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Measurement of Radon Concentration and the Effective Dose Rate in the Soil of the City of Karbala, Iraq

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Abstract: In this study, we used the can technique, containing CR-39, to estimate the radon concentration from the soils in Karbala city, Karbala governorate, Iraq, radon concentrations and effective dose rate in soil have been measured by using a long-term technique for alpha particle emission with solid state nuclear track detector type CR-39. It has been selected fifty-five different locations for soil houses in the city of Karbala. One detector was buried in the garden of each selected house at 50 cm depth. The results showed variable values for concentrations of radon gas and the effective dose rate, the concentrations of radon ranged from (0.05∓0.02 to 7.80∓3.53 kBq/m^3 with a mean value of 2.87kBq/m^3 and a standard deviation of 1.80 kBq/m^3. The annual effective dose values varied from (0.23 to 34.74 mSv/y with a mean value of 12.80 mSv/y and a standard deviation of 8.03mSv/y. These results were compared with the local and global results.

Keywords: Radon, Effective Dose Rate, CR-39, Karbala.

1 Introduction

Radon (^{222}Rn is a naturally revolving α−emitting radioactive noble gas. It is generated during the natural decay chain of uranium. As the radium decays, radon is formed and is released into small air or water containing pores between soil and rock particles. The exhalation of radon from soil two mechanisms, the emanation and transport. These mechanisms are affected by many factors, including the properties of the soil [1].

The half-life of radon isotope ^{222}Rn is 3.82 days that are long enough to allow it to migrate through the soil and enter the atmosphere, thus, reaching the human environment [2]. Natural radioactivity in the soil measurement is large importance to many researchers all over the world, which led to a worldwide national survey in the past two decades, measurement of natural radioactivity in the soil is very important to determine the amount of change of the natural background activity with time due or leakage radioactive [3].

Natural radionuclides in soil comes from the ^{238}U series, ^{232}Th and ^{40}K, the concentration of radionuclides Taipei hive soil and found that vary greatly from one place to another [4]. Radon concentrations in soil gas within a few meters of the surface of the ground, are clearly important in determining radon rates of entry into pore spaces and subsequently into the atmosphere and it's depend on the radium concentration in the bedrock and on the permeability of the soil [5]. The aim of the present study is to measure the concentrations of radon gas and the effective dose rate resulting from it in the soil of fifty-five houses were randomly selected from the city of Karbala, see Figure1.

2 Geological Setting

Karbala is the center of the governorate of Karbala, which is located in the middle of Iraq as a part of the alluvial plain, the river Al-Husseineya, a branch of the Euphrates (29 km, runs across its land. Geographically, it's bordered by the capital Baghdad at (105 km from the city center to the North, Al-Anbar governorate at (112 km to the North and the Western North, Al-Najaf governorate at (74 km to the South and the Western South, and Babylon governorate at (45 km to the South and the Eastern South. Karbala city occupies the Northern East part of Karbala governorate. In the North it is neighbored by Al-Hur district, the South by desert, at the East Al-Husseineya district and Al-Hindeya, while the desert and Al-Razzazah lake borders the West indicated in Fig. 1, with location of lati-tude (32`,34º-32`.37º N , and longitude (58`,43º- 60`,44º E . Karbala city resides on (2793 km^2 [6].

