Volume 14, Number 3, 2021. pp. 267-274

Jordan Journal of Physics

ARTICLE

Assessment of Natural Radioactivity in Some Soil Samples from Kutha District in Babylon Governorate, Iraq

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Doi: **https://doi.org/10.47011/14.3.9**

Received on: 09/08/2020; *Accepted on: 14/10/2020*

Abstract: The activity concentrations of natural radionuclides of the elements (^{40}K, ^{238}U and ^{232}Th), collected from Kutha district of Babylon governorate are studied and evaluated. Twenty soil samples with (0-15) cm in depth are collected. Gamma spectrometer NaI (TI) source is used for calibration. The radioactivities of natural isotopes K-40, U-238 and Th-232, were assessed. These studies show that radio activities of isotopes are acceptable according to the standard levels. Also, the activity of radium equivalent, the rate of annual effective dose, average air volume and external risk index are evaluated. The results are found within the internationally tolerable values. The results show that the mean of the radioactivity of ^{238}U is (19.1565)Bq / kg, while it is (54.501) Bq/kg for ^{232}Th and (179.578) Bq/kg for ^{40}K. The study results showed that the average of radiological effects, like the Radium equivalent (Ra_{eq}), the rate of absorbed dose (Dr), the index of external hazard (H_{ex}), the index of internal hazard (H_{in}), the index of representative gamma hazard (I_γ), the Annual Effective Dose Equivalent (AEDE) and the Excess Lifetime Cancer Risk (ELCR) are as follow: 110.920 Bq/kg, 50.1838 nGy/h, 0.29953, 59.1530, 27.996, 0.34 mSv/y and 1.268x10^{-3}, respectively.

Keywords: Natural radioactivity, Absorption, External hazard, Effective annual dose, Excess lifetime cancer risk.

Introduction

As a fact of life, the human lives in a medium of natural radioactive materials, where humans are exposed daily to beta, alpha and gamma radiations. The traces of radioactive materials can be easily found in nature, including water, soils, and plants [1]. A crucial source of natural radioactivity of the materials exists in the crust of the earth [2]. Radiation rays are mainly categorized as natural and artificial radiations [3]. ^{238}U, ^{232}Th and ^{40}K are naturally occurring radionuclides which are considered as the sources of the natural radioactivity present in the soil, easily entering into the human body organs *via* food products, drinking water and forestry products. Almost 90% of human radiation exposure arises from natural sources, such as cosmic radiation, exposure to radon gas and terrestrial radiation [4]. The aim of this investigation is to assess the natural radioactivity of U-238, Th-232 and K-40 in different locations of Kutha district of Babylon. Different studies measured the natural radioactivity in soil and assessed its hazards for different regions around the Kutha district of Babylon as indicated in the references: [5], [6], [7], [8], [9] and [10]. The references mentioned showed different measurements in comparison with Kutha district.

Experimental Method

Twenty soil samples were collected with 15 cm in depth from different locations from Kutha district in Babylon governorate. The group has been guided by the standards recommended by the International Atomic Energy Agency (IAEA). Firstly, the soil samples were cleaned

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by removing the undesired materials. Then, the samples were sun-dried for ten days. Thereafter, the samples were analyzed for the selection of homogeneous particle size using a cylinder sieve, 300 µm, with a net weight of 750 g. The samples were filled in cubic Marinelli cups with a constant size to ensure the homogenous distribution around the detector. The multivariate analyzer 1024 channel range was used for the surrounding by using ORTEC cylindrical chamber including two parts made of stainless steel and lead with widths of 20 and 5cm, respectively. The energy acquisition was calibrated using a set of radioactive standard source spectrometers, such as ^{60}Co, ^{137}Cs and ^{22}Na. The efficiency of energy was performed in a gamma spectrometer using these sources of calibration in a Marinelli cup applying a power in the range of 511.006 to 2500 keV. The process was followed by placing the calibration source in the detector with an exact geometry consort between the geometric sample and the sample detector. The sample has been placed in the centre of the chamber inside the shield for 4 hours. The equilibrium energy was determined as 1764 keV from gamma power transitions of ^{214}Bi with the probability of 15% and 2614 keV from gamma energy transfer of ^{208}Tl, with the probability of 98%. The activity of ^{40}K was balanced accordingly; however, the activity of ^{40}K was determined using a power of 1460 keV and a gamma-ray line probability of 12% was reported.

