

STUDY OF INDOOR RADON /THORON AND ITS HAZARDS INSIDE KINDERGARTENS IN IRAQI KURDISTAN USING CR- 39 NUCLEAR TRACK DETECTORS

As'ad. H. Ismail

*Physics Department, Science Education College, Salahaddin University –Erbil/
Iraqi Kurdistan Region-Erbil
asadhawlery@yahoo.com*

Indoor radon /thoron levels with potential alpha energy concentration (PAEC), effective dose (H_E) and equilibrium factor (F) were measured using closed and open-can technique, containing CR-39 nuclear track detector. Measurements were carried during summer season inside different Kindergartens in three main regions (Erbil, Duhok and Sullimaniye) in Iraqi Kurdistan. We found that the radon and thoron densities range from {(11 to 33 track.cm⁻².d⁻¹) for radon and (8 to 29 track.cm⁻².d⁻¹) for thoron}, with the average radon concentration (96.815±26.939Bq/m³). While an average (PAEC) and (H_E) was (7.68±2.298 mWL), (2.306±0.689 mSv/Y) respectively. On the other hands the average equilibrium factor was (0.291±0.01). Consequently, we believe that our results were done when we comparing them with the action levels were recommended by (ICRP66). The results obtained indicate that various locations have different values of radon /thoron concentration. The differences can be ascribed to variations in grades of uranium at different locations and to some environmental factors such as ventilation, particle concentration, and the deposition of the progeny on surfaces or on the atmospheric aerosol.

Keywords: *Radon Risks, Kindergarten, CR-39 Detector, Effective Dose, Iraqi Kurdistan.*

INTRODUCTION

Radon (²²²Rn) is a radioactive gas with a half- life of 3.824 days. It is the immediate progeny of radium (²²⁶Ra), in the decay series of uranium (²³⁸U). The half- life of thoron (²²⁰Rn; radon isotopes) is 55.6 sec which is much shorter than that of radon. Because of such a short half-life of thoron, its emanation from building materials, as well as, its infiltration from the ground and further migration is restricted to a few centimeters only ^[1]. When radon is inhaled into the lungs it decays by means of alpha –emission and which causes ionization damage when it strikes the lung tissue. Over time, this damage causes lung cancer. It has been shown that the risk coefficient for lung cancer is higher for children than that for adults (ICRP) ^[2, 3]. This fact rose interest in studying the radon/thoron levels inside Kindergartens (Planinic et al., 1993, and M. K. Kullab et al., 1997) ^[4, 5]. Therefore, it is very important to measure indoor radon /thoron levels with potential alpha energy concentration (PAEC) and effective dose (H_E) inside Kindergartens in Iraqi Kurdistan region for the first time. This region was chosen because it has about more than 40 Kindergartens distributes all over Kurdistan region (Three main governorates: Erbil, Duhok and Sullimaniye) with different geological deformation through summery season. Most of these Kindergartens are one-story building. Together, they host about 4000 children of four to six years old, where the children are staying there for (6-8) hours each day, six days a week.

MEASURING AND EXPERIMENT PROCEDURES

Now Iraqi Kurdistan region consist of three main governorates; Erbil, Duhok and Sullimaniye. So this region is divided into three major areas coded by Er (Erbil), Dh (Duhok) and Su (Sullimaniye).These area are different from each other by their geographical location (see Fig.1). We distributed closed diffusion chambers {(closed with sponge as a filter with 0.5cm thick compressed): the filter slows down the diffusion of noble gases into the chamber and discriminates in favor of radon vs. thoron ^[6]}, together with open (with out filter) can technique containing CR-39(Pershare Mouldis, U.K., 300mm thick) inside the 30 Kindergartens (10 in Erbil, 9 in Duhok and 11 in Sullimaniye). The structure of these dosimeters had been described in previews works (Farid S. M., 1992 and Abou-Murad et al., 2005) as shown in fig.(2). Three month later (91days), the dosimeters were collected and chemically etched (6N NaOH at 70C^o for 10h). An optical microscope was used to count the number of tracks per cm² occurred in each detector. The optical microscope with a magnification of 400X was used, and typically standard deviation for track density was 2 (tracks.cm⁻².d⁻¹). The background mean value was 0.4 tracks per microscope field of 0.0113 cm². The attempts have been made to avoid the plate out effect caused by radon on the surface of the CR-39 detector, by discriminating the small tracks during the counting. For the estimation of the effective dose from ²²²Rn progeny in schools, it is necessary to know potential alpha energy concentration (PAEC) of ²²²Rn progeny in terms of working level (WL) units.

