Evaluation of Natural Radioactivity of Soil Samples From Different Regions in Baghdad Governorate

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Abstract

In this paper, the measurement of natural radioactivity in various areas of Baghdad governorate using NaI(Tl) system, twenty soil samples were collected (ten from the surface and ten form 20cm depth). Analysis of gamma spectrum for each sample and calculations of specific activity appears to show that the average concentrations of U-238, Th-232 and K-40 were (55.30, 49.18, 545.24) Bq/kg respectively, which was more than the worldwide average. While the average values of Radium equivalent, absorbed dose, annual effective dose, internal and external hazard index for each sample were found to be (160.82 Bq/kg, 67.48 nGy/h, 0.08 mSv/y, 0.39, 0.50) respectively, all of these values were lower than the permissibility limit except the absorbed dose value which higher than the global limit (55nGy/h).

Keyword: natural radioactivity, gamma spectrometer, soil.

تقييم النشاط الاشعاعي الطبيعي لعينات تربة من مناطق مختلفة في محافظة بغداد

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الخلاصة:

تم في هذا البحث قياس النشاط الاشعاعي الطبيعي في مناطق مختلفة من محافظة بغداد باستخدام منظومة ايوديد الصوديوم المطعم بالثاليوم NaI(Tl) ، عشرون عينة تربة تم جمعها من عشرة مناطق (١٠ عينات من السطح و ١٠ عينات من عمق ٢٠سم). تحليل طيف كاما لكل عينة وحسابات الفعالية النوعية تبين ان معدل تركيز كل من اليورانيوم-٢٣٨، الثوريوم-٢٣٢ والبوتسيوم-٤٠ كانت Bq/kg (55.30, 49.18, 545.24) على التوالي وهي اعلى من المعدل العالمي.

اما قيم معدل مكافئ الراديوم، الجرعة الممتصة، الجرعة السنوية المؤثرة ومعامل الخطورة الداخلي والخارجي كانت تساوي (160.82 Bq/kg, 67.48 nGy/h, 0.08 mSv/y, 0.39, 0.50) على التوالي وان هذه القيم هي اقل من الحدود المسموحة عالميا ما عدا قيمة الجرعة الممتصة والتي كانت اعلى من الحد المسموح (55nGy/h).

الكلمات المفتاحية: النشاط الاشعاعي الطبيعي، مطياف كاما، تربة.

Introduction

The natural radioactive chains from ^{238}U, ^{235}U and ^{232}Th produce a group of radionuclides with a wide range of half-lives. Most of the radioisotopes are alpha emitters, so when they are ingested or inhaled, they contribute significantly to the radiation dose that people receive [1]. On the other hand, taking into account that uranium and thorium are always present in soil, their gamma radiation causes external exposures with the consequent absorbed doses [2].

The study of natural soil radioactivity (background radiation) is one of the most important topics that are taught by researchers to aligned to the subject of the environmental importance of the effect on human health, especially if we consider the existence of areas containing high concentrations of natural radioactive isotopes due to the geological composition of these areas, where the focus was on natural chains of Uranium-238 and Thorium-232 in addition to Potassium-40, which is considered the most important actors on increasing the radiation dose absorbed by human [3], where the average global concentrations of these isotopes in the Earth's crust are up to (35Bq/kg, 30Bq/kg and 400Bq/kg) respectively [4].

One of the most important natural isotopes is Potassium-40, where he owns an abundance of nature is 0.012% and has a half-life of 1.28×10^{9}year [5], either match the other is Radon-222, one of the noble elements colorless and tasteless severe and smell toxic and consists result radioactive decay of the element radium Ra-226 and consists of Radium as a result of Uranium radioactive decay chain [6].

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world. The specific levels of terrestrial environmental radiation are related to the composition of each lithologically separated area, and to the content of the rock from which the soils originate. There

are many types of soils depending upon the physical and chemical composition (UNSCEAR, 2000)[7].

