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Radon Concentrations and Annual Effective Dose in Some Dwellings of Aun Region in Kerbala Governorate, Iraq

تراكيز الرادون والجرعة السنوية المؤثرة في بعض المساكن في منطقة عون في محافظة كربلاء

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Abstract

radon concentrations and annual effective dose were measured in some dwellings of Aun region in Kerbala governorate, Iraq. Radon concentrations were determined using time-integrated passive radon dosimeters open and closed containing (CR-39) solid state nuclear track detectors. Measurements were carried out during the months (January and February of 2015). Twenty open and twenty closed dosimeters were distributed in twenty dwelling of the study area. After two months of exposure the detectors were etched in a (NaOH) solution of normality (6.25 N) at a temperature of 70^o C for eight hours. The tracks were counted using an optical microscope having a magnification of 400X.

In closed dosimeters, the results show that, the radon concentrations varied from (20.508 ±0.603Bq/m^3) to (137.149±4.033 Bq/m^3) with an average value (63.767±1.875 Bq/m^3), while the values of the indoor annual effective dose vary from (0.016±0.004 mSv/y) to (0.266±0.078 mSv/y) with an average value (0.115±0.033 mSv/y). In open dosimeters, the results show that, the radon concentrations varied from (21.790 ±0.640 Bq/m^3) to (152.530±4.486 Bq/m^3) with an average value (75.047±2.207 Bq/m^3), while the values of the indoor annual effective dose vary from (0.017±0.005 mSv/y) to (0.357±0.105 mSv/y) with an average value (0.145 ±0.042 mSv/y). These values, which are less than the lower limit of the recommended range (200-300 Bq/m^3) (ICRP, 2009) and (3-10 mSv/y) (ICRP, 1993) for indoor radon concentrations and indoor annual effective dose, respectively. The values of equilibrium factor vary from (0.010±0.002) to (0.567±0.166) with an average value (0.088±0.025) which is less than the lower limit of the recommended range (0.4-1) (ICRP, 1993). The radon concentrations and annual effective dose were found to be lower than the higher level recommended by ICRP(200-300)Bq/m^3 and (3-10) mSv/y, respectively. These levels were found to be consistent with those measured by other workers in other countries and these values are within safe limits.

Key Words: indoor radon concentration, Annual effective dose,CR-39 detector, Kerbala.

ملخص

في هذه الدراسة تم قياس تراكيزالرادون وحساب الجرعة السنوية الفعالة في هواء بعض منازل منطقة عون في محافظة كربلاء، العراق. وحددت تراكيز الرادون باستخدام مجراعات الرادون السلبية التراكمية المغلقة والمفتوحة التي تحوي كواشف الاثر النووي (CR-39) . واجريت القياسات في شهري كانون الثاني وشباط من عام 2015.

تم توزيع 20 مجراعا مفتوحا و20 مجراعا مغلقا على 20 منزلا في منطقة الدراسة . وقد جمعت المجراعات بعد التعرض واجريت عملية القشط الكيميائي للكواشف باستخدام محلول هيدروكسيد الصوديوم بعيارية 6.25 N وبدرجة حرارة 70 مئوية وبزمن قشط ثمان ساعات. وتم عد المسارات النووية باستخدام مجهر ضوئي بتكبير 400X.

في المجراعات المغلقة، تباينت تركيزات غاز الرادون من (20.508 ±0.603Bq/m^3) إلى (137.149±4.033 Bq/m^3) بمتوسط قيمة (63.767±1.875 Bq/m^3), اما قيم الجرعة الفعالة السنوية في المجراعات المغلقة تراوحت بين