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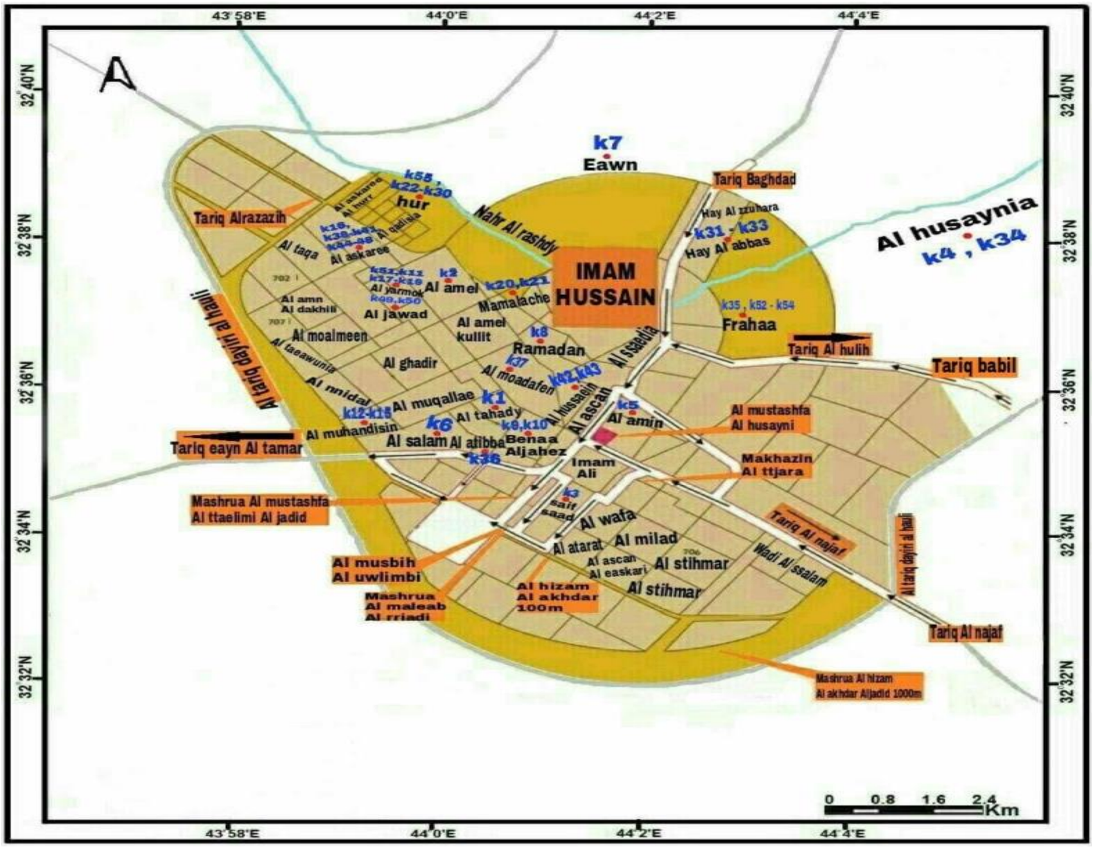

Figure 1. Site soil houses on the map of the city of Karbala in this study.

3 Experimental methods

In this study, we used dosimeters radon passive cumulative for the purpose of measuring the concentration of radon in the soil of fifty-five houses were selected from some neighborhoods of Karbala city, as in table (1 , detectors were distributed in the soil on (31-10-2015 , dosimeters was buried in the garden of dwelling at a depth of 50 cm below the earth's surface and are covered with a tight enclosure and have its bottom to top, It was cutting detector to expel (1.5cm×1.5cm and fixed in the bottom of the plastic box by adhesive two-sided so that the face engraved upon it the figure is heading for the highest for the purpose of distinguishing between places and homes that have been developed which then covered enclosure lid tightly the hole diameter of(1.5 cm covered with a spongy thickness of(0.5 cm as in Figure 2.

The detector records the tracks of α-particles emitted by radon gas produced through the α-decay of radium contents of the soil. The detectors were exposed for a period of about 40 days. After exposure, the detectors were retrieved and etched for eight hours in 6.25N NaOH solution at a temperature of (70 ± 1 °C in a constant temperature water bath to reveal the tracks. The detectors were washed and dried. Subsequently, α-tracks were counted using an optical microscope (kruss-mbl 2000 at a magnification of 400x.

