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NORM in soil of some locations in Baghdad governorate, Iraq

Ali Abid Abojassim and Leith Hani Rasheed

Department of Physics, Faculty of Science, University of Kufa, Najaf, Iraq

Abstract
In this study, ^{238}U, ^{232}Th and ^{40}K were measured in the soil samples for some locations in the Rasafa Side of Baghdad Governorate. The study was carried out using gamma ray spectroscopy NaI(Tl) with "3x3" crystal. Thirty eight regain were selected randomly from study area, from 1/11/2018 to 1/1/2019. The results showed that, the specific activity of ^{235}U, ^{238}U, ^{232}Th and ^{40}K were ranged from (0.456 to 1.510) Bq/kg, (9.89±0.61 to 32.77±0.39) Bq/kg, (5.79±0.23 to 14.46±0.37) Bq/kg, (204.16±2.38) to (529.48±3.83) Bq/kg respectively. After measured the specific activity, we found radiological hazard index the mean radium equivalent activity (Raeq), external hazard index (Hex), internal hazard index (Hin), representative level index (Iγr), alpha index (Iα) were (25.64 to 77.11) Bq/kg, (0.069 to 0.208), (0.111 to 0.232), (0.175 to 0.592), (0.049 to 0.164) respectively. In addition, the mean Exposure rate ($\dot{X}$), absorbed dose rate in air (Dr,), annual gonadal equivalent dose (AGED), annual effective dose equivalent indoor, outdoor and total(AEDEindoor, AEDEoutdoor, AEDEtotal) and excess lifetime cancer risk (ELCR)) were (2.35 to 4.94)μR/h , (0.284 to 38.06)nGy/h , (143.10 to 301.52)mSv/y , (0.056 to 0.187) mSv/y, (0.014 to 0.047)mSv/y , (0.070 to 0.234)mSv/y , (0.246 to 0.817) respectively. The results indicate that across the area the effective dose from terrestrial gamma radiation is everywhere within the acceptable level according to UNSCEAR, OCDE and ICRP, so there is no risk of propels that life in area under study.

Keywords: Natural radioactivity; Radiological hazard index; Gamma ray spectroscopy; Soil; Baghdad governorate.

1. Introduction

Human beings are exposed to ionizing radiation from natural sources throughout their lifetime, and sometime from man-made sources Therefore, the knowledge of radionuclide distribution and radiation levels in the environment are important for assessing the effects of radiation exposure due to both terrestrial and cosmologic sources. Terrestrial background radiation represents the main external source of irradiation of the human body. Human beings are exposed also naturally from sources outside their bodies; mainly cosmic rays and gamma ray emitters in soil, building materials, water, food and air [1]. The study of natural radioactivity is important because naturally occurring radioactive materials (NORM) can served as good biochemical and geochemical tracers in environment in case of geological events such as earthquakes and eruptions volcanic [2]. It is well known that even if a small amount of these radionuclides due to the gamma ray exposure of the body and irradiation of lung tissues from inhalation of radon and its daughters the biological effects harmful is produce [3]. So is necessary to know the dose limits of exposure to measure the level of radiation provided by land, air, water, food, building and etc., to estimate exposure and protection of human and natural sources of radiation [4, 5]. Since soil is one of the main contributors to background radiation, it is very interest to know the radioactivity content of the soil over the world, natural radioactivity in the mainly soil comes from the ^{238}U, ^{232}Th series and ^{40}K during creation the earth [5, 6]. According to the foregoing, the need has arisen to study the radiation effect, detection mechanisms and to know the extent of environment pollution. Therefore, several studies and research have been conducted, many techniques for calculating radioactive concentration, in soil, water, air, building materials, food and plants have been introduced too. Also, to determine the effect of radioactive substances existed in those above –mentioned materials on living beings [7]. The justification for this action is the following**;** Baghdad is the capital of Iraq as well as it is very densely populated, the absence of previous studies covering this number of residential areas, as well as no study covering the risk factors to this extent in previous studies, it was subjected to military bombardments as well as to many blast and absence of a radiation map for the province of Baghdad and there is no national number of levels allowed for Iraq, like the rest of the Arab world and the world. Measurements of the natural radiation levels due to ^{238}U, ^{232}Th and ^{40}K in soil were investigated by several studies using different techniques like gamma spectroscopy. In this part of our study, it is review some of the previous studies that focused on gamma spectroscopy techniques in Iraq and other countries in the world [8-13]. Overall aim of this study is to measure the natural radioactivity in samples of soil for some locations in the Rasafa Side from Baghdad Governorate in Iraq using gamma-ray spectroscopy with NaI(Tl) "3×3" detector in low-background. Also, there are many objective can be found in the study such as determine specific activity of ^{238}U, ^{232}Th, ^{40}K and ^{235}U in soil samples under study, estimate ten radiological hazard parameters which include:(Radium Equivalent Activity(Ra_{eq}), Absorbed Gamma Dose Rate ($D\gamma$), external hazard index(H_{ext}), internal hazard index(H_{int}), Representative gamma index ($I_{\gamma r}$),Annual effective dose equivalent (AEDE) which include indoor and outdoor effective dose rate, and ELCR) in all samples under studies and the results have been compared with the limits of international recommended values of safety standards.

