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The Impact of Long-Lived Gamma Emitters on Human Health in Selected Soil Samples at Karbala University-Fariha Site

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Abstract

When people are exposed to certain levels of ^{238}U, ^{232}Th and ^{40}K for a long period of time cancer of the bone and hazard cavity may result. Radiation causes damage in living tissue by ionization of the atoms and molecules which make up the constituent cells. The soil is one of the most of natural sources of ionizing radiation radioactivity nuclides such as uranium-238(^{238}U) series nuclides as well as a series of thorium-232(^{232}Th) in addition to the isotope potassium-40 (^{40}K), so it must be studied to see the changes in the doses of human exposure. In present study, Soil samples were collected from different locations of Karbala University Fariha site, the specific activity of natural radionuclides for soil samples were measured using gamma-ray spectroscopy with NaI(Tl) "3×3" detector. Moreover, Radiological hazard index in all samples such as (radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), representative level index ($I_{\gamma r}$), alpha index (I_{α}), Exposure rate ($\dot{x}$), absorbed dose rate in air (D_r), annual gonadal equivalent dose (AGED), annual effective dose equivalent outdoor, and excess lifetime cancer risk (ELCR)) were calculated. The results show that, the values of specific activity of ^{238}U, ^{232}Th and ^{40}K in Bq/kg were ranged from 10 to 23, from 2 to 12 and from 100 to 500 respectively. All results of radiological hazard index due to natural radioactivity within the acceptable level as indicated by UNSCEAR, OCDE and ICRP. Therefore, there is no significant radiological hazard in Karbala University- Fariha site.

Keywords: Natural Radioactivity; Radiological Hazard Index; Soil and Kerbala University

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Introduction

Radiation causes damage in living tissue by ionization of the atoms and molecules which make up the constituent cells. The process of ionization is one in which the bonds holding the constituent atoms of the molecules in tissue together are broken. These broken ionized fragments may be reformed but may also react with other molecules to form new reactive materials which may be harmful to the cell [1]. These ionizations result in the removal of electrons from the atoms, forming ions or charged atoms. The ions formed then can go on to react with other atoms in the cell, causing damage. In the right circumstance, these cells may become cancerous [2]. One particularly important molecule is deoxyribonucleic acid, DNA found mainly in the nucleus of the cell. DNA controls the structure and function of the cell. There are two ways in which this can happen. Radiation may ionize a DNA molecule leading directly to a chemical change, or the DNA may be changed indirectly when it interacts with a free hydroxyl radical produced in the water of the cell by radiation. In other cases, the chemical change can cause a harmful biological effect leading to the development of cancer or inherited genetic defects [3]. Exposure to ionizing radiation from radon is the second leading cause of lung cancer mortality in the United States. The Environmental Protection Agency calculates that radon is responsible for approximately 21,000 lung cancer deaths per year, and 2,900 of these deaths occur in patients who were never smokers [4]. In a risk analysis study that assessed 413 women with lung cancer and prolonged radon exposure in Iowa, the risk of development of lung cancer was directly proportional to the amount of radon exposure [3]. Natural radioactivity and associated external exposure due to gamma radiation depends mainly on the local geographical and geological conditions that appear on different levels in every region of the world. The rate of natural gamma dose ground is an important contributor to the medium dose that the world's population receives [4]. Therefore, knowledge of natural radioactivity of important soil evaluation of radiation risks. Natural radioactivity in the soil measurement is great importance too many researchers all over the world, which led to a worldwide national surveys 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 leak radioactive [5]. Many studies have been performed to investigate and measure the concentrations of radioactive elements in soil samples using scintillation detector NaI(Tl) in different locations in Iraq [6-9]. The purposes of the present work are detecting and measuring the specific activities of the radionuclides in soil samples from Kerbela university in Kerbela governorate using NaI(Tl) detector. Also, radium

equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index(H_{in}), representative level index ($I_{\gamma r}$), alpha index (I_{α}), Exposure rate (X˙) , absorbed dose rate in air (D_r), annual gonadal equivalent dose (AGED), annual effective dose equivalent outdoor, and excess lifetime cancer risk (ELCR) were calculated in all samples under study.