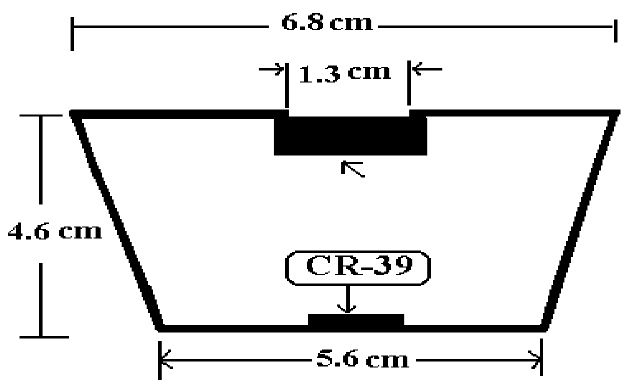

Figure 2. Dosimeter radon passive cumulative.

In order to measure radon concentration levels in soil (C_{Rn} , the surface density of tracks on the employed detectors (ρ measured in (track/cm^2 and used the following equation[7-10]:

$$C = \frac{\rho}{Kt} \quad (1$$

Where t is the exposure time (day and K is the calibration factor to convert track density to the radon concentration [(track/cm^2 per (Bq. day / m^3]. The calibration factor (K value was determined by the calibration process which used standard radon source (Radium ^{226}Ra and used the following equation [8,11] :

$$K = \frac{\rho_o}{C_o\, t_o} \qquad (2$$

Where, C_o is the standard radon concentration (Bq/m^3 , ρ_o is the number of track density (track/cm^2 , and t_o is the exposure time (day for the calibration process. The calibration experiment performed at nuclear laboratory, department of physics, collage of sciences, Kerbala University.

Five detectors were exposed to the standard radon concentration; the average value of calibration factor and its standard deviation was 0.223 ±0.011 track/cm^{2}per (day .Bq/m^3 .The estimated calibration factor of radon measurements is in good agreement with those reported by other investigators [9, 12, 13, 14].

The annual effective dose equivalent, E(WLM.y^{-1} , was related to the radon concentration C in soil by Eq (3 [15]:

$$\mathrm{E(\,WLM.y^{-1}} = \frac{8760\times n\times F\times C}{170\times 3700} \qquad (3$$

Where: C is in Bq. m^{-3}; n is the fraction of time spent indoors; F is the equilibrium factor; 8760 is the number of hours per year; and 170 is the number of hours per working month. The values of n = 0.8 and F = 0.4 [5]. For radon exposure, the effective dose equivalents were estimated by using a conversion factor of 6.3 mSv.WLM^{-1}[16, 17].

4 Results and Discussion

In the present work, we have adopted the style of the burial dosimeters cumulative passive containing nuclear track detectors and his name is known commercial CR-39 in the soil of the garden each house was chosen in this study.

Table (1 shows the areas that have been randomly selected for the purpose of measuring the concentration of radon in the soil of home gardens. After that the effective dose resulting from radon gas rate is calculated so as to its impact on human health.

Table (2 shows the range of soil gas radon concentrations in different soil locations for dwellings in Karbala city which is form(0.05±0.02 kBq/m^3 in K5,which is the lowest value, to(7.80±3.53 kBq/m^3 in K4,which is the highest value with an average of 2.87 kBq/m^3 and a standard deviation of 1.80 kBq/m^3, which was as in Figure (3 .

The average all values of soil gas radon concentration in karbala city are lower than that found in Saudi Arabia of 6.71 kBq/m^3 [18], and that recorded in Iraq of 5.74 kBq/m^3 [19], slightly lower than the value founded in Egypt of 4.35 kBq/m^3 [20] and similar to that recorded in Kassala, Sudan of 2.63 KBq/m^3 [21] and in France of 2.71kBq/m^3[22].

Table 1. Sites that have been selected in the city of Karbala, Karbala governorate, Iraq.