Human beings have always been exposed to natural radiations from their surroundings. The exposure to ionizing radiations from natural sources occurs because of naturally occurring radioactive elements in the soil and rocks, cosmic rays entering the earth's atmosphere from outer space and the internal exposure from radioactive elements through food, water and air. Therefore the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population [8].

Theoretical part

1- Activity Concentration

Since all the elements of radioactive chains effective in the case of late balance so it is possible to calculate the concentration of an element in the series in terms of the concentration of another element, it has been the focus of effectiveness of a series of Uranium account ^{238}U (Radium ^{226}Ra) by focusing effectively account for nuclide Bismuth ^{214}Bi (1764keV), as well as in Thorium ^{232}Th series has been the focus of effectiveness of the radioactive nuclide Thallium ^{208}Tl (2614keV), which represents the concentration of thorium ^{232}Th account, and then the concentration of Potassium ^{40}K account radioactive nuclide (1460keV) can be the effective concentration which is calculated by the following equation [9]:

$$A = \frac{NET}{\varepsilon * I_{\gamma} * m * t} \quad \text{.....} \quad (1)$$

Where: A: activity concentrations of the sample units Bq/kg, ε: Energy efficiency, m: mass of sample units kg, t: time measurement (14400sec)

2- Radium Equivalent Activity (Ra_{eq})

Radium equivalent calculation from the following equation [9] :

$$Ra_{eq}(Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \quad (2)$$

Where A_k, A_{Th}, A_{Ra} activity concentration of a series of Radium and a series of Thorium and Potassium, respectively, in the equation (2) Assume that 10Bq/kg of Radium and 7Bq/kg of Thorium and 130Bq/kg of Potassium produces an equal dose of radiation [10].

3- Absorbed Dose Rate

The total rate of the absorbed dose in the air is calculated in terms of the concentrations of Radium, Thorium and Potassium through the following equation [10]:

$$D_{\gamma} = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{K} \quad (3)$$

4- The Annual Effective Dose

To calculation the annual effective dose must take the following consideration, first: conversion factor of absorbed dose to effective dose, second: Internal occupation factor. Use the factor 0.7Sv as a conversion factor from absorbed dose in the air to the annual effective received by the adult dose and use 0.8 as an internal occupation (which is the ratio of time spent at home) and 0.2 is the ratio of time spent abroad, and this data found that the annual effective dose calculated as follows [11] :

$$\mathrm{E_{in}\,(mSv/y) = D\,(nGy.h^{-1}) \times 10^{-6} \times 8760(h/y) \times 0.80 \times 0.7(SvGy^{-1})} \quad (4)$$

$$\mathrm{E_{out}\,(mSv/y) = D\,(nGy.h^{-1}) \times 10^{-6} \times 8760(h/y) \times 0.20 \times 0.7(SvGy^{-1})} \quad (5)$$

where 8760 is the number of hours a year. The global average annual effective dose is 0.48 mSv.

5- External Hazard Index

The external guide is a hazard assessment of the risk of natural gamma radiation, is calculated from the following equation [12] .

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \leq 1 \quad (6)$$

Where this factor must be less than one , if equal to or greater than one indicates the presence of radiation risk.

6- Internal Hazard Index

The internal exposure is caused by the inhalation of radon gas and daughters which can be expressed in terms of the internal hazard index and calculates by the following equation [13] :

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \leq 1 \quad (7)$$

And this factor must be less than the one to be within the allowable universally border.

Experimental Part

The soil samples were collected from different areas of Baghdad city, and mass samples range between 0.983 kg to 1.494 kg to full (1 liter) in volume container, and by Statistics drilling tools, has been taking two samples for each site, one of the surface and the other at 20cm depth from ten different and far between sites in Baghdad city which has a population

and job density to measure and calculate the concentrations of its effectiveness should be free of moisture because the concentrations effectiveness calculation depends on the form of weight and get rid of this moisture should be dried until it reaches a constant weight, to drying these samples, we used 6h in 150C^{o} German oven origin of type (DUO-VAC OVEN) because the humidity It was very high in the soil due to heavy rains in the city of Baghdad during the sampling collection, after drying the samples were fully we have removed impurities such as fragmentation and then crushed by Chinese origin mill (Graining machine) sifts and samples fine sieve (mesh: 630micron) German origin to become a homogeneous fine powder free of impurities.

