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Measurement of Natural Radionuclide Activity in Soil Samples from Different Regions in Al-Hilla City, Iraq

Saif M. Alghazaly

Department of Physics, College of Science, University of Babylon, Babylon, saifmn1979@gmail.com

***Corresponding author email:** saifmn1979@gmail.com

قياس نشاط النويدات المشعة الطبيعية في عينات التربة من مناطق مختلفة في مدينة الحلة، العراق

سيف محمد الغزالي

قسم الفيزياء، كلية العلوم، جامعة بابل، محافظة بابل، العراق

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ABSTRACT

Background:

The active levels of natural radioactivity Potassium-40, Uranium-238, and Thorium-232 were examined and evaluated in various soil samples from Al-Hilla city by analyzing the results of these samples and comparing them to internationally accepted levels.

Materials and Methods:

30 soil samples were collected from different areas in the city of Hilla at a depth of 10–15 cm and examined using a gamma-ray spectrometer.

Results:

The radioactivity rate for U-238 was (9.36±0.144) $Bqkg^{-1}$, while it was (16±0.148) $Bqkg^{-1}$ for Th-232 and (141.5±0.894) $Bqkg^{-1}$ for K-40. The study's findings showed that the average radiation effects, such as Radium equivalent (Ra_{eq}), the outdoor external dose (D_{out}), the indoor external dose (D_{in}), the external hazard index (H_{ex}), the internal hazard index (H_{in}), the representative level index (I_{γ}), the annual effective dose equivalent (AEDE), and the lifetime cancer risks (ELCR), are as follows: (43.13) $Bqkg^{-1}$, (20.16) $nGyh^{-1}$, (37.67) nGy/h, (0.12), (0.11), (0.32), (0.185) $mSvy^{-1}$, and (0.69) $x10^{-3}$, respectively.

Conclusions:

The examination of the echelons of naturally occurring radioactivity in the areas in the center of Hilla has produced a wealth of data demonstrating that the measured concentrations of natural radionuclides are within acceptable bounds and represent typical levels of radioactivity.

Keywords: Natural Radionuclides, Gamma Spectrometer, Radioactivity, Soil, Al-Hilla City.

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INTRODUCTION

People are constantly exposed to many types of radiation, such as beta, alpha, and gamma radiation, as they live in an environment that is penetrated by naturally occurring radioactive materials. Water, soil, and plants are just a few examples of the different natural elements where trace amounts of these radioactive compounds can easily be found[1]. The earth's crust itself serves as a major source of its intrinsic radioactivity. The two main categories of radiation emissions are natural and man-made. The predominant source of natural radioactivity found in soil originates from naturally occurring radionuclides, namely potassium, uranium, and thorium[2]. These radionuclides are easily absorbed into human organs through the consumption of food, water, and industrial products. In reality, natural sources comprise approximately 90% of human radioactivity exposure. This includes exposure to thoron and radon nuclides, cosmic radiation, and terrestrial radiation[3, 4]. The dissolution of rock formations that are then transported by rainfall and water flows and eventually incorporated into the soil matrix is the main cause of naturally occurring radioactive materials (NORMs) in soil. Different terrestrial places' noticeable differences in ambient radiation levels are carefully correlated by the interaction of geological characteristics, location, elevation, and geochemical dynamics. The radiological activity associated with radionuclides in granite formations has been shown to be greater in this setting than that seen in mud, sandstone, and travertine soil. Because it provides information on the level of radioactive activity present in the environment, the quantification of natural radioactivity in soil is important. Additionally, this approach produces useful data that is crucial for the efficient monitoring of levels of radioactivity in the environment[5, 6]. Knowing how radionuclides behave and are distributed in soil, especially with regard to radium isotopes and their offspring, acquires crucial significance in explaining the various aspects of the natural radiation environment. The transfer of radionuclides between the upper soil layers and the atmosphere, the absorption of radioactive materials from the exosphere, and the interaction of radionuclides produced by human intervention are all part of this complex process[7, 8]. For complete safety evaluations, natural radioactivity must be considered, since it is both an inherent part of the environment and an integral part of how all natural systems work together[9, 10]. The need to safeguard public health and successfully forestall any adverse consequences of elevated radiation levels has motivated efforts to monitor and quantify radioactivity. Taking this precaution is important for the community's health as well as its genetic diversity in the long run. It includes examining soil samples from the majority of Al-Hilla city, one of the cities of Babylon Governorate, for the presence of terrestrial gamma radiation and determining the extent of the impact of this radiation on public health through analysis of radiation risk factors. A radial map was created to serve as a reference for determining subsequent search locations using the Global Positioning System (GPS).

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MATERIALS AND METHODS

Area of Study

Hilla is located in central Iraq along the Euphrates River, about 100 kilometers south of Baghdad. The city covers an area of 49,816 Km^2 and is a prominent city in Iraq, at 32°29 N and 44°26 E. Al-Hillah is located near important historical landmarks, including the ancient city of Babylon and nearby historical sites such as Kish. It is considered an agricultural area, receiving large amounts of irrigation through the Hilla Canal. Crops, fruits, and textiles are just a few of the agricultural outputs supported by irrigation infrastructure. Date palm trees and other types of vegetation adorn the area, which helps to moderate the climate and lessen the negative effects of dust and desert winds. In the current study, 30 sites were selected[11]. The areas were identified using the Global Positioning System (GPS), as shown in Figure 1.