Sample Code	Location	Sample Cod.	Location	Sample Cod.	Location	Sample Cod.	Location
K1	Tahady	K15	Al muhandisin	K29	Al hur	K43	Al hussein
K2	Amel	K16	Askaree	K30	Al hur	K44	Askaree
K3	Saif Saad	K17	Yarmouk	K31	Al abbas	K45	Askaree
K4	Hosainia	K18	Yarmouk	K32	Al abbas	K46	Askaree
K5	Alamin	K19	Yarmouk	K33	Al abbas	K47	Askaree
K6	Salam	K20	Mamalachy	K34	Hosainia	K48	Askaree
K7	Eawn	K21	Mamalachy	K35	Frehaa	K49	Al jawad
K8	Ramadan	K22	Al hur	K36	Al atibba	K50	Al jawad
K9	Benaa al jahez	K23	Al hur	K37	Al moadafeen	K51	Yarmouk
K10	Benaa al jahez	K24	Al hur	K38	Askaree	K52	Frehaa
K11	Yarmouk	K25	Al hur	K39	Askaree	K53	Frehaa
K12	Al muhandisin	K26	Al hur	K40	Askaree	K54	Frehaa
K13	Al muhandisin	K27	Al hur	K41	Askaree	K55	Al hur
K14	Al muhandisin	K28	Al hur	K42	Al hussein		

All values for radon concentrations in this study are lower than that found in Rabak town Sudan of 8.20 kBq/m^3 [23] and obtained in Slovenia of 40.1 kBq/m^3 [24]. Table 3 shows the comparison between concentrations of radon in the soil of the city of Karbala and some of the results of the concentrations of radon levels in the soil of some countries of the world. Also, from Table (2 , it can be noticed that, the effective dose rate varies from (0.23 mSv /y to (34.74 mSv/y with an average value of 12.80 mSv/y and a standard deviation of 8.03mSv/y, as in figure (4 . In addition, it can surface and ground water and drinking water from the main sources that contribute to the increased concentrations of radon in the soil considered, because some nuclei associated with natural chained radioactive may degrade in water, especially groundwater beneath the earth's surface, where the precipitant researchers in many studies and research to find out[25-28].

Figure 5 shows an excellent correlation between the concentration of radon in the soil and the effective dose rate resulting from it. In other words, the amount of increase and decrease the concentrations of radon in the soil as well as lead to an increase and decrease the effective dose rate resulting from it.

Table 2. Statistical summary of tracks density(ρ , radon concentrations(C and the annual effective dose rate(AED in soil for Karbala city.

