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# Measurement of indoor radon concentration levels in Iraqi Kurdistan region

**Zakariya A. Hussein[1*], Mohamad S. Jaafar[1] and Asaad H. Ismail[2*]**

[1]*Radiation and Medical Physics, School of Physics, Universiti Sains Malaysia, Pulau Penang, Malaysia*
[2]*Medical Physics, Physics Department, Education College, Salahaddin University-Erbil, Iraqi Kurdistan, Iraq*

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**ABSTRACT**

*An impact of floor levels and geological formation on the concentrations of indoor radon and its progeny studied inside 8 hospitals, and for three floor levels: ground, first and second. Locations of the selected hospitals had different geological formation and located in three main governorates: Erbil, Duhok and Sulaymaniya. Nuclear track detector type CR-39 (CR-39NTDs) used to measure track density of alpha particles that emitted from radon and its progeny. During winter season, 72 pair of exposure chambers (open-close chamber) equipped with 144 pieces of CR-39NTDs installed inside 24 rooms for three floors. After 90 day of exposure, exposed detectors etched in 6N NaOH at 70 ◦C for 10 h. The highest and lowest radon concentration was in the hospitals of Shaheed Aso (Sulaymaniya city: 131.73±9.42 Bq.m$^{-3}$) and Erbil Teaching (Erbil city: 82.13±10.05 Bq.m$^{-3}$) .This depended on the geological formation, type of building material, and the floor level. Therefore, the results showed that the average radon concentration and annual effective dose decreases gradually as the floor level increases. The highest and lowest of annual effective dose was found in ground and second floor, respectively. Thus, according to the annual exposure dose data, the workers are safety in most of the hospitals. More details about the type of building materials of the hospitals are listed in full paper.*

**Key words:** CR-39NTDs, Indoor radon, lung cancer and hospitals

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## INTRODUCTION

Radionuclides in the $^{238}$U decay series, including $^{226}$Ra, the parent of $^{222}$Rn, occur in trace amounts throughout the Earth's crust with varying concentrations. Once formed, radon can move due to its inertness through earth or structural material, with a half-life of 3.82 days to reach the outdoor or indoor air[1-2]. It is decay and produce a series of short lived particulate daughter products ($^{218}$Po, $^{214}$Po, and $^{210}$Po) . After inhalation, it may cause significant damage to the delicate inner cells of the bronchioles which may lead to the occurrence of lung cancer [3-4]. Deposition of the radon's daughter on the lung and trachea makes a risk of the carcinoma. Because radon's progeny produce by emitting a heavy particles (alpha particles) and this make a mutating of the DNA. And this refers to increase of the free radicals of the lung and trachea tissue [5]. ] Assessment of health effects due to exposure to ionizing radiation from natural sources requires knowledge of its distribution in the environment. The estimated global average annual dose of the population receiving natural radiation equals 2.4 mSv [6]. It is well established that the inhalation of radon ($^{222}$Rn) and mainly its radioactive decay products, contributes more than 50% of the total radiation dose to the world population from natural sources [7]. According to the last research of the risks of radon by Ismail & Jaafar [8].

Therefore, in the present study, beside of measure indoor radon concentration, we have measure most of important that related to estimate a risks of inhalation of radon gas by the workers inside the hospitals. Potential alpha energy concentration, equilibrium factor between radon and its daughter, and the annual effective dose considered important parameters. As well as, and to find variation in radon concentration for three floors ground, first, and second.