TABLE 1. Standard sources with energies and efficiency

No.	Source	Energy (keV)	Efficiency
1	Na-22	511	0.08413
		1274.5	0.04119
2	Cs-137	661.6	0.070137
3	Co-60	1173.24	0.02531
		1332.5	0.0225
		2505.74	0.004107

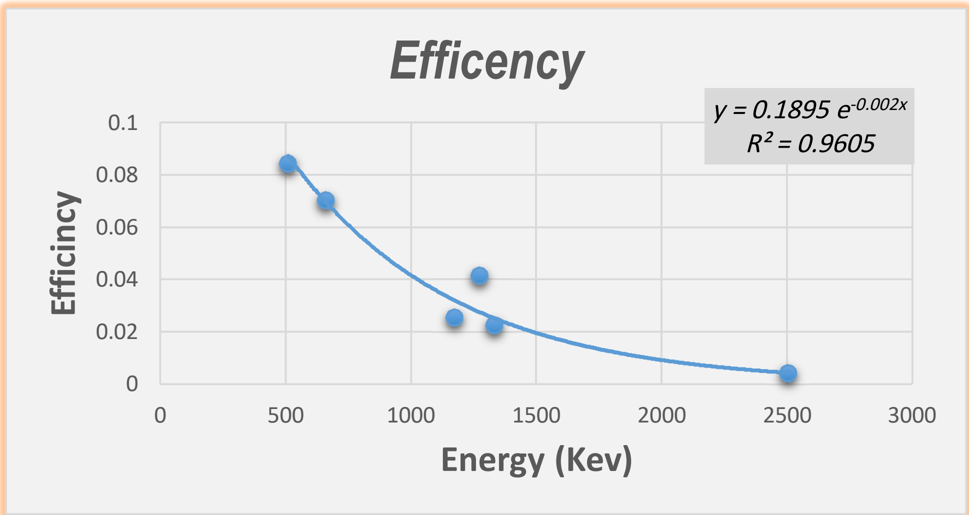

FIG. 1. The relationship between efficiency and energy.

Through the above figure, it is clear that the relationship between efficiency and energy is represented by the following equation:

$$\mathcal{E} = 0.1895\, e^{-0.002x}$$

where Ɛ is representing the efficiency and E is the energy of radiation source.

Theoretical Calculations

Specific Activity (S_A)

The qualitative (specific) activity (S_A) can be measured by Eq. (1):

$$S_A = \frac{n}{\varepsilon \times m \times I_\gamma \times \tau} \quad (1)$$

where n is the counts per second of gamma, ε is the detector efficiency, I_γ is the intensity of gamma line in the radionuclides, m is the mass of the sample in kilogram and τ is the lifetime of the collected spectrum measured in seconds [11].

The variation of specific activity with the sample number is shown in Fig. 2, Fig. 3 and Fig. 4 for Potassium-40, Uranium-238 and Thorium-232, respectively.