After the completion of the samples preparation, they stored for 30 days in one liter Marinelly beaker to achieve the radiative equilibrium between Uranium, Thorium and their Daughters. NaI(Tl) system, 3"×3" crystal detector Canberra company was used to collect and analyst of the gamma spectrum to measure and calculate the specific activity and other radiation parameters. Table 1 show the code numbers and location of each samples. We used three radioactive elements point source in order to calibrate the system (Ba-133, Cs-137 and Co-60) as shown in table 2 and its spectrum in figure 1.

Table 1: Cods, locations and depth of the samples.

No.	***Sample Code***	***Sample Location***	***Sample Depth***
1	O1	Greaat	Surface
2	O2	Greaat	20 cm
3	K1	Karada	Surface
4	K2	Karada	20 cm
5	C1	New Baghdad	Surface
6	C2	New Baghdad	20 cm
7	D1	Mansur	Surface
8	D2	Mansur	20 cm
9	E1	Dura	Surface
10	E2	Dura	20 cm
11	G1	Bayaa	Surface
12	G2	Bayaa	20 cm
13	J1	Abo Ghraib	Surface
14	J2	Abo Ghraib	20 cm
15	M1	Zaafaraniah	Surface
16	M2	Zaafaraniah	20 cm
17	P1	Park Al-Saadoun	Surface
18	P2	Park Al-Saadoun	20 cm
19	Z1	Al-Sader city	Surface
20	Z2	Al-Sader city	20 cm

Table 2: The radioactive isotopes detail used in energy and efficiency calibration.

Isotope	A_o (µCi)	manufacture date	$t_{1/2}$ (y)	E (keV)	I (%)
Ba-133	10.8	27-4-1978	10.51	81.00	34.06
				365.02	62.05
Cs-137	1	1-3-1982	30.07	661.66	85.10
Co-60	1	1-1-2009	5.27	1173.24	99.97
				1332.50	99.99
				2505.69	2×10^{-6}

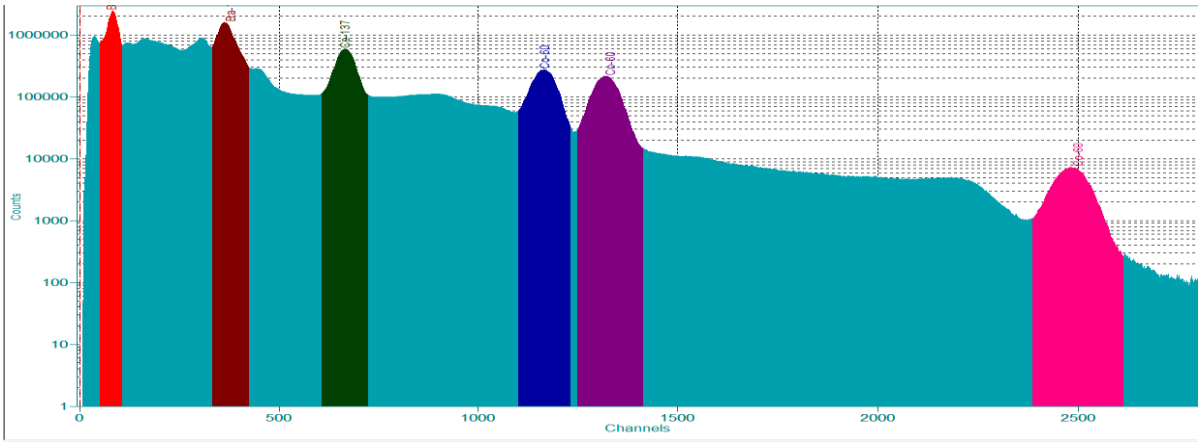

Figure 1: Gamma spectrum of (Ba-133,Cs-137,Co-60) radioactive elements.

