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Natural Activity assessment for soil samples in various buildings of the University of Kufa, Iraq

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ABSTRACT

People are continuously exposed to background radiation, or ambient radioactivity, from radionuclides that are manufactured or naturally occurring. One of the biggest sources of terrestrial radiation is soil. This study uses gamma-ray spectroscopy with "3 x 3" NaI (Tl) crystal to investigate soil samples collected from different buildings at University of Kufa in the Al-Najaf governorate of Iraq to evaluate the concentrations of natural radionuclides of ^{238}U, ^{232}Th, and ^{40}K as well as radiological hazard factors. The average activity values for ^{238}U, ^{232}Th, and ^{40}K in unit of Bq kg^{-1} were 15.37±4.85, 12.76±2.81, and 260.10±83.47, respectively. External hazard (H_{ex}), absorbed dose rate (D_r), annual effective dose outside (AEDE), and cancer risk (ELCR×10^{-3}) were among the radiological risk indicators with average values of 0.14±0.03, 25.66±5.95 nGy/h, 0.16±0.04 mSv/year, and 0.11±0.03 respectively All specific activities result for natural radionuclides and radiological hazard parameters in the research area were found to be under the worldwide limit.

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النشاط الاشعاعي الطبيعي لعينات من التربة في مباني مختلفة لجامعة الكوفة

امنة كاظم الحميدات، رقية جابر دوش

قسم الفيزياء، كلية العلوم، جامعة الكوفة، النجف، العراق

الكلمات المفتاحية:

الانوية المشعة الطبيعية
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الـــخُـــلاصـــة

يتعرض الناس باستمرار لإشعاع الخلفية، أو النشاط الإشعاعي المحيط، من النويدات المشعة، والتي يمكن ان تكون صناعية او طبيعية. أحد أكبر مصادر الإشعاع الأرضي هو التربة. تستخدم هذه الدراسة التحليل الطيفي لأشعة كاما لفحص عينات التربة التي تم جمعها من مبان مختلفة في جامعة الكوفة في محافظة النجف العراقية لتقييم تركيزات النويدات المشعة الطبيعية ^{238}Uو ^{232}Th و ^{40}K بالإضافة إلى عوامل الخطر الإشعاعي. كانت قيم النشاط لـ ^{238}U و ^{232}Th و ^{40}K في الوحدة 15.37 ± 4.85 Bq kg^{-1} و 12.76±2.81 Bq kg^{-1} و 260.10±83.47 على التوالي في مجال البحث. كان الخطر الخارجي(H_{ex}) ، ومعدل الجرعة الممتصة(D_r) ، والجرعة الفعالة السنوية في الخارج(AEDE) ، وخطر الإصابة بالسرطان (ELCR×10^{-3}) من بين مؤشرات الخطر الإشعاعي بمتوسط قيم 0.14±0.03، و25.66±5.95 nGy/h ، و 0.16±0.04

mSv/year ، و 0.11±0.03 على التوالي، كانت جميع نتائج التراكيز النوعية وباراميترات الخطر الاشعاعي في منطقة الدراسة تحت المستوى المسموح به عالميا.

1. INTRODUCTION

Cosmic radiation that originates from the atmosphere and radionuclides present in rock and soil are the two main sources of natural radiation, which are inherent elements of the environment. [1]. The environment contains radiation from a wide variety of sources. Gamma radiation from radionuclides, like Potassium-40, Uranium-238,Thorium-232, as well as the byproducts of their disintegration, is the primary external source of radiation exposure for humans. Terrestrial radionuclides are found in tiny amounts in all rock formations that can be considered as the cause of exposure to gamma radiation outdoors. Thus, the primary determinants of natural environmental radiation are subjected to geological and geographical conditions [2]. The assessment of natural activity in the soil is crucial for evaluating the temporal variations in background radioactivity due to the emission of radiation. Investigations of natural radioactivity are essential not only for their radiological implications but also for their capacity to serve as superior biochemical and geochemical markers in the surroundings. Although rocks and soils throughout the world contain natural radioactivity, the amount in certain locations varies rather within limited boundaries [3]. Soil in the earth's crust may be seen as a radioactive threat to the environment since it exposes people to radioactive elements continuously and because agricultural soil permits the radionuclides to enter the food chain and then contaminate humans through crops. Furthermore, the public may be exposed to higher levels of radiation due to natural radioactive decay processes that move to reservoirs of surface water after dissolving in water [4]. Radioactive contamination is a major public health issue in developed nations due to its potential to harm the environment, animals, and humans [5]. Consequently, many scientists throughout the world are studying how radiation affects biological systems by estimating the terrestrial radiation from soil radionuclides [6–9]. This study used gamma-ray spectroscopy to ascertain the levels of ^{238}U, ^{232}Th, and ^{40}K in samples of soil obtained from some buildings in the University of Kufa in order to evaluate external exposure of gamma-ray.