2. Material and method

2.1 Collection and preparation of samples

The 38 soil samples were collected from different sites of Baghdad governorate (Rasafa side) during October and November 2018 at a depth of (10-15) cm from the ground surface in order to estimate the specific activity and radiological hazard index of ^{238}U, ^{232}Th families and ^{40}K. The samples locations were determined of coordinates by "Global Positioning System." GPS is a satellite navigation system used to determine the ground position of an object. By: GARMIN, Model: 010-00779-00, Sku:ETREXLEGEND (2017). The sample codes, locations, and coordinates are shown in Table 1.

The collected samples were transferred to labeled closed polyethylene bags and taken to the laboratory of radiation detection and measurement in the physics department, faculty of science, university of Kufa. The samples are prepared for analysis by drying, and keeping them moisture-free by putting them for 60 minute in an oven at 100˚C to ensure that moisture is completely removed. It was mechanically crushed using electric mill of micro soil grinded to reach a suitable homogeneity. Next, the samples were sieved through of 500µm pore size diameter sieve to get homogeneity. To remove the air completely from the sample the latter is pressed on by the light cap of the Marinelli beaker the respective net weights were measured and recorded with a high sensitive digital weighting balance with a percent of ±0.01%. After that about (1kg) of each sample was then packed in a standard Marinelli beaker, that was hermetically sealed and dry weighted to get homogeneity. Before use, the containers were washed with dilute hydrochloric acid and rinsed with water. All samples were 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, each sample was placed in face to face geometry over the detector for a long time measurement.

Table 1. Locations of samples.

No.	Location name	Sample code	Coordinates	
1	AL-Rassa	S1	33 21 25.6	44 31 06.4
2	AL-Ubaidi	S2	33 22 05.4	44 31 29.0
3	Maghreb	S3	33 22 02.2	44 22 40.8
4	Tahrir Square	S4	33 19 45.9	44 24 39.2
5	Tuwaitha (Ishtar)	S5	33 11 32.9	44 31 57.2
6	AL-Husseinia	S6	33 32 34.2	44 23 33.9
7	Al-Nasr	S7	33 23 57.5	44 32 07.4
8	Al Baiueia	S8	33 26 05.2	44 32 30.0
9	Algeria	S9	33 25 20.2	44 23 15.2
10	Al Sa'adah	S10	33 29 05.0	44 31 36.2
11	Al Tugaer	S11	33 24 15.8	44 23 44.8
12	Qahira	S12	33 22 27.9	44 23 20.9
13	Nahrawan	S13	33 22 28.8	44 41 11.4
14	Pasmaya(Alf Dar)	S14	33 10 01.2	44 36 53.3
15	Jadrayah	S15	33 16 20.2	44 23 07.9
16	Falastin St	S16	33 22 19.8	44 24 30.2
17	Talbiyah	S17	33 23 15.4	44 24 47.7
18	Ur	S18	33 24 32.8	44 25 11.8
19	End of Sadr City	S19	33 24 40.7	44 26 31.5
20	Hamidiayh	S20	33 25 53.3	44 28 21.0
21	First inside	S21	33 21 37.1	44 26 18.7
22	Suleikh	S22	33 23 25.8	44 22 42.8
23	Adamiyah	S23	33 23 17.0	44 21 52.1
24	Ghereiat	S24	33 23 37.7	44 20 50.2
25	Al-Kasrah	S25	33 21 26.1	44 22 37.9
26	Fellah street	S26	33 22 49.8	44 27 23.4
27	Khanas	S27	33 21 07.2	44 27 56.2
28	7 Th Nisan	S28	33 20 28.5	44 28 41.7
29	Amin	S29	33 19 06.5	44 30 50.5
30	Tal Muhammad	S30	33 18 38.8	44 28 06.0
31	AL-Zafraniya	S31	33 15 32.8	44 30 30.2
32	Zayouna	S32	33 19 16.6	44 27 09.1
33	Kamaliyah	S33	33 20 52.0	44 31 03.4
34	AL-Shuhadaa	S34	33 22 43.0	44 30 53.2
35	AL-wazireya	S35	33 21 41.2	44 23 19.2
36	Andalus Sq.	S36	33 18 53,5	44 25 16.2
37	Jurf Naddaf	S37	33 12 12.6	44 32 10.7
38	Al Tuwaitha Nuclear Center	S38	33 12 18.4	44 31 04.8