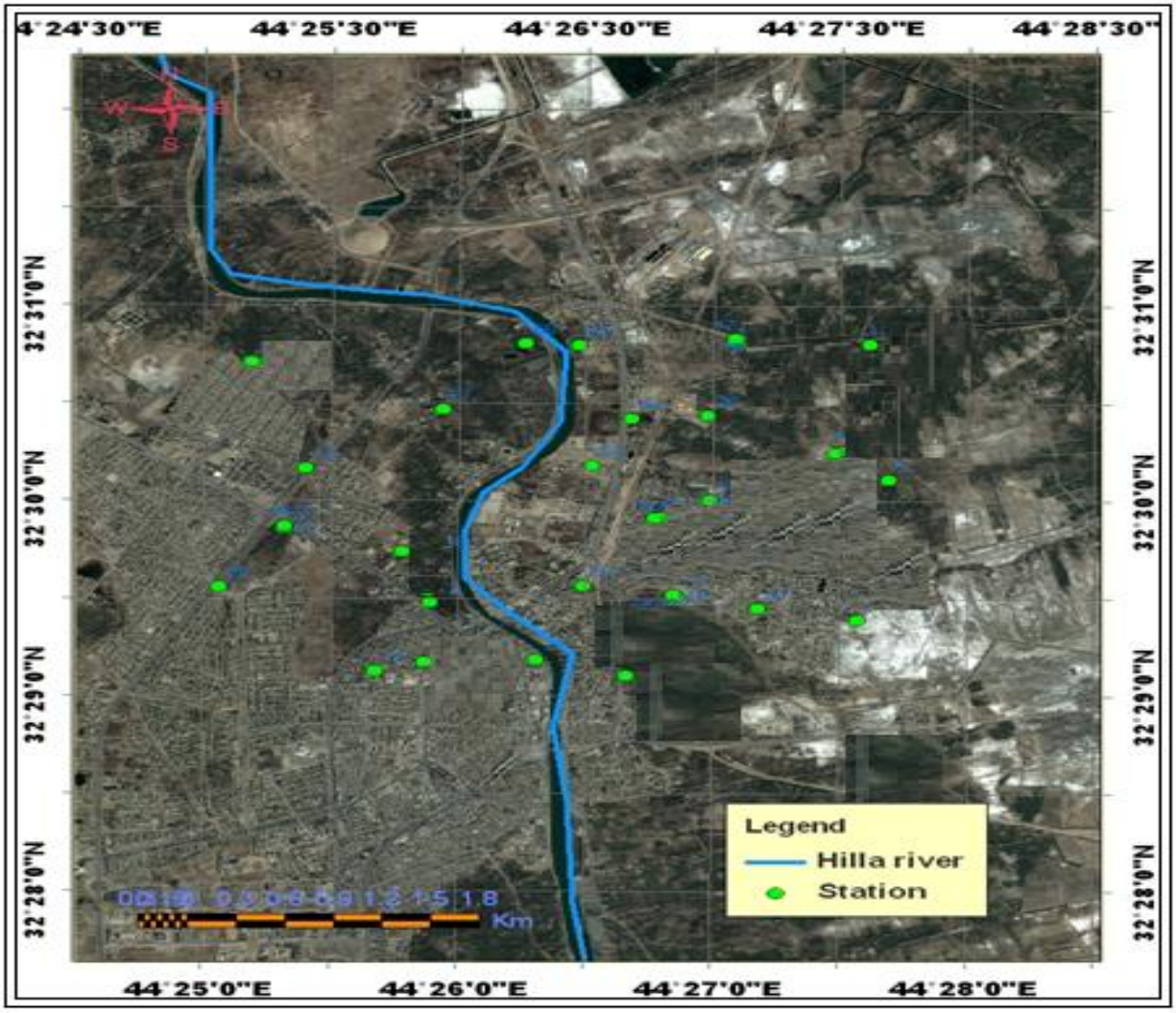

Figure 1. Distribution map of soil sample sites in Al-Hilla city.

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Preparation of the Samples

Thirty samples of the soil were collected, at a depth of (10–15 cm), from various points in Al-Hilla city The International Agency for the Effects of Atomic Radiation established rules and principles that guided laboratory work. Prior to analysis, soil samples were cleansed by re-transferring unwanted material. Then, the specimens underwent a drying process using an electric oven set to a temperature of one hundred degrees Celsius. Then, the soil samples were examined after determining the uniform particle size using a cylindrical sieve, (350μm) in diameter, possessing a mass of 1000 gm. The revised soil models were added to the cylindrical container of the testing device after a one-month break and were created to have specific dimensions that encourage a uniform distribution pattern around the detection device[12]. The careful use of these procedural stages ensures the reliability and consistency of the samples that are gathered for later analytical analysis.

Experimental Analysis System

A NaI (TI) detector measuring (3"× 3") was secondhand to gauge the concentrations of radioactive activity in the radioactive nuclei. This set-up included an ORTEC cylindrical chamber that was divided into two sections comprising lead and stainless steel. The widths of these parts were 20 cm and 5 cm, respectively. The design of the chamber made it easier to evaluate the radiation environment in its entirety. The technique began with the calibration of energy acquisition using a number of radioactive standard sources, including ^{60}C0, ^{133}Ba, ^{57}Co, ^{137}Cs, and ^{22}Na, as shown in Table 1. This calibration process helped ensure precise measurements of energy[8]. Using the aforementioned calibration sources, the effectiveness of energy acquisition within a gamma spectrometer was carefully determined. The power range covered by the calibration process was 511.006 keV to 2500 keV. The calibration source was then positioned so that it was perfectly aligned with the detection device in terms of geometry. At this point, a Marinelli cup was used, and the calibration sources were placed within. In order to get the best alignment between the sample being examined and the detection device[13]. The actual analysis ensued by introducing the soil sample into the central area of the chamber, positioned within the protective shield, and maintaining this configuration for a duration of 5 hours. ^{214}Bi distinctive gamma power transitions, which had a 15% probability, were used to determine the energy equilibrium's attainment at 1764 keV. The gamma energy transition of ^{208}Tl was also attributed to an energy equilibrium at 2614 keV with a far higher probability of 98%. Parallel to this, ^{40}K activities were evaluated. The utilization of a power level of 1460 KeV and its associated likelihood of a line of gamma rays at 12% were employed in the study. As described, the calibration and measurement routine followed exacting scientific procedures, ensuring the correctness and dependability of the provided results[14, 15].

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Table 1. Standard sources used to calibrate the NaI (TI) detector.