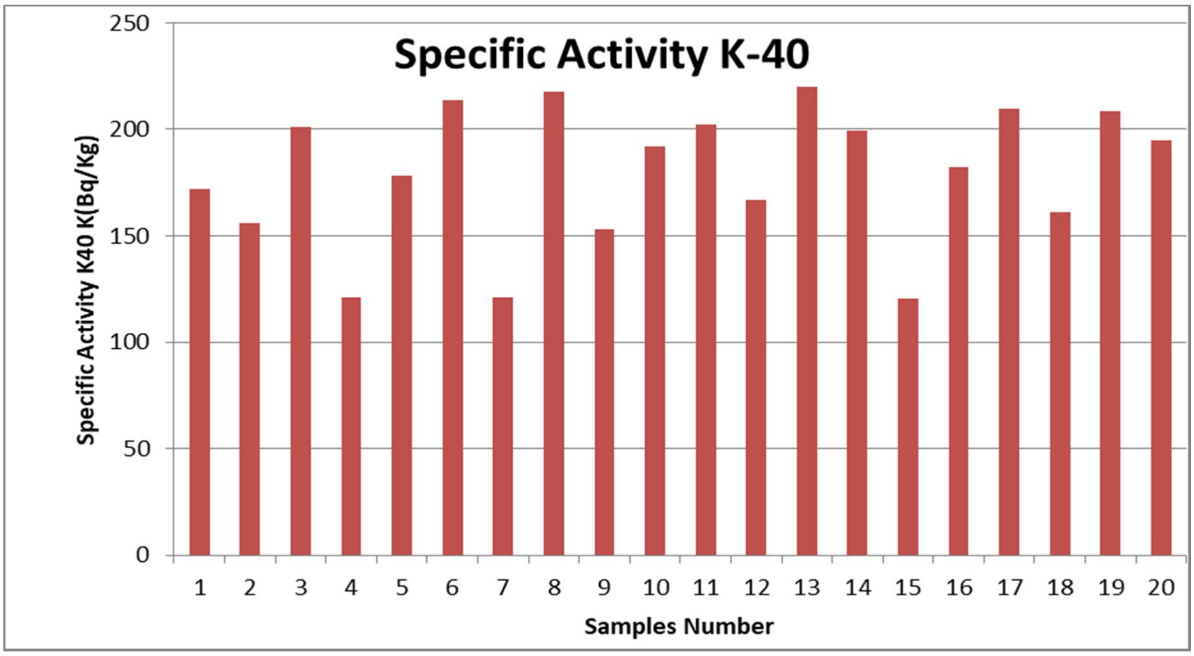

FIG. 2. The variation of specific activity of Potassium-40 with sample number.