2. Materials and Methods

2.1: The Area of Study

Najaf Governorate is located in southwest Iraq, roughly 160 kilometers southwest of Baghdad the capital of Iraq. It is located on the line that joins latitudes 44°19°E and 31°59°N. It is rising seventy meters above sea level [10]. The University of Kufa is one of the Iraqi institutions located in the Al-Najaf governorate, which has 21 faculties and housing for its faculty and personnel as shown in Figure (1). The ^{238}U, ^{232}Th, and ^{40}K concentrations were measured at 23 sites throughout the six buildings of the University of Kufa using a NaI (Tl) detector.

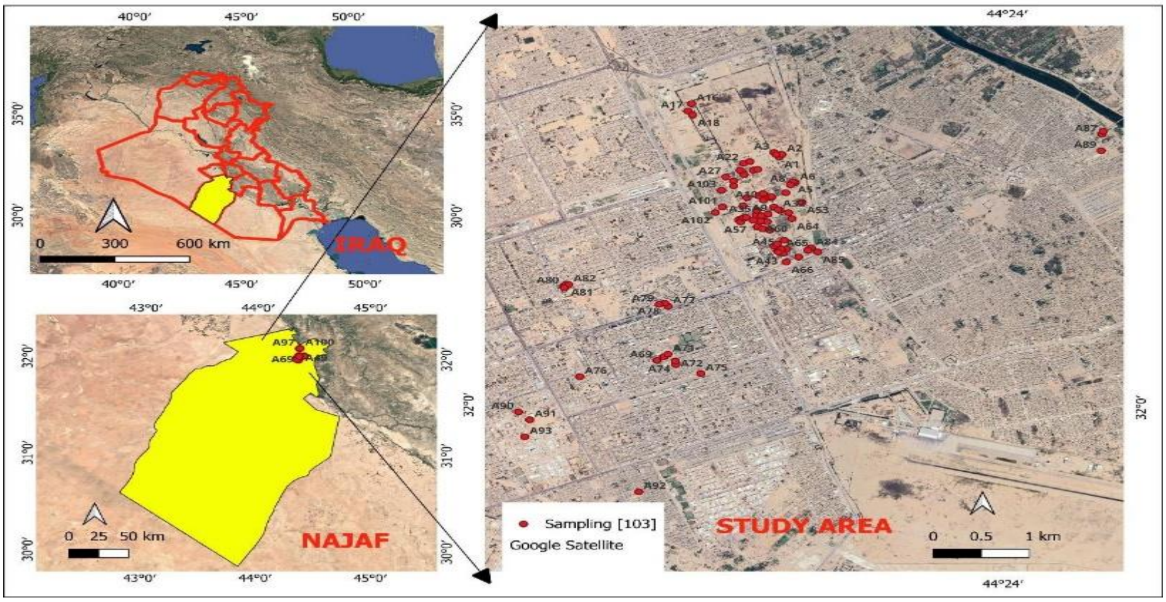

Figure (1): The map of the study area

2.2-Collecting and Preparing the Samples

Between May and July 2024, 23 soil samples were taken from various buildings in the University of Kufa in the Al-Najaf region of Iraq. As shown in Table 1, the GPS was utilized to find and record the locations of the sample sites. Three to four soil samples were taken from the front, back, right, and left of each location that was the focus of the study. Every soil sample was taken at a depth of 15 cm. The soil samples were gathered and appropriately labeled before being put in polypropylene plastic bags. After that, they were moved to Kufa University's nuclear laboratory of the Department of Physics for additional processing and analysis. To eliminate all moisture and produce a uniformly dry mass, the samples were heated to 100°C for 24 hours using electric oven. An electric blender was then used to grind the dry samples into a fine powder after they had passed through a 1 mm mesh screen according to the methods of Osman, et. al, and Chhangte, et. al. [5, 6]. This was followed by the samples being carefully confined and moved into 500 ml Marinelli beakers. Appropriate codes indicating the sample name and relevant details were affixed to the samples. To establish a secular equilibrium between the ^{238}U and ^{232}Th, along with their short-lived daughters, the samples were kept in the lab for four weeks without being touched [7].

Table 1: Location information for the samples that were gathered in the research area

The name of the location	Direction	The code of the sample	Coordinates	
			E	N

University accommodation (boys)	left	A_1	44° 22′ 29.900″	32° 1′ 55.500″
	behand	A_2	44° 22′ 30.900″	32° 1′ 56.700″
	right	A_3	44° 22′ 27.800″	32° 1′ 57.600″
	In front of	A_4	44° 22′ 28.600″	32° 1′ 56.600″
guest house	left	A_5	44° 22′ 35.300″	32° 1′ 44.000″
	In front of	A_6	44° 22′ 36.300″	32° 1′ 43.600″
	behand	A_7	44° 22′ 35.300″	32° 1′ 44.000″
	Right	A_8	44° 22′ 34.400″	32° 1′ 42.600″