Number	Source	E(keV)	Efficiency
1	^{133}Ba	383.7	0.186152
2	^{22}Na	511	0.14431
		1274.5	0.031342
3	^{137}Cs	661.6	0.106779
4	^{54}Mn	834.8	0.075517
5	^{60}Co	1173.24	0.038378
		1332.5	0.027909
		2505.74	0.002671

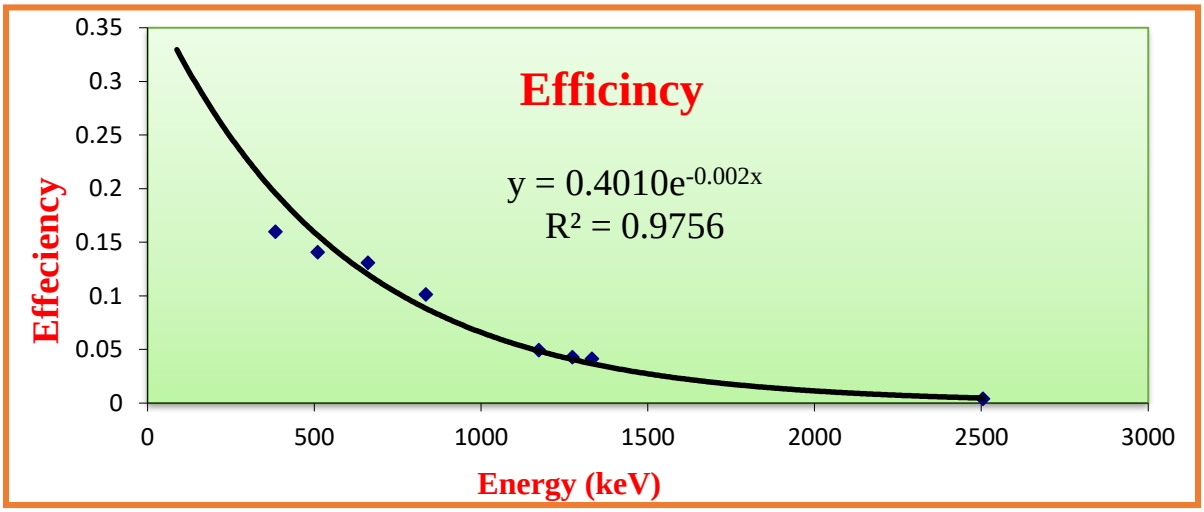

Figure 2. The relationship between efficiency and energy.

From Figure 1, which shows the relationship between efficiency and energy for the standard sources used, a curve was drawn by connecting the points between absolute efficiency values on the one hand and energy on the other hand, and the appropriate fitting process was performed on this curve to obtain a comprehensive empirical equation between absolute efficiency and energy. Then they chose the best empirical equation based on the value of the correction factor R^2 to describe the curve in the energy range (380–2500) keV. Therefore, the general form of the overall empirical equation is:

$$\varepsilon = 0.4010 \times e^{-0.002 \times E} \quad (1)$$

In this context, the symbol ε is used to denote efficiency. While the symbol E is used to represent energy.

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THEORETICAL COMPUTATIONS

To calculate the concentration of natural radionuclides and their dangerousness coefficients, this is done after calibrating the efficiency of the nuclear detector and detecting background radiation using the following equations:

Specific Activity (A)

The determination of the quality, or specific activity (A), is guided by the subsequent equation (2):

$$A(Bq/Kg) = \frac{N}{t \times \varepsilon \times I_\gamma \times m} \quad (2)$$

In this context, N represents the net area beneath the photo peak, t denotes the time of counting in seconds, I_γ signifies the likelihood of gamma emissions, m represents the weight of the model in kilograms, and ε denotes the efficiency of the detector at a specific gamma energy. This formulation captures the mathematical underpinnings for evaluating the qualitative activity, employing a number of critical parameters to reach a thorough grasp of the particular radioactivity within the sample under consideration[16].

Absorbed Dose Rates (Dr)

The radiation coming from ^{238}U, ^{232}Th, and ^{40}K, which is assumed to be spread equally in the ground, is used to calculate the outdoor external dose (D_{out}) at one meter above the earth[17]. The subsequent equation was employed to calculate the outdoor external dose:

$$D_{out}\ (nGy/h) = 0.4620A_U + 0.6210A_{Th} + 0.041070A_K \quad (3)$$

The equation (4) is used to compute the -ray dose (D_{in}) that is imported by the presence of ^{238}U, ^{232}Th, and ^{40}K inside[5, 17].

$$D_{in}\ (nGy/h) = 0.920A_U + 1.10A_{Th} + 0.0810A_K \quad (4)$$

The Equivalent of Radium-232 (Ra_{eq})

The mathematical definition of this indicator, which deals with measuring the sum of the radium-equivalent activities present in naturally radioactive nuclei and is measured in the unit Bq/kg, is given by the formula (5). It is used to evaluate the risks associated with materials containing these elements[18].

$$Ra_{eq}\ (Bq/kg) = A_U + 1.430A_{Th} + 0.0770A_K \quad (5)$$

Radiation Hazard Indices Calculation

Scientists evaluate biological risks from gamma rays using the External Hazard Index (Hex) to estimate the risks of natural radiation caused by radionuclides. The effect of different types of

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radiation on human health can vary[18, 19]. This indicator's value is determined by the following formula:

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

Researchers should consider the intrinsic hazard index (H_{in}) when assessing the radiation risk from natural radionuclides in any given scenario. (H_{in}) is largely responsible for the final biorisk assessment. In this context, the focus is on the radionuclide ^{222}Rn, which is associated with gamma rays and other components of internal radioactive contamination. Although Radon-222 decays quickly due to its short half-life, it has a long-term cumulative effect. To account for the cumulative effect of ^{222}Rn and the transient effect of its exceptionally short half-life, double factor adjustment is used. This modification increased the risk of radioactivity of Uranium-238[20]. This indicator's value is determined by the following formula:

$$H_{in}= \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (7)$$

The Representative Level Index (I_γ)

One of the most important statistics to consider when evaluating the potential risks posed by gamma radiation resulting from natural gamma emissions found in naturally occurring soil radionuclides is the Representative Level Index, also known as Iγ. This indicator can assess the level of radiation risk associated with these radionuclides[21]. The value of this indicator is determined by the following formula:

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

It should be noted that the I_γ value should be less than one, and this value will indicate that the radiation risk remains minimal and within internationally permissible limits, according to the International Commission on Radiation Protection (ICRP). Using this indicator is limited and directed to following a systematic analysis to evaluate and manage the radiological consequences of soil samples in a comprehensive and rational manner.