2.2 Gamma-Ray spectrometer

Gamma-ray spectrometer consists of a scintillation detector NaI (Tl) system of (3"×3") crystal dimension and the supplier of the company (Alpha Spectra, Inc.-12I12/3) coupled with a multi-channel analyzer (MCA) (ORTEC -Digi Base) that contains a 4096 channel connecting unit called ADC (Analog to Digital Convertor) through interface. 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 voltages used in the research is 787 volts which is within the range of stability of the operating voltage of the detector and was equipped with voltages of type. The spectrometer was calibrated for energy by acquiring a spectrum from radioactive standard sources of known energies and gamma-ray. A ^{137}Cs, ^{54}Mn, ^{60}Co, ^{22}Na and ^{152}Eu radioactive sources were used to be calibration sources. The relationship between gamma energy and number of channel was obtained and it showed a straight line with excellent correlation (0.99). Energy resolution in present study of a detector was 7.9%, for the energy of 661.66 keV of ^{137}Cs standard source, while it normally 5-10% for NaI(Tl) detectors for the ^{137}Cs 0.662 MeV gamma [14]. The relationship between the absolute photo-peak detector efficiency with gamma-ray energy was calibrated using five sources: ^{137}C, ^{60}Co, ^{22}Na, ^{54}Mn and ^{152}Eu was obtained and it showed a straight line with excellent correlation (0.98).

2.3 Gamma radiation measurement

The net area under the corresponding photo peaks is calculated in the energy spectrum by subtracting count due to background sources from the net area of a certain peak by using MAESTRO-32 data analysis package. The background spectrum measured by using capacity empty (1L) polyethylene plastic Marinelli. Because of the poor resolution of NaI (TI) detector, at low gamma energies which haven't well-separated photo-peaks, beakers on the detector and counting at the same time for the sample measurements [14]. Thus, the measuring of the Specific activity (Bq/kg) activity concentrations is possible at well-separated photo-peaks at high energies as that obtained in our results from the gamma rays emitted by the progenies of (^{232}Th) and (^{238}U), which are in secular equilibrium with them while (^{40}K) was estimated directly by its gamma-line of 1460 keV. Hence, the specific activity of (^{238}U) was determined using the gamma-lines 1765 keV (^{214}Bi). Similar results have been calculated of (^{232}Th) were identified using the gamma-ray lines 2614 keV (^{208}Ti) [15].

3. Calculations

- Specific Activity (A): The specific activity (activity concentration) of the gamma emitting radionuclides in the sample can be calculated from the following equation [16, 17]:

$$A\left(\tfrac{Bq}{kg}\right) = \frac{N}{I_\gamma \times \varepsilon \times M \times T} \tag{1}$$

where A is the specific activity of the radionuclide in the sample, N is the net area under photo peak, I_γ 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. But, to calculate specific activity of ^{235}U by [17, 18]:

$$A_{^{235}U} = \frac{A_U}{21.7} \tag{2}$$

- External hazard index (H_{ex}): The external hazard index for samples under investigation is given by the following equation [18]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{3}$$

where 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 [20]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{4}$$