Materials and Methods

Sample Collection and Preparation

The sixteen soil samples were collected from different sites of Kerbala University (Fariha site) during November 2019 in order to estimate the specific activity ^{238}U, ^{232}Th and ^{40}K. The collected sample taken from random places as in the figure with depth of (10-15) cm (Figure 1). Table 1 shows the sampling locations at the study area.

In the advance of nuclear physics laboratory located in the Physics Department at faculty of Science, University of Kufa, the samples were crushed and dried. Some of these samples dried in an oven at 120°C for 60 min to ensure that any significant moisture was removed. After that a sieve with diameter holes 500 μm was used to obtain a homogeneous powder and then weighed by 0.750 kg each one. Then the samples were packed into 1 litre polyethylene plastic Marinelli beakers of constant volume to ensure geometric homogeneity around the detector. Plastic Marinelli beakers were sealed with a tape and stored for about one month before counting to allow secular equilibrium to be attained between ^{222}Rn and its parent ^{226}Ra in uranium chain [10]. After one month each sample was exposed to 4 hour, and all the steps required achieving the measurements of radioactivity for soil samples were carried out using low background gamma-ray detection system.

Table 1: Locations of the soil samples collected from different sits of Karbala University.

No.	Location name	Sample code	Coordinate
1	Behind the student's internal departments	U1	3235'33.49"N 4405'25.62"E
2	From behind science	U2	3235'47.31"N 4405'28.27"E
3	Near the Deanship of engineering	U3	3235'53.78"N 4405'24.07"E
4	Close to human education	U4	32035'51.75"N 4404'21.60"E
5	In front of human education	U5	3235'53.58"N 4405'22.69"E
6	In front of the electrical station	U6	3235'52.62"N 440545.72"E
7	Behind Islamic sciences	U7	3236'01.92"N 4405'20.14"E
8	In front of tourism sciences	U8	3236'05.83"N 4405'21.82"E
9	In front of the central library	U9	3236'10.57"N 4405'29.67"E
10	Left of the central library	U10	3236'13.73"N 4405'27.97"E
11	Near veterinary medicine	U11	3236'14.2"N 4405'30.31"E
12	Near the gate	U12	3236'15.31"N 4405'30.91"E
13	Close managements and economics	U13	3236'14.16"N 4405'11.78"E
14	Behind of the law	U14	3236'07.37"N 4405'26.44"E
15	Before the law	U15	3236'04.66"N 4405'24.06"E
16	Right of the law	U16	323603.49"N 4405'27.54"E

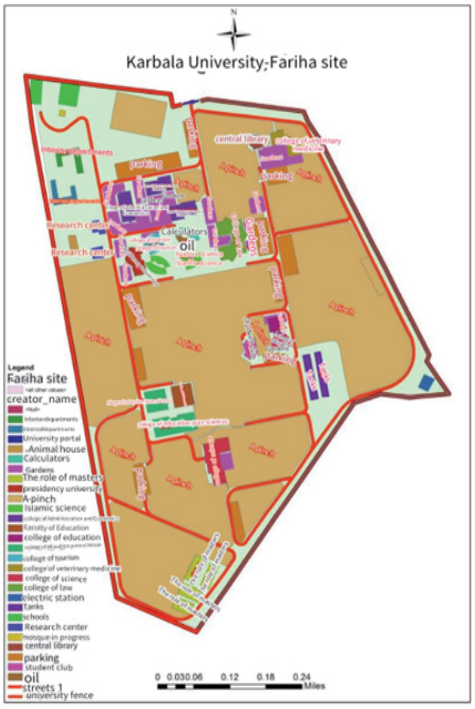

Figure 1: Map of area of study.