(0.016±0.004 mSv/y)و (0.266±0.078 mSv/y) و بمعدل قيمة (0.115±0.033 mSv/y). اما في المجراعات المفتوحة، تباينت تركيزات غاز الرادون من (21.790 ±0.640 Bq/m^3) إلى (152.530±4.486 Bq/m^3) وبمعدل (75.047±2.207 Bq/m^3). اما قيم الجرعة الفعالة السنوية في المساكن المغلقة تتفاوت من (0.017±0.005 mSv/y)إلى (0.357±0.105 mSv/y)وبمعدل (0.145 ±0.042 mSv/y). هذه القيم هي أقل من الحد الأدنى الذي توصى به (200-300Bq/m^3)(ICRP,2009)و(3-10mSv/y)(ICRP,1993)
لتراكيز الرادون والجرعة الفعالة السنوية في المنازل ، على التوالي.
قيم عامل التوازن تتفاوت من (0.010±0.002) إلى (0.567±0.166) بمتوسط قيمة (0.088±0.025) وهو أقل من الحد الأدنى الذي توصى به (ICRP, 1993) (0.4-1). هذه المستويات تبين بانها كانت متطابقة مع قياسات باحثين اخرين في بلدان اخرى وهذه المستويات ضمن الحدود الامنة.

1. Introduction

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 [1]. 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 [2]. Radon is a natural radioactive noble gas and has three important isotopes. These isotopes are ^{219}Rn (‘*Actinon’*), ^{220}Rn (‘*Thoron*’) and ^{222}Rn (*‘Radon’*) with half-lives of 3.96 seconds, 55.6 seconds and 3.82 days, respectively. ^{222}Rn is a member of the ^{238}U decay series, whereas ^{219}Rn and ^{220}Rn are members of the ^{235}U and ^{232}Th decay chains, respectively [3,4].

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 [5, 6].

In the literature the term radon and ^{222}Rn are often used interchangeably. This approach has been also adopted in the present work. ^{219}Rn has a relatively low abundance in the earth's crust, i.e. only about 0.7%, and has the shortest half-life. Because of its very short half-life, ^{219}Rn usually disappears soon after its production. ^{220}Rn is also not able to travel far (i.e. decays before reaching the earth's surface due to its-short half-life, and can often be eliminated from the monitoring system by introducing filters or other delaying techniques. The most important isotope of radon is ^{222}Rn. Its half-life is 3.82 days and can move substantial distances from its point of origin [5]. That is why only ^{222}Rn is generally considered as a health hazard when estimating risk factors from exposure to radon. There are no sinks for radon, and it is estimated that only negligible quantities escape to the stratosphere [7]. As a result, the ultimate and sole fate of ^{222}Rn is transformation or degradation through radioactive decay. In recent years, more attention has been paid to the measurement of radon in dwellings in many countries worldwide including, Kosovo (M. Bahtijari et al.)[8], Egypt(Abd El-Zaher and Fahmi) [9], Iran(Hadad et al.)[10], Ghana(Nsiah-Akoto et al.)[11], Mali(Traore et al.) [12], Iraq(Zakariya et al.) [13], Peru (Pereyra et al.) [14].

The aims of the present study are to determine indoor radon level in the dwellings in Aun region of Kerbala governorate and to calculate the annual effective dose (AED) due to radon.

2. Area of study

Aun area is located just 10 km from the Kerbala city center on the road link between the cities of Kerbala and Baghdad, and on the line length (44^o) to the east of view (32^o) to the north. An area of about 375 km^2 and an estimated population of 15,000 pepole.

Most of the houses that have been studied used to build bricks and blocks used as well as other building materials such as sand, gravel, cement and plaster. In addition, use of ceramic wall coverings, While marble and kashi used for packing houses floors. Majority of the houses were single storey. The size of the rooms was approximately$4 \times 5 \times 3\ m^3$ with single window. They've been building these homes in the nineties of the last century. As for the soil was a mixture of sand and clay. Homes that have been studied with symbols indicating A1 to A20, as in Figure 1.