University accommodation (girls)	In front of	A_9	44° 21′ 54.900″	32° 2′ 20.000″
	behand	A_{10}	44° 21′ 53.500″	32° 2′ 16.600″
	left	A_{11}	44° 21′ 55.300″	32° 2′ 14.800″
Presidency	In front of	A_{12}	44° 22′ 27.900″	32° 1′ 32.300″
	left	A_{13}	44° 22′ 33.700″	32° 1′ 29.700″
	behand	A_{14}	44° 22′ 30.300″	32° 1′ 30.700″
	right	A_{15}	44° 22′ 29.500″	32° 1′ 31.100″
Central Library	In front of	A_{16}	44° 22′ 33.000″	32° 1′ 12.900″
	left	A_{17}	44° 22′ 31.600″	32° 1′ 10.800″
	behand	A_{18}	44° 22′ 29.400″	32° 1′ 11.900″
	right	A_{19}	44° 22′ 30.200″	32° 1′ 13.300″
health center	right	A_{20}	44° 22′ 15.800″	32° 1′ 27.200″
	In front of	A_{21}	44° 22′ 16.900″	32° 1′ 27.400″

	left	A_{22}	44° 22′ 22.600″	32° 1′ 25.700″
	behand	A_{23}	44° 22′ 26.900″	32° 1′ 37.100″

2.3 Detection systems

To evaluate the specific activities of ^{238}U, ^{232}Th, and ^{40}K within the soil samples, a gamma spectrometry device was utilized. The system had a "3 x 3" NaI (Tl) crystal in addition to a scintillation and gamma-ray detector. The detector was provided by Alpha Spectra, Inc. (Model 12I12/3). The device was linked to the 4096-channel Analog-to-Digital Converter (ADC) of the ORTEC Digi Base, a multi-channel analyzer (MCA). The "MAESTRO-32" software within the laboratory computer was utilized by the system to collect and analyze data. The voltage utilized in this experiment was 788 V, which falls within the detector's continuous functioning range. The spectrometer was calibrated for gamma-ray energy by obtaining spectra from radioactive reference sources, including ^{137}Cs, ^{54}Mn, ^{60}Co, ^{22}Na, and ^{152}Eu. A correlation coefficient of 0.99 indicates a strong linear relationship between gamma energy and channel number during the calibration phase. In this work, the detector's energy resolution for the ^{137}C standard source's whose energy is 661.66 keV was 7.9%. On the other hand, while detecting the ^{137}Cs gamma radiation at 661.66 keV, NaI(Tl) detectors have a resolution range of 5–10%. Due to the inadequate resolution of a NaI(Tl) system at low gamma-ray energies, which lack distinctly separated photo-peaks, it is feasible to measure specific activity solely at elevated gamma energies, exemplified by the results obtained from the gamma rays emitted by the progeny of ^{238}U and ^{232}Th, which exist in a state of secular equilibrium with their parent isotopes. At the same time, ^{40}K was computed directly by its gamma [12]. Consequently, the concentration of ^{238}U was calculated using the gamma lines 1764.5 keV (^{214}Bi). The ^{208}Tl gamma-ray lines at 2614 keV were used to obtain the corresponding