Annual Effective Dose Equivalent

Exposure to radiation over a year can be very harmful to health, and the annual effective dose equivalent (AEDE) is a measure of this risk. Both the type and amount of radiation an individual is exposed to contribute to the evaluation of AEDE. Each type of radiation, such as gamma rays, alpha particles, and beta particles, has unique "weighting factors" compared to each other. These factors highlight the relative risks of different radiations compared to conventional X-rays. When these two factors are considered, the AEDE produces a simplified value in millisieverts (mSv). Comparing this number to the amount of radiation absorbed provides a clearer picture of the public health consequences of radiation exposure. Calculating the risk of AEDE involves using a

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conversion factor of 0.70 Sv/Gy. Therefore, the internal equivalent effective dose is determined using an occupancy rate of 80%,, while the external equivalent effective dose is determined using an occupancy rate of 20% resulting from the radiation absorption rate[22, 23]. The value of this indicator is determined by the following formula:

$$AEDE_{outdor}=D_{out} \times 1.2264\times10^{-3}(mSv/y) \quad (9)$$

$$AEDE_{indoor} =D_{in} \times 4.9056\times10^{-3}(mSv/y) \quad (10)$$

Lifetime Cancer Risk

Lifetime cancer risk (ELCR) is one way to measure the potential risk of radiation exposure from naturally occurring radionuclides. Because ELCR takes into account a person's lifespan, this factor is calculated using the amount of radiation to which the person is exposed. Typically, a person's age is assumed to be 65 for this calculation. It disregards all other potential health effects associated with radiation in favor of the cancer risk. This can arise from a variety of places, including exposure at work, medical treatments, background radiation (both natural and man-made), or other sources. As a result, it is useful for assessing radiation exposure risks in different environments and activities[24, 25]. The following is a description of the ELCR calculation formula:

$$ELCR = AEDE \times LE \times RF \quad (11)$$

RESULTS AND ANALYSIS

Specific Activity and $Ra_{(eq)}$

Table 2 shows the findings of the specific activity of the radionuclide's Potassium-40, Thorium-232 and Uranium-238 in the soil samples of the city of Hilla. The highest activity of ^{238}U was (35.4±0.313)Bq/kg. The activity of Thorium and Potassium, respectively, was (39.07±0.184)and (368.52±1.507)(Bq/kg). As we can see, the activity of thorium in the majority of models is greater than that of uranium. The reason for this was the geochemical composition of the soil in the study area, which is mixed soil.

Since K-40 is prevalent in some soil samples, its radioactivity has been shown to be higher than that of Uranium-238 and Thorium-232. The application of various fertilizers that are rich in Potassium in the area around the sample site is to blame. According to the results of this evaluation, as for radium equivalent (Ra_{eq}), the range extends from (13.39±5.29) Bq/kg to (106.11±15.4) Bq/kg, with a calculated mean of (13.39±5.29) Bq/kg. The average radioactivity and mean Ra_{eq} of the samples that were taken were lower compared to global values as reported by UNSCEAR 2017[26, 27]. The radioactivity of K-40, U-238, Th-232, and Ra_{eq} was reported by UNSCEAR 2017 to be 420, 33, 45, and 370 Bq/kg, the permissible limits, respectively. These

observations capture clear contrasts amongst the specific activity averages for the aforementioned radionuclides in the research area.

Table 2. Natural radioactive results in the soil of Al-Hilla city.

Number	Specimen Code	Specific Activity[Bqkg^{-1}]			(Ra_{eq}) [Bqkg^{-1}]
		K-40	U-238	Th-232	
1	H. A.$_1$	142.9±0.934	2.59±0.053	31.06±0.121	58.09±10.45
2	H. A.$_2$	135.33±0.908	7.54±0.131	31.23±0.123	62.61±11.7
3	H. A.$_3$	109.08±0.813	3.08±0.065	11.59±0.182	28.05±7.42
4	H. A.$_4$	39.017±0.476	6.65±0.121	13.33±0.119	28.71±8.28
5	H. A.$_5$	153.49±0.968	11.8±0.172	19.14±0.118	50.98±10.7
6	H. A.$_6$	185.82±1.067	13.2±0.184	21.97±0.099	58.93±11.4
7	H. A.$_7$	116.98±0.843	12.8±0.18	17.87±0.160	47.34±10.5
8	H. A.$_8$	51.423±0.551	2.65±0.054	4.74±0.1740	13.39±5.30
9	H. A.$_9$	350.52±1.47	29.7±0.286	30.72±0.190	100.59±14.8
10	H. A.$_{10}$	119.05±0.851	8.03±0.136	8.05±0.1150	28.71±7.73
11	H. A.$_{11}$	368.52±1.507	18.1±0.219	20.59±0.274	75.91±12.2
12	H. A.$_{12}$	182.1±1.056	6.23±0.116	5.948±0.117	28.75±7.02
13	H. A.$_{13}$	38.055±0.47	6.16±0.115	5.948±0.067	17.58±6.44
14	H. A.$_{14}$	170.17±1.02	10.9±0.165	14.03±0.207	44.12±9.66
15	H. A.$_{15}$	128.22±0.883	8.36±0.14	8.109±0.116	29.82±7.83
16	H. A.$_{16}$	18.989±0.32	4.95±0.098	7.604±0.147	17.28±6.50
17	H. A.$_{17}$	150.55±0.96	5.15±0.101	10.52±0.163	31.78±7.85
18	H. A.$_{18}$	329.38±1.43	35.4±0.313	31.73±0.255	106.1±15.4
19	H. A.$_{19}$	46.586±0.52	2.2±0.04	19.22±0.062	33.26±8.27
20	H. A.$_{20}$	119±0.8500	10.4±0.159	6.313±0.185	28.54±7.65
21	H. A.$_{21}$	139.2±10.921	2.13±0.038	19.02±0.086	40.05±8.60
22	H. A.$_{22}$	155.36±0.974	2.36±0.046	39.07±0.184	60.18±10.6
23	H. A.$_{23}$	57.171±0.582	14.6±0.194	23.6±0.063	52.73±11.34
24	H. A.$_{24}$	63.754±0.617	7.47±0.13	10.66±0.135	27.62±8.01
25	H. A.$_{25}$	204.17±1.119	4.98±0.099	19.28±0.112	48.26±9.61
26	H. A.$_{26}$	210.15±1.135	26.5±0.269	19.81±0.217	71.1±12.63
27	H. A.$_{27}$	46.486±0.883	2.2±0.194	5.948±0.163	14.28±5.49
28	H. A.$_{28}$	118±0.3200	10.4±0.130	14.03±0.255	39.58±9.41
29	H. A.$_{29}$	139.2±10.959	2.23±0.099	8.109±0.062	24.44±6.44
30	H. A.$_{30}$	155.36±1.425	2.36±0.269	7.604±0.185	25.19±6.43
Max.		368.52±1.507	35.4±0.313	39.07±0.184	106.1±15.4
Min.		18.989±0.32	2.13±0.038	4.742±0.174	13.39±5.29
Average		141.5±0.894	9.36±0.144	16±0.148	43.13±9.18