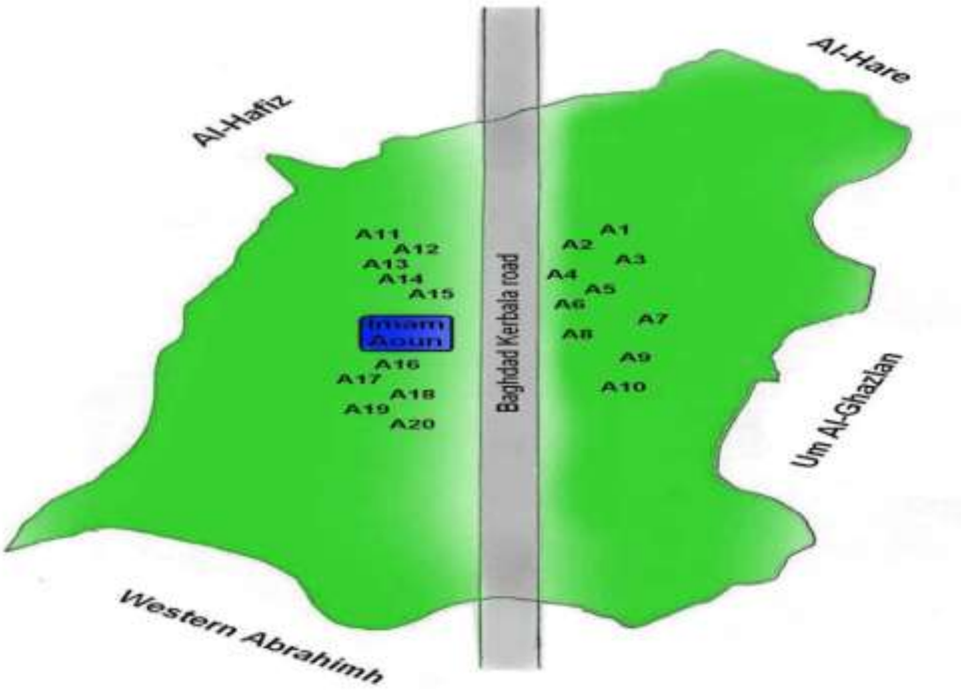

Figure 1. The study area

3. Meterial and Methodology

radon concentrations were measured by using twenty dosimeter passive open and twenty dosimeter closed can technique employing solid state nuclear track detector (SSNTD) CR-39 was used. Which is commercially marketed as CR-39, the detector was manufactured by Pershore Molding Ltd., U.K. 500μm thick in the form of large sheets which were cut into 1.5 cm×1.5 cm which is fixed by double side solo tape on the bottom of the plastic cup. The can technique is usually used in this study. A brief description is given below, Figure 2.

To measure radon concentrations in the air some of the dwelling in the region of Aun in Kerbala governorate, we used dosimeter passive radon cumulative (Integrated Passive Radon Dosimeter), which contains the detectors solid-state CR-39 and the dimensions of where they are digging a certain number on the upper right corner of the detector to facilitate the process of gathering information and the distinction between all detectors in the different dwellings. So that the face engraved upon the figure is heading up then covered enclosure lid tightly the hole diameter cm (1.3) and covered with a spongy thick (0.5) cm to impede the isotopes of other radon remains a number of these cans without a cover. One dosimeter open and one dosimeter closed were distributed in each house of the houses have been selected.

The dosimeter at each dewlings was installed vertically at approximately 2 meters from the floor (breathing zone). During the decay process of radon in the chamber to its progeny, alpha particles are emitted. Some of these alpha particles will hit the CR-39 detector if it falls within their ranges. In this way, the detector will accumulate over time a number of tracks proportional to the concentration of radon gas in the room. The dosimeters were exposed to the indoor for a period of two months(January and February, 2015).

After two months the detectors were removed from cans and chemically etched for eight hours in a (NaOH) solution of normality (6.25 N) in a constant temperature bath at 70 ^{O}C. After etching, the detector was washed in distilled water and then air-dried. The tracks alpha particle on the surface of the detectors were counted manually under an optical microscope of type ((Nikon YS Alphot Japan)) magnification of 400X and then I went back tracks in at least 20 different locations for each detector, because the phenomenon of radiation resulting from the decomposition of radon is a random statistical phenomenon purely.