- Representative Level Index (I_γ): Radiation hazards due to the specified radionuclides of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K were assessed by another index called representative level index, ($I_{\gamma r}$), The following equation can be used to calculate $I_{\gamma r}$ for soil samples under study [17].

$$I_{\gamma r} = \left(\frac{1}{150}\right)A_U + \left(\frac{1}{100}\right)A_{Th} + \left(\frac{1}{1500}\right)A_K \tag{5}$$

- Alpha index (Iα): Alpha index have been developed to assess the excess alpha radiation due to the radon inhalation originating from building materials. The alpha-indexes were determined using Equation below [21]:

$$I_\alpha = \frac{A_U}{200(\frac{Bq}{kg})} \tag{6}$$

- Radium Equivalent Activity (Ra_{eq}): 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 [22]. It can be expressed mathematically as:

$$Ra_{eq}\left(\frac{Bq}{kg}\right) = A_U + 1.43A_{Th} + 0.077A_K \tag{7}$$

- Exposure rate ($\dot{X}$): 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 [23, 24]:

$$\dot{X}\left(\frac{\mu R}{h}\right) = 1.9A_U + 2.82A_{Th} + 0.197A_K \tag{8}$$

where $\dot{X}$ is the exposure rate (μR/h), the activity concentrations are given in pCi/g. The constants on the right-hand side of Equation 3 are related to the mean gamma ray energies for each radionuclide or series.

- Absorbed Dose Rate in Air (D_r): 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 [25]:

$$D_r\left(\frac{nGy}{h}\right) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \tag{9}$$

- Annual gonadal equivalent dose (AGED): According to UNSCEAR [28], the gonads is considered organs of interest. However, the annual gonadal equivalent dose [AGED] for the residents in the study area due to the specific activities of ^{238}U, ^{232}Th and ^{40}K was calculated using Equation 5 given by Arafa [26, 27] as:

$$AGED\left(\frac{mSv}{y}\right) = 3.09A_U + 4.18A_{Th} + 0.314A_K \tag{10}$$

- Annual Effective Dose Equivalent (AEDE): The annual effective dose equivalent (AEDE) can be calculated from the absorbed dose by applying the dose conversion factor of 0.7 (Sv/Gy) with an outdoor occupancy factor of 0.2 and 0.8 for indoor UNSCEAR, 1993 and 2000 [28, 29]

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right) = [D_r(mGy/hr) \times 8760hr \times 0.2 \times 0.7Sv/Gy] \times 10^{-6} \tag{11}$$

$$AEDE_{indoor}\left(\frac{mSv}{y}\right) = [D_r(mGy/hr) \times 8760hr \times 0.8 \times 0.7Sv/Gy] \times 10^{-6} \tag{12}$$

- Excess Lifetime Cancer Risk (ELCR): This gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the mean duration of life for human being. It is given as [16, 22]:

$$ELCR = AEDE \times DL \times RF \tag{13}$$

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where AEDE is the total of Annual Effective Dose Equivalent ($AEDE_{outdoor}$ + $AEDE_{indoor}$), DL is the mean Duration of Life (estimated to be 70 years) and RF is the Risk Factor (Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

4. Results and discussion

4.1 The specific activity

The specific activities of radionuclides ^{238}U, ^{232}Th, ^{40}K and ^{235}U were measured in selected soil samples from different locations of Rasafa side from Baghdad governorate are listed in Table 2. From table 2, the specific activity of ^{238}U ranged from 0.33±0.58 Bq/kg in sample R18 to 32.77±0.39 Bq/kg in sample R38 with the mean value of 17.42±0.95 Bq/kg. However, the specific activity of ^{232}Th varied from 1.38±0.12 Bq/kg in sample R3 to 14.76±0.37 Bq/kg in sample R61 with the mean value of 9.08±0.33 Bq/kg. In addition, the values of ^{40}K were 147.54±2.18 Bq/kg in sample R25and 1695.34±7.39 Bq/kg in sample R3 with the mean value of 381.26±22.009, while for ^{235}U were ranged (0.015-1.510) Bq/kg with the mean value of 0.80±0.044.
From results for natural radioactivity in Table 2, it is found that the difference between values of ^{238}U, ^{232}Th, ^{40}K and ^{235}U. 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 worlds mean specific activity of ^{238}U, ^{232}Th and ^{40}K are 33 Bq/kg, 45 Bq/kg and 420 Bq/kg respectively [30]. It was found that all values of ^{238}U specific activities were lower than the worlds mean activity that recommended by UNSCEAR 2008. Also, it is found all values of specific activity of ^{232}Th were within the UNSCEAR 2008 report. While, for ^{40}K, it is clear that the specific activities, with the exception of S2, S4, S9, S15, S20, S22, S23, S30, S31, S35, S36 and S37 samples were only found to be higher than worldwide mean. 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 [31].