## MATERIALS AND METHODS

Iraqi Kurdistan region consist of three main governorates; Erbil, Duhok and Sulaymaniya. These areas are different from each other geographical location is shown in Fig. 1. Passive radon dosimeter geometry is a closed-opened chamber into which radon diffuses, and it has been calibrated by Ismail and Jaafar [9]. The schematic diagram of the chamber is shown in Fig. 2. The technique used in this survey is based on CR-39NTDs (Moulding, UK, manufactures the detectors), it has area of $1.5\times1.5$ $cm^2$ which is fixed by double-stick tape at the bottom of the dosimeter. In the cover there is a hole covered with a 5-mm thick soft sponge. The design of the chamber ensures that all aerosols and radon decay products are deposited on the soft sponge from the outside and that only radon gas. The design of the chamber ensures that the aerosol particles and radon decay products are deposited on the sponge from outside and only radon, among other gases, diffuses through it to the sensitive volume of the chamber. The dosimeters were distributed inside 8 government hospitals in three main regions (Erbil, Duhok and Sulaymaniya) in Iraqi Kurdistan region, in each hospital distributed on three floors (ground, first and second). Nuclear track detector type CR-39 (CR-39NTDs) used to measure track density of alpha particles that emitted from radon and its progeny. During winter season, 72 pair of exposure chambers (opened-closed chamber) equipped with 144 pieces of CR-39NTDs installed inside 24 rooms for three floors ; 3 rooms in each floor, on the top about 2m above the floor. After 90 day of exposure, exposed detectors etched in 6N NaOH at 70 ◦C for 10 h. The counting of alpha damage tracks was done using an optical microscope with a magnification of 400X was used.

Measurements of potential alpha energy concentration (PAEC) are necessary to estimate effective dose from $^{222}$Rn progeny and its concentration in the present locations. PAEC be measure in terms of working level (WL) unit [10].

$$WL = F\, C_{Rn} / 3700 \qquad (1)$$

Where F is the equilibrium factors, which can be obtained from the following relation [11]

$$F = a \exp (bD_O / D) \qquad (2)$$

D and $D_o$ represents the track densities (track/cm$^2$. day) of the open (D: without filter) and closed ($D_o$: with a filter) – can technique respectively. The values of the two constant a and b are a =14.958 and b = -7.436.

$C_{Rn}$ is the $^{222}$Rn concentrations (Bq/m$^3$) which can be obtained by relation

$$C_{Rn} = D_o / K \qquad (3)$$

Where, K is the detector sensitivity (K = 0.23 track.cm$^{-2}$ per Bq.m$^3$) obtained from the calibration experiment in the works of Ismail and Jaafar [9].

The effective dose (H in units' mSv/y) of radon and its progeny can be calculated from the following relation [6].

$$H = C \times F \times O \times T \times D \qquad (4)$$

Where C is the radon concentration in Bq.m$^{-3,}$ F equilibrium factor, O for occupancy factor (o.8 as taken in UNSCEAR 2000 report), T for time (8760 h.y$^{-1}$) and D for dose conversion factor (9 x 10$^{-6}$ mSv.h$^{-1}$ (Bq.m$^{-3}$)$^{-1}$ ).

## RESULTS AND DISCUSSION

Average value of indoor radon concentration ($C_{Rn}$), potential alpha energy concentration (PAEC), equilibrium factor (F) and annual effective dose ($H_E$) inside 8 Iraqi Kurdistan hospitals summarized in Table 1 The highest indoor radon concentration was found in Shahid Dr.Aso hospital in Sulaymaniya city (131.73±9.42 Bq.m$^{-3}$). Lowest indoor radon concentration was found in Erbil Teaching hospital in Erbil city (82.13±10.05 Bq.m$^{-3}$) .This refer to the different building material, ventilation rate, and the geological formation. The geological formation of Erbil governorate different than the geological formation of Duhok and Sulaiminia . More details about geological formation are listed in Table 2 [12].

Table 3 shows the maximum and minimum radon concentration and annual effective dose for each level. The highest average radon concentration and annual effective dose was found in ground floor in the Shaheed Dr.Aso hospital in Sulaymaniya city ( 141.56±2.01 Bq. m$^{-3}$, 3.3± 0.07 mSv/y) . The lowest was found in second floor in the Rizgary Teaching hospital in Erbil city (106.23±2.005 Bq. m$^{-3}$, 2.34 ± 0.005 mSv/y) , as shown in Fig.5 and Fig. 6 . Average indoor radon concentration decreases as the floor level increases, this due to the reduced effect of radon exhalations from the ground. This variation may be attributed to how close or how far the floor is from ground since soil represents the main source of indoor radon. In addition, many other reasons such as the fact that upper floors are better ventilated than lower floors that are exposed to dust and other forms of contaminations.