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For a visual representation of the differences, Figures 3, 4, and 5 show the link between a particular activity in Bq/kg and the associated site numbers for soil samples. The resulting intrinsic differences in activity values determined across all samples, as illustrated by the graphical representation, are caused by the various geological structures that distinguish the research area sites. The specific activity levels of the radionuclides being studied in soil samples from the study area are thoroughly compared using our analytical approach, which allows for this. Important fresh views on the geological and human processes that contribute to the observed inequalities are provided by the comparison of these values to international norms and by the graphical representation.

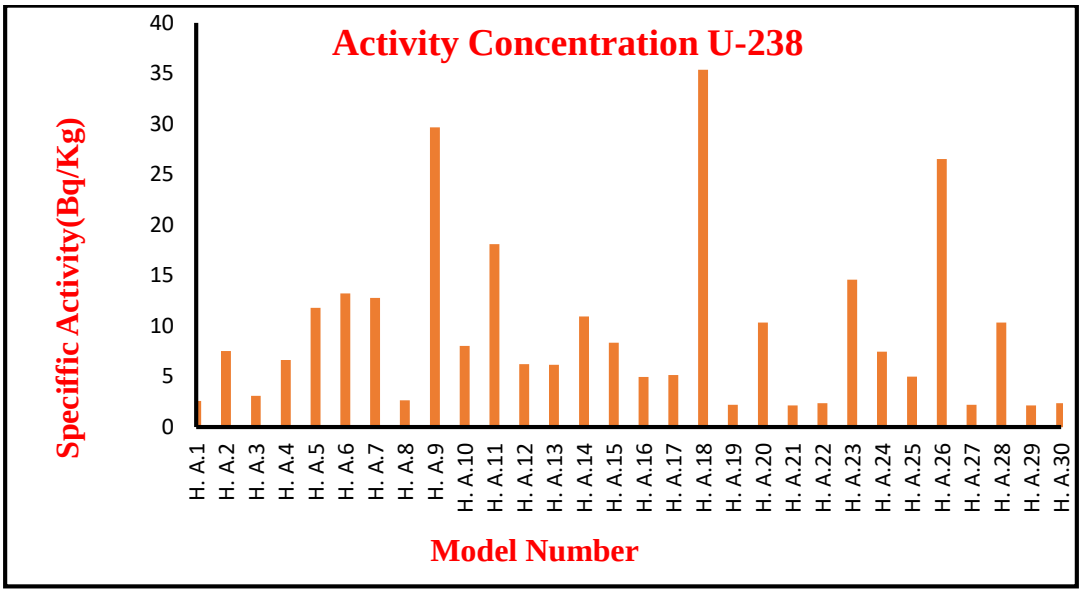

Figure 3. Fluctuation in the effectiveness of Uranium-238 with the sample number.

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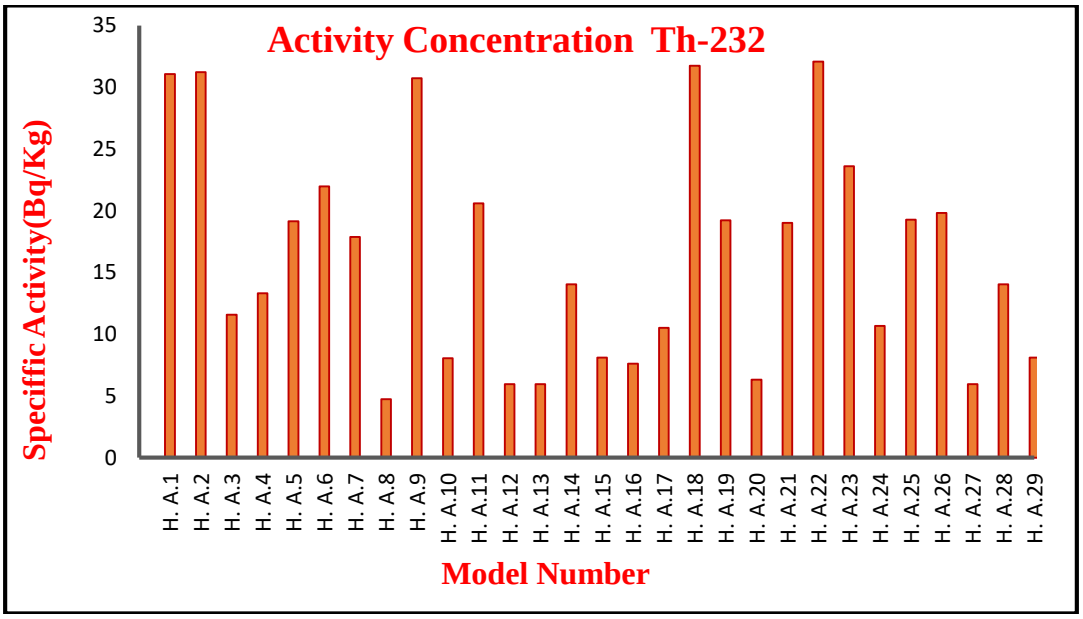

Figure 4. Fluctuation in the effectiveness of Thorium-232 with the sample number.

