проведено 72 два активних вимірювання з використанням детекторів RAD-7 у тих же будинках для дослідження кореляцій між двома видами вимірювань (тобто пасивними та активними). Результати показують, що концентрації радону були загалом низькими, що коливаються від 38,4 до 77,2 Бк/м^3, із середнім значенням 50 Бк/м^3. Середнє значення рівноважного еквіваленту концентрації радону та річної ефективної дози оцінені як 19,9 Бк/м^3 та 1,2 мЗв/рік відповідно; ризик виникнення раку легенів становить приблизно 11,6 на 1 мільйон. Виявлено високу кореляцію між методами вимірювань (тобто за допомогою LR-115 типу II та RAD-7), R^2 = 0,99, що є значним при $P < 0{,}001$. Результати цієї роботи показали, що концентрація радону є нижче критичного рівня, установленого Агентством охорони навколишнього середовища Сполучених Штатів Америки, 148 Бк/м^3. Отже, це свідчить про відсутність радіологічної небезпеки для здоров'я. Відносно високі концентрації в деяких кабінетах можуть бути зменшені за допомогою природної вентиляції або встановленням вентиляторів із функцією поглинання.

Ключові слова: концентрація радону, надлишок ризику для легенів, будівлі Технічного інституту Куфи.

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ОЦЕНКА ОНКОЛОГИЧЕСКОГО РИСКА ОТ РАДОННОГО ОБЛУЧЕНИЯ В НЕКОТОРЫХ СТРОЕНИЯХ ТЕХНИЧЕСКОГО ИНСТИТУТА КУФЫ, ИРАК

Ряд международных организаций по охране здоровья рассматривает влияние жилого радона как вторую основную причину рака легких после курения сигарет. Было установлено, что базы данных по концентрации радона для строений Технического института Куфы в литературе нет. Таким образом, существует потребность в таких измерениях. Целью данного исследования было изучение внутренних уровней радона в строениях Технического института Куфы впервые с помощью разных методов измерения радона, таких как активные (RAD-7) и пассивные методы (LR-115 тип II). 78 твердотельных ядерно-трековых детекторов (SSNTD) LR-115 типа II было установлено на четырех строениях в исследуемой области. Эти детекторы накапливали облучение на протяжении трех месяцев. Параллельно с этим было проведено 72 активных измерения с использованием детекторов RAD-7 в тех же строениях для исследования корреляций между двумя видами измерений (т.е. пассивными и активными). Результаты показывают, что концентрации радона были в общем низкими, от 38,4 до 77,2 Бк/м^3, со средним значением 50 Бк/м^3. Среднее значение равновесного эквивалента концентрации радона и годовой эффективной дозы оценено как 19,9 Бк/м^3 и 1,2 мЗв/год соответственно; риск возникновения рака легких равен приблизительно 11,6 на 1 миллион. Обнаружена высокая корреляция между методами измерений (т.е. с помощью LR-115 типа II и RAD-7), $R^2 = 0,99$, что существенно при $P < 0,001$. Результаты этой работы показали, что концентрация радона ниже критического уровня, установленного Агентством охраны окружающей среды Соединенных Штатов Америки, 148 Бк/м^3. Таким образом, это свидетельствует об отсутствии радиологической опасности для здоровья. Относительно высокие концентрации в некоторых кабинетах могут быть уменьшены с помощью природной вентиляции или установкой вентиляторов с функцией поглощения.

Ключевые слова: концентрация радона, излишек риска для легких, строения Технического института Куфы.

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