**Table (1) Radon Concentration, Equilibrium Factor, PAEC and annual effective dose inside hospitals in Iraqi Kurdistan Region.**

| Regions | Hospital | Equilibrium Factor (F) | PAEC (mwL) | Annual effective dose (mSv/y) | Radon Concentration ( Bq.m$^{-3}$) |
|---|---|---|---|---|---|
| Erbil | Rizgary | 0.351±0.001 | 9.15±0.87 | 2.13±0.2 | 96.50±9.34 |
| | Emergency west | 0.355±0.004 | 8.3±0.85 | 1.93±0.21 | 86.45±9.16 |
| | Erbil Teaching | 0.357±0.002 | 7.92±0.94 | 1.84±0.22 | 82.13±10.05 |
| | Paediatric | 0.361±0.003 | 10.37±0.95 | 2.44±0.23 | 106.24±10.04 |
| Duhok | Azadi Teaching | 0.363±0.001 | 11.07±1.004 | 2.57±0.23 | 113.05±10.72 |
| | Emergency Teaching | 0.364±0.002 | 10.11±0.21 | 2.35±0.27 | 102.68±8.87 |
| Sulaymaniya | Shahid Dr. Aso | 0.371±0.001 | 13.2±0.90 | 3.08±0.12 | 131.73±9.4 |
| | Shorsh General | 0.374±0.002 | 12.51±0.72 | 2.91±0.17 | 123.62±7.23 |

**Table 2: Geological formation of Iraqi Kurdistan region as related to the case study**

| Regions | Hospital | Equilibrium Factor (F) | Building materials |
|---|---|---|---|
| Erbil | Rizgary | Region consists of the plains and hills . It consists of sandstone, limestone and shale | clay brick, cement concrete, gypsum and gypsum bord |
| | Emergency west | | |
| | Erbil Teaching | | |
| | Paediatric | | |
| Duhok | Azadi Teaching | Region consists of the plains, sediment logical and mountains. It consists of marly limestone, calcarenite shale, sandly limestone and conglomerate | clay brick slimestone bricks , cement gypsum and gypsum bord |
| | Emergency Teaching | | |
| Sulaymaniya | Shahid Dr. Aso | Region consists of the Rocky Mountains and valleys. It consists of rocks, limestone, conglomerate, biogenic limestone, pebbly, calcarenite and sandstone | clay brick slimestone bricks and cement concrete gypsum |
| | Shorsh General | | |

**Table (3) Indoor radon concentration and Annual effective dose for different floors inside hospitals in Iraqi Kurdistan Region.**

| Hospitals | Levels | Radon Concentration (Bq.m-3) | | | Annual effective dose (mSv/y) | | |
|---|---|---|---|---|---|---|---|
| | | Min | Max | Average | Min | Max | Average |
| Rizgary (Erbil) | Ground | 102.44±0.16 | 109.56±0.12 | 106.23±2.005 | 1.35±0.016 | 1.99±0.022 | 2.34±0.05 |
| | First | 92.11±0.23 | 98.36±0.42 | 95.70±1.94 | 1.26±0.018 | 1.92±0.042 | 2.12±0.02 |
| | Second | 84.74±0.52 | 90.54±0.36 | 87.59±2.004 | 1.22±0.028 | 1.86±0.038 | 1.93±0.04 |
| Azadi Teaching (Duhok) | Ground | 120.43±0.25 | 127.62±0.22 | 124.67±1.94 | 2.15±0.011 | 2.83±0.11 | 2.41±0.11 |
| | First | 107.16±0.18 | 114.78±0.52 | 110.94±2.04 | 2.08±0.018 | 2.53±0.18 | 2.39±0.18 |
| | Second | 100.45±0.18 | 106.25±0.38 | 103.54±2.15 | 2.02±0.026 | 2.37±0.06 | 2.30±0.06 |
| Shahid Dr. Aso (Sulaymany) | Ground | 138.26±0.28 | 144.56±0.56 | 141.56±2.01 | 2.82±0.012 | 2.84±0.046 | 3.30±0.07 |
| | First | 127.36±0.26 | 1343.58±0.46 | 130.84±2.1 | 2.32±0.034 | 2.74±0.056 | 3.06±0.03 |
| | Second | 119.72±0.32 | 125.42±0.42 | 122.81±1.98 | 2.18±0.022 | 2.66±0.035 | 2.88±0.02 |