Code	$\rho \times 10^4$ Track/cm^2	C kBq/m^3	AED (mSv/y	Code	$\rho \times 10^4$ Track/cm^2	C kBq/m^3	AED (mSv/y
K1	2.08∓1.00	2.33∓0.90	10.37	K30	4.02∓2.42	4.51∓2.66	20.08
K2	0.96∓0.25	1.07∓0.27	4.79	K31	0.05∓0.03	0.05∓0.03	0.25
K3	1.59 ∓0.68	1.78∓0.74	7.95	K32	3.37∓1.94	3.77∓2.13	16.81
K4	6.96. ∓3.23	7.80∓3.53	34.74	K33	3.00∓1.72	3.36∓1.87	14.97
K5	0.04∓0.02	0.05∓0.02	0.23	K34	0.54∓0.13	0.61∓0.14	2.71
K6	0.71∓0.35	0.79∓0.38	3.55	K35	3.77∓1.40	4.23∓1.52	18.83
K7	3.12∓2.15	3.50∓2.37	15.59	K36	1.00∓0.58	1.13∓0.64	5.02
K8	1.59∓0.90	1.78∓0.90	7.95	K37	3.78∓1.93	4.24∓2.11	18.89
K9	6.81∓3.36	7.64∓3.67	34.00	K38	4.66∓1.64	5.22∓1.78	23.25
K10	3.51∓2.45	3.94∓2.69	17.53	K39	5.17∓2.97	5.79∓3.25	25.80
K11	0.19∓0.06	0.21∓0.07	0.95	K40	2.35∓1.126	2.63∓1.22	11.73
K12	0.10∓0.01	0.12∓0.11	0.53	K41	1.28∓1.190	1.43∓1.30	6.38
K13	1.57∓0.76	1.76∓0.83	7.87	K42	1.81∓0.65	2.03∓0.70	9.04
K14	2.47∓1.23	2.77∓1.35	12.34	K43	0.96∓0.37	1.07∓0.39	4.78
K15	4.37∓3.02	4.90∓3.33	21.81	K44	2.74∓1.13	3.07∓1.23	13.70
K16	5.90∓4.42	6.62∓4.88	29.48	K45	2.48∓0.89	2.78∓0.97	12.39
K17	2.54∓0.83	2.85∓0.90	12.69	K46	3.55∓1.94	3.98∓2.12	17.72
K18	2.36∓1.90	2.65∓2.10	11.81	K47	3.87∓1.93	4.34∓2.10	19.34
K19	1.12∓0.53	1.25∓0.58	5.58	K48	1.99∓0.58	2.23∓0.63	9.95
K20	1.87∓0.75	2.10∓0.81	9.36	K49	1.31∓0.49	1.47∓0.53	6.54
K21	1.21∓0.51	1.35∓0.56	6.03	K50	4.32∓1.00	4.84∓0.90	21.57
K22	1.10∓0.81	1.23∓0.89	5.50	K51	2.77∓0.57	3.10∓0.60	13.83
K23	2.15∓1.47	2.41∓1.62	10.74	K52	1.90∓1.04	2.13∓1.14	9.49
K24	2.61∓1.76	2.92∓1.94	13.03	K53	2.80∓1.15	3.14∓1.25	13.99
K25	3.10∓1.22	3.48∓1.32	15.51	K54	2.88∓1.82	3.22∓2.00	14.36
K26	4.23∓3.69	4.74∓0.90	21.12	K55	4.45∓2.98	4.99∓3.28	22.21
K27	1.46∓0.87	1.64∓0.96	7.31	mean	2.56	2.87	12.80
K28	1.26∓0.57	1.41∓0.62	6.35	max.	6.96. ∓3.23	7.80∓3.53	34.74
K29	3.12∓1.40	3.50∓1.52	15.59	min.	0.04∓0.02	0.05∓0.02	0.23
Standard Deviation					1.61	1.80	8.03

Table 3. Comparison between concentrations of radon in the soil of the city of Karbala and some of the results of the concentrations of radon levels in the soil of some countries of the world.

No.	Country	Radon concentration kBq/m^3	References
1	Saudi Arabia	6.71	[18]
2	Iraq	5.74	[19]
3	Egypt	4.35	[20]
4	Sudan	2.63	[21]
5	France	2.71	[22]
6	Sudan	8.20	[23]
7	Slovenia	40.1	[24]
8	Karbala city ,Iraq	2.877	This study

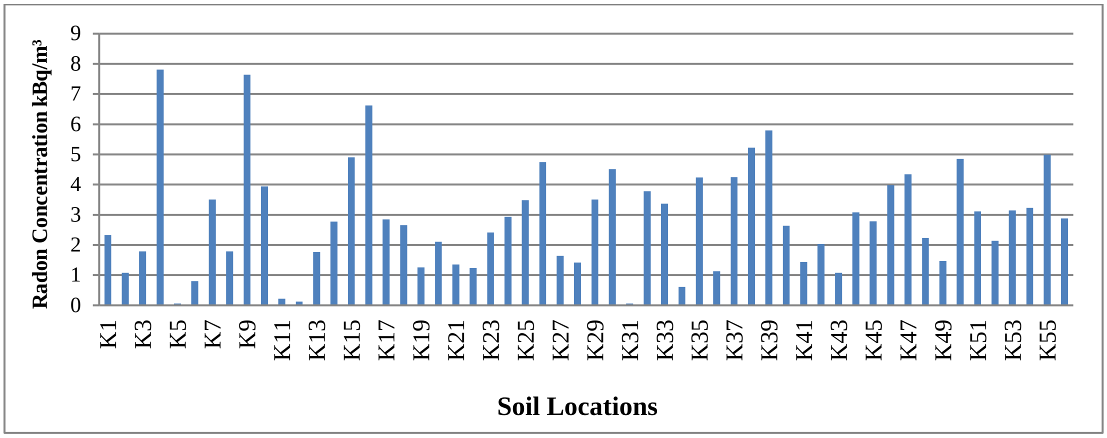

Figure 3. Radon concentration kBq/m^3 for different locations in Karbala city .