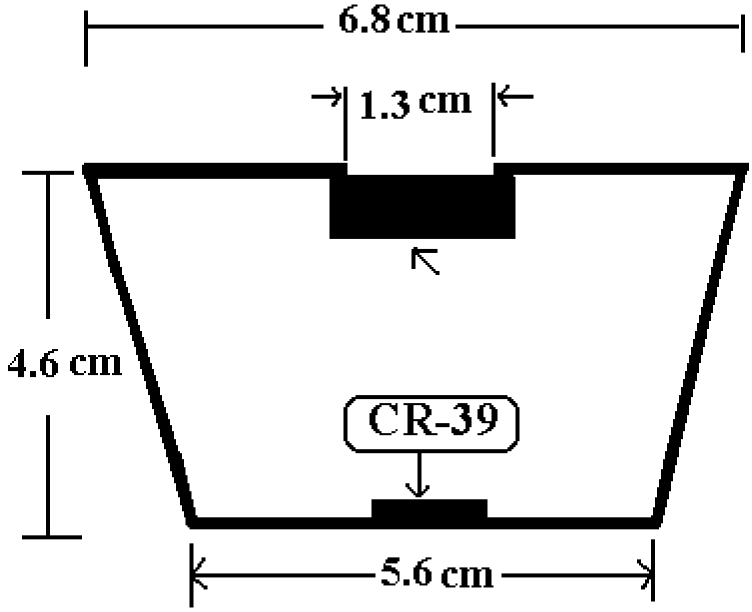

Figure 2: Configuration of the Sealed - Can Technique used in the experiment.

4. Results and discussion

In the present work indoor radon concentrations were measured and calculate annual effective dose for 20 different dwellings in Aun region of Kerbala governorate, Iraq.

The radon concentration C, in units of Bq/m^3, is then calculated using the following relation[15,16]:

$$C = \frac{C_o\, t_o\, \rho}{\rho_o\, t} \qquad (1)$$

where C_o is the activity density of the calibration chamber in kBq/m^3, t_o is the calibration exposure time, ρ is the measured number of tracks per cm^2 on the CR-39 detectors that were inside our dosemeters used in the studies, ρ_o is the measured number of tracks per cm^2 on the calibrated CR-39 detectors and t is the exposure time on the distributed dosimeters.

After concentrations of radon account closed and open dosimeters in all dwelling , we were able to calculate the equilibrium factor (F) in all the dewlling of the study, using the following relationship [15, 17]: -

$$F = a \exp\left(-b\frac{C_c}{C_o}\right) \qquad (2)$$

where a and b are constants magnitude 15 and 7.5 respectively. C_c concentration radon passiv**e** closed dosimeter $(Bq\,/\,m^3)$. C_o concentration radon passive open dosimeter $(Bq\,/\,m^3)$.

The annual effective dose (AED) in terms of (mSv /y) units was obtained using the relation [18-20]:

$$AED\ (m\,Sv/y) = C_{Rn} \times F \times H \times T_h \times D \qquad (3)$$

Where H) is the occupancy factor which is equal to (0.8), (T_h) is the time in hours in a year, ($T_h = 8760\ h/y$), and (D) is the dose conversion factor which is equal to [9×10^{-6} (m Sv)/(Bq. h. m^{-3})].

Table 1 summarizes the results obtained in the present work for radon gas concentrations in indoor dwellings in different sites in Aun region of Kerbala city. For closed dosimeters, it can be noticed that, the highest average radon concentration in indoor dwellings was found in A7 dwelling which was (137.140±4.033 Bq/m^3), while the lowest average radon concentration was found in A19 dwelling which was (20.508 ±0.603Bq/m^3), see Figure (3), with an average value of (63.767±1.875 Bq/m^3). In addition that, for open dosimeters, Table 1 it can be noticed that, the highest average radon concentration in indoor dwellings was found in A7 dwelling which was (152.530±4.486 Bq/m^3), while the lowest average radon concentration was found in A19 dwelling which was (21.790 ±0.640 Bq/m^3), see Figure (3), with an average value of (75.047±2.207 Bq/m^3), In all the dwellings surveyed in the present work,radon concentrations is less than even the lower limit of the recommended range (200- 300 Bq/m^3) (ICRP, 2009) [21]. Also from Table 1 and Figure 4, for closed dosimeters, it can be noticed that the annual effective dose (AED) received by the residents of the study area varies from (0.016±0.004 mSv/y)) (A19 dwelling) to (0.266±0.078 mSv/y) (A10 dwelling) with an average value of (0.115±0.033 mSv/y).While in open dosimeter, it can be noticed that, the annual effective dose (AED) received by the residents of the study area varies from (0.017±0.005 mSv/y) (A19 dwelling) to (0.357±0.105 mSv/y) (A10 dwelling) with an average value of (0.145 ±0.042 mSv/y). In all the dwellings surveyed in the present work, the indoor annual effective dose is less than even the lower limit of the recommended range (3-10 mSv/y) (ICRP, 1993) [22].