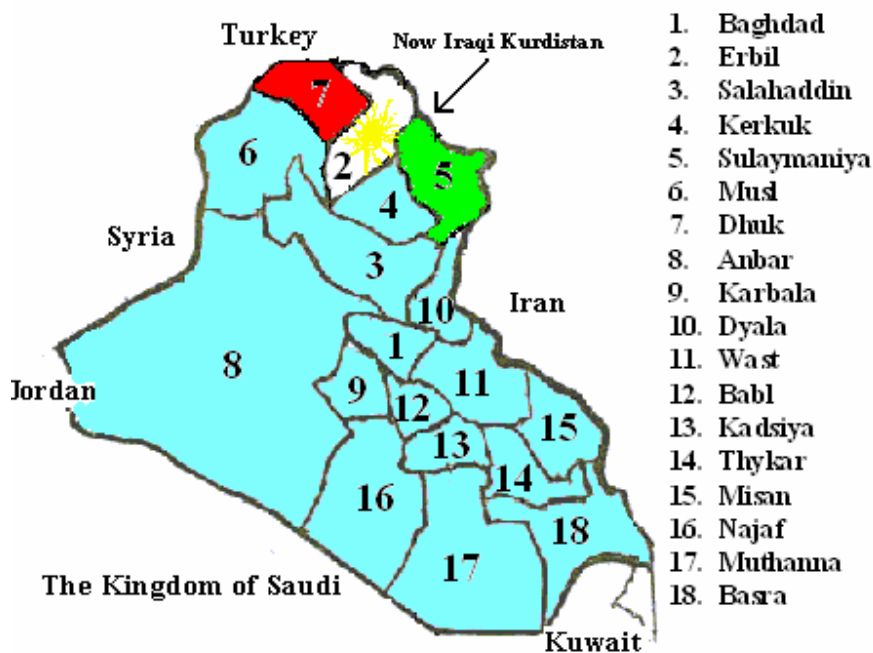


Figure1. Sketch Map (Iraq) of the Area under Study (Kurdistan Region).

The measured ²²²Rn values can be converted into (WL) if the equilibrium factor, F, is known from the following relations ^[7];

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

Where F is the equilibrium factor, which can be obtained by relation ^[6, 8]

$$F = a \exp (bD_o/D) \quad (2)$$

D and D_o represent track densities (track/cm².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.

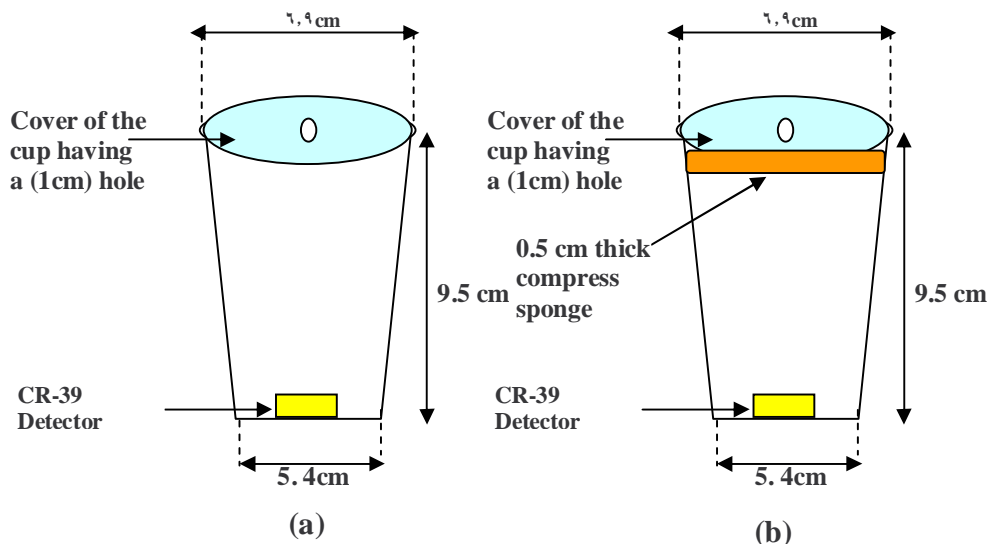


Figure 2. The Structure of These Dosimeters Two Modes; (a) Bare and (b) Cup with a Sponge As a Membrane for Discrimination Between Radon and Thoron.

C_{Rn} is the ²²²Rn concentration (Bq/m³) which can be obtained by relation

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

Where, K is the detector sensitivity (K=0.22 track.cm⁻² per Bq.m³) obtained from the calibration experiment of the previous works (Farid S.M. 1992)^[9].