4.2 Radiological effects

The values obtained for radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), representative level index ($I_{\gamma r}$) and alpha index (I_{α}) are presented in Table (3). As can be seen from Table 3., The results of Ra_{eq}, H_{ex}, H_{in}, $I_{\gamma r}$ and I_{α} were ranged from 0.043 to 0.379 with an mean value of 0.121±0.005, from 0.044 to 0.401 with an mean 0.168±0.006, from 0.132 to 1.197 with an mean 0.333±0.017 and from 0.002 to 0.164 with an mean 0.087±0.004 respectively. All values of Ra_{aq} is still in the range of the permissible level which it is equal 370 Bq/kg [32]. The results of hazard indexes (H_{ex}, H_{in}, $I_{\gamma r}$ and I_{α}) 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 [33].
The results of Exposure rate ($\dot{X}$), absorbed dose rate in air (D_r,), annual gonadal equivalent dose (AGED), annual effective dose equivalent indoor, outdoor and total($AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$), excess lifetime cancer risk (ELCR) were listed in Table 4. The $\dot{X}$ is the maximum values in sample R3 8.72μR/h and the minimum values in sample R18 0.96μR/h , with mean value of 0.087±0.004 μR/h. The results of D_r ranges from 0.284 nGy/h to 75.22 nGy/h with mean value of 21.19±1.14nGy/h. The values of D_r were small than the value of the world mean which it is equal to (55 nGy/h) according to UNSCEAR 2000 [21]. The values of AGED as shown in Table (4) are ranged from 60.79 mSv/y to 562.79mSv/y with mean 211.53±8.35mSv/y. The annual gonadal equivalent dose values are lower than when compared with the world mean permissible limit of ≤ 300 mSv/y(expect sample S31), as relates to radiation [34]. The calculated values of $AEDE_{indoor}$, $AEDE_{outdoor}$ and $AEDE_{total}$ in this study were ranged from 0.040 mSv/y to 0.369mSv/y, with mean 0.105±0.005mSv/y, from 0.010mSv/y to 0.092mSv/y with mean 0.026±0.001 mSv/y and from 0.050 mSv/y to 0.462mSv/y with mean 0.131±0.006mSv/y respectively. Since all values of $AEDE_{indoor}$, $AEDE_{outdoor}$ and $AEDE_{total}$ are lower than the corresponding worldwide values of 0.42, 0.08 and 0.50 mSv/y respectively [35]. The calculated Excess lifetime cancer risk of this location are shown in table 4. These values vary from 0.176×10^{-3} to 1.615×10^{-3} with mean $0.461\pm0.023\times10^{-3}$. According to these results, the values of ELCR are little therefore, it may be decided that the risk of cancer is negligible.

Table 2. Results of natural radioactivity.

