Determination of radon concentrations near mobile towers in selected cities of Babylon governorate, Iraq

Anees A. Al-Hamzawi¹*, Nada F. Tawfiq², Murtadha Sh. Aswood¹, Firas A. Najim¹
¹Department of physics, College of Education, University of Al-Qadisiyah, Al-Diwaniyah, Iraq
²Department of physics, College of Science, Al-Nahrain University, Baghdad, Iraq
*E-mail: aneesphys@gmail.com; anees.hassan@qu.edu.iq

Abstract. Determination of radon concentration in a dwelling is preferred method for monitoring the internal exposure of radiological contaminants. Measurement the concentration of radon and their daughter products in indoor and outdoor of dwelling for Al-Medhatyah and Al-Hashimiyah cities, Babylon governorate near mobile stations were carried out by nuclear track detectors (CR-39) in a bare mode. The results show that the concentrations of indoor radon were found to vary from 85.51 Bq/m³ to 157.48 Bq/m³ with an average value of 131.43 ± 20.71 Bq/m³. This value was lower than the ICRP recommended values of (200 – 300 Bq/m³) and thus is within safe limits. The outdoor radon concentrations was vary from 100.75 Bq/m³ to 110.06 Bq/m³ with average 105.26 ± 3.8 Bq/m³, the outdoor radon concentration is usually low and less than average indoor levels. The equilibrium-equivalent radon concentration (EECRN), potential alpha energy concentration (PAEC), annual exposure to potential alpha energy (EP), annual effective dose (AED) and the lung cancer cases per year per million people (CPPP) were calculated.

1. Introduction
Naturally occurring radiation and artificial sources are the important source of environmental radiation. Major sources of natural radioactivity are nuclides with very long half-lives which have persisted since the formation of earth, and nuclides from cosmic origin. Manmade radionuclides can exist in the environment and increment of its level through a variety of different processes. Radon (222Rn) is produced by the alpha decay of 226Ra; it comes from spontaneous decay of uranium which is found in all types of soil samples [1].
Radon gas spontaneously decays with a half-life equals to 3.825 days, it typically moves up from the ground to the air which produces short nuclides called radon daughters namely, 218Po, 214Pb, 214Bi and 214Po; where some nucleis leave the soil and enter the surrounding water or air. As a result of the presence of radon internally and externally, emission of alpha particles takes place within the lungs due to the inhalation of radon progenies. Decay products of radon gas are the most important contributors to the inhalation dose. The main natural sources of irradiation inside the human body are radon and its decay daughters in the air [2]. Indoor radon levels are higher, but there is a substantial level external also. Radon causes unhealthy problems of the human where many researchers indicated that the radon is the main reason for cancerous diseases among uranium miners [3, 4]. In spite of the difference of the ionizing radiations in the abilities of ionization and penetration can produce similar harm to living cells, but at different levels. The effects of the ionizing radiation in humans can occur...
by depositing its energy in the body tissues, resulting in breaking up the molecules then destroying the internal biological systems; which causes changes in the chemical balance of the cell. [5]. There are a linearly proportional between the damages that occur in the cells and the dosage received, where these damages depend on many factors including radiation type, energy deposited, intensity and period of exposure [6]. Ionizing radiation has two types of action in human cells are directly by dissociating molecules which causing loss of the biological function of the molecules, and indirectly by producing free radicals in the body fluids where about (60 % to 70 %) of cellular DNA damage caused by free radicals [7, 8]. Solid state nuclear track detectors (SSNTDs) in CR-39 are normally used to detection the alpha particles [9 – 11]. The influence of mobile towers on radon concentrations are not well known, for this reason this research was aimed to study whether there is a relationship between mobile towers and radon concentrations in nearby houses in Babylon governorate (central of Iraq) and identify houses with high indoor radon levels.

2. Materials and Methods
Radon gas concentrations in seventeen locations of investigation in (Al-Medhatyah and Al-Hashimiyah) city southern of Babylon governorate (central of Iraq) as shown in figure (1) were measured using CR-39 track detectors. CR-39 track detectors (Preshore Company, UK) with thickness 500μm and area 2×2 cm² were suspended in the room at a height more than 2m above the ground level and about 1m below the ceiling of the room, in bare mode during which time the alphas originating from 222Rn and its progeny leave tracks on it. The distance of the CR-39 from the walls was kept 2m. Thirteen detectors were placed in rooms for different dwelling of the ground floor and three detectors placed outdoor. After the exposure period 60 days, the detectors were chemically etched using 6.25 Normality (NaOH) liquid at 60°C for 5 hours as reported elsewhere [9 – 11]. After etching, the detectors were washed with tap water, then with distilled water and dried. The tracks were counted using an optical microscope at magnification of 400X.