Results and Conclusions

After the completion of the collection, drying process and sift samples and stored for 30 days, we collect the gamma spectrum for each sample (14400 sec) periodic time using NaI(Tl) system and determined the specific activity of U-238, Th-232 and K-40 for each sample to calculate Radium equivalent, absorbed dose, annual effective dose, internal and external hazard index. It Was found that the concentration of U-238 was ranged from 15.69 Bq/kg to 55.32 Bq/kg with an average value 35.30 Bq/kg, for Th-232 was between 23.19 Bq/kg and 75.18 Bq/kg in average of 49.18 Bq/kg, while the concentration of K-40 was 417.21 Bq/kg to 673.26 Bq/kg with the average value 545.24 Bq/kg, average values for the three radionuclides were higher than the worldwide average comparing with (30Bq/kg), (35Bq/kg) and (400Bq/kg) respectively[7]. The highest concentration of Uranium was in Dura site at 20cm depth (E2), while for Thorium was in Dura site too at the surface (E1), and for Potassium was in Park Al-Saadoun 20cm depth (P2) sample as shown in table 3 and figure 2.

Table 3: Specific activity of Uranium, Thorium and Potassium in soil samples.

No.	Sample code	Ac. U-238 (Bq/kg)	Ac. Th-232 (Bq/kg)	Ac. k-40 (Bq/kg)
1	O1	35.64	39.82	452.95
2	O2	22.98	23.19	428.04
3	K1	28.62	37.59	509.71
4	K2	49.95	70.26	535.05
5	C1	31.65	50.59	449.71
6	C2	30.55	26.58	476.89
7	D1	51.88	42.86	490.97
8	D2	50.64	43.91	518.70
9	E1	28.76	75.18	530.07
10	E2	55.32	42.04	461.73
11	G1	24.36	63.35	465.95
12	G2	15.69	52.81	421.98
13	J1	52.57	53.99	417.21
14	J2	50.23	50.36	448.08
15	M1	49.54	56.80	470.72
16	M2	40.18	55.39	515.99
17	P1	16.51	61.36	552.71
18	P2	54.91	65.23	673.26
19	Z1	36.19	40.05	491.51
20	Z2	54.35	62.65	557.26
Minimum		**15.69**	**23.19**	**417.21**
Maximum		**55.32**	**75.18**	**673.26**
Average		**35.30**	**49.18**	**545.24**
Worldwide average[7]		**30**	**35**	**400**