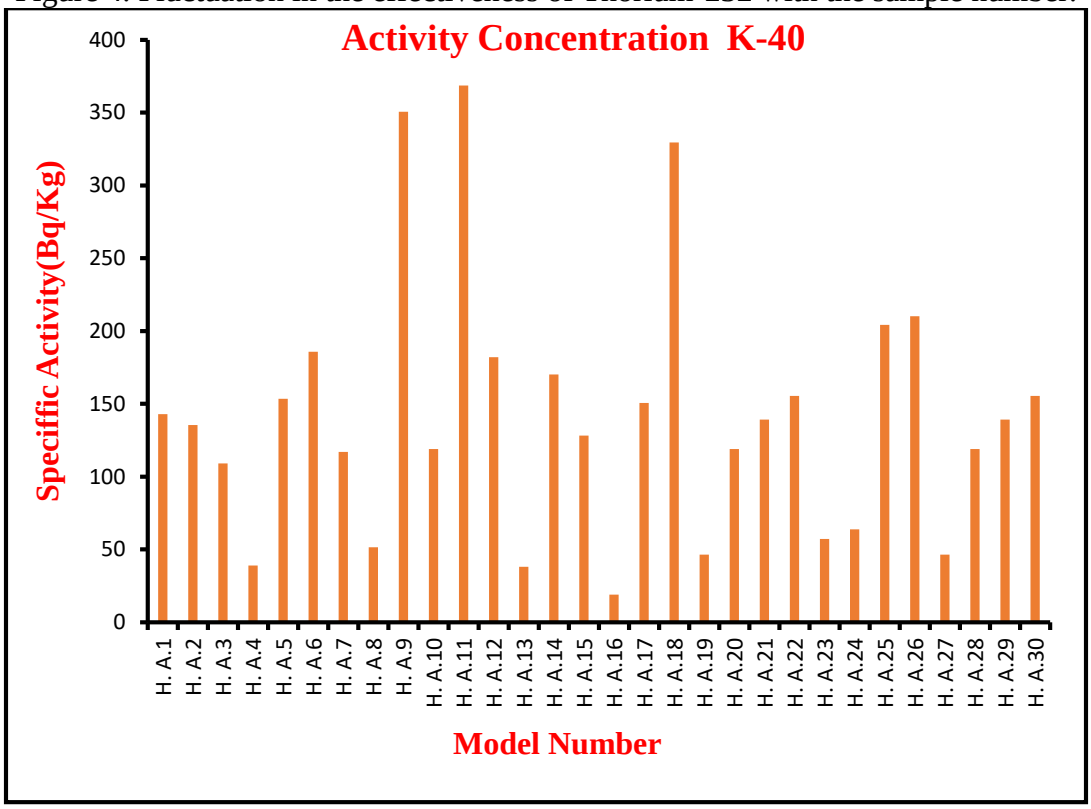

Figure 5. Fluctuation in the effectiveness of Potassium-40 with the sample number.

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The Results of D_{out}, D_{in}, H(ex), H(in) and I_γ Parameters

The observed dose, H_{ex}, H_{in}, and I_γ results for soil samples taken from the study area in Babylon governorate are depicted in Table 3. The global average absorbed dosage of exposure to external gamma radiation (nGy/h) is about 59 nGy/h, according to UNSCEAR 2017[26]. The results obtained do not indicate any prior effects of cancer on the residents of the city of Hilla, and the values recorded in the study area for many samples are critical for health. Finally, a specific activity provided externally in the form of a dose was used to detect radioactive doses. According to the report of the United Nations Committee on Atomic Radiation Protection, the average permissible values are less than (1), although the external hazard index has been evaluated and reported to be 0.29±0.04. According to the radiation protection report, radionuclides have an internal exposure of about 0.77±0.11and a representative gamma hazard index of about 0.38±0.06; hence, the estimated values are less than one. These values shown in Table 3 are within the permissible limit of the universal values[28].

Table 3. Results of H_{ex}, H_{in}, I_γ, D_{out}, and D_{in} soil samples taken from Al-Hilla city.

Number	Specimen Code	Hazard Index		(I_γ)	Observed dose (nGy /h)	
		(H_{ex})	(H_{in})		D_{out}	D_{in}
1	H. A.$_1$	0.16±0.03	0.16±0.03	0.42±0.07	26.44±4.7	48.12±8.6
2	H. A.$_2$	0.17±0.03	0.19±0.04	0.45±0.08	28.52±5.2	52.25±9.6
3	H. A.$_3$	0.08±0.02	0.08±0.02	0.21±0.05	13.17±3.4	24.42±6.2
4	H. A.$_4$	0.08±0.02	0.10±0.03	0.2±0.06	12.98±3.7	23.94±6.9
5	H. A.$_5$	0.14±0.03	0.17±0.04	0.37±0.07	23.74±4.8	44.34±9.0
6	H. A.$_6$	0.16±0.03	0.19±0.04	0.43±0.08	27.49±5.2	51.37±9.6
7	H. A.$_7$	0.13±0.03	0.16±0.04	0.34±0.07	21.88±4.7	40.90±8.8
8	H. A.$_8$	0.14±0.01	0.05±0.02	0.10±0.04	6.316±2.4	11.82±4.5
9	H. A.$_9$	0.27±0.04	0.35±0.05	0.74±0.1	47.4±6.7	89.48±13
10	H. A.$_{10}$	0.08±0.02	0.10±0.03	0.21±0.05	13.68±3.5	25.89±6.6
11	H. A.$_{11}$	0.21±0.03	0.25±0.04	0.57±0.09	36.52±5.6	69.15±10
12	H. A.$_{12}$	0.08±0.02	0.09±0.03	0.22±0.05	14.16±3.2	27.02±6.1
13	H. A.$_{13}$	0.05±0.02	0.06±0.02	0.13±0.05	8.128±2.9	15.29±5.5
14	H. A.$_{14}$	0.12±0.03	0.15±0.04	0.33±0.07	20.87±4.4	39.29±8.2
15	H. A.$_{15}$	0.08±0.02	0.10±0.03	0.22±0.06	14.24±3.6	26.99±6.7
16	H. A.$_{16}$	0.05±0.02	0.06±0.02	0.12±0.05	7.80±2.90	14.46±5.4
17	H. A.$_{17}$	0.09±0.02	0.10±0.03	0.24±0.06	15.19±3.6	28.50±6.6
18	H. A.$_{18}$	0.29±0.04	0.38±0.06	0.77±0.11	49.78±6.9	94.12±13
19	H. A.$_{19}$	0.09±0.02	0.10±0.03	0.24±0.06	14.89±3.7	26.93±6.7
20	H. A.$_{20}$	0.08±0.02	0.11±0.03	0.21±0.05	13.67±3.5	26.11±6.6
21	H. A.$_{21}$	0.11±0.02	0.11±0.03	0.30±0.06	18.60±3.9	34.16±7.1
22	H. A.$_{22}$	0.16±0.03	0.17±0.03	0.44±0.08	27.48±4.7	50.03±8.7
23	H. A.$_{23}$	0.14±0.03	0.18±0.04	0.37±0.08	23.78±5.1	44.01±9.5