results for ^{232}Th. The calibrations yielded a linear correlation with a high correlation coefficient of 0.98 in assessing the relationship between gamma-ray energy and the absolute efficiency of the photo-peak detector. Spectrum collected for 18,000 seconds (5h) for every sample and the analysis was carried out with computer software to determine the activity concentrations of the 3 natural radionuclide. The laboratory evaluated the site's background gamma radiation level before evaluating the sample. This was accomplished by utilizing an empty Marinelli beaker with a plastic container comparable to those employed for sample measurement. Therefore, conducting counts concurrently with the sample spectra [8].

2.4 Indicators of Radiological Hazard

The following formula was used to calculate the soil sample-specific activity in Bq kg^{-1} [9]:

$$(1) A = \frac{Net\ area}{I_{\gamma}\ \varepsilon\ M\ T}$$

The net area is the count that results from deducting the background for the gamma radiation peak. The duration of spectrum capture, expressed in seconds, is denoted by the sign T. The letter M stands for the dried sample's mass, which is measured in kilograms. The absolute effectiveness of the detector is represented by the symbol ε. Additionally, several radiological indices, including "Radium Equivalent Activity (Ra_{eq})," "External Hazard Index (H_{ex})," "Absorbed dose rate in the air (D_r)," "Annual Effective Dose Equivalent (AEDE)," "the representative level index ($I_{\gamma r}$)," and "Excess Lifetime Cancer Risk (ELCR)," were evaluated using mathematical formulas (2–7) and are linked to the presence of ^{238}U, ^{232}Th, and ^{40}K. [10-17]

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

$$H_{ex} = \frac{A_u}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ldots\ldots\ldots. (3)$$

$$D_r = 0.462\ A_U + 0.604\ A_{Th} + 0.0417 A_K \ldots\ldots\ldots (4)$$

$$AEDE = [D_r \times 8760 \times OF \times 0.7] \times 10^{-6} \ldots\ldots\ldots\ldots. (5)$$

$$I_{\gamma r} = \left(\frac{1}{150}\right) A_U + \left(\frac{1}{100}\right) A_{Th} + \left(\frac{1}{1500}\right) A_K \ldots\ldots\ldots.. (6)$$

$$ELCR = AEDE \times DL \times RF \ldots\ldots\ldots\ldots.. (7)$$

The A_U, A_{Th}, and A_k , denote the specific activity of ^{238}U, ^{232}Th, and ^{40}K, respectively. Outdoor spaces have an occupancy factor (OF) of 0.2, while indoor spaces have an OF of 0.8 [21]. "DL" refers to "Mean Duration of Life," which is currently thought to be approximately 70 years. RF stands for Risk Factor.

3-Results and Discussion

Table 2 lists the specific activities of ^{238}U, ^{232}Th, and ^{40}K for soil samples from some buildings of Kufa University. Dry weight Bq kg^{-1} was used to express the given values. For the specific activity of ^{238}U, the minimum value was 4.04 Bq kg^{-1} in sample coded A10 (University accommodation (girls)), while the maximum value was 25.70 Bq kg^{-1} in sample coded A20 (health center) with a mean of 15.37±4.85 Bq kg^{-1}. For the specific activity of ^{232}Th, the minimum value was 8.72 Bq kg^{-1} in sample coded A23 (health center), while the maximum value was 18.24 Bq kg^{-1} in sample coded A1 (University accommodation (boys)) with a mean of 12.76±2.81 Bq kg^{-1}. For the specific activity of ^{40}K, the minimum value was 45.73 Bq kg^{-1} in sample coded A12 (Presidency), while the maximum value was 427.1 Bq kg^{-1} in sample coded A1 (University accommodation (boys)) with a mean 260.10±83.47 Bq kg^{-1}. The data presented in Table 2 indicates that the specific activity of ^{40}K is greater than that of ^{238}U and ^{232}Th and can be expressed in the following order: ^{40}K > ^{238}U > ^{232}Th. All results of specific activity for ^{238}U, ^{232}Th, and ^{40}K were seen to be lower than the worldwide levels of 33 Bq kg^{-1}, 45 Bq kg^{-1}, and 420

Bq kg^{-1}, respectively, according to UNSCEAR 2000 [18] as shown in Figure 2.