The effective dose (H_E) of radon and its progeny, for measuring track density (track/cm².day) of the open (D) and filtered (D_o) solid state nuclear detector can be calculate from the following relation^[8, 10];

$$H_E = D_o / K \{ d_o + d_e a \exp (b D_o / D) \} \quad (4)$$

Where, **d_o** and **d_e** are the recommended values for the effective dose conversion factors for radon and its progeny as **d_o** =0.33 μSv·a⁻¹ per Bq.m⁻³ and **d_e**=80 μSv·a⁻¹. From equations (2, 3 and 4) direct relation between effective dose (H_E) and radon concentration C_{Rn} can be finding a in the following form:

$$H_E = C_{Rn} (d_o + d_e F) \quad (5)$$

Suppose that F = constant, and since d_o & d_e are also constant we obtain G (constant) = (d_o+d_e F), Therefore

$$H_E = G C_{Rn} \quad (6)$$

RESULTS AND DISCUSSION

The first part of this study included measurements of track densities due to radon/thoron inside 30 Kindergarten in three major areas Er (Erbil), Dh (Duhok) and Su (Sullimaniye) in Iraqi Kurdistan region, by using passive closed-and open-can techniques. The data (for each major area) are present in Table 1. The figure 2 shows the variation of track densities due to radon and thoron in the major areas, because there are variations in grades of uranium at different locations.

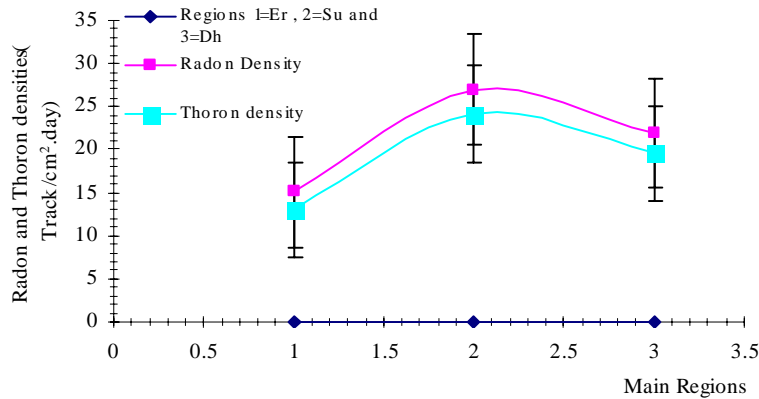


Figure 3. Variation of Track Density Due To ²²²Rn and ²²⁰Th With the Location Number Inside kindergartens In Iraqi Kurdistan Region.

Table 1. Average Track Densities from Radon and Thoron Inside 30 Kindergartens in Three Major Areas in Iraqi Kurdistan Region.

Locations	ρ_{Rn}	ρ_{Th}	Locations	ρ_{Rn}	ρ_{Th}	Locations	ρ_{Rn}	ρ_{Th}
Su1	40	35	Er1	23	18	Dh1	32	25
Su2	48	38	Er2	21	19	Dh2	26	22
Su3	31	24	Er3	26	20	Dh3	36	30
Su4	43	35	Er4	15	14	Dh4	40	35
Su5	46	34	Er5	19	17	Dh5	22	18
Su6	28	22	Er6	24	22	Dh6	43	37
Su7	41	32	Er7	20	18	Dh7	19	16
Su8	38	30	Er8	18	16	Dh8	30	25
Su9	47	41	Er9	29	26	Dh9	20	17
Su10	44	35	Er10	22	17			
Su11	36	29						
average	40.181	32.272		21.7	18.7		29.777	25
SDV\pm	6.477	5.693		4.056	3.368		8.728	7.681

Average ρ_{Rn} and ρ_{Th} in whole major area was $\{(30.552 \pm 6.42) \text{ and } (25.324 \pm 5.58)\}$ track.cm⁻².d⁻¹ respectively

Note: ρ_{Rn} and ρ_{Th} represent radon and thoron density respectively by unites of (track.cm⁻².d⁻¹)

The second part of this study involved measurements of indoor radon concentration (C_{Rn}), potential alpha energy concentration (PAEC), equilibrium factor between radon and its progeny

(F) and annual effective dose (H_E) inside 30 Kindergartens for each major area. Data are presented in Tables 2, 3 and 4). The Figure 4 shows distribution of radon concentration inside kindergarten for different locations in Iraqi Kurdistan region. Table (5) represents average data with standard deviations for (C_{Rn}), (PAEC), (F) and (H_E) inside 30 Kindergartens in Iraqi Kurdistan region. From Figure 3 one can observe that the relation between radon concentration and effective dose was linear, and this fact is consequence of the Equation 6.