Experimental Setting and Measurements of Sample

The detection system used for this project consists of a sodium iodide detector NaI (Tl) system of (3"×3") crystal dimension and the supplier of the company (Alpha Spectra, Inc.-12I12/3) connected to an MCA (ORTEC-Digi Base) contains a 4096 channel connecting unit called ADC (Analogue to Digital Converter) through interface and high- voltage measurement reagent 0 to 1500V. The operating voltage of the detector is 787. The spectroscopic measurements and are analyzed by a computer program called (MAESTRO-32) software into the PC in the laboratory as it is linked to parts of the system measurements and analysis. The cylindrical shield of two layers, the upper one is composed of lead 5cm thick and 20cm long surrounding the crystal with a cover that is 5cm thick and has a diameter of 22cm. The lower part forms the base. It is used to reduce the background radiation that reaches the detector. The spectrometer was aligned for energy by obtaining a range from radioactive standard sources of known energies and gamma-ray. A set of radioactive sources with activities ^{137}Cs, ^{60}Co, ^{22}Na, ^{54}Mn and ^{152}Eu were used to be calibration sources. The background spectrum measured by using Empty (1L) polyethylene plastic Marinelli beakers on the detector and counting under the same time for the sample measurements. Because of the poor resolution of NaI(Tl) detector, at low gamma energies which haven't well-separated photo-peaks, thus the measuring of the activity concentrations is possible at a good separated photo- peaks at high energies as that obtained in our results from the gamma rays emitted by the progenies of ^{238}U and ^{232}Th which are in secular equilibrium with them while, ^{40}K was estimated directly by its gamma-line of 1460 keV. Hence the specific activities of ^{238}U were determined using the gamma-lines 1765 keV (214Bi). The corresponding results of ^{232}Th were determined using the gamma-ray lines 2614 keV (208Tl) [11].

Theoretical Equations

Specific Activity (A): The specific activity (activity concentration)

of the gamma emitting radionuclides in the sample can be calculated from the following equation (Al-Hamidawi 2014; Salman et al. 2019).

$$A\ \frac{Bq}{kg} = \frac{N}{I_\gamma\ \varepsilon\ M\ T}$$

A is the specific activity of the radionuclide in the sample, N is the net area under photo peak, Iγ is the probability of gamma decay, ε is the efficiency of the gamma-ray detector, M is the weight of the measured sample in Kg, and T is the live time for collecting the spectrum in seconds.

External Hazard Index (H_{ex})

The external hazard index for samples under investigation is given by the following equation [12].

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

A_U, A_{Th} and A_k are the specific activity of ^{238}U, ^{232}Th and ^{40}K, respectively.

Internal Hazard Index (H_{in})

Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index .It can be calculated according to the following equation.

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

Representative Level Index (Iγ)

$$I_{\gamma r} = \frac{1}{150}\ A_U + \frac{1}{100}\ A_{Th} + \frac{1}{1500}\ A_K$$

Radiation dangers due to the predetermined radionuclides of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K were evaluated by another file called representative level index (Iγr). The coming equation can be utilized to ascertain Iγr for soil samples under study [8].

Alpha Index (I_α)

Alpha index has been created to evaluate the excess alpha radiation because of the radon inhaled breath beginning from building materials. The alpha-index was resolved utilizing equation beneath [13].

$$I_\alpha = \frac{A_U}{200\ (\frac{Bq}{kg})}$$

Radium Equivalent Activity (Ra_{eq})

$$Ra_{eq}\ \frac{Bq}{kg} = A_U + 1.43\ A_{Th} + 0.077A_K$$

The radiological hazard associated with samples contained radionuclides, namely ^{238}U,^{232}Th, and ^{40}K, can be assessed using a common radiological index, called radium equivalent activity [13]. It can be expressed mathematically as:

Exposure Rate (ẋ)

$$X\ \frac{\mu R}{h} = 1.90\ A_U + 2.82\ A_{Th} + 0.197A_K$$

The gamma ray exposure rate in air, at 1 m above an infinitely extended and thick slab, due to ^{238}U, ^{232}Th series and ^{40}K uniformly distributed in the material, is given by [8]:

ẋ is the exposure rate (μR/h), the activity concentrations are given in pCi/g.