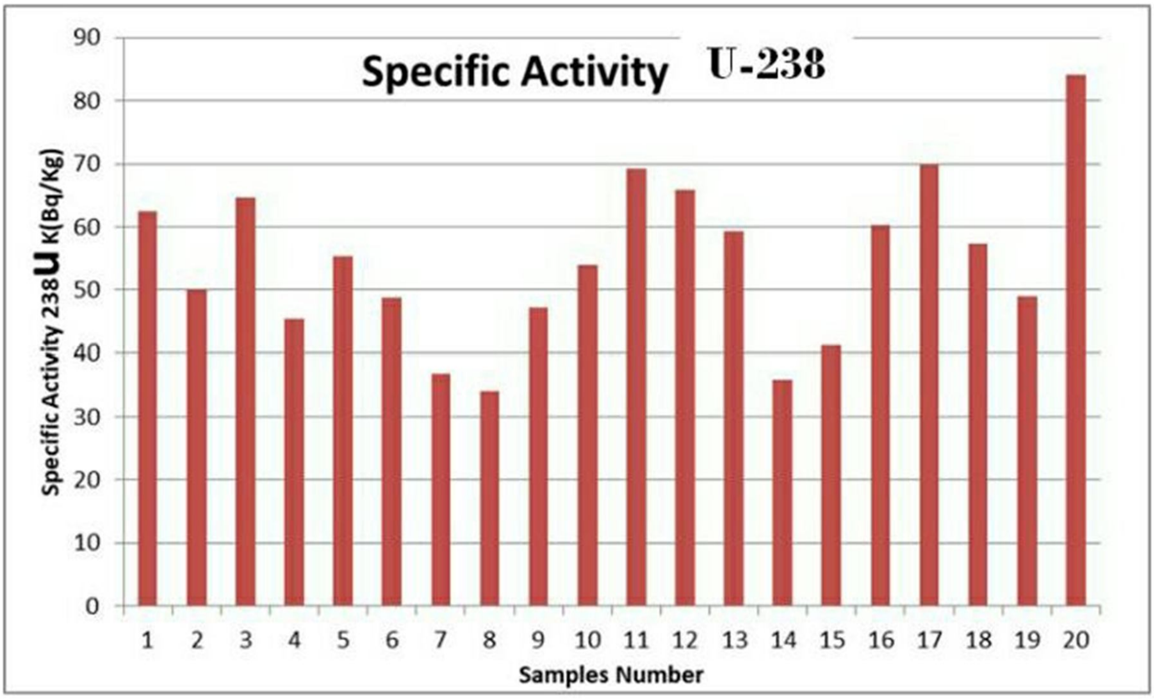

FIG. 3. The variation of specific activity of Uranium-238 with sample number.

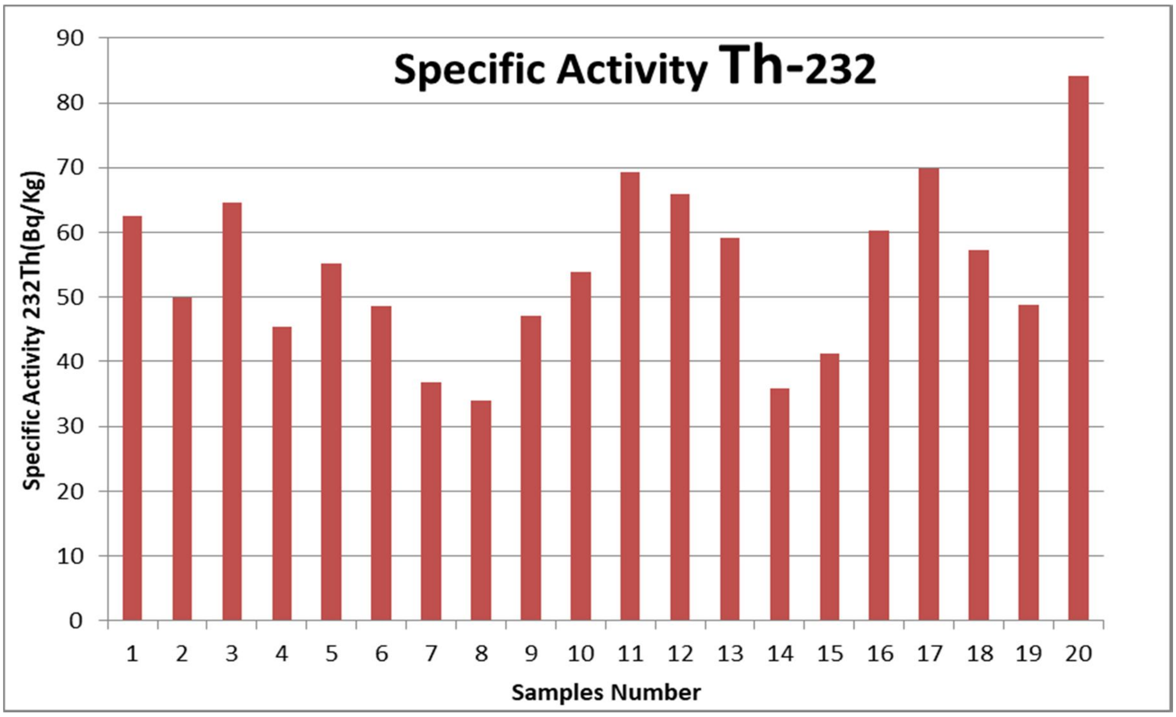

FIG. 4. The variation of specific activity of Thorium-232 with sample number.