Table 2. Radon Concentration, Equilibrium Factor, PAEC and Effective Dose inside Kindergarten in Erbil Governorate (Er).

Locations	C_{Rn} ($Bq.m^{-3}$)	Equilibrium Factor F	PAEC (mWL)	H_E ($mSv.Y^{-1}$)
Er1	104.545	0.23	6.498	1.958
Er2	95.454	0.3	7.739	2.322
Er3	118.181	0.22	7.027	2.119
Er4	68.181	0.319	5.878	1.762
Er5	86.363	0.295	6.885	2.066
Er6	109.09	0.3	8.845	2.654
Er7	90.909	0.298	7.321	2.197
Er8	81.818	0.291	6.434	1.931
Er9	131.818	0.296	10.545	3.164
Er10	100	0.225	6.081	1.833
Average	98.636	0.277	7.325	2.2
SDV\pm	18.438	0.036	1.424	0.426

Table 3. Radon Concentration, Equilibrium Factor, PAEC and Effective Dose inside Kindergarten in Duhok Governorate (Dh).

Locations	C_{Rn} ($Bq.m^{-3}$)	Equilibrium Factor F	PAEC (mWL)	H_E ($mSv.Y^{-1}$)
Dh1	113.636	0.31	9.52	2.855
Dh2	86.363	0.264	6.162	1.852
Dh3	131.818	0.296	10.545	3.164
Dh4	140.909	0.32	12.186	3.653
Dh5	68.181	0.319	5.878	1.762
Dh6	136.363	0.278	10.245	3.077
Dh7	54.545	0.309	4.555	1.366
Dh8	104.545	0.254	7.176	2.158
Dh9	59.09	0.313	4.998	1.499
Average	99.494	0.295	7.918	2.376
SDV\pm	33.82	0.024	2.755	0.826

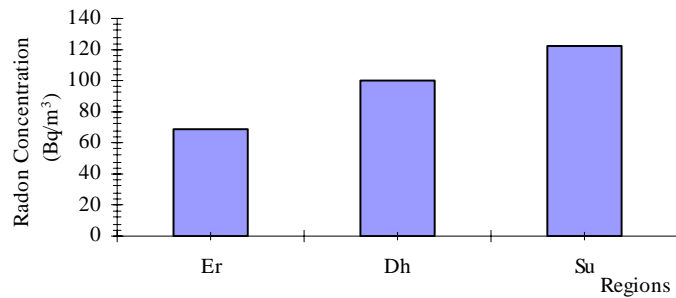


Figure 4. Distribution of Radon Concentration inside Kindergartens in the Major Areas in Iraqi Kurdistan Region

Table 4. Radon Concentration, Equilibrium Factor, PAEC and Effective Dose inside Kindergarten in Sullimaniye Governorate (Su).

Locations	C _{Rn} (Bq.m ⁻³)	Equilibrium Factor F	PAEC (mWL)	H _E (mSv.Y ⁻¹)
Su1	113.636	0.24	7.371	2.219
Su2	140.909	0.32	12.186	3.653
Su3	95.454	0.31	7.765	2.33
Su4	136.363	0.319	11.756	3.525
Su5	150	0.267	10.824	3.253
Su6	90.909	0.298	7.321	2.197
Su7	118.181	0.313	9.997	2.998
Su8	127.272	0.316	10.869	3.259
Su9	145.454	0.247	9.71	2.922
Su10	109.09	0.335	9.8771	2.959
Su11	118.181	0.337	10.764	3.225
Average	122.314	0.299	9.858	2.958
SDV±	19.651	0.033	1.698	0.507

Table 5. Radon Concentration, Equilibrium Factor, PAEC and Effective Dose inside Kindergarten in Iraqi Kurdistan Region.

Locations	C _{Rn} (Bq.m ⁻³)	Equilibrium Factor F	PAEC (mWL)	H _E (mSv.Y ⁻¹)
Er	68.636±17.467	0.279±0.042	5.278±1.924	1.584±0.574
Dh	99.494±33.820	0.295±0.024	7.918±2.755	2.376±0.826
Su	122.314±19.651	0.299±0.033	9.858±1.698	2.958±0.507
Average	96.815	0.291	7.684	2.306
SDV±	26.939	0.01	2.298	0.689