Absorbed Dose Rate in Air (D_r)

$$D_r\ \frac{nGy}{h} = 0.462\ A_U + 0.604\ A_{Th} + 0.0417A_K$$

The main contribution to the absorbed dose rate in the air comes from terrestrial gamma-ray radionuclides present in trace amounts in the soil. The measurements of dose rate depend on measurements of specific activity concentrations of radionuclides, mainly ^{238}U, ^{232}Th and ^{40}K. The UNSCEAR 2008 report explains that the absorbed dose rate in air 1 meter above the ground surface can be given by UNSCEAR [14].

Annual Gonadal Equivalent Dose (AGED)

The gonads are viewed as organs of intrigue. The yearly gonads identical portion [AGED] for the occupants in the study region because of the particular activities of ^{238}U, ^{232}Th and ^{40}K was determined using the following equation as [15]:

$$AGED\ (\frac{mSv}{y}) = 3.09\ A_U + 4.18\ A_{Th} + 0.314A_K$$

Annual Effective Dose Equivalent (AEDE)

The yearly successful portion equivalent (AEDE) can be determined from the consumed portion by applying the portion transformation factor of 0.7 (Sv/Gy) with an outside inhabitance factor of 0.2 [8].

$$AEDEoutdoor\ (\tfrac{mSv}{y}) = [D_r(mGy/hr) \times 8760\ hr \times 0.2 \times 0.7Sv/Gy] \times 10^{-6}$$

Excess Lifetime Cancer Risk (ELCR)

This gives the likelihood of creating cancer over a lifetime at a given exposure level, considering 70 years as the normal life-span for an individual. It is given as [12,13]:

$$ELCR = AEDE \times DL \times RF$$

AEDE is the Annual Effective Dose Equivalent in outdoor (AEDEoutdoor), DL is the normal Duration of Life (evaluated to be 70 years) and RF is the Risk Factor (Sv) for example lethal cancer hazard per Sievert. For stochastic impacts, ICRP utilizes RF as 0.05 for people in general.

Results and Discussion

The results of natural radioactivity of radionuclides ^{238}U, ^{232}Th, and ^{40}K were determined in selected soil samples from different locations of Karbala University- Fariha Site in Karbala governorate are listed in the below table (Table 2).

From the table 2, the specific activity of ^{238}U ranged from 3.0±0.358Bq/kg in sample U11 to 28.6±1.32 Bq/kg in sample U9. While, the specific activity of ^{232}Th varied from 2.8±0.21 Bq/kg in sample U11 to 10. ±0.49 Bq/kg in sample U9. In addition, the values of ^{40}K were ranged from 160 ±2.69 Bq/kg in sample U11 to 4^{40}.7±5.38 Bq/kg in sample U9. The values obtained for radium equivalent activity (Raeq), external hazard index (Hex), internal hazard index(Hin), representative level index (Iγr), alpha index (Iα), Exposure rate (ẋ), absorbed dose rate in air (Dr), annual gonadal equivalent dose (AGED), annual effective dose equivalent in outdoor (AEDEoutdoor) and excess lifetime cancer risk (ELCR) are presented in the below table (Table 3).

It can be seen from the table 3. The results of Raeq, Hex, Hin, Iγr, Iα, Dr, AGED, AEDEoutdoor, and ELCR were ranged 19.3-78.1, 0.052-0.211, 0.060-0.288, 0.155-0.593, 0.015- 0.143, 45.2-171.9, 9.8- 38.2, 71.3-

Table 2: Results of specific activity of ^{238}U, ^{232}Th and ^{40}K in present study.