24	H. A.$_{24}$	0.07±0.02	0.09±0.03	0.20±0.06	12.73±3.6	23.77±6.8
25	H. A.$_{25}$	0.13±0.03	0.14±0.03	0.36±0.07	22.79±4.4	42.33±8.1
26	H. A.$_{26}$	0.19±0.03	0.26±0.05	0.51±0.09	33.32±5.7	63.21±11
27	H. A.$_{27}$	0.04±0.01	0.03±0.02	0.11±0.04	6.647±2.5	12.33±4.6
28	H. A.$_{28}$	0.11±0.03	0.13±0.03	0.29±0.07	18.46±4.3	34.60±8.1
29	H. A.$_{29}$	0.07±0.02	0.07±0.02	0.19±0.05	11.82±2.9	22.16±5.4
30	H. A.$_{30}$	0.07±0.02	0.07±0.02	0.20±0.05	12.29±2.9	23.12±5.5
Min.		0.04±0.01	0.03±0.02	0.10±0.04	6.647±2.5	12.33±4.6
Max.		0.29±0.04	0.38±0.06	0.77±0.11	49.78±6.9	89.48±13
Average		0.12±0.02	0.11±0.03	0.32±0.06	20.16±4.2	37.67±7.7

The Results of Annual Effective Dose Equivalent and Lifetime Cancer Risk

Table 3 presents the effects of radiation on soil samples taken from the study area, including uptake rate (AEDE (external) and AEDE (indoor)) and lifetime cancer risk (ELCR (outside) and ELCR (inside)). The values of the external effective dose rate regarding the models extended amongst (0.008±0.003 to 0.061±0.009) mSv/y with an average of (0.025±0.005) mSv/y, and the values of the internal effective dose rate for the samples ranged amongst (0.058±0.02 to 0.462±0.05) mSv/y with a mean of (0.185±.03) mSv/y, as shown in Table 3, and all of these results fall within the internationally permissible the report's upper limit of the United Nations Scientific Committee on Atomic Radiation's effects[26]. According to Table 3, the AEDE value for outdoor exposure ranged from (0.026±0.29) to (0.201±0.82), with a mean value of (0.082±0.59). Indoor exposure ranges from (0.191±0.79) to (1.524±2.24), with an average of (0.61±1.37). The total ELCR value ranges from (0.217±0.6) to (1.725±1.68) x 10^{-3}, with an average value of (0.69±1.03) x 10^{-3}. In light of this, the outcomes of this table belong to the acceptable range set by the International Committee on Protection from the Effects of Radiation[27]. Figure 6 presents the ELCR graphical representation of all samples in the sample city of Hilla[10, 26].

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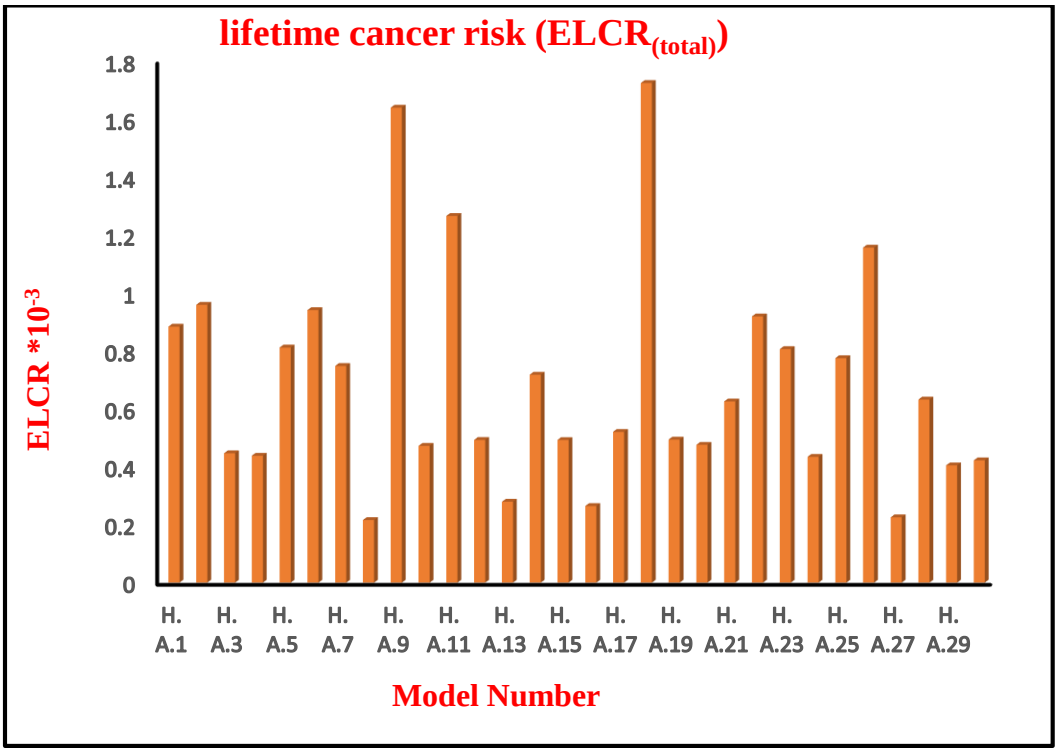

Figure 6: Total lifetime risk of cancer (ELCR (total)) for soil models from Al-Hilla city.

Figure 6 displays all ELCR results for the study samples, highlighting the consistency of the calculated ELCR values within the specified constraints. This detailed examination captures the radiological implications of the soil sample and provides information on potential health risks associated with radiation exposure[26].

Table 4: Results AEDE $_{(internal)}$, AEDE $_{(external)}$ and ELCR $_{(total)}$ in the soil samples of Al-Hilla city.