The radon concentration (C_Rn) was calculated as [12]:

\[ C_{Rn} (Bq.m^{-3}) = \frac{C_o \rho}{\rho_o T} \] …………… (1)

Where (\( \rho \)) is the track density (track /mm²), \( \rho_o /C_o \) is the calibration factor for dosimeters exposed as reported elsewhere [12], and (T) is the exposure time which is equal to (60) days.

The concentration of short-lived radon daughters, expressed in term of an equilibrium-equivalent radon concentration (EECRN), is related to the activity concentration (C_Rn) of radon by the relation [13]:

\[ \text{EECRN (Bq/m}^3) = F \cdot C_{Rn} \] …………… (2)

Where F is an equilibrium factor. On the basis of ICRP recommendations, the equilibrium factor for radon daughters in indoor air is assumed to be 0.40 and the mean equilibrium factor in outdoor air is 0.7 and somewhat higher than indoor air [14].

The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units was obtained using the relation [15]:

\[ \text{PAEC (WL)} = F \cdot C_{Rn} / 3700 \] …………… (3)

Where (F) is the equilibrium factor between radon and its progeny and it is equal to (0.4) as suggested by UNSCEAR [16].

The annual exposure to potential alpha energy (EP) is then related to the average radon concentration CRn by following expression [17]:

\[ \text{EP (WLM Y}^{-1}) = 8760 \times n \times F \times C_{Rn} / 170 \times 3700 \] ……… (4)

where C_Rn is in Bq.m^{-3}, n is the fraction of time spent indoors which is equal to (0.8) ,8760 is the number of hours per year, 170 is the number of hours per working month and F is the equilibrium factor for radon is equal to 0.4.

The annual effective dose (AED) in terms of (mSv /y) units was obtained via the following relation [18]:

\[ \text{AED (mSv/y)} = C_{Rn} \times F \times H \times T \times D \] …………… (5)
Where $F$ is the equilibrium factor and it is equal to (0.4), $(H)$ is the occupancy factor which is equal to (0.8), $(T)$ is the time in hours in a year, $(T=8760 \text{ h/y})$, and $(D)$ is the dose conversion factor which is equal to $[9\times10^{-6} (\text{m Sv}) / (\text{Bq.h.m}^{-3})]$.

The lung cancer cases per year per million people (CPPP), was obtained using the following equation [19]:

$$\text{CPPP} = \text{AED} \times (18\times10^{-6} \text{ mSv.y}^{-1}) \quad ................................ (6)$$

![Figure 1. Map of Iraq showing the location of study](image)

### 3. Results and Discussion

The study was conducted during spring season. The results of outdoor radon and its daughter concentrations were varied from 104.98 Bq/m$^3$ to 110.06 Bq/m$^3$ with average value equals to $105.26 \pm 3.8$ Bq/m$^3$, see Table 1 and Figure 2 radon concentration was found less than the recommended range $(200 - 300 \text{ Bq/m}^3)$. The values of equilibrium equivalent radon concentration (EECRN) were ranged from 70.52 to 77.04 Bq/m$^3$ with average value equals to $73.68 \pm 2.66$ Bq/m$^3$, the potential alpha energy concentration (PAEC) ranged from 0.011 to 0.012 WL with average $0.011 \pm 5 \times 10^{-3}$ WL, the potential alpha energy (Ep) ranged from 0.45 to 0.49 WLMY$^{-1}$ with average $0.47 \pm 0.02$ WLMY$^{-1}$, the annual effective dose (AED) varied from 2.54 to 2.77 mSvy$^{-1}$ with average $2.65 \pm 0.09$ mSvy$^{-1}$ and the lung cancer cases per year per million people (CPPP) varied from $45.72$ to $49.86 \times 10^{-6}$ with average $47.7 \pm 1.69 \times 10^{-6}$.