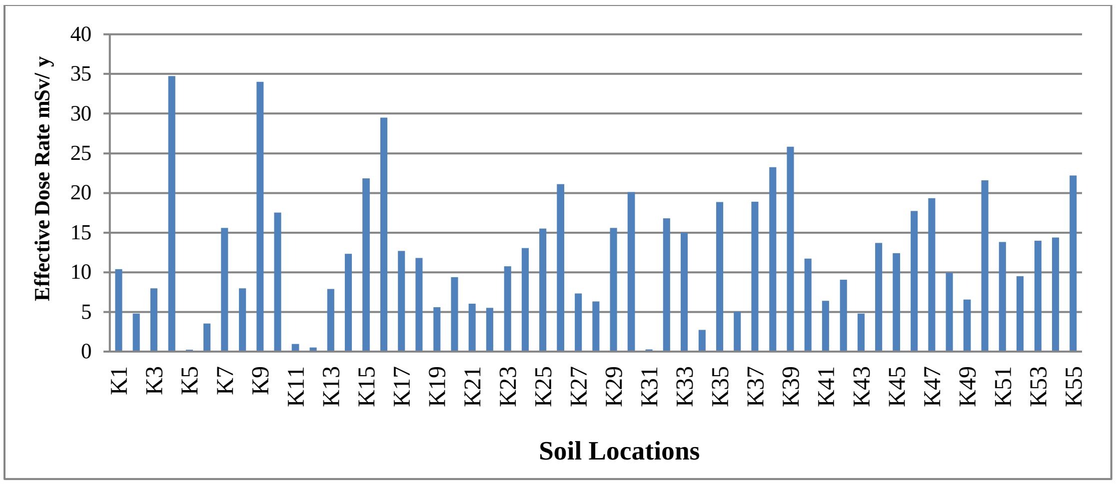

Figure 4. Effective dose rate values for different sites in soil in Karbala city.

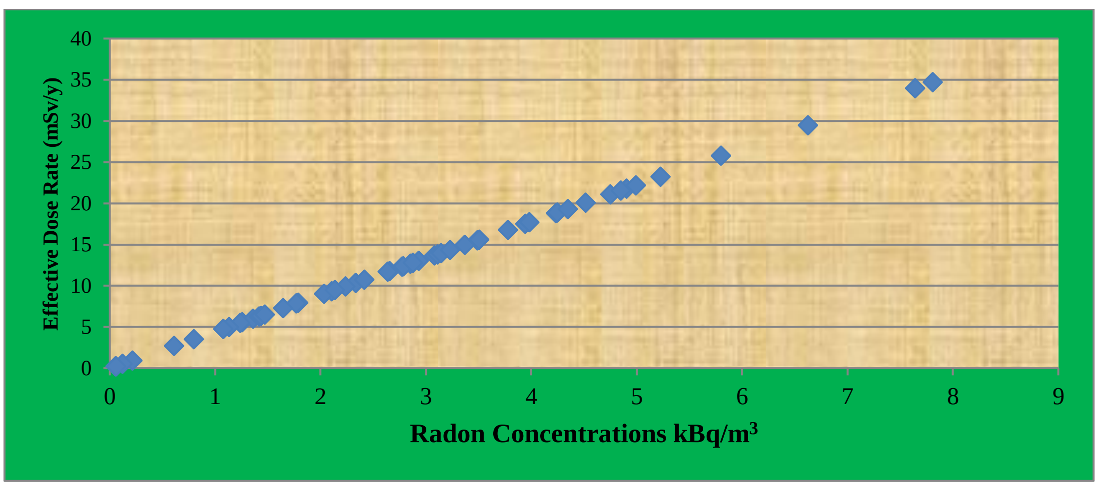

Figure 5. The correlation between radon concentrations and effective dose rate for soil dwellings in Karbala city.