No.	Sample code	Specific activity in Bq/kg					
		Uranium-238		Thorium-323		Potasium-40	
		Average	±S.D	Average	±S.D	Average	±S.D
1	U1	16.3	0.94	7.1	0.38	362.2	4.62
2	U2	8.6	0.66	8.4	0.39	310.8	4.09
3	U3	11.3	0.77	5.7	0.33	300.1	4.10
4	U4	7.7	0.59	3.2	0.23	274.2	3.64
5	U5	4.3	0.47	6.7	0.35	277.1	3.91
6	U6	7.3	0.60	9.8	0.42	247.3	3.66
7	U7	19.1	0.98	9.2	0.41	373.1	4.49
8	U8	16.1	0.94	10.8	0.47	394.7	4.86
9	U9	28.6	1.32	10.9	0.49	440.7	5.38
10	U10	8.7	0.68	7.3	0.38	241.3	3.72
11	U11	3.0	0.35	2.8	0.21	160.2	2.69
12	U12	8.2	0.72	3.1	0.27	303.5	4.54
13	U13	4.1	0.46	3.6	0.26	253.0	3.75
14	U14	11.3	0.77	6.5	0.35	332.2	4.35
15	U15	6.3	0.50	4.3	0.25	210.8	3.01
16	U16	8.7	0.68	6.9	0.37	286.4	4.06
Worldwide average		**33**		**45**		**420**	

Table 3: Results of radiological hazard index in present study.

No.	Sample code	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}	$I_{\gamma r}$	I_{α}	Exposure (μR/h)	Dr (nGy/h)	AGED (mSv/y)	$AEDE_{outdoor}$ (mSv/y)	$ELCR\times10^{-3}$
1	U1	54.3	0.147	0.191	0.421	0.0815	122.3	26.9	193.8	0.033	0.116
2	U2	44.5	0.120	0.144	0.349	0.043	101.3	22.0	159.3	0.027	0.094
3	U3	42.6	0.115	0.145	0.332	0.057	96.7	21.2	153.0	0.026	0.091
4	U4	33.4	0.090	0.111	0.266	0.039	77.7	16.9	123.3	0.021	0.073
5	U5	35.2	0.095	0.107	0.280	0.022	81.7	17.6	128.3	0.022	0.075
6	U6	40.4	0.109	0.129	0.312	0.037	90.2	19.6	141.2	0.024	0.084
7	U7	61.0	0.165	0.216	0.468	0.096	135.7	29.9	214.6	0.037	0.129
8	U8	61.9	0.167	0.211	0.478	0.081	138.8	30.4	218.8	0.037	0.131
9	U9	78.1	0.211	0.288	0.593	0.143	171.9	38.2	272.3	0.047	0.164
10	U10	37.7	0.102	0.125	0.292	0.044	84.7	18.5	133.2	0.023	0.079
11	U11	19.3	0.052	0.060	0.155	0.015	45.2	9.8	71.3	0.012	0.042
12	U12	36.0	0.097	0.119	0.288	0.041	84.1	18.3	133.6	0.022	0.079
13	U13	28.7	0.078	0.089	0.232	0.021	67.8	14.6	107.2	0.018	0.063
14	U14	46.2	0.125	0.155	0.362	0.057	105.2	23.0	166.4	0.028	0.099
15	U15	28.7	0.077	0.094	0.226	0.032	65.6	14.3	103.6	0.018	0.061
16	U16	40.6	0.110	0.133	0.318	0.044	92.4	20.1	145.7	0.025	0.086
Worldwide mean		**<370**	**<1**	**<1**	**<1**	**<1**	**------**	**57**	**≤ 300**	**0.08**	**------**