Index of External Hazard (H(ex))

Measuring of hazard indices depends on the specific efficacies of Potassium-40, Uranium-238 and Thorium-232. Several risk factors have been measured, including:

The Equivalent of Radium-232 (Ra(eq))

It is used to obtain the sum of the activities of Th-232, U-238 and K-40 in (Bq/kg) unit and assesses hazards associated with materials which contain Th-232, U-238 and K-40 in (Bq/kg) by using the Radium Equivalent Activity that is defined in Eq. (2) [12]:

$$Ra(eq) = 1.43A_{Th} + A_U + 0.077A_K \quad (2)$$

where A_U is the specific efficiency of Uranium, A_{Th} is the specific efficiency of Thorium and A_K is the specific efficiency of Potassium series. In Eq. (2), it is assumed that 10 Bq/kg for Uranium, 7 Bq/kg for Thorium and 130 Bq/kg for potassium produce equal doses of radiation. The highest value of Ra_{eq} must be less than the global limit of 370 Bq/kg [13].

Absorbed Dose Rate in Air (AD)

The total rate of the absorbed air dose (AD) measures in terms of concentrations of terrestrial nuclei by Eq. (3) [14]:

$$AD(nGy/h) = 0.462\, A_U + 0.621\, A_{Th} + 0.0417\, A_K \quad (3)$$

Annual Effective Dose

The effective annual dose has been measured using Eq. (4) and Eq. (5) as follows [15]:

$$AEDE\ Indoor\ (mSv/y) = 0.8 \times 0.7 \frac{Sv}{Gy} \times 10^{-6} AD\left(\frac{nGy}{h}\right) \times 8760h \quad (4)$$

$$AEDE\ Outdoor\ (mSv/y) = 0.7 \frac{Sv}{Gy} \times 10^{-6} AD\left(\frac{nGy}{h}\right) \times 8760h \times 0.2 \quad (5)$$

The coefficient $0.7 \frac{Sv}{Gy}$ is used as a coefficient of conversion from the dose of air absorbed to the annual effective dose received by an adult and 0.8 refers to the period spent inside and 0.2 is the proportion of period spent. 8760 refers to the number of hours in a year and the total average effective annual dose is 0.47 *mSv* [16].

External Hazard Index (H(ex))

The external hazard index is an assessment of the risk of natural gamma radiation, as explained in Eq.(6) [17]:

$$H(ex) = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (6)$$

H(ex) must be less than one. If H(ex) is greater than or equal to one, that indicates radiological hazard [18]. The internal exposures are the result of the inhalation of Radon-232, that can be expressed in terms of the factor of internal risk (H(in)) [19], which is calculated by Eq. (7) [20]:

$$H(in)=\frac{A_U}{158}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \quad (7)$$

H(in) should be less than one to be within the range of the internationally permissible limits [21].

Index of Activity Concentration (Iγ)

The representative level index (Iγ) of the soil is used to assess the gamma level radiation hazards associated with natural gamma emitters in the sample and can be evaluated using Eq. (8) [22]:

$$I\gamma=\frac{A_U}{150}+\frac{A_{Th}}{100}+\frac{A_K}{1500} \quad (8)$$

Lifetime Cancer Risk (ELCR)

The value of excess lifetime cancer risk can be calculated as in Eq. (9) [15]:

$$ELCR = RF \times AEDE \times DL \quad (9)$$

where ELCR is the excess lifetime cancer risk Sv^{-1}, DL is the average period of life that is estimated at seventy years, RF: risk factor, Sv; i.e., fatal cancer risk per sievert of random effect. ICRP uses an RF of 0.05.

Result and Discussion

Specific Activity

Table 2 displays the results of specific activity for U-238, Th-232 and k-40 radionuclides in samples from the district of Kutha, Babylon governorate. The activity of ^{238}U was (19.1565) Bq/kg as maximum. The activity of ^{232}Th was about (54.501) Bq/kg, and the activity of ^{40}K was (179.578) Bq/kg, while the geochemical composition of the soil was sandy soil. As we note, the activity of Thorium is larger than the activity of Uranium in most of the samples. The radioactivity of Th-232 in a part of the cases is larger than that of U-238 in samples collected from some locations.

It has been observed that radioactivity of K-40 was higher than those of U-238 and Th-232, which is due to the abundance of K-40 in some soil samples. The reason for this is the use of a great deal of potassium-containing fertilizers in the neighbourhood of the sample site. The results in this assessment show that the average radioactivity of the collected samples is lower than the total average values according to UNSCEAR 2017 [23]. The UNSCEAR 2017 has reported radioactivities of 420 for K-40, 33 Bq/kg and 45 Bq/kg for U-238 and Th-232.