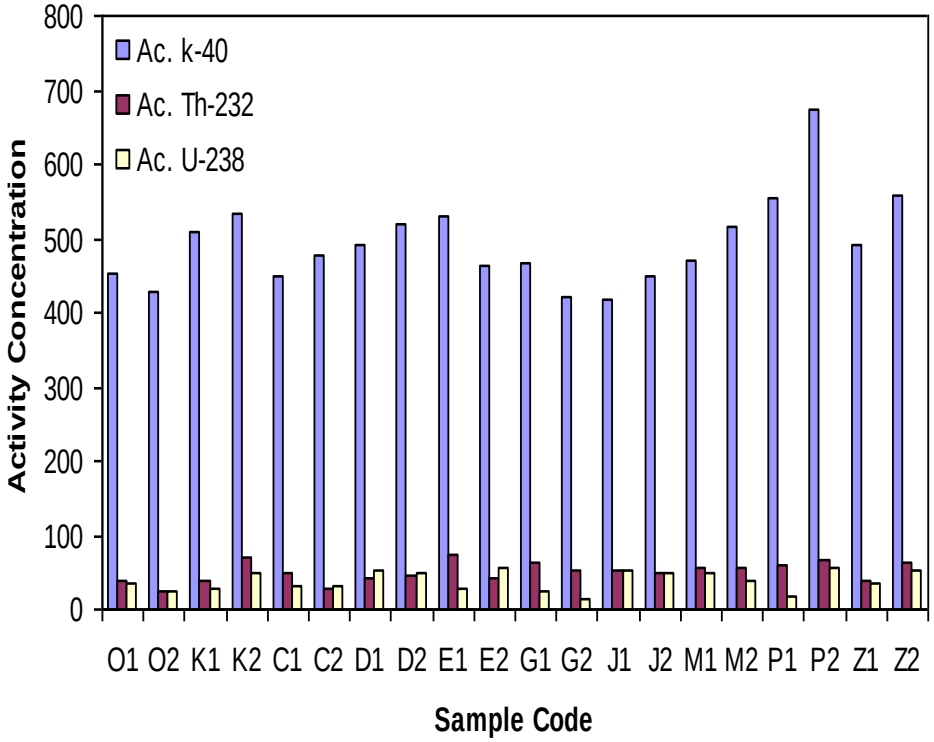

Figure 2: Activity concentration of U-238, Th-232 and K-40 in studied samples.

After determination of U-238, Th-232 and K-40 concentration, we calculate the radiation and hazard parameter, the most important is Radium equivalent which varies from 89.10 Bq/kg to 200.02 Bq/kg with an average of 160.82 Bq/kg, and all values were lower than the global limit (370 Bq/kg). While absorbed dose were between 42.38 and 92.58 with the average of 67.48 nGy/h, most of the sample higher than global limit (55 nGy/h). The annual effective dose for soil outside the buildings (E_{out}) were calculated to be in between (0.05, 0.11) mSv/y with an average 0.08 mSv/y, which are very lower than permissible limit (1 mSv/y). External and internal hazard index were calculated too, the values ranged from 0.24, 0.30 to 0.54, 0.69 with the averages 0.39, 0.50 respectively. All these values were lower than the global limit (1).

The above areas inhabited by thousands of citizens so it must know the natural radioactivity of the soil in order to maintain the safety of the human being. So we must take action to treatment this area from that radioactive contamination may be due reason for the existence of that radioactivity to geological influences such as shifts in the soil or the possible existence of contaminated soil have been moved to this place or because of the explosions, as well as the country's exposure to the bombing

of the different weapons by forces Alliance or due to different climatic conditions. The increasing of Uranium and Thorium in al-Dura site may be because of exist of Dura refinery, which contains remnants of oil and drilling operations during the construction of the refinery. While Park Al-Saadoun soil is not suitable for cultivation and that the serious injuries that may be transmitted to humans through plants and also must alert the population and peasants in the gardens of the region and caution them because they exceeded the allowed universally border. From this study, the mean value of absorbed dose are higher than UNCEAR values. But the external radiation hazard index is less than 1. These are an indication that the area is safe for the human activity.

Table 4: Radium equivalent, absorbed dose, annual effective dose, external and internal hazard index of the studied samples.

Sample code	Radium Equivalent (Bq/kg)	Absorbed Dose (nGy/h)	Annual Effective Dose (E_{out}) (mSv/y)	Hazard Index	
				External (H_{ex})	Internal (H_{in})
O1	127.45	59.24	0.07	0.34	0.44
O2	89.10	42.38	0.05	0.24	0.30
K1	121.62	57.03	0.07	0.33	0.41
K2	191.63	87.55	0.11	0.52	0.65
C1	138.62	63.73	0.08	0.37	0.46
C2	105.28	49.95	0.06	0.28	0.37
D1	150.97	70.16	0.09	0.41	0.55
D2	153.38	71.37	0.09	0.41	0.55
E1	177.08	80.50	0.10	0.48	0.56
E2	150.99	70.04	0.09	0.41	0.56
G1	150.83	68.70	0.08	0.41	0.47
G2	123.70	56.53	0.07	0.33	0.38
J1	161.89	74.07	0.09	0.44	0.58
J2	156.74	72.10	0.09	0.42	0.56
M1	167.00	76.59	0.09	0.45	0.58
M2	159.12	73.31	0.09	0.43	0.54
P1	146.82	67.49	0.08	0.40	0.44
P2	200.02	92.58	0.11	0.54	0.69
Z1	131.31	61.25	0.08	0.35	0.45
Z2	186.85	85.94	0.11	0.50	0.65
Minimum	**89.10**	**42.38**	**0.05**	**0.24**	**0.30**
Maximum	**200.02**	**92.58**	**0.11**	**0.54**	**0.69**
Average	**160.82**	**67.48**	**0.08**	**0.39**	**0.50**
Global limits[7]	**370**	**55**	**1**	**1**	**1**