272.3, 0.012- 0.047 and 0.042×10-3 - 0.164×10-3 respectively. From the results for natural radioactivity in Table 2, it is found that the difference between values of ^{238}U, ^{232}Th, and ^{40}K. These differences are attributable due to soil type in this location which is sandy and clay soils. Also, it is found that the specific activity of uranium is higher than thorium in all samples. It is also observed that the measured specific activity of ^{40}K exceeds markedly the values of both uranium and thorium, as it is the most abundant radioactive element under concentration. The UNSCEAR 2008 recommended standard indicate that the world's mean specific activity of ^{238}U, ^{232}Th and ^{40}K are 33 Bq/kg, 45 Bq/kg and 420 Bq/kg respectively [14]. It was found that all values of ^{238}U specific activities were lower than the world's mean activity recommended by UNSCEAR 2008 (33 Bq/kg). Also, it is found all values of the specific activity of ^{232}Th were within the UNSCEAR 2008 report (45 Bq/kg). While, for ^{40}K, it is clear that the specific activities, with the exception of U11 samples, were only found to be higher than the worldwide mean according to UNSCEAR 2008 report (420 Bq/kg). The highest allowable concentration in region the soil in some samples because of the increase in the concentration of potassium nuclide in some areas of the reason is due to the existence of agricultural land and areas containing phosphate fertilizers, in which the focus increasingly peer-potassium (^{40}K). Also, the cause of high activity in some samples is the geological layer of the area [16]. All values of Raaq are still in the range of the permissible level which it is equal 370 Bq/kg (OECD 1979). The results of hazard indexes (Hex, Hin, Iγr and Iα) of all values for all samples studied in this work is less than one which is the maximum value of the permissible safety limit recommended [17]. The values of Dr were small than the value of the world means which it equal to (57 nGy/h) is according to UNSCEAR 2008 [14]. The annual gonadal equivalent dose values are lower than when compared with the world mean permissible limit of ≤300 mSv/y, as relates to radiation [15]. Since all values of AEDEoutdoor is lower than the corresponding worldwide values of 0.08 mSv/y (ICRP1993). According to these results, the values of ELCR are little therefore, it may be decided that the risk of cancer is negligible. When we compare the results of the values of natural radioactivity and radiological hazard which obtained from the current

study with the results recorded in different locations in Iraq, Karbala [18], Kurdistan [19], Baghdad [20] and Babylon [21], Najaf [22] and Missan [23]. The specific activities for ^{238}U and ^{232}Th in the present study are compatible with the values less than all these studies, but the specific activities for ^{40}K in the present study are compatible with the values higher than Karbala and Kurdistan are less than Baghdad, Babylon, Missan and Najaf [24-26].

Conclusion

The sixteen soil samples collected from different locations in university of Karbala-Fariha Site have been measured and analysed using gamma-ray spectrometry with NaI (Tl) detector. It is found that the most values of specific activities for these nuclides (^{238}U, ^{232}Th and ^{40}K) were less than the world-wide values for UNSCEAR. The relative increase in the specific activity of ^{40}K in the U9 sample may be attributed to chemical fertilization. Moreover, all values of the radiological hazard (of Raeq, Hex, Hin, Iγr, Iα, ẋ, Dr, AGED, AEDEoutdoor, and ELCR) were less than the average value of the world-wide (UNSCEAR, OCDE, and ICRP). Our gamma spectroscopic investigations allow us to confirm that soil samples in present study were safe. Also, there is no significant radiological hazard in Karbala university- Fariha Site.