| Place | $C_{\text{Rn}}$ Bq/m$^3$ | EECRN Bq/m$^3$ | PAEC WL | Ep WLMY$^{-1}$ | AED mSv/y | CPP×10$^{-6}$ |
|-------|-------------------------|-----------------|---------|---------------|----------|--------------|
| Out 1 | 110.06                  | 77.04           | 0.012   | 0.49          | 2.77     | 49.86        |
| Out 2 | 105.23                  | 73.66           | 0.011   | 0.47          | 2.65     | 47.7         |
| Out 3 | 100.75                  | 70.52           | 0.011   | 0.45          | 2.54     | 45.72        |
| Out 4 | 104.98                  | 73.49           | 0.011   | 0.47          | 2.64     | 47.52        |
| Average | $105.26 \pm 3.8$ | $73.68 \pm 2.66$ | $0.011 \pm 5 \times 10^{-3}$ | $0.47 \pm 0.02$ | $2.65 \pm 0.09$ | $47.7 \pm 1.69$ |
Indoor radon and its daughter’s concentrations in the dwellings of Al-Medhatyah and Al-Hashimiyah city were given in table 2 and figure 3. Indoor radon and its daughter’s concentrations were varied between 85.51 to 157.48 Bq/m³ with average value 131.43 ± 20.71 Bq/m³. The average value is less than the safety limits that recommended by ICRP which is (200 - 300 Bq/m³) [20]. The highest radon concentration in indoor dwellings was found in bedrooms and Bath room which have poor ventilation condition, commonly with one door and one small window, while the lowest concentration of radon was found in kitchen and living room. The variation of indoor radon concentrations is due to the difference in the ventilation methods used, while other rooms of the houses have open area and well ventilation conditions. The values of equilibrium equivalent radon concentration (EECRN) were ranged from 62.99 to 34.20 Bq/m³ with average 52.57 ± 8.3 Bq/m³, the potential alpha energy concentration (PAEC) ranged from 0.01 to 0.036 WL with average value 0.015 ± 0.0061 WL, the potential alpha energy (Ep) ranged from 0.38 to 0.70 WLMY⁻¹ with average value equals to 0.58 ± 0.09 WLMY⁻¹, annual effective dose (AED) varied from 2.15 to 3.97 mSv/y with average 3.3 ± 0.5 mSv/y and the lung cancer cases per year per million person (CPPP) varied from 38.7×10⁻⁶ to 71.46×10⁻⁶ with average 59.6 ± 9.4×10⁻⁶.

### Table 2. Indoor radon concentrations at different places in Al-Medhatyah and Al-Hashimiyah

| Sample | Place           | $C_{Rn}$ Bq/m³ | EECRN Bq/m³ | PAEC WL | Ep WLMY⁻¹ | AEDE mSv/y | CPP × 10⁻⁶ |
|--------|-----------------|----------------|-------------|---------|-----------|------------|------------|
| M1     | Bed room        | 157.40         | 62.99       | 0.017   | 0.70      | 3.97       | 71.46      |
| M2     | Bed room        | 148.17         | 59.27       | 0.016   | 0.66      | 3.73       | 67.14      |
| M3     | Bath room       | 157.48         | 62.99       | 0.017   | 0.70      | 3.97       | 71.46      |
| M4     | Kitchen         | 123.61         | 49.44       | 0.013   | 0.55      | 3.11       | 55.98      |
| M5     | Reception room  | 119.38         | 47.75       | 0.013   | 0.53      | 3.0        | 54.0       |
| H1     | Reception room  | 124.46         | 49.78       | 0.013   | 0.55      | 3.14       | 56.52      |
| H2     | Bed room        | 128.69         | 51.48       | 0.014   | 0.57      | 3.24       | 58.32      |
| H3     | Living room     | 104.98         | 41.99       | 0.011   | 0.47      | 2.64       | 47.52      |
| H4     | Kitchen         | 85.51          | 34.20       | 0.01     | 0.38      | 2.15       | 38.7       |
| H5     | Bed room        | 157.48         | 62.99       | 0.017   | 0.70      | 3.90       | 71.46      |
| H6     | Reception room  | 133.77         | 53.51       | 0.036   | 0.59      | 3.37       | 60.66      |
| H7     | Kitchen         | 143.08         | 57.23       | 0.015   | 0.64      | 3.6        | 64.80      |
| H8     | Living room     | 124.46         | 49.78       | 0.013   | 0.55      | 3.13       | 56.34      |

| Average value ± S.D | 131.43 ± 20.71 | 52.57 ± 8.3 | 0.015 ± 0.0061 | 0.58 ± 0.09 | 3.3 ± 0.5 | 59.6 ± 9.4 |
Figure 3. Indoor radon concentrations: (a) Al-Medhatyah; (b) Al-Hashimiyah city

Figure 4 shows the mean value of internal and external radon concentration. From this figure, mean value of indoor radon concentration is higher than outdoor radon concentration. Based on these mean values, about 80% increase of radon concentration was observed in the indoor and outdoor. The cause behind such results can be attributed to the natural radioactive of building material in the dwellings; and this finding is in agreement with those of other researchers [21, 22].