5 Conclusions

In this study, it was done a total of 55 measurements of radon concentration in the soil in the city of Karbala. The study was conducted using a dosimeters cumulative passive containing nuclear track detectors CR-39 that has been calibrated in the laboratory of nuclear physics at the University of Karbala. It was compared calculated values of the concentration of radon in the soil of all the houses that have been selected in this study with data from different geographic areas. Excellent correlations between concentrations of radon gas and the rate of effective dose for soil houses in the city of Karbala. It is advisable not to establish homes in areas that contain high concentrations of radon gas for the prevention of radiation exposure that leads to cancer morbidity. We recommend other researchers to carry out similar studies in other parts of Iraq, the importance of large studies on the health and lives of people.

References

[1] Munazza Faheem, Matiullah, Radon. Exhalation and its dependence on moisture content from samples of soil and building materials, *Radiations Measurement* 43: 1458-1462(2008 .

[2] M. Shakir Khan, A.H. Naqvi, A. Azam, D.S. Srivastava, Radium and radon exhalation studies of soil, *Iran. J. Radiat. Res.*, 8(4 207-210(2011 .

[3] I.F. Al-Hamarneh, M.I. Awadallah, Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan, *Radiat. Meas.* 44, 102–110 2009.

[4] K.M. Thabayneh, M.M. Jazzar, Natural radioactivity levels and estimation of radiation exposure in environmental soil samples from Tulkarem Province-Palestine, *Open J. Soil Sci.* 2, 7-16 2012.

[5] Ionizing radiation". Report to General Assembly, with Scientific Annexes. New York: United Nations, 2000.

[6] Muayed,Sajet, "Spatial analysis of residential waste solid in the city of Karbala a study in environment geography ",Master Thesis, College of education for Humanities Geography, University of Karbala, 2015

[7] Abdalsattar Kareem Hashim., A Study of Radon Concentration in the Soil and air of Some Villages in Irbid Governorate., " M.Sc. Thesis, Yarmouk University, Jordan 2003

[8] Mayya Y. S., Eappen K. P., K. and Nambi S. V., "Methodology for mixed field inhalation dosimetry in monazite areas using a twin-cup dosimeter with three track detector" Rad. Prot. Dosim., 77 3 , 177-184 1998.

[9] Farid, S. M., "Measurement of concentrations of radon and its daughters in dwellings usingCR-39 nuclear track detector", Journals of Islamic Academy of Sciences:, 5:1,4-7 1992 .

[10] Asaad H. I. and Salih O. H. "Analysis of Radon Concentrations in Drinking Water in Erbil Governorate Iraqi Kurdistan and its Health Effects "Tikrit Journal of Pure Science Vol. 13 No. 3 2008 .

[11] Marcia Pires de Campos and Elaine Wirney Martins,2007" Calibration of the solid state nuclear track detector CR-39 for radon measurements" International Nuclear Atlantic Conference - INAC 2007.

[12] Ferdoas S. Al-Saleh, "Measurements of indoor gamma radiation and radon concentrations in dwelling of Riyadh City, Saudi Arabia", Applied Radiation and Isotopes :65 ,843-848 2007 .

[13] Younis M., KhrtamAbd-Aladel, Hameed B. and Muhammed A., "Determination of radon-22 concentration in center of Misan City using nuclear track detectors CR-39",Basrah Journal of Sciences A Vol.6 No.36,35-38 2010 .