From Table 1 and Figure 5, The equilibrium factor values varies from (0.010±0.002) (A12 dwelling) to (0.567±0.166) (A12 dwelling), with an averge value of (0.088±0.025), The equilibrium factor is less than even the lower limit of the recommended (0.4 -1)[23].

All values obtained in this work [24], depending on the type of house construction, ventilation conditions and location.

The cause of the uneven results of this study due to the handling and disposal of the residents of these homes through the use of different means in cooling, heating and means used in cooking. In addition, the significant role played by ventilation in homes increase or decrease the concentrations of radon Moreover smoking cigarettes of the factors affecting those concentrations. Through the results of the study that has been reached it can be said that there were no health risks to the lives of the people living in these homes, compared with the levels set by the ICRP and other international organizations that are interested in the study of radiation and prevention organization.

Our study showed that a secondary source of indoor radon is associated with the natural radioactivity of bricks, concrete, cement and gravel used in construction of dwellings in Aun region of Kerbala governorate. Radon levels in room air can be lowered in a number of ways, from sealing cracks in floors and walls to changing the flow of air into the building. Among the principle ways of reducing the amount of radon entering a dwelling are:

1- Improving the ventilation of the dwelling through open doors and windows regularly and continuously.

2- Sealing floors and walls, also repair and restoration of cracks and faults that occur in construction.

3- Increasing under-floor ventilation.

4- Installing a radon sump system.

5- Installing a whole dwelling positive pressurization or positive supply ventilation system.

However, some of these solutions are not suitable for all types of dwellings, nor are they suitable for all levels of radon. In some cases, more than one solution is needed in resolving the radon problem.

Table 1: Radon gas concentration (C_{Rn}),equliberium factor(F) and annual effective dose (AED) for passive closed and open dosimeters in dewllinge Aun regions in Kerbala city.

Location Sample	Dosimeters Type	ρ (Trac/cm^2)	C_{Rn} (Bq/m^3)	F	AED (mSv/y)
A1	Closed	663.093±19.502	60.243±1.771	0.034±0.010	0.130±0.038
	Open	818.284±24.067	74.343±2.186		0.161±0.047
A2	Closed	1029.910±30.291	93.569±2.752	0.015±0.004	0.094±0.027
	Open	1128.668±33.196	102.541±3.015		0.103±0.030
A3	Closed	733.634±21.577	66.652±1.960	0.022±0.006	0.095±0.027
	Open	846.501±24.897	76.906±2.261		0.109±0.032
A4	Closed	1015.801±29.876	92.287±2.714	0.024±0.007	0.140±0.041
	Open	1185.102±34.855	107.669±3.166		0.164±0.048
A5	Closed	959.368±28.216	87.160±2.563	0.039±0.011	0.219±0.064
	Open	1213.318±35.685	110.232±3.242		0.277±0.081
A6	Closed	1114.560±32.781	101.260±2.978	0.022±0.006	0.142±0.041
	Open	1283.860±37.760	116.641±3.430		0.164±0.048
A7	Closed	1509.594±44.399	137.149±4.033	0.017±0.005	0.152±0.044
	Open	1678.894±49.379	152.530±4.486		0.170±0.050
A8	Closed	550.226±16.183	49.989±1.470	0.043±0.012	0.136±0.040
	Open	705.418±20.747	64.088±1.884		0.174±0.051
A9	Closed	648.984±19.087	58.961±1.734	0.433±0.127	0.161±0.047
	Open	832.393±24.482	75.624±2.224		0.206±0.060
A10	Closed	818.284±24.067	74.343±2.186	0.567±0.166	0.266±0.078
	Open	1100.451±32.366	99.978±2.940		0.357±0.105
A11	Closed	902.935±26.556	82.033±2.412	0.228±0.067	0.118±0.034
	Open	1044.018±30.706	94.851±2.789		0.136±0.040
A12	Closed	1269.752±37.345	115.359±3.392	0.010±0.002	0.076±0.022
	Open	1312.077±38.590	119.204±3.506		0.079±0.023
A13	Closed	761.851±22.407	69.215±2.035	0.019±0.005	0.085±0.025
	Open	860.609±25.312	78.188±2.299		0.096±0.028
A14	Closed	310.384±9.128	28.199±0.829	0.101±0.029	0.179±0.052
	Open	465.576±13.693	42.298±1.244		0.269±0.079
A15	Closed	296.275±8.713	26.917±0.791	0.109±0.032	0.185±0.054
	Open	451.467±13.278	41.017±1.206		0.282±0.082
A16	Closed	282.167±8.299	25.635±0.753	0.028±0.008	0.046±0.013
	Open	338.600±9.958	30.762±0.904		0.056±0.016
A17	Closed	324.492±9.543	29.481±0.867	0.015±0.004	0.028±0.008
	Open	352.709±10.373	32.044±0.942		0.030±0.008
A18	Closed	253.950±7.469	23.072±0.678	0.012±0.003	0.017±0.005
	Open	268.059±7.884	24.354±0.716		0.018±0.005
A19	Closed	225.734±6.639	20.508±0.603	0.013±0.003	0.016±0.004
	Open	239.842±7.054	21.790±0.640		0.017±0.005
A20	Closed	366.817±10.788	33.326±0.980	0.014±0.004	0.029±0.008
	Open	395.034±11.618	35.890±1.055		0.032±0.009