No.	Sample Code	Specific activity Bq/kg			
		U^{238}	Th^{232}	K^{40}	U^{235}
1	S1	9.89±0.61	9.32±0.32	234.35±2.75	0.456
2	S2	11.95±0.56	10.58±0.34	453.55±3.82	0.551
3	S3	17.52±0.40	9.07±0.31	319.49±3.21	0.807
4	S4	27.59±0.47	8.83±0.31	479.13±3.93	1.271
5	S5	15.26±0.14	12.92±0.38	379.38±3.50	0.703
6	S6	25.91±0.57	10.65±0.32	415.81±3.40	1.194
7	S7	25.17±0.36	10.33±0.31	415.76±3.40	1.160
8	S8	32.77±0.39	11.69±0.33	361.37±3.17	1.510
9	S9	22.83±0.10	11.36±0.33	430.50±3.46	1.052
10	S10	13.10±0.52	11.09±0.32	359.20±3.16	0.604
11	S11	18.50±0.53	7.27±0.26	335.79±3.05	0.853
12	S12	16.38±0.53	8.84±0.29	398.15±3.32	0.755
13	S13	23.42±0.76	9.61±0.30	319.16±2.98	1.079
14	S14	24.69±0.78	11.52±0.33	380.63±3.25	1.138
15	S15	21.10±0.77	14.46±0.37	448.19±3.53	0.972
16	S16	27.67±0.57	11.02±0.32	394.71±3.31	1.275
17	S17	23.29±0.45	11.27±0.33	400.96±3.34	1.073
18	S18	23.03±0.75	5.79±0.23	204.16±2.38	1.061
19	S19	21.53±0.66	10.48±0.31	377.05±3.24	0.992
20	S20	16.87±0.78	11.26±0.33	441.44±3.51	0.777
21	S21	15.34±0.80	7.05±0.26	284.90±2.81	0.707
22	S22	24.77±0.65	8.25±0.28	529.48±3.83	1.141
23	S23	24.97±0.54	12.26±0.34	498.61±3.72	1.151
24	S24	27.85±0.60	11.06±0.32	400.18±3.33	1.283
25	S25	19.80±0.72	7.69±0.27	311.69±2.94	0.912
26	S26	16.05±0.91	7.94±0.27	356.34±3.15	0.740
27	S27	22.60±0.75	11.61±0.33	396.99±3.32	1.041
28	S28	22.52±0.67	10.08±0.31	416.51±3.40	1.038
29	S29	21.61±0.87	10.13±0.31	408.21±3.37	0.996
30	S30	25.76±0.62	11.93±0.34	442.27±3.50	1.187
31	S31	32.18±0.67	14.76±0.37	447.10±3.52	1.483
32	S32	29.20±0.81	13.22±0.35	434.61±3.47	1.346
33	S33	20.18±0.80	11.17±0.32	418.89±3.41	0.930
34	S34	23.21±0.91	9.21±0.29	307.50±2.92	1.070
35	S35	24.49±0.76	10.92±0.32	492.53±3.70	1.129
36	S36	22.14±0.58	12.18±0.34	422.42±3.42	1.020
37	S37	25.45±0.69	11.34±0.33	434.28±3.47	1.173
38	S38	30.32±0.65	8.58±0.28	414.42±3.39	1.397
Mean ± S.E		22.28±0.87	10.44±0.31	393.83±11.15	1.02±0.04
Worldwide mean [30]		33	45	420	---------

Table 3. Results of Ra_{eq}, H_{ex}, H_{in}, $I_{\gamma r}$ and I_{α}.

No.	Sample code	Ra eq (Bq/kg)	H_{ex}	H_{in}	I_{γ}	I_{α}
1	S1	41.26	0.111	0.138	0.315	0.049
2	S2	62.00	0.167	0.200	0.488	0.060
3	S3	55.09	0.149	0.196	0.420	0.088
4	S4	77.11	0.208	0.283	0.592	0.138
5	S5	62.95	0.170	0.211	0.484	0.076
6	S6	41.40	0.112	0.182	0.282	0.130
7	S7	40.20	0.109	0.177	0.273	0.126
8	S8	49.73	0.134	0.223	0.337	0.164
9	S9	39.34	0.106	0.168	0.268	0.114
10	S10	29.20	0.079	0.114	0.200	0.066
11	S11	29.13	0.079	0.129	0.198	0.093
12	S12	29.28	0.079	0.123	0.200	0.082
13	S13	37.39	0.101	0.164	0.254	0.117
14	S14	41.41	0.112	0.179	0.282	0.123
15	S15	42.05	0.114	0.171	0.288	0.106
16	S16	43.68	0.118	0.193	0.297	0.138
17	S17	39.66	0.107	0.170	0.270	0.116
18	S18	31.49	0.085	0.147	0.213	0.115
19	S19	36.77	0.099	0.158	0.250	0.108
20	S20	33.24	0.090	0.135	0.227	0.084
21	S21	25.64	0.069	0.111	0.175	0.077
22	S22	36.86	0.100	0.167	0.250	0.124
23	S23	42.79	0.116	0.183	0.292	0.125
24	S24	43.92	0.119	0.194	0.298	0.139
25	S25	31.02	0.084	0.137	0.211	0.099
26	S26	27.65	0.075	0.118	0.189	0.080
27	S27	39.46	0.107	0.168	0.269	0.113
28	S28	37.20	0.100	0.161	0.253	0.113
29	S29	36.36	0.098	0.157	0.248	0.108
30	S30	43.09	0.116	0.186	0.293	0.129
31	S31	53.56	0.145	0.232	0.364	0.161
32	S32	48.37	0.131	0.210	0.329	0.146
33	S33	36.42	0.098	0.153	0.249	0.101
34	S34	36.61	0.099	0.162	0.249	0.116
35	S35	40.39	0.109	0.175	0.275	0.122
36	S36	39.82	0.108	0.167	0.272	0.111
37	S37	41.93	0.113	0.182	0.285	0.127
38	S38	42.85	0.116	0.198	0.290	0.152
Mean ± S.E.		41.21±1.67	0.111±0.004	0.171±0.005	0.287±0.013	0.111±0.004
Worldwide mean		<370[32]	<1[33]	<1[33]	<1[33]	<1[33]