TABLE 2. The natural radioactivity results in the centre of Kutha district if Babylon governorate.

Number	Sample symbol	S_A (1 Bq/kg)		
		K- 40	U- 238	Th- 232
1	S1	172.18±1.55	5.87±1.31	62.5±1.57
2	S2	156.18±2.28	7.42±0.72	49.91±2.50
3	S3	201.2±2.18	4.98±1.28	64.62±1.95
4	S4	121.05±2.81	11.12±0.92	45.36±2.88
5	S5	178.05±2.02	14.83±1.34	55.22±1.96
6	S6	213.6±2.77	15.15±0.73	48.72±2.05
7	S7	120.89±2.12	18.35±1.62	36.85±1.40
8	S8	217.67±3.03	16.97±1.07	33.98±2.38
9	S9	153.04±3.11	20.22±0.63	47.11±2.03
10	S10	192.13±3.77	25.13±0.43	53.91±2.11
11	S11	202.05±2.28	19.87±1.32	69.28±1.81
12	S12	167.11±3.31	22.12±0.63	65.88±2.12
13	S13	220.05±3.54	29.11±0.49	59.23±1.14
14	S14	199.17±3.00	23.91±1.9	35.81±2.19
15	S15	120.48±2.69	17.42±0.63	41.25±2.38
16	S16	182.23±3.31	20.71±1.23	60.28±2.01
17	S17	209.87±1.99	27.31±1.02	69.81±2.15
18	S18	161.39±2.88	30.48±1.91	57.23±1.02
19	S19	208.41±3.11	32.93±0.77	48.87±0.08
20	S20	194.81±2.77	19.23±1.99	84.2±1.09
Average ± S.D.		179.578	19.1565	54.501

The Results of Ra(eq), Dr, H(ex), H(in) and Iγ Parameters

Table 3 shows the results of Ra(eq), Dr, H(ex), H(in) and Iγ for the soil samples collected from Kutha city, Babylon governorate. The measured equivalent Ra-232 activity of the samples shows an average of (110.920) Bq/kg. The minimum activity value of 370 Bq/kg has been reported for the analyzed soil samples of Ra-232 [24]. According to UNSCEAR 2000, the rate of absorbed dose for the world's outdoor exposure due to gamma radiation (nG/h) is about 50.1838 nGy/h [23]. Recorded values in the region under study for many samples are necessary for health and the results obtained do not show any premalignant effects on people who live in Kutha. Finally, specific activity was used for detecting of the radioactivity doses and has been delivered externally in the form of γ dose. The index of external risk has been calculated and reported to be 0.29953, while according to the radiation protection report, the average value is less than one [24]. Those radionuclides have an internal exposure of about (27.996) and an index of representative gamma hazard of about (59.153038); so the calculated values are below one according to the radiation protection report [25]. The calculated values of the parameters under study are shown in Table 3. These values are lower than the international values [19-18-24]. The internal, external and total values of the (AEDE) are shown in Table 4. The mean value is (0.34) and the average of 0.459848 mSv/y does not correspond to the global value of 0.34183 mSv/y [25]. The results show an increase in the lifetime risk of cancer in these locations, which is represented in Table 3. These values have an average of 1.267 x 10^{-3}.

TABLE 3. The results of Ra(eq), Dr, H(ex), H(in) and Iγ of the samples from Kutha city, Babylon.