Figure 4. Contribution of radon concentrations (Bq/m³) indoor and outdoor

Conclusions
The indoor radon concentration was found to vary with ventilation condition, occupant’s behavior and lower than recommended value under normal ventilation condition. The average outdoor radon concentration was less than indoor radon concentration and less than the recommended range (200 - 300 Bq/m³). Mobile Towers dose not effect on radon gas concentrations.

Acknowledgments
Support from Department of Physics, College of Education, University of Al-Qadisiyah is gratefully acknowledged.
References:

[1] Eisenbud M and Gesell T 1997 Environmental radioactivity from natural, industrial and military sources: from natural, industrial and military sources. Elsevier

[2] UNSCEER United Nations Scientific Committee on the Effect of Atomic Radiation Sources 2000 Effects and Risks of Ionizing Radiation. Report to the General Assembly, with Scientific Annexes, United Nations, New York

[3] Kreuzer M, Grosche B, Schnelzer M, Tschense A, Dufey F and Walsh L 2010 Radon and risk of death from cancer and cardiovascular diseases in the German uranium miners cohort study: follow-up 1946–2003. Radiation and environmental biophysics 49(2) 177-185

[4] Tirmarche M, Raphaelen A, Allin F, Chameaud J and Bredon P 1993 Mortality of a cohort of French uranium miners exposed to relatively low radon concentrations. British journal of cancer 67(5) 1090

[5] Belk C, and Borden V 2004 Biology: Science for life. Prentice Hall, USA

[6] Wright J 2004 Environmental chemistry. Routledge publishing, London

[7] Despopoulos A and Silbernagl S 2003. Color atlas of physiology. Thieme, Germany

[8] Wallace S 1998 Enzymatic processing of radiation-induced free radical damage in DNA. Radiation Research 150(5) S60-S79

[9] Al-Hamzawi A, Jaafar S and Tawfiq N 2014 Uranium concentration in blood samples of Southern Iraqi leukemia patients using CR-39 track detector. Journal of radioanalytical and nuclear chemistry 299(3) 1267-1272

[10] Al-Hamzawi A, Jaafar S and Tawfiq N 2015 Concentration of uranium in human cancerous tissues of Southern Iraqi patients using fission track analysis. Journal of Radioanalytical and Nuclear Chemistry 303(3) 1703-1709

[11] Al-Hamzawi A, Jaafar S and Tawfiq N 2014 The measurements of uranium concentration in human blood in selected regions in Iraq Using CR-39 track detector. In Advanced Materials Research 925 679-683

[12] Al-Hamidawi A and Husain A 2016 Radiation hazards due to radon concentrations in dwellings of Kufa Technical Institute, ‘Iraq’. Phys Int, 7, 28-34.

[13] ICRP, International Commission on Radiological Protection Publication 1987 Lung Cancer Risk for Indoor Exposure to Radon Daughters. ICRP Publications 50 pergamon press.

[14] UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation 1982 Ionizing radiations: Sources and biological effects. United Nations Publication No.E.82.IX.8, New York.

[15] Kansal S, Mchra R and Singh P 2012 Life time fatality risk assessment due to variation of indoor radon concentration in dwellings in western Haryana, India. Applied Radiation and Isotopes 70 1110-1112

[16] UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation 2000 Sources and Effects of Ionizing Radiation. United Nations, New York

[17] ICRP, International Commission on Radiological Protection Publication 1994 Protection against Radon-222 at home and at work. Annals of ICRP, Oxford, Pergamon press

[18] Abumurad K and Al-Omari R 2008 Indoor radon levels in Irbid and health risks from internal doses. Radiation Measurements 43 S389-S391

[19] Battawy A, Jaafar S, Tawfiq N, Mustafa I, Ali A and Hussein Z 2013 Indoor radon concentration measurement in selected factories in northern and central Iraq. Measurement 4

[20] ICRP, International Commission on Radiological Protection Publication 2007 The 2007 Recommendations of the International Commission on Radiological Protection, Oxford, Pergamon press

[21] Gruber V, Bossew P, De Cort M and Tollefsen T 2013. The European map of the geogenic radon potential. Journal of Radiological Protection, 33(1) 51

[22] Faheem M and Mati N 2007 Seasonal variation in indoor radon concentrations in dwellings in six districts of the Punjab province, Pakistan. Journal of Radiological Protection, 27(4) 493