Table 4. Results of $\dot{X}$, D_r, AGED, $AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$ and ELCR.

No.	Sample code	Exposure (μR/h)	D_r (nGy/h)	AGED (mSv/y)	$AEDE_{indoor}$ (mSv/y)	$AEDE_{outdoor}$ (mSv/y)	AEDE (mSv/y)	ELCR×10^{-3}
1	S1	2.35	19.97	143.10	0.098	0.025	0.123	0.429
2	S2	3.61	30.82	223.56	0.151	0.038	0.189	0.662
3	S3	3.14	26.90	192.37	0.132	0.033	0.165	0.578
4	S4	4.41	38.06	272.61	0.187	0.047	0.234	0.817
5	S5	3.60	30.67	220.28	0.151	0.038	0.188	0.659
6	S6	4.15	18.54	255.14	0.091	0.023	0.114	0.398
7	S7	4.09	18.01	251.50	0.088	0.022	0.111	0.387
8	S8	4.32	22.33	263.59	0.110	0.027	0.137	0.480
9	S9	4.12	17.55	253.21	0.086	0.022	0.108	0.377
10	S10	3.26	12.88	199.62	0.063	0.016	0.079	0.277
11	S11	3.13	13.07	192.99	0.064	0.016	0.080	0.281
12	S12	3.44	13.05	212.58	0.064	0.016	0.080	0.280
13	S13	3.48	16.75	212.75	0.082	0.021	0.103	0.360
14	S14	3.99	18.50	243.96	0.091	0.023	0.114	0.397
15	S15	4.35	0.284	266.37	0.091	0.023	0.114	0.400
16	S16	4.17	19.58	255.50	0.096	0.024	0.120	0.420
17	S17	3.99	17.71	244.98	0.087	0.022	0.109	0.380
18	S18	2.61	14.24	159.47	0.070	0.017	0.087	0.306
19	S19	3.73	16.41	228.73	0.081	0.020	0.101	0.352
20	S20	3.86	14.74	237.81	0.072	0.018	0.090	0.317
21	S21	2.70	11.46	166.33	0.056	0.014	0.070	0.246
22	S22	4.46	16.59	277.28	0.081	0.020	0.102	0.356
23	S23	4.63	19.10	284.97	0.094	0.023	0.117	0.410
24	S24	4.21	19.69	257.94	0.097	0.024	0.121	0.423
25	S25	3.11	13.91	191.20	0.068	0.017	0.085	0.299
26	S26	3.15	12.34	194.67	0.061	0.015	0.076	0.265
27	S27	3.97	17.59	243.02	0.086	0.022	0.108	0.378
28	S28	3.94	16.63	242.51	0.082	0.020	0.102	0.357
29	S29	3.86	16.24	237.30	0.080	0.020	0.100	0.349
30	S30	4.37	19.25	268.34	0.095	0.024	0.118	0.413
31	S31	4.94	23.93	301.52	0.117	0.029	0.147	0.514
32	S32	4.61	21.62	281.96	0.106	0.027	0.133	0.464
33	S33	3.91	16.21	240.58	0.080	0.020	0.099	0.348
34	S34	3.38	16.41	206.77	0.081	0.020	0.101	0.352
35	S35	4.47	18.06	275.97	0.089	0.022	0.111	0.388
36	S36	4.11	17.73	251.96	0.087	0.022	0.109	0.381
37	S37	4.27	18.75	262.41	0.092	0.023	0.115	0.403
38	S38	4.22	19.33	259.68	0.095	0.024	0.119	0.415
Mean ± S.E.		3.84±0.09	18.28±1.006	236.17±5.97	0.092±0.004	0.023±0.001	0.115±0.005	0.40±0.018
Worldwide mean		--------	55[21]	≤ 300 [34]	0.42 [35]	0.08 [35]	0.50 [35]	--------