Table 2: Specific activity outcomes for ^{232}Th, ^{40}K, and ^{238}U in the buildings that are being examined

	Specific activity Bq/kg		
	^{238}U	^{232}Th	^{40}K
A_1	17.34	18.24	427.10
A_2	19.34	10.66	282.70
A_3	14.87	13.58	221.45
A_4	14.43	10.59	279.27
A_5	10.08	13.50	295.11
A_6	19.39	14.84	387.49
A_7	13.74	11.30	229.25
A_8	12.56	15.24	268.00
A_9	13.95	15.56	369.32
A_{10}	4.04	10.32	182.15
A_{11}	7.17	9.89	196.21
A_{12}	10.61	9.85	45.73
A_{13}	19.82	12.55	159.24
A_{14}	17.17	12.55	212.41
A_{15}	16.47	13.15	301.50
A_{16}	14.0	17.43	256.13
A_{17}	22.5	17.04	370.83
A_{18}	14.9	12.86	288.90
A_{19}	13.6	13.46	304.01
A_{20}	25.7	14.37	261.93
A_{21}	15.2	8.72	194.02
A_{22}	21.3	9.03	209.54
A_{23}	15.3	8.72	240.11
Average ± S.D.	15.37±4.85	12.76±2.81	260.10±83.47
MIN	4.04	8.72	45.73
MAX	25.70	18.24	427.1