Number	Specimen Code	$AEDE_{(out)}$ (mSv/y)	$AEDE_{(in)}$ (mSv/y)	$ELCR_{(out)}$ $x10^{-3}$	$ELCR_{(in)}$ $x10^{-3}$	ELCR(t) $x10^{-3}$
1	H. $A._1$	0.032±0.006	0.236±0.03	0.107±0.59	0.779±1.60	0.886±1.21
2	H. $A._2$	0.035±0.007	0.256±0.04	0.115±0.62	0.846±1.67	0.961±1.26
3	H. $A._3$	0.016±0.004	0.12±0.02	0.053±0.42	0.395±1.14	0.449±0.86
4	H. $A._4$	0.016±0.004	0.117±0.02	0.053±0.42	0.388±1.13	0.44±0.85
5	H. $A._5$	0.029±0.006	0.218±0.03	0.096±0.56	0.718±1.54	0.814±1.16
6	H. $A._6$	0.034±0.006	0.252±0.04	0.111±0.61	0.832±1.66	0.943±1.25
7	H. $A._7$	0.027±0.006	0.201±0.03	0.089±0.54	0.662±1.48	0.751±1.11
8	H. $A._8$	0.008±0.003	0.058±0.02	0.026±0.29	0.191±0.79	0.217±0.6
9	H. $A._9$	0.058±0.008	0.439±0.05	0.192±0.80	1.449±2.19	1.64±1.64
10	H. $A._{10}$	0.017±0.005	0.127±0.02	0.055±0.43	0.419±1.18	0.474±0.88

11	H. A.$_{11}$	0.045±0.007	0.339±0.04	0.148±0.70	1.119±1.92	1.267±1.44
12	H. A.$_{12}$	0.017±0.005	0.133±0.03	0.057±0.43	0.437±1.20	0.495±0.90
13	H. A.$_{13}$	0.01±0.003	0.075±0.02	0.033±0.33	0.248±0.9	0.28±0.68
14	H. A.$_{14}$	0.026±0.006	0.193±0.03	0.084±0.53	0.636±1.45	0.72±1.09
15	H. A.$_{15}$	0.017±0.005	0.132±0.03	0.058±0.44	0.437±1.2	0.495±0.9
16	H. A.$_{16}$	0.01±0.003	0.071±0.02	0.032±0.32	0.234±0.88	0.266±0.66
17	H. A.$_{17}$	0.019±0.005	0.14±±0.03	0.061±0.45	0.461±1.23	0.523±0.93
18	H. A.$_{18}$	0.061±0.009	0.462±0.05	0.201±0.82	1.524±2.24	1.725±1.68
19	H. A.$_{19}$	0.018±0.005	0.132±0.03	0.06±0.45	0.436±1.20	0.496±0.91
20	H. A.$_{20}$	0.017±0.005	0.128±0.03	0.055±0.43	0.423±1.18	0.478±0.89
21	H. A.$_{21}$	0.023±0.005	0.168±0.03	0.075±0.50	0.553±1.35	0.628±1.02
22	H. A.$_{22}$	0.034±0.006	0.245±0.03	0.111±0.61	0.81±1.63	0.921±1.23
23	H. A.$_{23}$	0.029±0.006	0.216±0.03	0.096±0.56	0.712±1.53	0.809±1.15
24	H. A.$_{24}$	0.016±0.004	0.117±0.02	0.052±0.41	0.385±1.13	0.436±0.85
25	H. A.$_{25}$	0.028±0.006	0.208±0.03	0.092±0.55	0.685±1.50	0.777±1.13
26	H. A.$_{26}$	0.041±0.007	0.31±0.040	0.135±0.67	1.023±1.84	1.158±1.38
27	H. A.$_{27}$	0.018±0.003	0.06±0.020	0.027±0.30	0.20±0.810	0.226±0.61
28	H. A.$_{28}$	0.023±0.005	0.17±0.030	0.075±0.50	0.56±1.360	0.635±1.02
29	H. A.$_{29}$	0.015±0.004	0.109±0.02	0.048±0.40	0.359±1.09	0.407±0.82
30	H. A.$_{30}$	0.015±0.004	0.113±0.02	0.05±0.410	0.374±1.11	0.424±0.83
Min.		0.008±0.003	0.058±0.02	0.026±0.29	0.191±0.79	0.217±0.60
Max.		0.061±0.009	0.462±0.05	0.201±0.82	1.524±2.24	1.725±1.68
Average		0.025±0.005	0.185±0.03	0.082±0.59	0.61±1.37	0.69±1.03

CONCLUSION

The examination of the echelons of naturally occurring radioactivity in the areas in the center of Hilla has produced a wealth of data demonstrating that the measured concentrations of natural radionuclides are within acceptable bounds and represent typical levels of radioactivity. This evaluation is confirmed by the computed values of radium equivalent, yearly effective dose equivalent, and H_{ex}, emphasizing the lack of major radioactive dangers. This research advances knowledge of Hilla's radiological environment and provides important information for well-informed decisions on urban planning and public health activities.

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Conflict of interests.

There are no conflicts to declare.

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الخلاصة

مقدمة:

تم فحص وتقييم المستويات النشطة للنشاط الإشعاعي الطبيعي البوتاسيوم-40 واليورانيوم-238 والثوريوم-232 في عينات التربة المختلفة من مدينة الحلة من خلال تحليل نتائج هذه العينات ومقارنتها بالمستويات المقبولة عالمياً.

طرق العمل:

تم جمع 30 عينة من التربة من مناطق مختلفة في مدينة الحلة على عمق 10-15 سم وفحصها باستخدام مطياف أشعة جاما.

الاستنتاجات:

لقد أدى فحص مستويات النشاط الإشعاعي الطبيعي في مناطق وسط الحلة إلى إنتاج ثروة من البيانات التي تثبت أن التركيزات المقاسة للنويدات المشعة الطبيعية تقع ضمن الحدود المقبولة وتمثل مستويات نموذجية للنشاط الإشعاعي.

الكلمات المفتاحية: النويدات المشعة الطبيعية، مطياف اشعة كاما، النشاط الإشعاعي، التربة، مدينة الحلة.