References

1. Luckey TD (2019) Hormesis with ionizing radiation. CRC press, United Kingdom.
2. L'Annunziata MF (2016) Radioactivity: introduction and history, from the quantum to quarks. (2nd edtn), Elsevier, Netherlands.
3. Brown BH, Smallwood RH, Barber DC, Lawford PV, Hose DR (2017) Medical physics and biomedical engineering. Taylor & Francis, CRC Press, United Kingdom.
4. L'Annunziata MF (2012) Handbook of radioactivity analysis. (1st edtn), Academic press, Elsevier, United States.
5. Ojovan MI, Lee WE, Kalmykov SN (2019) An introduction to nuclear waste immobilisation. (3rd edtn), Elsevier, Netherlands.
6. Abojassim AA (2017) Estimation of human radiation exposure from natural radioactivity and radon concentrations in soil samples at green zone in Al-Najaf, Iraq. IJEE 8: 239-248.https://dx.doi.org/10.5829/ijee.2017.08.03.10
7. Yousif SA, Abojassim AA, Hayder A (2019) Mapping of natural radioactivity in soil samples of Badra oil field project using GIS program. Nucl Phys At Energy 20: 60-69. https://doi.org/10.15407/jnpae2019.01.060
8. Abojassim AA, Rasheed LH (2019) Mapping of terrestrial Gamma radiation in soil samples at Baghdad governorate (Karakh Side), using GIS technology. Nat Env & Poll Tech 18.
9. Majeed FA, Abojassim AA, Ali AM (2019) Radiological risk due to naturally occurring radioactive materials in the soil of Al-Samawah desert, Al-Muthanna Governorate, Iraq. Iran J Med Phys16: 323-328.https://dx.doi.org/10.22038/ijmp.2019.33154.1405
10. Abid Abojassim A, Hamad Al-Gazaly H, Sabah Obide E, Madlool Al-Jawdah A (2020) Radioactivity in samples of cleaning materials. Int J Environ An Ch 100: 99-108. https://doi.org/10.1080/03067319.2019.1631302
11. Aswood MS, Abojassim AA, Al Musawi MS (2019) Natural radioactivity measurements of frozen red meat samples consumed in Iraq. Rad Det Tech Methods3: 57.https://doi.org/10.1007/s41605-019-0136-9
12. Al-Hamidawi A (2014) Assessment of radiation hazard indices and excess life time cancer risk due to dust storm for Al-Najaf, Iraq. Wseas Trans Environ Dev 10: 312.
13. Abojassim AA, Oleiwi MH, Hassan M (2016) Natural radioactivity and radiological effects in soil samples of the main electrical stations at babylon governorate. Nucl Phys At Energy 17: 308-315.
14. United Nations Scientific Committee on the Effects of Atomic Radiation (2008) Sources and effects of ionizing radiation: Report to the general assembly, United States.
15. Okogbue C, Nweke M (2018) The ^{226}Ra, ^{232}Th and ^{40}K contents in the Abakalikibaked shale construction materials and their potential radiological risk to public health, south eastern Nigeria. J Environ Geol 2.
16. Tanasković I, Golobocanin D, Miljević N (2012) Multivariate statistical analysis of hydrochemical and radiological data of Serbian spa waters. J Geochem Explor 112: 226-234.https://doi.org/10.1016/j.gexplo.2011.08.014
17. Trevisi R, Risica S, D'alessandro M, Paradiso D, Nuccetelli C (2012) Natural radioactivity in building materials in the European Union: a database and an estimate of radiological significance. J Environ Radioact 105: 11-20.https://doi.org/10.1016/j.jenvrad.2011.10.001
18. Kadhim IH, Muttaleb MK (2016) Measurement of radioactive nuclides present in soil samples of district Touirij of Karbala province for radiation safety purposes. Int J Chem Tech Res 9: 228-235.
19. Yousuf RM, Abullah KO (2013) Measurement of natural radioactivity in soil collected from the Eastern of Sulaimany Governorate in Kurdistan-region, Iraq. ARPN J Sci Technol 3: 749-757.
20. Tawfiq NF, Mansour HL, Karim MS (2015) Natural radioactivity in soil samples for selected regions in Baghdad governorate. Int J Curr Res Rev 8: 1-7.
21. Hatif KH, Muttaleb MK (2015) Natural Radioactivity level and the measurement of soil gas Radon ,Thoron concentrations inHilla city. J KerbalaUniv Scient 13: 20-25.
22. Jaffer MA (2013) Measurement of natural radiation levels around uranium mine in Al-Najaf Al-Ashraf Governorate, University of Kufa. Iraq.
23. Jassim AZ, Al-Gazaly HH, Abojassim AA (2016) Natural radioactivity levels in soil samples for some locations of Missan government, Iraq. JEnviron Sci Pollut Res 2: 39-41.
24. International Commission on Radiological Protection (1993) Publication 65. Annals of the ICRP 23, Pergamon Press, United Kingdom.
25. Nuclear Energy Agency (1979) Exposure to radiation from the natural radioactivity in building materials: report. OECD, France.
26. Salman AY, Ahmed AQ, Kadhim SA, Abojassim AA (2019) Measurement of radiation contamination by ^{226}Ra, ^{232}Th and ^{40}K in different types of rice implanted in Iraq. Ann. Agri Bio Res 24: 289-293.