[14] Abbas, J. Al-saadi., Determination of Radon Concentration and the Annual Effective Dose in Karbala University Campus, Karbala, Iraq., Karbala J. Med. Vol.6, No.1, 1591-1599 June, 2013

[15] Abd-Elmoniem A. Elzain., Estimation of Soil Gas Radon Concentration and the Effective Dose Rate by using SSNTDs, International Journal of Scientific and Research Publications, Volume 5, Issue 2, February, 1-5 2015

[16] Abd-Elmoniem A. Elzain, Y. Sh. Mohammed, Kh. Sh. Mohammed, Sumaia S. M., "Radium and Radon Exhalation Studies in Some Soil Samples from Singa and Rabak Towns, Sudan using CR-39", International Journal of Science and Research IJSR, 3 11 : 632- 637 2014.

[17] ICRP, "Lung cancer risk from indoor exposures to radon daughters", International Commission on Radiological Protection, A report of a task group of the ICRP Publication 50, Oxford: Pergamon Press, 1987.

[18] S. M. Farid, "Indoor radon in dwellings of Jeddah city, Saudi Arabia and its correlations with the radium and radon exhalation rates from soil", *Indoor and Built Environment published online June 2014*.

[19] Shafik S. Shafik, Aamir A. Mohammed, "Measurement of Radon and Uranium Concentrations and Background Gamma Rays at the University of Baghdad -Jadiriyah Site", *International Journal of Application or Innovation in Engineering & Management IJAIEM* , 2, 5 , pp. 455-462, 2013

[20] K. A. Korany, A. E. Shata, S. F. Hassan, M. S. E. Nagdy, " Depth and Seasonal Variations for the Soil Radon-Gas Concentration Levels at Wadi Naseib Area, Southwestern Sinai, Egypt", *J. Phys. Chem. Biophys,* 2013, 3, pp. 123,DIO:10.4172/2161-0398.1000123.

[21] Abd Elmoniem A. Elzain, A. K. Sam, O. M. Mukhtar and M. A Abbasher " Measurements of Radon Gas Concentration in a Soil at Some Towns in Kassala State.", *Gezira Journal of Engineering & Applied Sciences,* 4 1 , pp.15-42 2009.

[22] C. Baixeras, H. Climent, L. I. Font, G. U. Bacmeister,

D. Albarracin and M.M. Monnin, "Using Passive Detectors in Soil and Indoors in Tow Mediterranean Locations for Radon Concentration Measurements", *Radiat. Meas*. 28 1-6, 713-716 1997.

[23] Abd-Elmoniem A. Elzain, Y. Sh. Mohammed, Kh. Sh. Mohammed, Sumaia S. M., "Radium and Radon Exhalation Studies in Some Soil Samples from Singa and Rabak Towns, Sudan using CR-39", *International Journal of Science and Research IJSR,* 3 11 : 632-637. 2014.

[24] D. Brajnik, U. Miklavžič, and J. Tomšič. Map of natural radioactivity in Slovenia and its correlation to the emanation of radon, Radiation Protection Dosimetry 45, 273–276 1992.

[25] S S ,Althoyaib and A, El-Taher, Natural Radioactivity levels of Radon, Radium and the associated health effects in Drinking water Consumed in Qassim area, Saudi Arabia. Journal of Environmental Science and Technology 9 2 208-213 2016.

[26] S S ,Althoyaib and A, El-Taher., The Measurement of Radon and Radium Concentrations in well water from Al-Jawa, Saudi Arabia, J Radioanal Nucl Chem, 304:547–552 2015 .

[27] A, El-Taher., Measurement of Radon Concentrations and Their Annual Effective Dose Exposure in Groundwater from Qassim Area, Saudi Arabia. Journal of Environmental Science and Technology 2012 , 5 6 475-481, 2012.

[28] Wedad Rayif Alharbi , Adel G. E. Abbady and A. El-Taher., Radon Concentrations Measurement for groundwater Using Active Detecting Method. American Scientific Research Journal for Engineering, Technology, and Sciences ASRJETS 14 1 1-11, 2015.