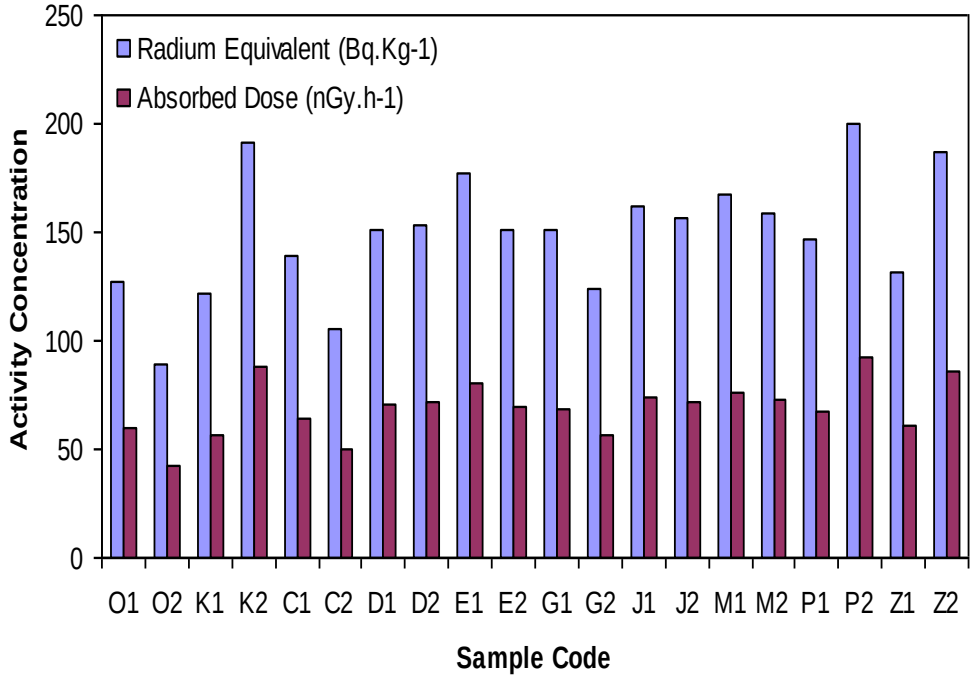

Figure 3: Radium equivalent and absorbed dose in studied samples.