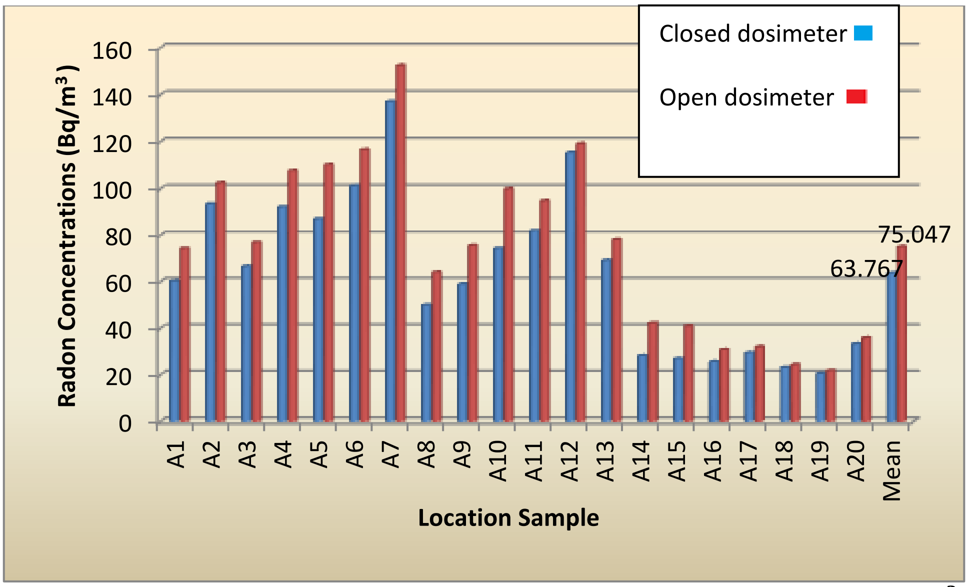

Figure3: A histogram illustrating the change in radon gas concentration (Bq/m^3) in indoor dwelling samples for closed and open dosimeters in all regions studied.