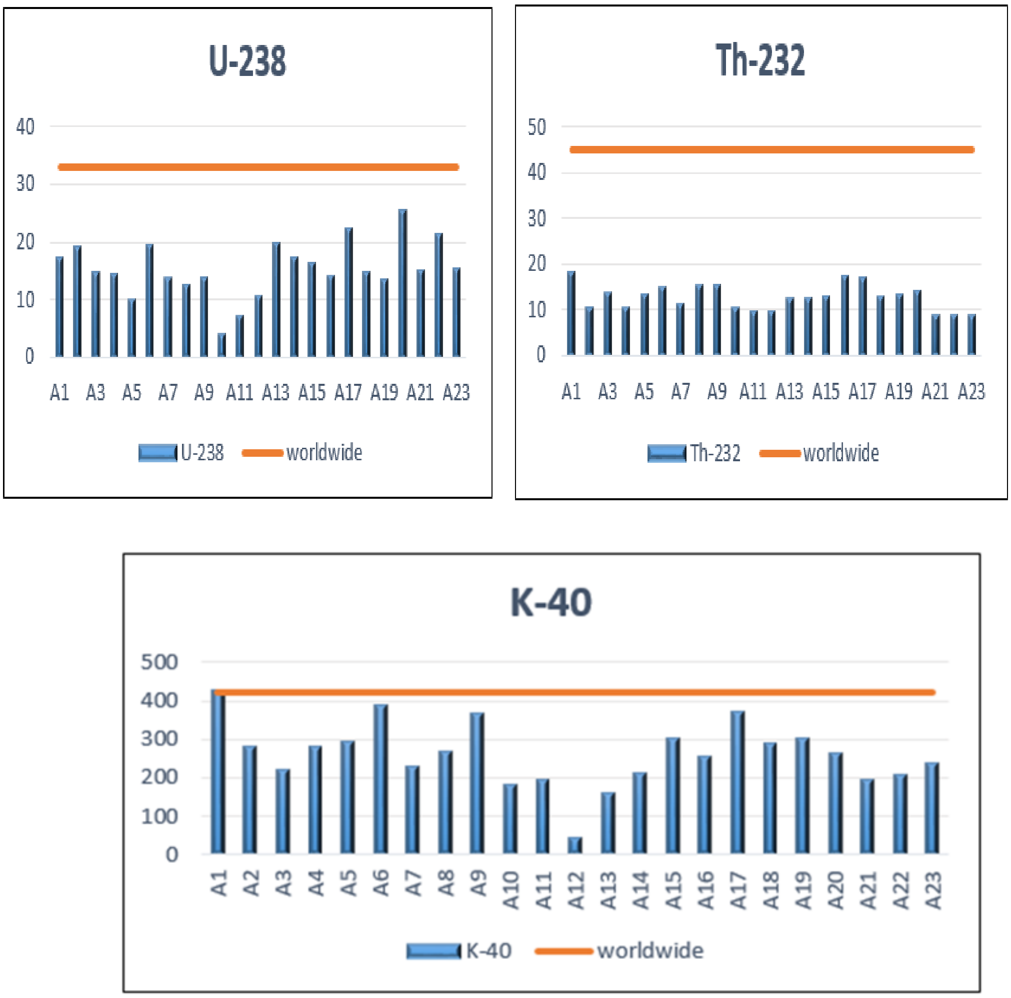

Figure (2): The specific activity for ^{238}U, ^{232}Th, and ^{40}K

The high concentrations of ^{40}K in some soil samples from Kufa University likely result from a combination of natural geological factors, soil mineralogy, agricultural inputs, and environmental influences. Further gamma spectroscopy analysis and mineralogical studies could provide a more detailed understanding of the exact sources.

While the calculated concentrations for the examined radioisotopes (^{238}U, ^{232}Th, and ^{40}K) are determined, they are unreliable for assessing the radioactive hazards. The assessment of radiation hazards holds significant importance in environmental protection studies due to the continuous influence of soil on inhabitants. Therefore, it is essential to investigate the radiological hazard indices to evaluate the potential danger faced by students and staff in the studied areas. The soil samples' radiological hazard indices (H_{ex}, $I_{\gamma r}$, Ra_{eq}, D_r, AEDE, ELCR) were determined and presented in Table 3. These indices were calculated based on ^{238}U, ^{232}Th, and ^{40}K-specific activity. The range and average values (in parentheses) for H_{ex}, $I_{\gamma r}$, Ra_{eq}, D_r, AEDE, ELCR are: 0.08 to 0.21 (0.14±0.03), 0.20 to 0.58 (0.40±0.09), 28.21 Bq $kg^{-1}$to 76.31 Bq kg^{-1}(53.64±12.17 Bq kg^{-1}), 12.80 nGy h^{-1} to 36.80 nGy h^{-1} (25.66±5.95 nGy h^{-1}), 0.08 mSv year^{-1} to 0.23 mSv year^{-1} (0.16±0.04 mSv year^{-1}), and 0.05 to 0.16 (0.11±0.03), respectively. Ra_{eq} values in soil samples were lower than the global limit of 370 Bq kg^{-1}, as reported by the OECD [19]. The values of AEDE are less than the worldwide results of 0.50 mSv y^{-1} [20]. The results of H_{ex}, $I_{\gamma r}$ were lower than the worldwide limit set by ICRP [21], which equals to 1. The results of the calculated absorbed dose rate (D_r) were lower than the world mean(55 nGy/h) [18]. The estimated results of ELCR were lower than the world average of 0.299 ×10^{-3} [22], as shown in Figure 3.

Table 3: The findings of the research area's natural radioactivity's radiological hazard parameters