Mean value of specific activity for (^{238}U, ^{235}U, ^{232}Th and ^{40}K) in all locations Baghdad Government (Rasafa side), Iraq were lower than the worlds mean according to UNSCEAR 2008. As well as, the radiological effects were found is still within normal limits and below the action level according to UNSCEAR, OCDE and ICRP.

4.3 Comparison of results

When we compare the results of the mean specific activity for ^{238}U, ^{232}Th and ^{40}k which obtained from the current study with the results recorded in different countries, it is found that the means of the specific activities for ^{238}U are higher than Saudi Arabia, Libya and Kuwait, but lower than the values recorded in Thailand, Malaysia, Jordan, Egypt, Iran and Qatar as shown in Table 5. The means of the specific activities for ^{232}Th in the current study are less than the values determined in Thailand, Malaysia, Jordan, Egypt, Iran, Kuwait and Saudi Arabia illustrated in Table 5. The mean of the specific activities for ^{40}K in this study were lower than Saudi Arabia, Egypt, Iran, Kuwait and Thailand and higher from Malaysia, Jordan, Libya and Qatar as shown in Table 5. The decrease or increase of the recorded values is due to several factors such as soil type, the geological nature of the area, the region selected (agricultural or industrial) or may be exposed to other external factors. The results of the mean values of the specific activities for ^{238}U, ^{232}Th and ^{40}k in this study are also comparable with the governorates and with values obtained from the same governorate. As shown in Table 6, the mean specific activities for ^{238} U in the present study are compatible with the values less than Karbala, Kurdistan, Missan and Najaf are higher than Baghdad and Babylon. The mean value of the specific activities for ^{232}Th are lower than Karbala, Kurdistan Baghdad and Babylon and very close form the recorded value in Missan and Najaf. Finally, 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.

Table 5. Comparison of the present study results in soil with different countries.

NO.	Country	Specific activity in Bq/kg			Reference
		^{238}U	^{232}Th	^{40}K	
1	Qatar	25.5	7.7	165.8	[36]
2	Jordan	49	70	291	[37]
3	Kuwait	3.82	11.27	384.47	[38]
4	Saudi Arabia	14.22	14	968.19	[39]
5	Malaysia	127	304	302	[40]
6	Thailand	64.48	67.04	447.7	[41]
7	Egypt	27	31.4	427.5	[42]
8	Iran	23	31	453	[43]
9	Libya	7.5	4.2	27.5	[44]
10	World mean (soil)	33	45	420	[30]
	Present Study	22.28	10.44	393.83	-------

Table 6. Comparison of the current study results in soil with different locations in Iraq.

NO.	Governorate	specific activity in Bq/kg			Reference
		^{238}U	^{232}Th	^{40}K	
1	Baghdad	14.09	11.53	402	[45]
2	Babylon	14.07	12.32	416.65	[46]
3	Karbala	19.45	24.47	245.1	[47]
4	Kurdistan	83.33	19.147	284.86	[48]
5	Najaf	77.33	9.36	426.31	[49]
6	Missan	21.19	9.72	453.91	[50]
7	World mean (soil)	33	45	420	[30]
	Present Study	22.28	10.44	393.83	-------

5. Conclusion

The values of specific activity of terrestrial gamma radiation (^{238}U, ^{232}Th and ^{40}K) for soil samples at some location of Rasafa Side in Baghdad Governorate were lower than the world average values according to UNSCEAR 2008. Also, It is found that the mean of all radiological hazard parameters 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 indoor, outdoor and total($AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$) were less than the world mean according to the radiation protection report UNSCEAR2000, UNSCEAR2008 , OCDE and ICRP1993, there for no significant radiological hazard in area under study.

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