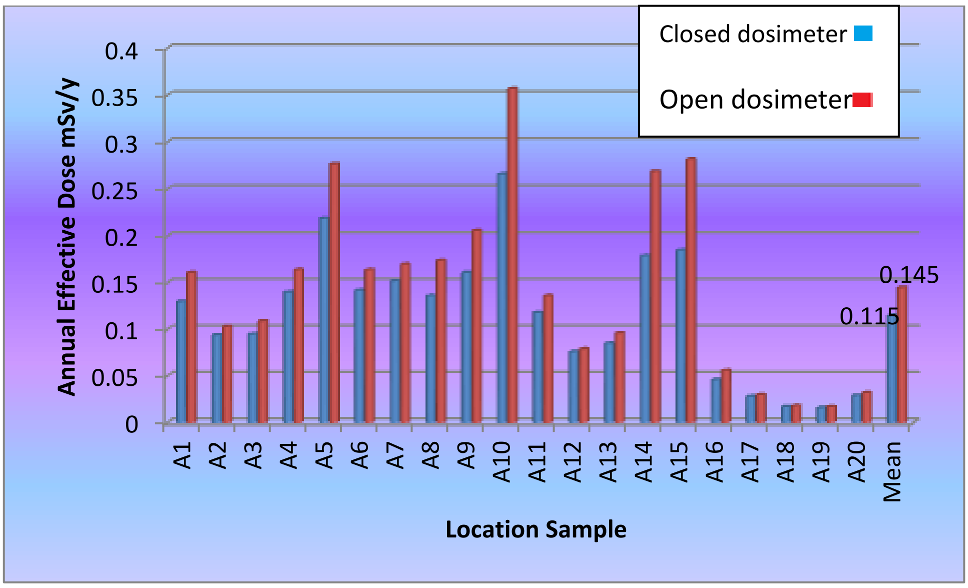

Figure 4: A histogram illustrating the change in annual effective dose of radon gas concentration (mSv/y) in indoor dwelling samples for closed and open dosimeters in all regions studied.

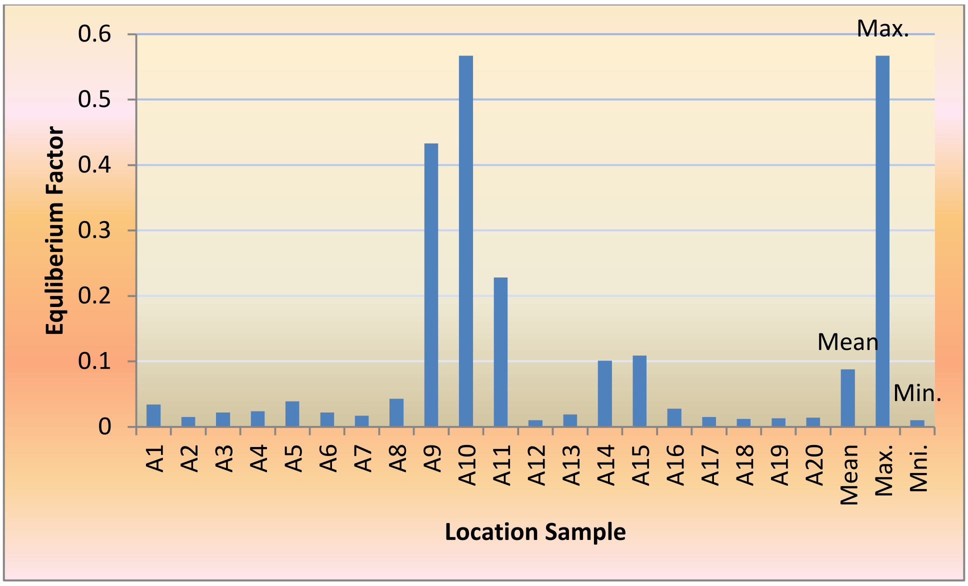

Figure5: A histogram illustrating the change in equilibrium factor of radon gas concentration in indoor dwelling samples for closed and open dosimeters in all regions studied.

5. Conclusions

The results of the present work provide an additional database on indoor radon level in Aun region in Kerbala governorate of Iraq. The indoor radon concentration for close and open dosimeters values measured in Aun region varies from (20.508 ±0.603Bq/m^3) to (137.149±4.033 Bq/m^3) with an average value (63.767±1.875 Bq/m^3)and (21.790 ±0.640 Bq/m^3) to (152.530±4.486 Bq/m^3) with an average value (75.047±2.207 Bq/m^3) respectively, which is lower than the range (200-300 Bq/m^3) recommended by (ICRP, 2009). The present values of indoor annual effective dose for closed and open dosimeters varies from (0.016±0.004 mSv/y) to (0.266±0.078 mSv/y) with an average value (0.115±0.033 mSv/y)and (0.017±0.005 mSv/y) to (0.357±0.105 mSv/y) with an average value (0.145 ±0.042 mSv/y) respectively, which is on the lower side of the recommended range (3-10 mSv/y) (ICRP, 1993). The radon concentration obtained from this work look similar to other researcher results in other countries and hence will pose relatively none serious health risk.

Acknowledgments

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