Number	Sample symbol	Ra(eq) (Bq/kg)	Dr (nGy/h)	H(ex)	H(in)	Iγ
1	S1	108.5028	48.7043	0.2929	0.3142	0.7789
2	S2	90.8171	40.9348	0.2452	0.2721	0.6526
3	S3	112.87	50.8198	0.3047	0.3228	0.8135
4	S4	85.3056	38.3537	0.2303	0.2706	0.6084
5	S5	107.5044	48.5677	0.2903	57.2607	27.1015
6	S6	101.2668	46.1615	0.2734	54.3501	25.7192
7	S7	80.3540	36.4026	0.2170	42.9002	20.3035
8	S8	82.3219	38.0185	0.2223	44.6752	21.1354
9	S9	99.3713	44.9787	0.2683	53.0140	25.0906
10	S10	117.0153	53.0999	0.3160	62.5620	29.6079
11	S11	134.4982	60.6283	0.3631	71.5040	33.8444
12	S12	129.1958	58.0994	0.3488	68.5464	32.4460
13	S13	130.7527	59.4067	0.3531	69.9796	33.1175
14	S14	90.4543	41.5898	0.2442	48.9041	23.1381
15	S15	85.6844	38.6883	0.2313	45.6169	21.5907
16	S16	120.9421	54.6008	0.3265	64.3804	30.4717
17	S17	143.2982	64.7208	0.3869	76.3081	36.1168
18	S18	124.7459	56.3515	0.3368	66.4387	31.4455
19	S19	118.8616	54.2526	0.3210	63.8640	30.2205
20	S20	154.6363	69.2960	0.4175	81.8001	38.7224
Average ± S.D.		110.920	50.1838	0.29953	59.153038	27.996

TABLE 4. The results of AEDE $_{indoor}$, AEDE $_{outdoor}$, AEDE and ELCR of samples from Kutha district in Babylon, Iraq.

Number	Sample symbole	AEDE $_{indoor}$ (mSv/y)	AEDE $_{outdoor}$ (mSv/y)	AEDE (mSv/y)	ELCR×10^{-3}
1	S1	0.2389	0.0597	0.2986	0.4778
2	S2	0.2008	0.0502	0.2510	0.4016
3	S3	0.2493	0.0623	0.3116	0.4986
4	S4	0.1881	0.0470	0.2351	0.3762
5	S5	0.1547	0.3308	0.3983	1.3909
6	S6	0.1468	0.3142	0.3779	1.3208
7	S7	0.1159	0.2479	0.2984	1.0422
8	S8	0.1207	0.2585	0.31056	1.0863
9	S9	0.1432	0.3063	0.3687	1.2879
10	S10	0.1690	0.3616	0.4351	1.5200
11	S11	0.1932	0.4130	0.4974	1.7367
12	S12	0.1852	0.3959	0.4769	1.6647
13	S13	0.1891	0.4045	0.4867	1.7003
14	S14	0.1321	0.2829	0.3400	1.1889
15	S15	0.1232	0.2635	0.3173	1.1080
16	S16	0.1739	0.3719	0.4479	1.5638
17	S17	0.2062	0.4409	0.5308	1.8536
18	S18	0.1795	0.3838	0.4622	1.6138
19	S19	0.1725	0.3693	0.4441	1.5521
20	S20	0.1825	0.4693	0.3441	1.2521
Average±S.D.		34..0	0.459848	0.34183	1.268

TABLE 5. The radioactivity of radionuclides in local studies and comparing them to the current study of soil samples from Kutha district in Babylon in Bq/kg units.

Sequence	Specific efficacy concentration (Bq/kg)			Study site	Source
	^{238}U	Th-232	K-40		
1	15.505	15.485	170.206	Iraq-Babylon	[26]
3	49.68±108	55.06±58.1	197.91±183.8	Iraq- (city of Hindia)	[27]
4	30.96±5.86	67.09±2.9	271.2±170	Iraq- Karbala	[28]
5	14.079 ± 0.46	12.326± 0.43	416.655 ± 2.86	Iraq- city of Hilla	[5]

Conclusion

The measurements of the natural radioactivity levels in Kutha district in Babylon governorate show normal concentration levels of radioactivity. The measured ^{40}K levels are within the natural permissible values. The values of Radium equivalent,(Ra_{eq}), annual effective dose equivalent and radiation hazard index (H_{ex}) refer to normal levels of radio activity.

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