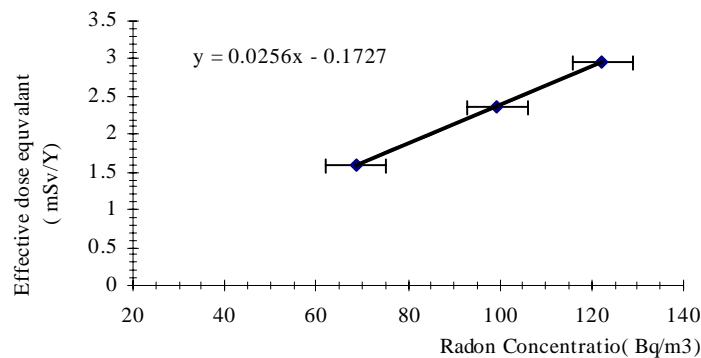


Figure 5. Linear Relation between Radon Concentration and Effective Dose Equivalent.

CONCLUSIONS

The average track densities from radon and thoron have been estimated inside 30 kindergarten in Iraqi Kurdistan region and they are equal to $\{(30.552 \pm 6.42) \text{ and } (25.324 \pm 5.58)\}$ track.cm⁻².d⁻¹ respectively. General ratio between radon and thoron density was larger than one and this ratio is variable from one region to another, because there are variations in concentration of uranium at different locations ^[11] From tables (2, 3, 4) and figure (3) we concluded that the lowest and highest indoor radon concentration were found in major areas Er and Su respectively and it is equal to $\{(98.636 \pm 18.438) \text{ and } (122.314 \pm 19.651)\}$ Bq/m³. There are variations in some environmental factors such as ventilation, particle concentration and geological formation. From these tables one can conclude that average radon concentrations was (96.815 ± 26.939) Bq/m³, and this results are below action levels recommended by (ICRP) ^[12] with acceptable radon level (50-150) Bq/m³. From the Figure 3 G factor was determined as $G = 25.6 \mu\text{Sv} \cdot \text{a}^{-1}$ while theoretically its value was, $G = 0.33 + 80F = 23.61 \mu\text{Sv} \cdot \text{aY}^{-1}$; here F is average equilibrium factor}. This means that there are good agreements between theoretical and experimental results and between previous works.

ACKNOWLEDGEMENTS AND RECOMMENDATIONS

I would like to thanks Dr. Nikezic for his computer program's and for reading the manuscript. I recommend that the ventilation rate inside kindergartens in Iraqi Kurdistan region (especial in Sullimaniye) must be considered.

REFERENCES

- [1] Guo, Q., Shimo, M., Ikebe, Y., and Minato, S., " The study of thoron and radon progeny concentrations in dwellings in Japan" , Radiation Protection Dosimetry, 45, 357-359, 1992.
- [2] ICRP "Lung cancer risk from indoor exposure to radon daughters" Publication 50, Annals of ICRP, 1989.

- [3] ICRP "Protection against Rn-222 at home and at work" Publication 65, Annals of ICRP, 1993.
- [4] Planinic, J., Vaupotic, J., and Kobal, I., "Indoor radon concentrations in Kindergartens "J. Environ. Radioactivity, 19,167-171, 1993.
- [5] Kullab, M.K, Al-Bataina, B.A., Ismail, A.M., Abumurad, K.M., and Ghaith, A.," Study of radon concentration levels inside Kindergartens in Amman", Radiation Measurement, 28, 1-6, 699-702, 1997.
- [6] Ab-Murad K.M., and Al-Tamimi, M.H., "Natural radioactivity due to radon in Soum region, Jordan", Radiation Measurement, 39, 77-80, 2005.
- [7] Khan A. J., Varshney, A.K., Prasad, R., Tyagi, R.K., and Ramachandran, T.V.," Calibration of CR-39 plastic track detector for the measurement of radon and its daughters in dwelling", Nuclear Tracks Radiation Measurements. 17, 497-502, 1990.
- [8] Faj, Z., and Planinic, J., "Dosimetry of radon and its daughters by two SSNTDs" Radiation Protection Dosimetry, 35,265-268, 1991.
- [9] Farid S. M., "Measurement of concentrations of radon and its daughters in dwellings using CR-39 nuclear track detector", Journals of Islamic Academy of Sciences, 5:1, 4-7,1992.
- [10] Planinic, J., and Faj, Z.,"Equilibrium factor and dosimetry of radon by nuclear track detector". Health Physics, 59:349-351, 1990.
- [11]As'ad H. I., "Measurement of Radon Activity concentration in Iraqi Kurdistan Soil by Using CR-39 Nuclear Track Detectors, M.Sc. Thesis, Univ. of Salahaddin, Iraqi Kurdistan (2004).
- [12] ICRP, Lung cancer risk from indoor exposure to radon daughters Publication 66, 2000.