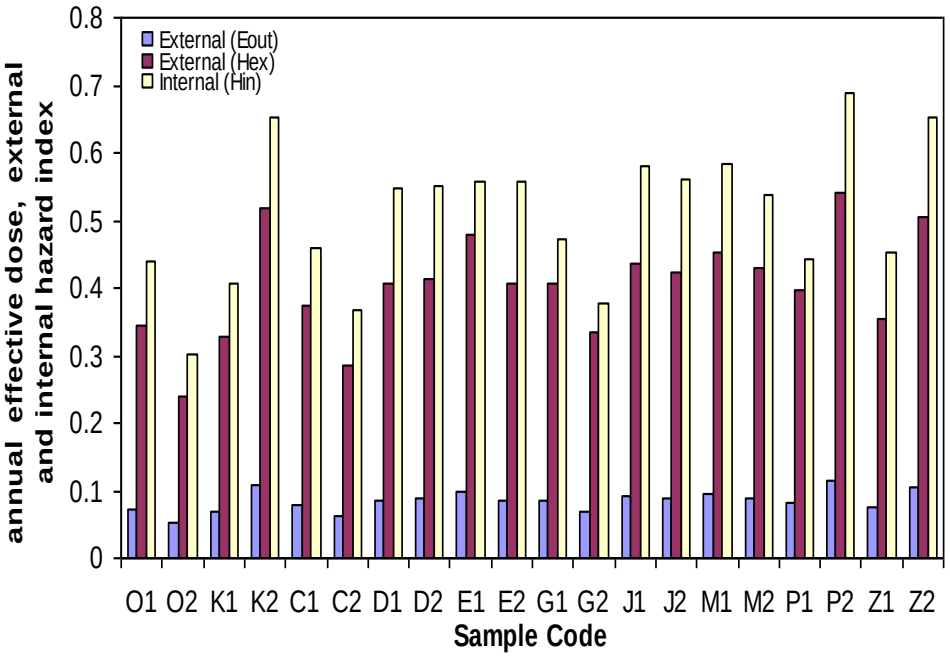

Figure 4: Annual effective dose, external and internal hazard index in studied samples.

References

1- Mireles, F., Davila, J.I., Quirino, L.L., Lugo, J.F., Pinedo, J.L. and Rios, C., "Natural soil gamma radioactivity levels and resultant population dose in the cities of Zacatecas and Guadalupe", Zacatecas, Mexico. Health Physics 84, 368–372 (2003).

2- Colmenero Sujo L., Montero Cabrera M.E., Villalba L., Renterıa Villalobos M., Torres Moye E., Garcıa Leon M., Garcıa-Tenorio R., Mireles Garcıa F., Herrera Peraza E.F. and Sanchez Aroche D.,"Uranium-238 and thorium-232 series concentrations in soil, radon-222 indoor and drinking water concentrations and dose assessment in the city of Aldama, Chihuahua, Mexico" Journal of Environmental Radioactivity 77, 205–219 (2004).

3- Vena C., "Advanced Nuclear Physics", 1st Edition, Global Media (2009).

4- Abusini, M., Al-ayasreh, K., Al-Jundi, J., "Determination of Uranium, Thorium and Potassium Activity Concentrations in Soil Cores in Arabia Valley, Jordan", Radiation Protection Dosimetry, 128, 2, 213–216 (2008).

5- Alsagii, Mohammed Abdel Wahed, "The damage caused by the use of radiological weapons on surface water and groundwater in Iraq", Master Thesis, University of Baghdad, (1999).

6- Gordon R.G., "Practical Gamma-ray Spectrometry", 2nd Edition, John Wiley & Sons, Britain, (2008).

7- (UNSCEAR) United Nations Scientific Committee on the Effects of Atomic Radiation, "Sources, Effects and Risks of Ionizing Radiation", New York, United Nations, (2000).

8- Standard Operating Procedure to surface and subsurface soil sampling. FSSO 002.00, California SOP (1999).

9- Dia H.M., Nouh S.A., Hamdy A. and EL-Fiki S.A., "Evaluation of Natural Radioactivity in a Cultivated Area around A Fertilizer Factory", Nuclear and Radiation Physics, 3, 1, 53-62 (2008).

10- Nashwan Shawkat, "Radioactive pollution and environmental sources in the province of Nineveh", Master Thesis Baghdad University (2000).

11- El-Arabi A.M., "Gamma activity in some environmental samples in south Egypt", Indian Journal of Pure & Applied Physics, 43, 422-426 (2005).

12- Al-Taher A. and Makhluf S., "Natural radioactivity levels in phosphate fertilizer and its environmental implications in as suit governorate, Upper Egypt", Indian Journal of Pure & Applied Physics, 48, 697-702 (2010).

13- Arman E., "An Investigation on the Natural Radioactivity of Building Materials, Raw Materials and Interior Coatings in Central Turkey", Turkish Journal of Medical Sciences, 37, 4,199-203 (2007).