**Fig.1: Sketch Map of the area under study (Kurdistan Region)**

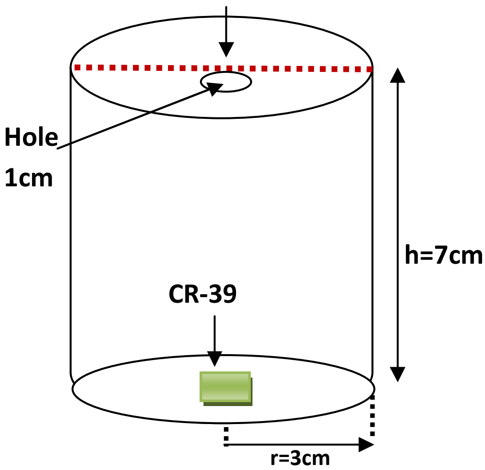


**Fig.2: Schematic diagram of the optimum Radon [8].**

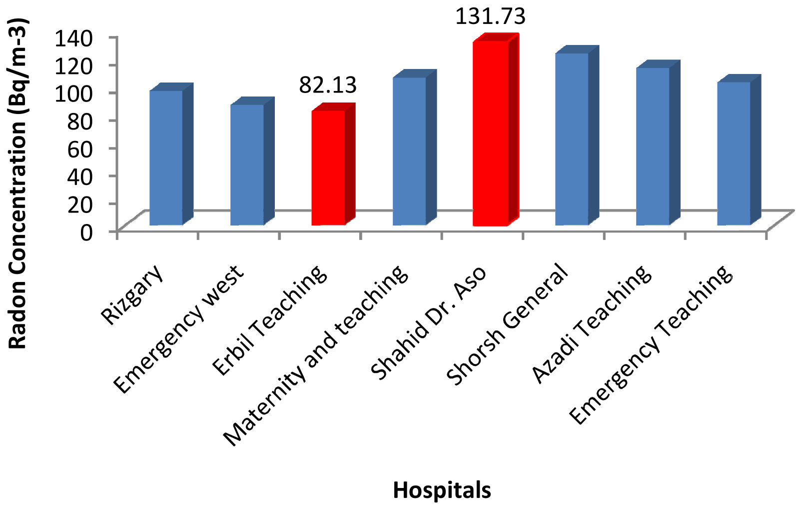


**Fig. (3) Distribution of Radon Concentration Inside Government Hospitals in Iraqi Kurdistan**

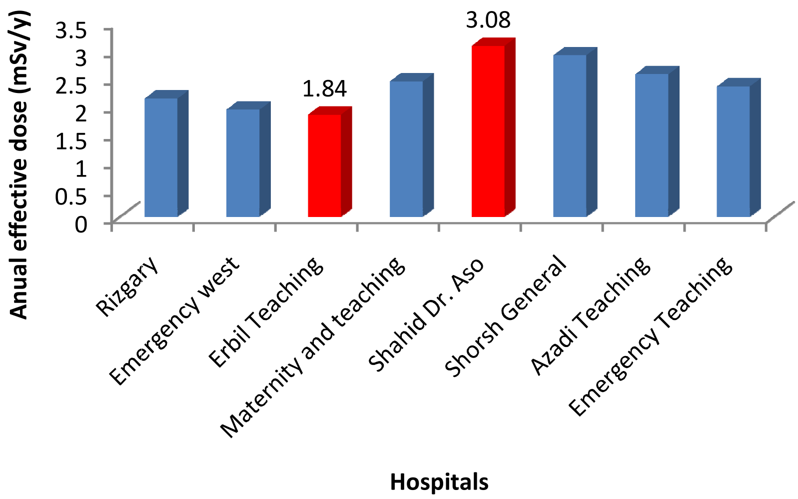


**Fig. 4: Distribution of annual effect dose inside Hospitals of Iraqi Kurdistan**

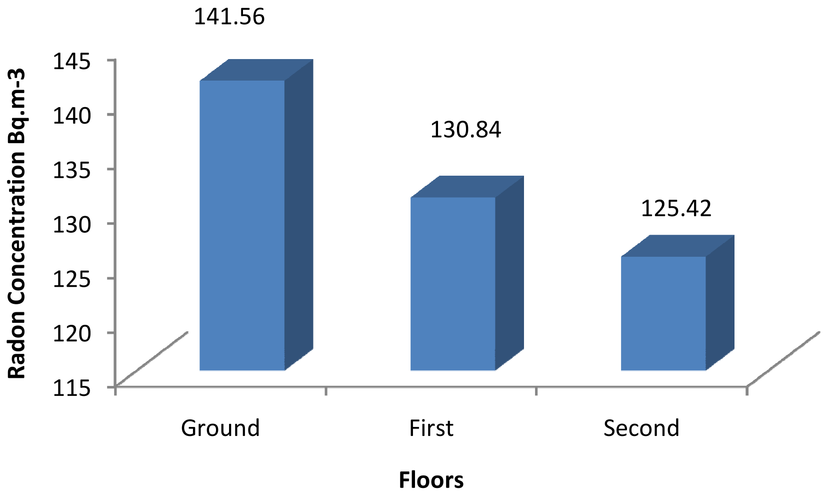


**Fig. (5) Variation of Radon Concentration with floor levels in Shaheed Dr. Aso Eye Hospital**

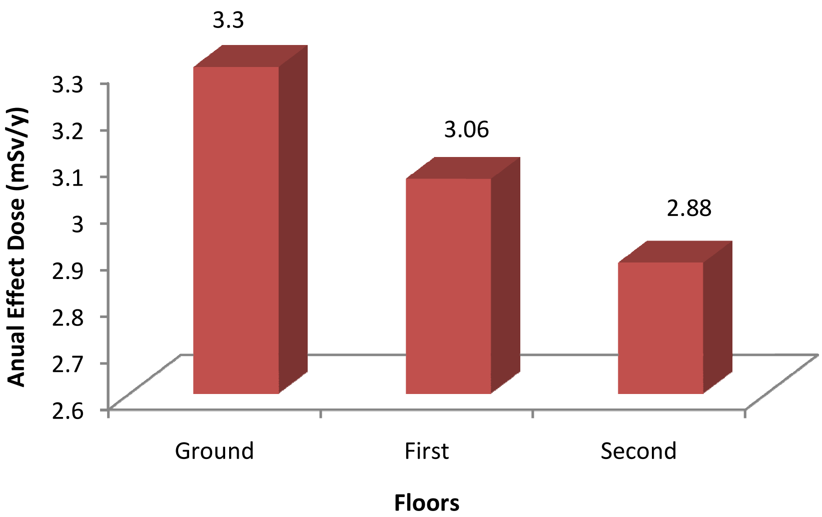


**Fig. (6) Variation of Annual effective dose with floor levels in Shahid Dr. Aso Hospital**

## CONCLUSION

Indoor radon concentrations have been measured inside 8 government hospitals in Iraqi Kurdistan region in winter season. Floor levels and geological formation of the Iraqi Kurdistan hospitals affect on the concentrations of indoor radon and its progeny Locations of the selected hospitals had different geological formation and located in three main governorates: Erbil, Duhok and Sulaymaniya. Nuclear track detector type CR-39 used to measure track density of alpha particles that emitted from radon and its progeny during spring season. The present study consisted of two main parts; first was the effect of the geological formation on indoor radon concentration, and this has been investigated. The highest and lowest radon concentration was in the hospitals of Shaheed Aso (Sulaymaniya city: mountain region) and Erbil Teaching (Erbil city). The second part related to the effects of floor level on the concentration of indoor radon. Therefore, the results showed that the average radon concentration and annual effective dose decreases gradually as the floor level increases. The highest and lowest of annual effective dose was found in ground and second floor, respectively

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