Sample Code	Ra_{eq} (Bq/kg)	H_{ex}	D_r (nGy/h)	$AEDE_{total}$(mSv/y)	$I_{\gamma r}$	ELCR× 10^{-3}
A_1	76.311	0.206	36.8	0.23	0.583	0.16
A_2	56.353	0.152	27.2	0.17	0.424	0.12
A_3	51.343	0.139	24.3	0.15	0.383	0.10
A_4	51.078	0.138	24.7	0.15	0.388	0.11
A_5	52.115	0.141	25.1	0.15	0.399	0.11
A_6	70.442	0.190	34.1	0.21	0.536	0.15
A_7	47.547	0.128	22.7	0.14	0.357	0.10
A_8	54.995	0.149	26.2	0.16	0.415	0.11
A_9	64.646	0.175	31.2	0.19	0.495	0.13
A_{10}	32.832	0.089	15.7	0.10	0.252	0.07
A_{11}	36.426	0.098	17.5	0.11	0.278	0.07
A_{12}	28.214	0.076	12.8	0.08	0.200	0.05
A_{13}	50.034	0.135	23.4	0.14	0.364	0.10
A_{14}	51.477	0.139	24.4	0.15	0.382	0.10
A_{15}	58.498	0.158	28.1	0.17	0.442	0.12
A_{16}	58.688	0.158	27.7	0.17	0.439	0.12
A_{17}	75.437	0.204	36.2	0.22	0.568	0.16
A_{18}	55.502	0.150	26.7	0.16	0.420	0.11
A_{19}	56.261	0.152	27.1	0.17	0.428	0.12
A_{20}	66.400	0.179	31.5	0.19	0.490	0.14
A_{21}	42.625	0.115	20.4	0.13	0.318	0.09
A_{22}	50.301	0.136	24.0	0.15	0.372	0.10
A_{23}	46.218	0.125	22.3	0.14	0.349	0.10
Average ± S.E.	53.64±12.17	0.14±0.03	25.66±5.95	0.16±0.04	0.40±0.09	0.11±0.03
Min	28.21	0.08	12.80	0.08	0.20	0.05
Max	76.31	0.21	36.80	0.23	0.58	0.16

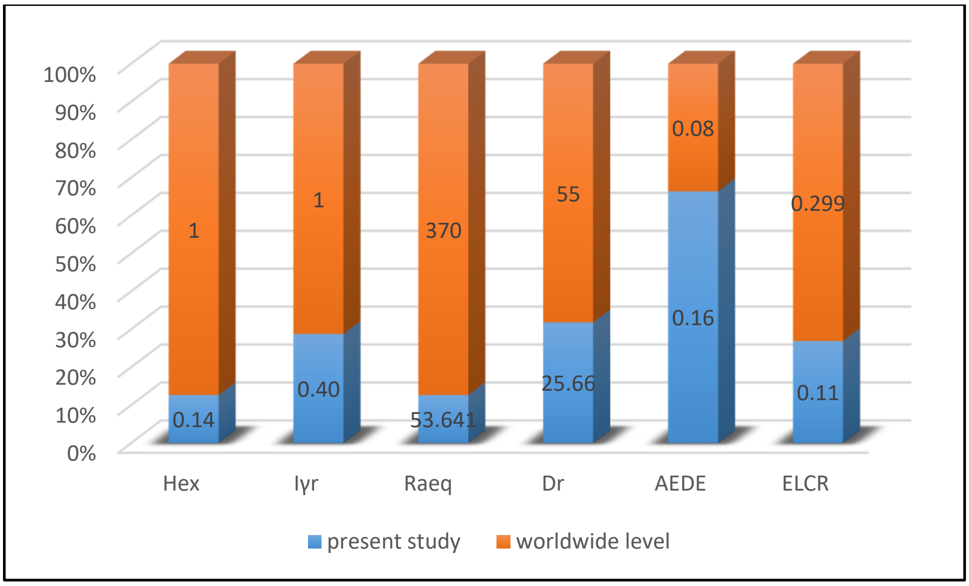

Figure 3: A comparison of the current study with global levels of the radiological parameters under investigation

Conclusion

This study used soil samples from some buildings at the University of Kufa in the Al-Najaf governorate, Iraq, to evaluate the specific activity of ^{238}U, ^{232}Th, and ^{40}K using the NaI (Tl) technique. The specific activity of studied radionuclides is in the order ^{40}K > ^{238}U > ^{232}Th. The ^{238}U, ^{232}Th, and ^{40}K obtained results were all below the global limit. Because the calculated radioactive danger factors for the selected soils are lower than the average values worldwide, they show that the soils are radiologically safe. From the soil samples taken from some buildings at the University of Kufa, it is advised that the natural radioactivity of soil in this area be measured regularly. Furthermore, soil activity concentration evaluation is recommended before siting infrastructure for public use.

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